PHYSICAL ACTIVITY, FITNESS AND CORONARY RISK IN 9-13 YEAR OLD LIVERPOOL SCHOOLCHILDREN

STEPHEN JOHN ATKINS

A thesis submitted in partial fulfilment of the requirements of Liverpool John Moores University for the degree of Doctor of Philosophy

July 1998

ABSTRACT

Abstract

The purposes of the current study were twofold. The first investigation sought to determine whether the free-living physical activity of 9-13 year old Liverpool children was related to coronary heart disease risk factors, cardiorespiratory fitness, anthropometric variables and physical self-perceptions. Secondly, changes in these variables over time were investigated. Children were measured twice, with testing being performed 12 months apart. Seventy-seven children gave written informed consent to take part in the current study. Sixty children (74%) agreed to be measured at a second test occasion. Physical activity was measured using short-range radio telemetry on three consecutive schooldays. Heart rate monitoring was also performed during sleep to determine a resting heart rate. The heart rate during sleep, together with a maximal heart rate recorded during maximal exercise testing, was then used to directly determine heart rate reserve (HRR) thresholds. The HRR thresholds were set at moderate (60%) and vigorous (75%) levels. Additionally, a lower 139 beats.min.$^{-1}$ threshold was used to represent lower intensity physical activities.

No child performed the recommended "3 x 20 min weekly" exercise prescription during either test visit. Children performed shorter duration (<5 min), continuous periods of physical activity more readily during both visits. Children performed less physical activity at higher intensities of effort (>75% HRR) than at the lower 139 beats.min.$^{-1}$ and >60% HRR thresholds. Children accumulated the recommended 30 min of moderate to vigorous physical activity daily at the lower HRR (<60% HRR), but again failed to perform sufficient activity at the more vigorous heart rate thresholds.

No child had elevated diastolic or systolic blood pressure during either test occasion. One boy maintained levels of total cholesterol above the 75th percentile for the test group on both test occasions. Several children had elevated blood cholesterol levels but did not maintain these levels between test occasion. Children were heavier, taller and had a greater sum of four skinfold thicknesses than those reported in other British studies. Children were also shown to have lower allometrically scaled peak VO_2 values.

Multiple logistical regression analyses revealed that anthropometric, morphological, risk factor and cardiorespiratory fitness variables did not account for significant amounts of variance in the cumulative minutes of physical activity at any heart rate threshold ($P>0.05$).

Cumulative minutes of physical activity, at the 75% HRR, tracked significantly between test occasion ($r = 0.65$; $P<0.01$) for boys but not for girls ($P>0.05$). Other physical activity variables did not track significantly ($P>0.05$). The volume of physical activity performed by boys and girls decreased between test occasion, though not significantly ($P>0.05$). Blood pressure ($P<0.01$), body fat ($P<0.05$), total cholesterol ($P<0.05$) and peak VO_2 ($P<0.05$) all tracked significantly between visits.

Following a principal component analysis, the factor structure of the Physical Self-Perception Profile (PSPP) was not supported for children of this age. Changes in physical self-perceptions, between test occasion, emphasised alterations in children's ability to perceive themselves within the physical domain. Perceptions of an attractive body decreased significantly between test occasion ($P<0.001$). Physical self-perceptions were poorly related to physical activity participation, risk factors and peak VO_2 on both test occasions.

Results from this study confirmed that children seldom experience the volume of free-living physical activity to provide health and fitness benefits. Free-living physical activities do not appear to be a sufficient stimulus for the promotion of health and fitness benefits in this age group. Participation in physical activities decreased between test occasion, and at an earlier age than previously reported. The predictors of physical activity participation remain to be identified in this age group. The prevalence of risk factors did not raise concern, yet several children were shown to have at least one elevated risk factor. Children appeared unable to differentiate self-perceptions within the physical domain at this age. Similarly, physical self-perceptions were not significantly related to physical activity participation ($P>0.05$). Promoting a healthy lifestyle must be considered essential in maintaining low levels of risk factors in children, and encouraging participation in physical activities through the life cycle.

ACKNOWLEDGEMENTS

This work was funded by a grant from the Liverpool John Moores University: Research Strategy/ and Funding Committee.

The current study was made possible by the help and co-operation of the children, parents and schools from the South Liverpool and Anfield areas, who agreed to participate in testing, both at pilot and main study stages. They each have my thanks for their valuable help and time.

The influence, expertise and mentorship of Gareth Stratton were tremendous during all phases of the project. I also owe much to the continuing advice and support of my other research supervisors, Lindsey Dugdill and Tom Reilly for their continuing guidance and support throughout this project. Additionally, I am indebted to Alan Nevill and Jim Waterhouse for their input and statistical advice to the study. I would also like to thank Colin Smith and his staff at the Growth Unit, Alder Hey Children's Hospital for their kind help in the early stages of the project.

To Mike, Frankie, Adam, Anne-Marie, Duncan and Richard, my colleagues at the Liverpool John Moores University, who helped me through the hard times, I owe a debt of gratitude.

Thanks also to my mother for being endlessly supportive and my family for their encouragement. Finally, I owe much to Gracie, whose love, support and belief have inspired me.

This work is dedicated to the memory of two wonderful friends, Elsi and Stuart, whose spirit will live forever with me.

LIST OF CONTENTS

List of Contents

Section	Title	Page No.
1.0	Introduction	1
2.0	Review of Literature	5
2.1	The health, physical activity and fitness continuum.	
2.2	Physical Activity – Measurement.	6
2.3	The physical activity patterns of British schoolchildren.	15
2.4	The concepts of growth and development.	30
2.5	The physical activity prescription.	31
2.5.1	The dose-response of physical activity required to provide beneficial changes in chronic disease risk factors and cardiorespiratory fitness.	32
2.5.2	Physical activity and blood pressure.	33
2.5.3	Physical activity and blood lipids.	36
2.5.4	Physical activity and body fat.	41
2.5.5	Physical activity and cardiorespiratory fitness.	45
2.5.6	The appropriate dose-response of physical activity for health and fitness benefits.	50
2.6	Changes in physical activity over time.	51
2.6.1	The tracking of free-living physical activity.	53
2.6.2	The determinants of physical activity participation over time.	55
2.6.3	The risk factor profile – changes over time.	58
2.6.4	Changes in blood pressure with age.	59
2.6.5	Changes in blood lipids with age.	60
2.6.6	Changes in body fat with age.	67
2.7	The health, fitness and activity continuum: psychological influences upon physical activity participation.	70
2.7.1	Physical activity and self-perception.	71
2.7.2	The physical self-perceptions of children.	76
2.8	Summary of literature relating to the role of physical activity in the health, physical fitness and physical activity continuum.	77
2.9	The major aims of the current study.	78

Section	Title	Page No.
3.0	Methodology	81
3.1	Recruitment of subjects.	
3.2	Selection of subjects for the study.	
3.3	Research design.	83
3.4	Classification of socio-economic status.	
3.5	Anthropometry.	84
3.6	Blood pressure.	86
3.7	Blood lipid profile.	87
3.8	Blood haemoglobin assaying.	89
3.9	Habitual physical activity.	
3.10	Cardiorespiratory fitness.	91
3.11	Morphological maturity.	94
3.12	Physical self-esteem.	96
3.13	Data analysis.	97
4.0	Results	100
4.1	Anthropometric data - descriptive variables.	
4.2	Study One: Habitual physical activity - descriptive data.	101
4.3	Study Two: Chronic Disease Risk Factors and Cardiorespiratory Fitness - descriptive data.	105
4.4	Study Three: The tracking of physical activity and chronic disease risk factors.	111
4.5	Study Four: Relationships between habitual physical activity and recognised risk factors for chronic disease.	114
4.6	Study Five: Physical Self-Perceptions.	122
5.0	Discussion of results	131
5.1	Study One: Habitual physical activity.	
5.2	Study Two: Chronic disease risk factors and the levels of cardiorespiratory fitness in Liverpool schoolchildren.	140
5.2.1	Blood pressure.	
5.2.2	Blood lipid profile.	142
5.2.3	Body fat.	145
5.2.4	Cardiorespiratory fitness.	147
5.3	Study Three: The tracking of physical activity and chronic disease risk factors.	155
5.4	Study Four: Relationships between habitual physical activity and chronic disease risk factors.	166
5.5	Study Five: Physical self-perceptions.	173
6.0	Synthesis of results and conclusions	179

7.0	Recommendations for further study	191
8.0	Bibliography	193

LIST OF FIGURES

List of Figures

Figure no.	Title	Page no.
Figure 1	Schematic model describing the interactions between health, fitness and physical activity.	2
Figure 2	Three-tier hierarchical organisation of Physical Self-Perceptions.	73
Figure 3	Longitudinal study design.	83
Figure 4	Relationships between PSPP subscales and Physical Self-Worth - Test Occasion 1.	125
Figure 5	Relationships between PSPP subscales and Physical Self-Worth - Test Occasion 1.	126
Figure 6	Relationships between PSPP and PIP items.	128
Figure 7	The components of physical activity applied specifically to children.	140
Figure 8	The revised framework for children's physical activity health and fitness – Physical Activity and Health Related Fitness.	154
Figure 9	The revised model for children's physical activity health and fitness – the contribution of development.	166
Figure 10	The revised model for children's physical activity health and fitness – relationships between physical activity, health related fitness and development.	172
Figure 11	The newer framework including relationships with social influence – peer group and parental.	183
Figure 12	The newer framework for children's physical activity and health-related fitness.	188

LIST OF TABLES

List of Tables

Table no.	Title	Page no.
Table 1	Principal methods of assessing habitual physical activity.	7
Table 2	Summary of findings assessing the physical activity of British children using heart rate monitoring - Armstrong and co-workers.	24
Table 3	Conversion of the percentage of total time spent with elevated heart rates during free-living physical activity - Armstrong and co-workers.	25
Table 4	Minutes spent with heart rate above set thresholds - a comparison of studies.	30
Table 5	Empirical studies investigating the dose-response of physical activity upon changes in blood pressure.	35
Table 6	Empirical studies investigating the dose-response of physical activity upon changes in children's blood lipids.	39
Table 7	Empirical studies investigating the dose-response of physical activity upon changes in children's body fat.	42
Table 8	Empirical studies investigating the dose-response of physical activity upon changes in children's cardiorespiratory fitness.	46
Table 9	The Canadian Consensus Conference Cholesterol Guidelines.	66
Table 10	Descriptive data for criterion 20-MST performance based upon a sample (n=480), of Merseyside schoolchildren (9-13 years).	82
Table 11	Treadmill protocol for cardiorespiratory fitness testing.	91
Table 12	Calculation matrix to predict adult stature using the non-invasive method of Roche et al., (1983).	95

Table no.	Title	Page no.
Table 13	Percentage of adult stature estimated without skeletal age.	95
Table 14	Descriptive data for age and socio-economic status of the study group.	100
Table 15	Anthropometric variables - descriptive data.	101
Table 16	Heart rate monitoring variables and calculated heart rate reserve thresholds.	102
Table 17	Heart rate monitoring variables; number of children achieving continuous periods of physical activity above the 139 beats.min.$^{-1}$, 60% HRR and 75% HRR thresholds.	104
Table 18	Cumulative minutes with elevated heart rate - descriptive data.	105
Table 19	Descriptive data for systolic and diastolic blood pressure.	105
Table 20	Descriptive data for total cholesterol, high-density lipoprotein cholesterol and the ratio of TC:HDL-C.	107
Table 21	Skinfold thickness - descriptive data.	108
Table 22	Cardiorespiratory fitness - descriptive data.	109
Table 23	Application of the Tanner (1949), special circumstance to cardiorespiratory fitness and body mass data, between gender and visit.	109
Table 24	Constants and exponents determined from the allometric scaling of peak VO_2 and body size (mass).	110
Table 25	Adjusted peak VO_2 values using power function exponents to partition out differences in body mass.	110
Table 26	Descriptive data for blood haemoglobin measurement	111
Table 27	Tracking correlation coefficients for heart rate variables.	112
Table 28	Tracking coefficients for anthropometric variables.	112

Table no.	Title	Page no.
Table 29	Tracking correlation coefficients for skinfold thickness.	113
Table 30	Tracking correlation coefficients for blood lipid concentrations.	114
Table 31	Relationships between cumulative minutes of physical activity at the 139 beats.min.$^{-1}$ threshold, anthropometric variables, risk factors and cardiorespiratory fitness.	115
Table 32	Relationships between cumulative minutes of physical activity at the 60% HRR threshold, anthropometric variables, risk factors and cardiorespiratory fitness.	116
Table 33	Relationships between cumulative minutes of physical activity at the 75% HRR threshold, anthropometric variables, risk factors and cardiorespiratory fitness.	117
Table 34	Multiple regression analysis with cumulative minutes of free-living physical activity used as dependent variables, and gender, biological age, test occasion, anthropometric variables and cardiorespiratory fitness used as independent variables.	118
Table 35	Fitted parameters (± SEE) when predicting changes* in peak VO_2 using stature, body mass, chronological age and gender as simultaneous covariates.	120
Table 36	Multiple regression analysis with blood lipids, blood pressure and sum of four skinfolds used as dependent variables, and gender, anthropometric variables, cumulative minutes of physical activity and cardiorespiratory fitness used as independent variables.	121
Table 37	Descriptive data for preliminary validation study, PSPP sub-scales.	123
Table 38	Principal components factor loadings for PSPP items.	124
Table 39	Descriptive statistics for PSPP subscales between test occasions.	125
Table 40	Inter-period correlation coefficients for PSPP sub-scales.	127

Table no.	Title	Page no.
Table 41	Descriptive statistics for PIP subscales between test occasions.	127
Table 42	Pearson Product Moment correlation coefficients: cumulative minutes of activity with elevated heart rate and PSPP sub-scales.	129
Table 43	Pearson product moment correlation coefficients for PSPP subscales and selected physiological variables.	134
Table 44	Hypothetical data set for cumulative minutes of physical activity performed at 12-month intervals.	158

LIST OF APPENDICES

List of Appendices

Appendix No.	Title
1	Example of approach letter to children and parents.
2	Copy of laboratory ethics document for the IM Marsh Human Performance Laboratory.
3	Reliability of measurements - descriptive data and reliability analysis.
4	Correlation matrices for chronic disease risk factors - boys and girls on test occasion 1 and 2.
5	The Physical Self-Perception Profile and instructions for completion by children.
6	Questionnaire to assess the socio-economic status of the head of children's household, using the Registrar General 5-tier classification.
7	Sample 24-hour heart rate time curve generated using Polar Version 4. Software (Polar, Kempele, Finland).
8	Copy of raw data for physiological measurements generated using Minitab software.
9	Copy of raw data for psychological measurements generated using SPSS/PC+ software.
10	Glossary of Terms.

INTRODUCTION

1.0 Introduction

Physical activities contribute to health and can confer a protective effect from the development of several chronic diseases, including coronary heart disease, osteoporosis and certain cancers. It is now known that these diseases have their foundations during childhood, and may be associated with modifiable and non-modifiable risk factors (Berlin and Colditz, 1990; Blair, 1993; Paffenbarger and Lee, 1996; Shephard and Bouchard, 1996). This has led to many researchers assessing the prevalence of, and relationships between, physical activities and chronic disease risk factors during childhood.

Relationships between physical activity, fitness and health are thought to encompass both internal and external variables (Bouchard et al. 1990). Internal variables include both physiological and psychological attributes. External variables include social and lifestyle behaviours. To adequately assess influences upon physical activity participation, research designs should measure both internal and external variables.

Much health research has focussed on physical activity participation and the prevalence of risk factors in children and adolescents. The contribution of psychological and sociological factors within a physical activity, health and fitness framework is less well understood. Similarly, whilst cross-sectional study designs provide important information, our understanding of changes in physical activity and the "risk-factor profile" during growth are less well understood. The formulation of many adverse lifestyle behaviours is thought to occur during childhood (Kemper, 1995). The degree to which these behaviours "track" during the life-cycle has important implications for the future health of children.

There have been few reports on the prevalence of, and changes in, physical activities and the risk factor profile from childhood to adulthood. From an English perspective, such information is limited. Moreover, our understanding of changes in the risk-factor profile is limited to studies from widely differing demographics, such as the Netherlands (Kemper, 1995), Belgium (Beunen et al., 1992) and North America (Roche et al., 1976; Clarke et al., 1978; Mirwald and Bailey, 1986; Shephard, 1994).

When reviewing current literature it is clear that our understanding of changes in physical activity participation, and the risk factor profile, is limited. The transition from childhood into adolescence is accompanied by great changes in physiological systems of the body. A milieu of sociological experiences and psychological influences may also influence physical activity participation. During growth, whether free-living physical activities confer health and fitness benefits remains unclear. Support for the contribution of physical activities in providing psychological benefits are even less well understood, especially during growth.

1.1 The Physical Activity, Health and Fitness Continuum – Consensus Opinion

The Second International Consensus Symposium on Physical Activity, Fitness and Health (Bouchard et al. 1993) proposed a model to specify the relationships between physical activity, fitness and health (Figure 1).

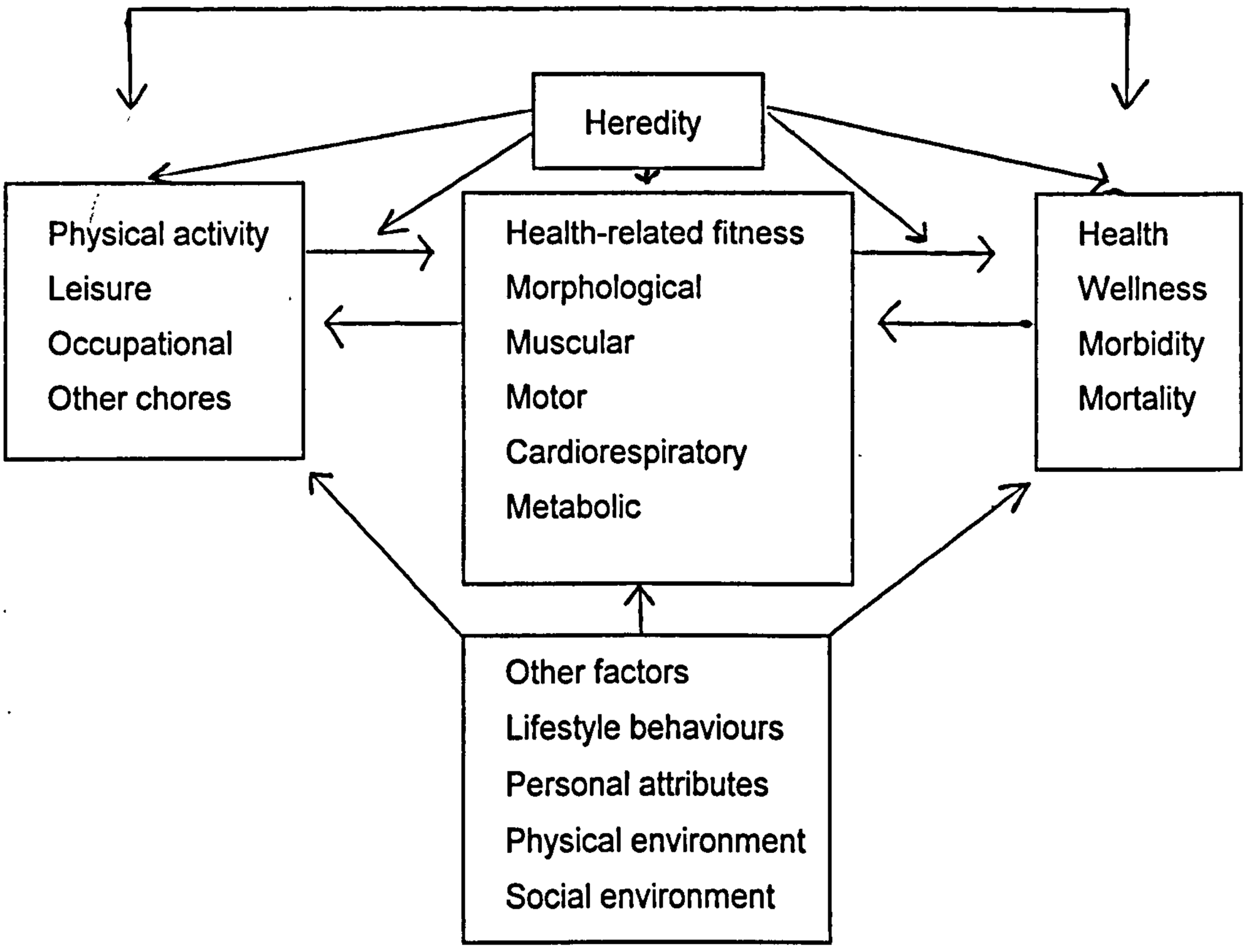


Figure 1 Schematic framework describing the interactions between health, fitness and physical activity. (Redrawn from Bouchard et al., 1993)

The model of Bouchard et al., (1993) suggests that physical activity will influence health-related fitness and subsequently general health state. Additionally, the

model specifies that fitness is related to health in a reciprocal manner. Other factors, such as lifestyle, psychological attributes and the physical and social environment, are also thought to affect the physical activity, health and fitness continuum. Whether such a model is appropriate for children is open to question.

Suggesting that children's physical activity participation will influence both health and fitness is inaccurate. The majority of relevant child research indicates that structured physical activities fail to promote favourable alterations in health and fitness. If structured activities do not provide an adequate stimulus for health and fitness benefits, it may be assumed that unstructured activity would fail to do so. Therefore, even when examining a small part of the model it appears that this framework may be less relevant for children.

A more suitable framework specific to children has yet to be determined. Interactions between physical activity, health and fitness have been partially examined. Cross-sectional studies of these relationships will commonly fail to describe the unique physiological changes that children undergo during normal growth. As such, any form of theoretical framework should include longitudinal analysis to fully explain changes in the physical activity, health and fitness of children during growth. Similarly, non-physiological factors, often overlooked during child studies, must be assessed. The contribution of psychological factors to the physical activity, health and fitness continuum has been rarely examined.

Physical activity has been associated with improved feelings of well being, elevated self-esteem and reductions in anxiety (Bouchard et al., 1993). Such relationships, whilst well established for adults, have yet to be established for children. This lack of evidence again questions the use of the framework of Bouchard and co-workers to accurately assess the relevant components of the physical activity, health and fitness continuum in children. Whilst we understand that physical activity participation will be influenced by a myriad of physical, social and environmental influences, a definitive framework has yet to be established.

To provide an accurate framework from which to describe a children's physical activity, health and fitness continuum, the Bouchard et al., (1993) model requires rebuilding. An assessment of the factors that affect physical activity participation

will be difficult. A multitude of techniques, innumerable testers and logistical constraints may make such a study difficult to implement. Additionally, the confounding effects of growth must be included in any framework involving children, so creating a further variable for analysis.

The current study was designed to provide a basic framework from which to recreate the physical activity, health and fitness continuum specifically for the developing child. Primarily, this study will focus upon relationships between physical activity and the health-related fitness of growing children.

Using the links outlined in the model of Bouchard et al., (1993) we hypothesised that;

"Children's participation in free-living physical activities will promote a favourable risk factor profile, increases in cardiorespiratory fitness levels and have a positive effect upon physical self-perceptions."
(Hypothesis 1)

And that;

"As children grow levels of physical activity participation, risk factor prevalence, cardiorespiratory fitness and physical self-perceptions will remain stable."
(Hypothesis 2)

Results from this study will facilitate our understanding of how physical activity participation will affect health-related fitness and provide a template for reconstructing the Bouchard et al., (1993) model specific to children. Additionally, this study will be unique in providing an analysis of the changes in Liverpool children's physical activity and health-related fitness during growth. Importantly, the current study will assess both physiological and psychological influences upon physical activity participation and their effects upon health and fitness. Health investigations during the growth period leading from childhood to adolescence are under-represented in literature, and will be addressed during this study.

2.0 Review of Literature

The inverse relationship between physical activity participation and chronic disease has been well-reported (Paffenbarger et al., 1986; Berlin and Colditz, 1990; Blair, 1995; Paffenbarger and Lee, 1996). Less is known about the effects of low levels of physical activity during youth, and subsequent influences upon health and well being during later life. Whilst children are generally free from chronic disease, this period of life may have the greatest influence upon the subsequent aetiology of chronic disease.

For children, the benefits of participating in free-living physical activities remain uncertain. In studies of the health benefits of physical activity, the focus has been on relationships between physical activity and chronic disease risk factors. These relationships, when derived from studies of children, remain equivocal and are often confounded by the effects of growth and development.

2.1 The health, fitness and physical activity continuum

Defining *health* is problematic. The basic definition, *an absence of illness* (Gyarfas, 1992), appears to be overly simplistic, and fails to encompass the many influences upon general health. Recent consensus statements include greater interaction with social influences, quality adjusted lifespan and survival prospects for the subject (Bouchard et al., 1993; Shephard, 1995). Definitions of health require the inclusion of physical, social and psychological dimensions (Bouchard et al., 1993). Positive health is associated with the enjoyment of life and the ability to withstand challenges, whilst negative health is related to morbidity and premature mortality (Shephard, 1995).

Physical activity is defined as any body movement produced by skeletal muscles that results in a substantial increase in energy expenditure from the resting state (Bouchard et al., 1993). This definition encompasses both free-living and structured exercise. Similarly, the contribution of *health-related fitness* to general health state has been highlighted (Bouchard et al., 1993; Shephard, 1995). Physical and motor fitness components provide an overall measurement of the functional capacity of the individual to perform free-living activities. When combined with the potentially confounding influence of genetic disposition the

framework of Bouchard et al., (1993), shown at Figure 1, provides a multi-variate approach to assessing relationships in both the social and physical environments.

This complex theoretical framework outlines the extrinsic and intrinsic influences from which to identify links between physical activity, health and fitness. Analysing these links will provide a more complete approach to identifying the determinants of physical activity. A fully inclusive examination of such a framework has yet to be reported. Whilst much information exists on individual components of this model, attempts to examine these postulated links remain uncommon.

Applying the framework of Bouchard et al., (1993) to children may be flawed. Several of the links may be considered relevant only to adults. Physical activity, defined as leisure, occupational or other chores, may not reflect the content of children's free-living activities. Similarly, the child's choice of physical activity may be restricted greatly by a myriad of extrinsic factors. The availability of resources, safety of an external physical environment and time or financial restraints upon both child and parents may affect physical activity participation. To apply such a framework to children a more comprehensive analysis must be performed, with non-relevant or non-measurable factors, such as occupational activity, removed for clarity.

In reconstructing an appropriate framework for children the three components of the physical activity, health and fitness continuum should be considered individually. A subsequent assessment of possible links between these areas may then be undertaken.

2.2 Physical Activity - Measurement

The measurement of free-living physical activity is contentious. No criterion method of assessing children's physical activity has been agreed upon. Monitoring the free-living physical activity of children has been performed by means of direct (physiological), or indirect (observational/questionnaire), methods. The most common methods used to measure children's physical activity are outlined in Table 1.

Table 1. Principal methods of assessing habitual physical activity.

Direct	Indirect
Indirect calorimetry	Direct observation
Motion sensors/ accelerometers	Activity questionnaire
Heart rate monitoring	Prospective/ retrospective diary recall
Doubly-labelled water	

Each of these methods has been utilised as a quantifiable measure of responses to free-living physical activity. The choice of a suitable instrument to assess children's physical activity must be subject to several primary considerations:

- Habituation effects for different age children -
  Heart rate monitoring/accelerometry/direct observation techniques
- Cognitive ability of children to report physical activities accurately -
  Questionnaires/diary recall
- Encumbrance to normal physical activity -
  Heart rate monitoring/accelerometry/direct observation

When choosing the most appropriate method of physical activity assessment, study design, fiscal constraints, study cohort outline and time resources must always be considered (Kemper, 1985).

- Indirect methods of assessing physical activity

Direct observations can provide information on the duration and pattern of children's physical activity, but are characterised by being intensive in use of human resources, financially restrictive and time consuming (Ballor et al., 1989). Observers employed in the study of Bailey and co-workers (1995) required 5.5 months of training to achieve a 90% agreement level between 2 researchers. Given that only 12 subjects were subsequently observed, it is clear that tester resources will be severely limited when using this technique. Importantly, if subjects react to being observed continually this may affect normal activity patterns. The familiarisation effect of being monitored creates a need for between

15.0 and 18.7 full days of monitoring to achieve reliability of r>0.80 (Sallis et al., 1995). Whilst this extended familiarisation period severely limits the use of this technique, especially for studies with limited testers/finance, direct observation provides important information as to the duration, tempo and frequency of children's physical activity.

A variety of questionnaires have been devised, often for specific population demands, and consequently with little validity to populations outside of the study cohort. The construct validity of child-specific questionnaires has rarely been reported. Moderate to high relationships (r= 0.43 to 0.70) have been reported between self-reported physical activity and heart rate monitoring (Simons-Morton et al., 1994; Gilson et al., 1997) yet poorer relationships have also been reported (Janz et al., 1995).

Commonly, diary and recall surveys overestimated physical activity by around 67% (Simons-Morton et al., 1994; Janz et al., 1995; Gilson et al., 1997). All studies are similarly flawed as no criterion method of physical activity assessment exists. The use of heart rate monitoring as a "gold standard" (Gilson et al., 1997) will reflect a relationship with increased energy expenditure (Freedson, 1989). Heart rate monitoring overestimated actual energy expenditure in children (Emons et al., 1992; Torun et al., 1996). Although the use of heart rate monitoring may be practical, it is of limited use to determine energy expenditure during free-living physical activities. Laboratory based assessments of the actual energetic cost of free-living activities are common, yet often fail to include a whole range of activities in "real time". Children's physical activity patterns consist of short high-intensity "bursts" often lasting less than 15 s (Bailey et al., 1995). Currently, no reported evidence exists examining the heart rate/energy expenditure relationship for such "bursts". Additionally, other factors known to influence heart rate, such as transient emotional state, illness and temperature (Saris, 1986; Freedson, 1989) may affect acute cardiac response. Consequently, in a free-living situation heart rate monitoring may not be a valid and reliable measure of actual energy expenditure and should not be used as a gold standard.

These findings emphasise the problems associated with using recall questionnaires in children. From an information-processing perspective, children may not have the ability to accurately encode, store and retrieve information

(Baranowski, 1988). Several sources of cognition-related error have been proposed, including memory decay with age, recall primarily of a rare event and lack of form completion motivation (Baranowski, 1988). These last two concerns are most commonly directed at children. The ability of the child to recall activities accurately has been questioned (Saris, 1986; Simons-Morton et al., 1994). Attention to the activity of concern, understanding the concepts behind such activity, understanding the levels of intensity of activity within the recall and accurately estimating the duration of activity may be difficult for children. It does appear that children do tend to overestimate the level of physical activities performed, and the use of questionnaire based methods should be treated cautiously.

Small, unobtrusive accelerometers have been proposed as a simple method to quantify physical activity. The Caltrac device contains a cantilevered beam, sensitive to movement in the vertical plane. When movement is instigated, the unit plots an acceleration curve to generate an energy value. Calorific expenditure is calculated using the subject's body mass, height, age and gender as covariates, whilst activity counts are determined using predetermined constants. For children aged 9-12 years, significant correlations have been reported between the Caltrac and direct and indirect measures of energy expenditure, during low, medium and high intensity exercise (Haymes and Byrnes, 1991; Bray et al., 1992; Aznar et al., 1995; Sallo, 1995).

Whilst the Caltrac system has proven to be a low-cost, socially acceptable method of quantifying physical activity, the reliability of the unit is questionable. Such findings indicate the potential unsuitability of the device in accurately assessing the energy expenditure of children at higher intensities of effort.

Haymes and Byrnes (1991) reported overestimation of 37% in children during running and walking protocols. In a meta-analysis of available validation studies, Aznar et al. (1995) reported over- and under-estimation of total energy expenditure by the Caltrac system, of between -13.3% and +46%. Under-estimation of energy expenditure was reported only when the subject was assessed using indirect calorimetry techniques. Residence in habitated calorimeters will restrict the pattern of children's free-living physical activity. Such restrictions will limit the use of accelerometers when validated against indirect calorimetry techniques. Bray et al.

(1992) utilised treadmill testing as a criterion for Caltrac validation and reported greatest over-estimation (+25%), during brisk walking. Underestimation by the Caltrac device of more precise, fine muscular movements may compensate for overestimation in terms of net energy expenditure (Ballor et al., 1989).

The use of single plane accelerometers may not be wholly suited to free-living physical activity. Uni-dimensional accelerometers appear to be insensitive in the assessment of sedentary and low-active movements. Additionally non-weight-bearing activities, such as cycling or swimming, may suffer when the vertical component of a movement is assessed. A multi-plane accelerometer may provide a measure of movement not just in the vertical plane.

Multi-plane accelerometers are a recent innovation. Information on the reliability and validity of multi-plane accelerometers, for children, is scarce. Matthews and Freedson (1995) compared energy expenditure using a multi-plane accelerometer, the Tritrac. Twenty-five adults (age 26.7 $\pm$ 3.9 year) wore the Tritrac unit for 7 days, and completed both 3 days and 7 days physical activity questionnaires. Energy expenditure was classified using conversion of physical activity into MET values (1.0 [*inactivity*] = sleeping; 8.0 [*very hard activity*] = running).

The Tritrac unit significantly underestimated total daily energy expenditure when compared to self-report measures by 14% ($P<0.01$). Considering that self-report measures tend to over-estimate energy expenditure, validating the Tritrac with this unit may be problematic. At present, direct measurements of energy expenditure must be considered the most effective method of determining energy expenditure. Whilst the unit agreed with self-report of physical activity (physical activity was significantly related to Tritrac values over 7 days [$r=0.77$; $P<0.001$] and 3 days [$r=0.82$; $P<0.001$]) the validity of the unit must be established using a more valid measure of energy expenditure.

Matthews and Freedson (1995) reported that the Tritrac system provided only a partially more accurate estimate of daily physical activity than single plane accelerometry (Caltrac). The Tritrac unit records minute by minute energy expenditure, and are advantageous over the Caltrac, which provides a cumulative score to assess physical activity and energy expenditure. The use of minute by minute recording provides information on the quantity, intensity and pattern of

physical activity. Importantly, the Tritrac unit provides a measure of physical activity within the multi-dimensional plane. This feature is important as free-living physical activity consists of movement within the diagonal vertical and horizontal planes of motion.

Whilst the validity and reliability of accelerometers have been investigated, a dearth of information exists on the free-living physical activity of children using this technique. Accelerometers fail to provide information upon the physiological responses of the body to physical activity. In determining the appropriate dose-response of physical activity for health and fitness benefits, the device provides little more than an estimate of energy expenditure during a whole day. Direct physiological monitoring of physical activity may be the only sensitive method of assessing the attainment of physical activity recommendations in a free-living environment. British research groups have utilised questionnaire and observation methods of physical activity assessment, and, more recently, physiological monitoring using heart rate telemetry systems.

- Physiological monitoring of physical activity

Physiological responses to physical activity can be measured using a variety of techniques. Indirect calorimetry, whilst providing valuable data on the energy cost of various activities, is both cumbersome and restrictive. The use of this technique would be expected to alter the free-living physical activity of subjects (Saris, 1986; Laporte et al., 1987). Stable isotopes have been used to assess energy expenditure under free-living conditions. The doubly-labelled water technique provides up to 10 days of continual measurements in children (Black et al., 1996), without undue encumbrance to the subject. The method does not provide information as to the pattern, duration or intensity or physical activity. The lack of "sensitivity" makes this technique unsuitable for assessing the tempo of physical activity, and provides little more than a direct measurement of energy expenditure over an extended period. Moreover, the doubly-labelled water method is costly, a major influence in large-scale, longitudinal studies (Kemper, 1986).

A widely used direct index of British children's physical activity is heart rate monitoring. Heart rate versus time curves may provide information upon the pattern, duration and intensity of physical activity. The heart rate response reflects

the relative stress placed upon the cardiorespiratory system. Additionally, by assessing the pattern of physical activity the relationship between heat rate and $\dot{V}O_2$ will provide indirect estimates of the energy cost of various activities.

Although heart rate has been proposed as a reliable indicator of daily physical activity in children (Durant et al., 1993), concern is raised as to the suitability of the technique to assess energy expenditure (Freedson, 1989). Emons et al. (1992) used residence calorimeters to assess the validity of heart rate monitoring to assess the daily energy expenditure of children aged 7-11 years. Nineteen subjects spent 24 hours in a residence calorimeter and completed a comparative study of energy expenditure using indirect calorimetry, doubly-labelled water and heart rate techniques. Short-range radio telemetry systems were set to record heart rate minute by minute. Further one day assessments of heart rate were made outside of the calorimeter to provide comparable data with the doubly-labelled water method. Emons et al. (1992) reported that heart rate overestimated daily energy expenditure by 10.4%, in agreement with adult studies (Torun et al., 1996). Hebestreit and Bar-Or (1995) reported climatic heat stress to be responsible for 1.6% of total energy expenditure overestimation. The limited activity undertaken by subjects in this study emphasises that heart rate monitoring may be an insensitive measure of children's physical activity at lower intensities of effort.

Other studies examining the validity of heart rate in assessing energy expenditure are rare. Despite this lack of data, Torun et al., (1996), in a meta-analysis of available studies, reported that heart rate may provide a suitable method of assessing energy expenditure in children, especially when validated using doubly-labelled water. The use of doubly-labelled water to validate free-living heart rate monitoring provides a "safety" measure in a free-living environment. Unfortunately, this study only utilised one day of heart rate data, contradicting the findings of Sallis et al. (1995), who recommended 1.9-8.9 days of measurement to achieve a reliability coefficient of $r>0.80$.

Whilst overestimating daily energy expenditure, heart rate does appear to be a more accurate index than accelerometry. When using heart rate to measure children's physical activity, the use of estimates of daily energy expenditure must be considered problematic. The heart rate-oxygen consumption relationship is

influenced by transient factors such as training state, the amount of active muscle mass, ambient temperature and psychological stress (Freedson, 1989). Adjusting heart rate to correct for actual energy expenditure is also problematic. Studies involving children have derived correction factors for heart rate during sleep (Hebestreit and Bar-Or, 1995) yet no available literature shows such correction during physical activities. Until such factors are made available, heart rate should not be considered a gold standard for the assessment of energy expenditure.

Despite limitations in assessing energy expenditure, heart rate monitoring may be the single best method of assessing the pattern, duration and intensity of physical activity. Recent technological advances have provided light-weight methods of heart rate monitoring which do not provide undue encumbrance to normal physical activities. Currently, over twenty short- range radio telemeters are available. The radio telemeters consist of a chest strap transmitter and wrist-watch receiver, which provide an unobtrusive method of assessing free-living physical activity. Several studies have established the reliability of short-range telemetry systems in assessing heart rate at varying intensities of effort (Tsanakas et al., 1986; Leger and Thivierge, 1988; Treiber et al., 1989; Durant et al., 1993).

In studies of children's free-living physical activity, recording times of 12 h are often used, approximating the waking period (09:00 to 21:00 h). The Polar Sportstester (Kempele, Finland) has a 33 h recording capacity when the recording interval is minute by minute. The Polar unit calculates initial heart rate via a pulse measuring algorithm of the first four readings, thereafter other results are calculated by averaging (Tsanakas et al., 1984). During exercise, the recording interval should be short enough to assess the acute increases and decreases in heart rate accurately.

Unfortunately, a 5 or 15 s interval will only allow between 2.5 and 7 h of continuous recording using the Polar Sportstester system. This is insufficient for the assessment of physical activity during waking hours (average recording time 12 hours, Armstrong et al., 1990; 1991; 1992; 1995; Gilson et al., 1997). Additionally at the 5 s interval time bradycardic responses, common to the resting and sleeping periods, may not provide a long enough interval time to provide an average heart rate accurately, once the initial algorithm has been calculated. In studies of free-living physical activity, 60 s recording will provide both the volume

and recording capacity for waking hour's activities and heart rate measurement during the sleeping period if required.

The Polar Sportstester short-range telemetry system appears to be the most suitable method of assessing heart rate responses during extended measurement periods. For young children, the validity of the Polar Sportstester system was established by Treiber et al. (1989). Ten children (10 years) had their heart rate measured by means of the Sportstester device and criterion electrocardiogram techniques. Children were measured at rest and during three exercise workloads, equating to 117, 137 and 162 beats.min^{-1}. Correlation coefficients were used to determine relationships. The Sportstester device was highly correlated with the ECG at baseline and all exercising workloads ($r = 0.97$ to 0.99; $P<0.01$). This relationship was also confirmed using activities such as walking, running and throwing in a field setting ($r = 0.98$ to 0.99; $P<0.01$). These findings confirmed the use of the Polar Sportstester device as a valid and reliable measure of heart rate in both a laboratory and field setting.

- A criterion method of physical activity assessment.

Whilst many physical activity measures have proven to be reliable question remains as to the validity of these methods in assessing children's physical activity. Of all measures discussed so far there remains no agreement as to a gold standard for physical activity assessment. Habitated calorimeters and direct measurement of gas exchange are reliable and valid measures of gas exchange. Unfortunately, these methods unduly restrict normal patterns of physical activity and are unsuitable in a free-living environment. Doubly labelled water measurements are costly and invasive and do not provide information upon the volume or mode of physical activity undertaken by the child. Questionnaires show a large over-estimation of physical activity participation by children. These methods also provide little information upon the tempo of physical activity performed. Accelerometers provide little more than an assessment of the energetic cost within restricted planes of movement, and again do not provide information as to the volume or tempo of physical activity.

Consensus recommendations of an appropriate physical activity prescription for adolescents use both time and intensity indices (Sallis and Patrick, 1994). Despite

overestimating the actual energy expenditure of children, heart rate monitoring may be the most effective method of assessing the volume, tempo and intensity of children's physical activity. Heart rate monitoring is a unobtrusive piece of equipment. The system should not interfere with children's normal patterns of physical activity as with direct observation and direct spirometry techniques. The ease of data retrieval also makes the heart rate monitoring system attractive to researchers.

2.3 The physical activity patterns of British schoolchildren

- Indirect measurements

Whilst no criterion method of physical activity exists, information suggests that British children are relatively sedentary. Reports of British children's physical activity patterns are rare. These studies have mainly used heart rate, direct observation and questionnaire-based techniques.

In a study of 56 pre-adolescent children (aged 5 to 10 years), Sleap and Warburton (1992) directly observed children for two 4-h periods. The problems associated with adequate habituation have previously been discussed, and this study failed to meet the recommended minimum period (Sallis et al., 1995). Results from this study showed that 30% of free-living physical activity was performed at "active" levels of intensity.

The definition of "active" was somewhat arbitrary. Moderate to vigorous physical activity was defined as activity that elicited a heart rate response in excess of 140 beats.min^{-1}. This value was derived from the direct observation system of O'Hara et al. (1989). O'Hara and co-workers quantified observed physical activity against the measurement of minute by minute heart rate in a sample of 36 children aged 8 to 10 years. Children were observed during physical education lessons and wore short-range heart rate telemetry systems. Observation occurred for 1-day only, representing a problem in the minimum habituation period for both direct observation and heart rate monitoring methods (Sallis et al., 1995). The "O'Hara system" used an activity point score based upon stationary, slow and rapid trunk movement. Time-series regression analysis showed that 72% of variance in heart rate was accounted for by physical activity scores ($P<0.05$). Activities that were of

a moderate to vigorous intensity were equivalent to heart rate thresholds above 140 beats.min^{-1}.

The heart rate equivalent scores proposed by O'Hara et al. (1989) must be interpreted with caution. Data collection was only performed during structured physical education lessons. This presents problems when applying these scores to free-living physical activity. No physical activity profile was reported to provide information as to the *tempo* of the lessons. Additionally, only 2 subjects per lesson had their heart rate monitored, possibly creating an unrepresentative sample. Whilst an increase in observed physical activity is associated with increased heart rate the lack of comparative data investigating such relationships suggest caution when using these thresholds in children from differing demographies.

Sleap and Warburton (1992) measured the likelihood that physical activity would be of a moderate to vigorous intensity (heart rate >140 beats.min^{-1}). This estimation must require some form of reliability and calibration using appropriate physiological measurement. In this study, such reliability testing was not performed. Despite such flaws, this study did provide important evidence that levels of free-living physical activity, in British schoolchildren, are not sufficient to promote health and fitness benefits. This study also emphasised that schoolchildren participate in unstructured moderate to vigorous physical activity, often lasting less than 5 min

Using questionnaire surveys, the Health Education Authority (1991) assessed the physical activity of 10 000 children (9-15 years) during the school-week. Children performed an average of 4.7 hours of exercise per week. Boys generally performed more exercise per week than girls did (5.2 v 4.2 hours respectively). Children of lower socio-economic groups performed less exercise than the mean for the study (4.4 hours). Exercise levels decline with increasing chronological age (>12-13 years). These findings echoed consensus, and empirical evidence showing the decline in exercise levels with age (Kemper, 1995; Shephard, 1995).

The study by the Health Education Authority (1991) provided basic descriptive data on the amount of exercise performed during the normal school-week. The Health Education Authority did not report the *tempo* of physical activity performed and provides little evidence on the volume of children's physical activity. Riddoch

et al. (1990) used 7-day recall questionnaires to assess the physical activity patterns of 3 211 Northern Irish secondary schoolchildren (aged 11-18 years). Results from this study showed that boys were more active than girls were at all ages, with younger age boys considerably more active than other age and gender groups. The decline in regular physical activity occurred at 13 years (girls), and 14 years (boys), echoing the findings of the Health Education Authority (1991) and Kemper (1995).

Other main findings of the Northern Ireland Fitness survey were that:

- 20% of boys and 30% of girls were involved in exercise for less than 2 hours during the preceding 7 days.
- 50% of boys and 70% of girls were involved in vigorous exercise for less than 1 hour during the preceding 7 days.
- 10% of boys and girls took no exercise at all during the preceding 7 days.
- 20% of boys and 30% of girls performed their only weekly exercise during physical education and games lessons.

The findings of the Northern Ireland survey reinforced opinion that children's free-living physical activity is low. Evidence to support the construct validity of retrospective physical activity questionnaires remains limited and other constraints are apparent when using these instruments with children. As previously discussed. appropriate skills required for accurate recall are essential for the completion of questionnaires (Baranowski, 1988).

In the Northern Ireland survey, moderate to vigorous physical activity was defined as exercises that causes slight or considerable breathlessness. Validation studies comparing these rating scales to direct physiological measurements are rare. Consequently, information derived from these studies will be subjective at best; a point emphasised, in their methodology, by Riddoch et al. (1990). Similarly, the design of such questionnaires provides little information as to the pattern of physical activity performed.

Selective recall of activities must be considered problematic during free-living activities. Daily variation in physical activities provides unique experiences that may not always be associated with concepts of physical activity. Without external guidance, the choice of selected activities as contributing to free-living physical

activity may be missed. Children may not perceive roller skating, skateboarding or dancing as being physically active in the way they perceive running or invasion games. Subsequently, they may fail to record such activities accurately in recalls. The systematic identification of all components of activity must be attended to. Without accurate recognition the ability to recall information about an activity characteristic must be limited (Baranowski, 1988).

The Northern Ireland Fitness Survey indicated that few children experience regular exercise during schooldays, reflecting the findings of other large-scale British surveys (Health Education Authority, 1991; Simmonds et al., 1995). Simmonds et al. (1995) assessed the physical activity of 702 children, from school year 7 (aged 11-12 years) using 7-days diary recall. Using guidelines for adolescent subjects (*Guideline 1*; 3 or more sessions per week of activity lasting 20 min or more), the authors reported only 28.6% of boys and 22.5% of girls attained these recommendations (Sallis and Patrick, 1994). Results from this study, whilst being limited by recall methods, indicate that younger children do not appear to be sufficiently active to gain health benefits.

Again, question is raised as to *Guideline 1* representing the normal physical activity of children. Children do not sustain physical activities for continuous periods. When physical activity is assessed as the cumulative minutes activity performed during the day (*Guideline 2*; 30 min or more of moderate to vigorous physical activity daily), Simmonds et al. (1995), reported 72.9% of boys and 62.3% of girls attained this guideline. These findings further emphasise the sporadic nature of children's free-living physical activity.

Results of direct observation and questionnaire-based studies showed that British children are inactive when using the consensus *Guideline 1*. In contrast, children did attain *Guideline 2* recommendations far more readily. Unfortunately, British studies commonly fail to assess the cumulative minutes of physical activity in empirical studies. Caution should be used when interpreting such findings, however, as little reported dose-response data exist on the contribution of cumulative physical activity to health and fitness.

- *Direct measurements*

Armstrong and co-workers, at the Physical Education Research Centre, Exeter, provided the first reported British information on the heart rate response to physical activity in schoolchildren. In the study of Armstrong et al. (1990a) 103 boys (13.1 ± 1.2 years) and 163 girls (13.1 ± 1.3 years) wore the Polar Sportstester 3000 system for 3 consecutive schooldays. A smaller sub-sample had physical activity measured on a Saturday. The number of continuous periods with heart rate elevated >139 beats.min^{-1} was assessed, as was the percentage of time with elevated heart rate above this threshold. Results showed that 3.9% of boys and 0.6% of girls achieved 3 or more continuous 20 min periods with heart rate >139 beats.min^{-1}. Seventy seven percent of boys and 87 percent of girls did not perform a single 20 min period with heart rate >139 beats.min^{-1}. Boys spent a significantly greater percentage of time with heart rate >139 beats.min^{-1} than girls during weekdays ($P<0.01$) and weekends ($P<0.05$). No significant differences were identified in the number of continuous periods of physical activity among maturity groups of either gender ($P>0.05$).

The first of the Exeter studies formed a basic "template" for subsequent physical activity assessment using heart rate techniques. Several studies have used the 3 consecutive days of monitoring protocol and the >139 beats.min^{-1} heart rate threshold (Armstrong et al., 1991; 1996; Armstrong and Bray, 1992; Riddoch et al., 1992; Al-Hazzaa and Sulaiman, 1993; Gilbey and Gilbey, 1995; MacManus and Armstrong, 1995; Sallo and Silla, 1997). Whilst the use of three consecutive days of monitoring meets the guidelines for habituation outlined by Sallis et al. (1995), the use of the >139 beats.min^{-1} heart rate threshold remains questionable.

- Heart rate thresholds used in studies of children's physical activity

The 139 beats.min.$^{-1}$ threshold, used in the first of the Exeter studies, was previously used in the study of MacConnie et al. (1982). MacConnie and co-workers assessed the free-living physical activity of 59 children aged 6-7 years using heart rate monitoring techniques. Their study design used three heart rate thresholds, 110-139 beats.min.$^{-1}$, 140-159 beats.min.$^{-1}$ and >159 beats.min.$^{-1}$. These thresholds were chosen based on those used by Massicote and Macnab (1974). In this training study 36 American boys (11-13 years) were assigned to

training groups based upon baseline fitness level. Children exercised for 12 min, three times weekly for a period of 6 weeks. The 139 beats.min.$^{-1}$ threshold was derived from the lowest training group. Higher training thresholds of 150-160 beats.min.$^{-1}$ and 170-180 beats.min.$^{-1}$ were also used. At submaximal workloads the physical work capacity of the children, as measured by heart rate, improved significantly at all thresholds ($P<0.05$). Changes in maximal aerobic power only improved in the higher intensity training group. The response of an individual's submaximal heart rate was, therefore, used as the basis for MacConnie and co-workers, when selecting the 139 beats.min.$^{-1}$ and 159 beats.min.$^{-1}$ thresholds.

Given the lack of supporting dose-response data it is surprising that many studies have continued to use the 139 beats.min.$^{-1}$ threshold. The 70% of $\dot{V}O_2$ max threshold has been used to provide an estimate of vigorous activity (Armstrong and Bray, 1991; Riddoch et al., 1991; Al-Hazzaa and Sulaiman, 1993; Gilbey and Gilbey, 1995; Armstrong et al., 1996) and equates to 159 beats.min^{-1} in children and adolescents. Again, empirical findings do not suggest that this heart rate threshold will be sufficient for health and fitness benefits. The variation in individual heart rate responses, and the gradient between exercising and resting heart rate, must question the use of percentage maximal heart rate as fitness thresholds.

Pre-determined heart rate thresholds do not account for individual baseline heart rate, and subsequent deflection during activity and exercise. As the individual response to similar workloads varies considerably (Astrand and Rodahl, 1986), the heart rate reserve (HRR) method would best express this "individualistic" response to physical activities.

The HRR is the percentage of difference between the resting and maximal heart rates and is calculated as:

$$HRR = HR_{rest} + TInt.(HR_{max} - HR_{rest})$$

where: Hr_{rest}- *resting heart rate*
HR_{max}- *maximal heart rate*
TInt. - *training intensity (e.g., 75% HRR = 0.75)*

Continuous exercise at, or above, the 75% HRR (equivalent to 170 - 180 beats.min^{-1}) has been shown to produce a cardiorespiratory training response in children (Massicote and Macnab, 1974). The 75% HRR prescription has recently been included within the consensus statement for appropriate physical activity

known to provide cardiorespiratory fitness benefits (Morrow and Freedson, 1994; Sallis and Patrick, 1994). Whilst several well-controlled training studies have provided compelling evidence for the benefits of higher-intensity exercise, HRR thresholds have rarely been used despite their relevance. Importantly, the expression of appropriate free-living physical activities above pre-determined HRR thresholds is uncommon.

The use of the HRR, at varying intensities of effort, will provide a sensitive method of accounting for differences in gender, age and individual variation in resting and maximal heart rate (Stratton, 1996). There is substantial intra-age variation, of between 10-15 beats.min^{-1}, for maximal heart rate (Malina and Bouchard, 1991). This variation must prevent the use of estimated maximal heart rate using the 220 - age formula (Astrand and Rodahl, 1986). Several studies have shown that the estimated 220 - age maximal heart rate is equivalent to heart rates measured at the cessation of incremental exercise (Saris et al., 1985; Welsman and Armstrong, 1992; Al-Hazzaa and Sulaiman, 1993; Armstrong et al., 1996). The motivation of the subject to continue to exhaustion must be considered essential in providing an accurate maximal heart rate, for subsequent inclusion in HRR estimation.

Similarly, estimation of HRR thresholds has rarely utilised true resting heart rate as measures of baseline. Resting heart rates (HR_{rest}) when seated or recumbent, may be easily measured in the laboratory setting. In a paper examining the reliability and validity of heart rate monitoring in children Durant et al., (1993) performed laboratory-based measurements of HR_{rest}. Children (n = 131, 5 to 7 years) were measured after lying at rest for 5 min Five heart rate recordings were taken 1 min apart, with the mean of the last 4 readings averaged. Between measurement correlation was highly significant (r = 0.93). Similar protocols have also been used by Durant et al., (1992), Kemper (1995), Pate et al., (1996) and Sallo and Silla (1997). Despite these well used protocols it is questionable that HR_{rest} provides a true approximation of basal heart rate.

Resting heart rate, measured during waking hours, will be subject to several extraneous influences. Climate, thermogenic effects of diet, illness and transient emotional state may affect the measurement of a true resting heart rate (Saris, 1986; Freedson, 1989; MacArdle et al., 1991; Hebestreit and Bar-Or, 1995). To

gain a more accurate assessment of baseline heart rate measurement should be undertaken during true "rest", the sleep phase.

Heart rates recorded during the sleep period (HR_{sleep}) are generally lower than HR_{rest} by up to 5 beats.min^{-1} for subjects aged 10 years and over (Anderson et al., 1987). Despite the relatively small variation between HR_{rest} and HR_{sleep} the true criterion baseline heart rate must be the HR_{sleep}. Assessing heart rate during sleep will alleviate those extraneous variables that may affect the heart rate response. Importantly, the inclusion of directly measured lowest and highest recorded heart rates will account for individual differences in HRR. Stratton (1996), referred to the problems of measuring HR_{sleep} and subsequent application of group-specific HRR thresholds for general populations. Heart rate reserve thresholds will provide a more sensitive measure of the heart rate response to physical activity.

Stratton (1996) estimated the 50% and 60% HRR for 10-12 year old children. The 50% HRR closely approximated the 139 beats.min^{-1} thresholds used in many heart rate monitoring studies. A more vigorous physical activity threshold of 159 beats.min^{-1} has also been used in many heart rate monitoring studies, equivalent to an estimated 60% HRR. In this review Stratton (1996) estimated HRR using HR_{rest} as a measure of baseline heart rate. Similarly, the use of the 220 - age criterion to determine HR_{max} does not reflect individual differences in the physiological response to maximal exercise.

The HRR appears to be a more sensitive method of assessing individual heart rate thresholds than an arbitrary percentage of $\dot{V}O_2$ max, or percentage of maximal heart rate. Unfortunately, there is a dearth of dose-response data, for physical activity at different HRR thresholds. Clearly, the appropriate heart rate thresholds shown to provide health and fitness benefits, remain to be identified. Whilst participation in vigorous activities remains a primary objective, the contribution of limited amounts of moderate activity to overall health has received limited attention. Elevations in heart rate to moderate levels of intensity may have positive health benefits (Sallis and Patrick, 1994; Blair, 1995) and assessment of physical activity must include recognition of such thresholds within analysis.

- Constructing an appropriate series of heart rate thresholds

When constructing appropriate heart rate thresholds, the 75% HRR will be most reflective of vigorous physical activity, and of probable health and fitness benefits. Given the overwhelming opinion that health and fitness benefits are gained above the 75% HRR using lower activity thresholds may be useless. By including the 60% HRR, however, information on children's participation in moderately vigorous activities may be gained. Similarly, the use of the 139 beats.min^{-1} threshold will allow for comparison with many other studies (MacConnie et al., 1982; Armstrong et al., 1991; Armstrong and Bray, 1991; Al-Hazzaa and Sulaiman, 1993; Armstrong et al., 1995 Gilbey and Gilbey, 1995; Armstrong et al.,1996).

- Other studies of British children's' physical activity, assessed using heart rate monitoring

Armstrong and co-workers (1990; 1991; 1996) have performed a series of direct measurements of children's' physical activity using a study cohort from South-west England. A summary of findings from the Armstrong group's studies is presented in Table 2.

The studies of Armstrong and co-workers consistently showed that British children did not experience the volume, duration or intensity of physical activity sufficient to promote health and fitness benefits (*Guideline 1*, 3 x 20 min weekly; Sallis and Patrick, 1994; Health Education Authority, 1998). The methodology employed by Armstrong's group commonly used fixed heart rate thresholds (139/140 and 159/160 beats.min^{-1}). These thresholds do not take into account individual variations in heart rate above the baseline. Consequently the deflection from baseline during free-living physical activity may be less if the subject has a lower baseline to begin with. The use of HRR methods would provide a more sensitive measure for estimating individual thresholds, yet Armstrong and co-workers did not utilise this method.

Table 2. Summary of findings assessing the physical activity of British children using heart rate monitoring - Armstrong and co-workers.

Study	Study Cohort	Method	Findings
Armstrong et al., (1990a)	n= 266 children (163 boys, 103 girls) 11-16 years	12 waking hours HRM on three schooldays and one weekend day. Thresholds set at >139 beats.min^{-1}	76.7% boys and 87.7% of girls did not achieve one sustained 20 min period with heart rate elevated >139 beats.min^{-1}
Armstrong et al., (1991)	n= 230 children (92 boys, 138 girls) mean age 13.0 ± 1.3 years	12 waking hours HRM on three schooldays. Thresholds set at >139 and >159 beats.min^{-1}	77.2% of boys and 86.2% of girls did not achieve one sustained 20 min period with heart rate elevated >139 beats.min^{-1}. 87.0% of boys and 93.5% of girls did not achieve one sustained 20 min period with heart rate elevated >159 beats.min^{-1}
Armstrong and Bray (1991)	67 boys and 65 girls (9-11 years)	12 waking hours HRM on three schooldays. Thresholds set at >139 and >159 beats.min^{-1}	46% of boys and 31% of girls did achieve one sustained 10 min period with heart rate elevated >139 beats.min^{-1} 46% of boys and 55% of girls did not achieve one sustained 10 min period with heart rate elevated >159 beats.min^{-1}
Welsman and Armstrong (1992)	28 boys (13.6 ± 1.3 years) and 45 girls (13.7 ± 1.3 years)	12 waking hours HRM on three schooldays. Thresholds set at >140 and >160 beats.min^{-1}	37% of boys and 40% of girls did achieve one sustained 10 min period with heart rate elevated >140 beats.min^{-1} 57% of boys and 69% of girls did not achieve one sustained 10 min period with heart rate elevated >160 beats.min^{-1}
Armstrong et al., (1996)	86 boys and 43 girls (11.0 ± 0.3 years) Classified prepubescent using Tanner staging.	12 waking hours HRM on three schooldays. Thresholds set at >139 and >159 beats.min^{-1}	62% of boys and 63% of girls did not achieve one sustained 20 min period with heart rate elevated >139 beats.min^{-1} 76% of boys and 86% of girls did not achieve one sustained 20 min period with heart rate elevated >159 beats.min^{-1}

Despite the problems of threshold determination, the studies of Armstrong and co-workers showed that British children consistently fail to meet the 3 x 20 min guidelines of Sallis and Patrick (1994). Children find great difficulty in performing continuous physical activity for periods above 20 min. To assess the contribution of shorter duration physical activities, Armstrong and co-workers assessed the prevalence of 5 and 10 min periods. Their findings indicated that children were able to attain these shorter physical activity periods more readily. Physical activity of a shorter duration will contribute to the cumulative recommendations (*Guideline 2*; Sallis and Patrick, 1994), yet evidence to support a dose-response of shorter duration activity remains equivocal.

Armstrong and co-workers reported cumulative physical activity as a percentage of total monitoring time. As all monitoring took place between 09:00 and 21:00 daily (720 min), these values have been converted into total minutes to provide a comparative assessment (Table 3). Caution must be used when interpreting these values as approximate recording times were not provided.

Table 3. Conversion of the percentage of total time spent with elevated heart rates during free-living physical activity - Armstrong and co-workers.

Study	Study Cohort	Percentage of time with elevated heart rate (beats.min.$^{-1}$)	Estimated cumulative minutes with elevated heart rate
Armstrong et al.,(1991)	92 boys and 138 girls mean age 13.0 ± 1.3 years	>139 boys 6% girls 5% >159 boys 3% girls 2%	>139 boys 43 girls 36 >159 boys 22 girls 14
Armstrong and Bray (1991)	67 boys and 65 girls (9-11 years)	>139 boys 9% girls 8% >159 boys 5% girls 4%	>139 boys 65 girls 58 >159 boys 36 girls 29
Welsman and Armstrong (1992)	28 boys (13.6 ± 1.3 years) and 45 girls (13.7 ± 1.3 years)	>140 boys 6% girls 5% >160 boys 3% girls 2%	>139 boys 43 girls 36 >159 boys 22 girls 14
Armstrong et al.,(1996)	86 boys and 43 girls (11.0 ± 0.3 years) Pre-pubertal	>139 boys 9% girls 8% >159 boys 4% girls 3%	>139 boys 65 girls 58 >159 boys 29 girls 22

Converted totals for the Exeter studies showed that schoolchildren attained Guideline 2 at lower heart rate thresholds (≥ 139 beats.min^{-1}) during schooldays. At the more vigorous physical activity thresholds (≥ 159 beats.min^{-1}) children

commonly failed to attain *Guideline 2*. These findings emphasise the failure of children to perform physical activity at more vigorous intensities. Moreover, describing the free-living physical activity of these children was hindered by failing to report the high-intensity activity thought to confer health and fitness benefits (>75% HRR). When measuring free-living physical activity, it would be prudent to use several heart rate thresholds. The use of this multi-level approach would provide detail of the *tempo* of children's physical activity, yet is rarely performed.

Riddoch et al. (1991) measured the physical activity of Northern Irish schoolchildren (n = 45; 11 to 16 years), for up to 4 consecutive schooldays, using heart rate monitoring. Their results showed that these children had lower cumulative minutes of physical activity than those did reported in the studies of Armstrong and co-workers. At heart rate thresholds between 50% and 70% of predicted maximum, boys engaged in 16 min of physical activity daily whilst girls attained 13 min. Vigorous physical activity above the 70% of maximum threshold was low. Boys performed 8 min of vigorous physical activity daily, whilst girls achieved 4 min daily. Whilst no significant gender differences were reported, for total physical activity at the 50% threshold, boys were significantly more active than girls at the 70% threshold (P<0.05). When chronological age was used as a simultaneous covariate in the analyses, younger boys were significantly more active than older boys were and all girls (P,0.05).

The findings of Riddoch and co-workers further emphasised that children are relatively inactive at higher heart rate thresholds. Again, problems arise from the selection of heart rate thresholds thought to confer health and fitness benefits. Using the percentage of $\dot{V}O_2$ max as a heart rate threshold does not allow for individual differences in HR_{rest} and HR_{max} to be accounted for. Similarly, the dose-response data available for physical activity at these intensities do not suggest that health or fitness benefits will be achieved.

In many heart rate studies the choice of heart rate threshold appears to follow the precedent set by Armstrong and co-workers. Few researchers, from Britain or abroad, have utilised more expansive heart rate thresholds to provide a more qualitative assessment of free-living physical activity. Durant et al. (1993) used heart rate to assess the physical activity of 131 Anglo-, African- and Mexican-

American children (aged 5 to 7 years). Monitoring was performed on 4 consecutive schooldays.

Durant and co-workers used heart rate thresholds above 120 beats.min^{-1}, and 25% and 50% above resting heart rate, equivalent to 128 and 136 beats.min^{-1} respectively. The higher heart rate threshold again fails to reflect empirical findings related to the dose-response of physical activity for health and fitness benefits. This study provided evidence to support the reliability of lower intensity heart rate thresholds to assess day-to-day physical activity patterns. Inter-day correlation coefficients ranged from r = 0.56 and 0.81. Importantly, this study provided evidence that the minimum period required achieving a reliability of r >0.90 was 2-days, reflecting the findings of Sallis et al. (1995).

Spurr and Reina (1990) utilised a multi-level approach in assessing the free-living physical activity of 6 to 16-yr old Colombian children. Heart rate responses to physical activity were assessed within frequency ranges of 20 beats.min^{-1} (for example 100-119; 140-159 beats.min^{-1}). Additionally, the pattern of physical activity was described as a percentage of $\dot{V}O_2$ max. Using frequency range assessment, the majority of children's physical activity was spent within the lower heart rate bands (<119 beats.min^{-1}). The authors reported that only a small amount physical activity (20-60 min) elicited a physiological response >50% $\dot{V}O_2$ max. Given that the 50% $\dot{V}O_2$ max threshold was equivalent to 100 beats.min^{-1}, these findings further emphasise the sedentary nature of children's physical activity.

The multi-level approach of Spurr and Reina (1990) provided useful evidence for the low levels of attainment of physical activity associated with health and fitness benefits. Their methodology does not provide information as to the tempo of physical activity. The failure to do so will not identify the performance of those shorter periods of physical activity characteristic of children's free-living physical activity (Bailey et al., 1995).

Armstrong et al. (1990; 1991; 1996) recognised the widespread distribution of 5-min periods of moderate to vigorous physical activity at intensities of both >139 and 159 beats.min^{-1} during waking hours physical activity. In the 1996 study, of

prepubescent children, 91.9% of boys and 88.4% of girls achieved ≥3 sustained 5 minute periods of activity >139 beats.min^{-1}. At higher intensities (>159 beats.min.$^{-1}$) 66.3% of boys and 53.2% of girls achieved a similar duration of activity. These findings are commonly replicated in studies of children's physical activity from around the world (Al-Hazzaa and Sulaiman, 1993; Armstrong and Bray, 1991; Gilbey and Gilbey, 1995; MacManus and Armstrong, 1995; Sallo and Silla, 1997).

Despite such common short-duration activity, no evidence currently exists for the influence of short duration physical activities on health and fitness variables. Importantly, the use of 5-min periods may be flawed when assessing the free-living physical activity of children. In the previously cited study of Bailey et al. (1995), the median duration of low to moderate physical activity was 6 s. Higher intensity physical activities lasted only 3 s. Results from this study suggested that 95% of children's' high intensity physical activity lasted fewer than 15 s. These findings demonstrated that intermittent high intensity activities were common to younger children. Bailey et al. (1995) utilised a cohort of elementary school-children from the Los Angeles area, with no record made as to socio-economic status or demographic variables. Such findings must, therefore, be interpreted with caution when applied to a general population. However, these findings do question the use of current heart rate monitoring techniques, and criteria, in correctly assessing the physical activity of younger children.

The recognition of short-duration, intermittent activity makes the use of minute-by-minute recording questionable. Current short-range radio telemetry systems have limited recording capacity for continuous monitoring at >15 s intervals. The Polar Sportstester (Polar, Kempele, Finland) device has a 7-hour recording capacity at 15 s recording intervals, with only 2.5 hours capacity at shorter, 5-s intervals. In assessing free-living physical activity, studies commonly assess 12 hours of activity as a minimum. This makes the use of these systems difficult in the recording of physical activities of less than 15 s duration.

When assessing the potential health and fitness benefits of shorter duration activities, the cumulative total of activity above certain thresholds may provide the most sensitive estimation of children's' physical activity. In assessing cumulative minutes' physical activity, attainment of the criteria of Sallis and Patrick (1994)

may be assessed (Guideline 2, Sallis and Patrick, 1994; Health Education Authority, 1998). Moreover, information as to the sporadic nature of children's physical activity will be more forthcoming. Unfortunately, few British studies, using heart rate monitoring, contain cumulative total of physical activity during waking hours. Armstrong's group (1990; 1991; 1996) commonly reported percentage of time with heart rate elevated above set thresholds, yet actual monitoring time was not reported. When Armstrong's data are converted into monitoring minutes estimates of time spent with heart rate elevated may be made and compared to other studies (Table 4).

Analysis of heart rate studies indicates that children appear to achieve cumulative minutes of activity with moderately elevated heart rates (<75% $\dot{V}O_2$ max; <159 beats.min^{-1}). This is in accordance with the consensus guidelines of Sallis and Patrick (1994). It is important to note again the lack of appropriate dose-response data relating to cumulative activity. Despite a lack of reported studies, the attainment of the cumulative 30 min guideline must be considered a positive, and more easily achievable threshold for young children.

- Relationships between physical activity, health-related fitness and health

The model proposed by Bouchard et al., (1993) suggests that the performance of free-living physical activities will be related to alterations in health related fitness and health. Children do appear to perform little in the way of structured physical activity. Evidence as to whether such a volume of physical activity is commensurate with favourable alterations in coronary heart disease risk factors and cardiorespiratory fitness remains equivocal. The dose-response of physical activity to changes in health-related fitness and health requires investigation.

Table 4. Minutes spent with heart rate above set thresholds – a comparison of studies.

Study	Study Cohort	Heart Rate Thresholds (beats.min^{-1})	Cumulative daily minutes above heart rate thresholds
Verschuur and Kemper (1985)	224 boys and 261 girls (12-18 years)	50-75% $\dot{V}O_2$ max >75% $\dot{V}O_2$ max	68 min day^{-1} boys 58 min day^{-1} girls 12 min day^{-1} boys/girls
Spurr and Reina (1990)	106 boys and 83 girls (6-16 years)	>50% $\dot{V}O_2$ max	20-60 min day^{-1}
Armstrong et al. (1990)	103 boys and 163 girls (13.1 ± 1.3 year)	>139 beats.min^{-1}	Est. 43.2 minutes boys Est. 31 minutes girls*
Riddoch et al. (1991)	23 boys and 23 girls (11-16 years)	50-70% $\dot{V}O_2$ max >70% $\dot{V}O_2$ max	16 min day^{-1} boys 13 min day^{-1} girls 8 min day^{-1} boys 4 min day^{-1} girls
Al-Hazzaa and Sulaiman (1993)	220 boys (7-12 years)	140-159 beats.min^{-1} >159 beats.min^{-1}	11-28 min day^{-1} 7-12 min day^{-1}
Sallis et al. (1993)	102 children (13 years)	>139 beats.min^{-1}	28-45 min day^{-1} boys 16-43 min day^{-1} girls
Gilbey and Gilbey (1995)	50 boys and 64 girls (9.93 ± 0.51 years)	>140 beats.min^{-1} >160 beats.min^{-1}	47 min day^{-1} boys 30 min day^{-1} girls
Gavarry et al. (1996)	13 boys and 19 girls (11-16 years)	>140 beats.min^{-1} >160 beats.min^{-1}	41 min day^{-1} boys 56 min day^{-1} girls 15 min day^{-1} boys 18 min day^{-1} girls
Sallo and Silla (1997)	25 boys and 29 girls (7.0 ± 0.9 years)	119-139 beats.min^{-1} 140-157 beats.min^{-1} >157 beats.min^{-1}	134 min d.$^{-1}$ at 119-139 37 min d.$^{-1}$ at 140-157 13 min d.$^{-1}$ at >157

*Estimated data

2.4 The Concepts of Growth and Development

Our understanding of the dose-response of physical activity to promote health and fitness is confounded by the growth of children. Malina and Bouchard (1991) referred to growth as the dominant biological activity during the first two decades of life. Consequently, a milieu of confounding biological variables may interfere with our understanding of physiological response to activity. Before investigating the dose-response of physical activity, an understanding of the terms used to define biological growth should be made.

Growth is an increase in the size of a segment or a whole body. Changes in size are outcomes of three processes, outlined by Malina and Bouchard (1991) as:

1. an increase in cell number (hyperplasia)
2. an increase in cell size (hypertrophy)
3. an increase in inter-cellular substances (accretion)

Maturation refers to the tempo and timing of progress towards a mature state (Malina and Bouchard, 1991). Whilst growth and maturation are essentially biological processes, *development* is both a biological and behavioural concept. Development may include both the differentiation of cells or social competence. As such, development should be referred to as a distinct physical or behavioural concept.

Human development is often categorised as childhood, adolescence and adulthood. Whilst adulthood refers to a fully mature state, childhood and adolescence are used interchangeably, often erroneously. Childhood refers to the events before the most rapid period of development. Adolescence is the period of life, generally between 10 and 15 years of age, when growth enters its most rapid phase. The events of adolescence occur in the same sequence for all individuals yet their timing is often staggered. This "time-lag" will see noticeable differences in the biological state of children with similar chronological ages. These differences must be addressed during investigations involving children and adolescents.

2.5 The physical activity prescription

The appropriate dose-response of physical activity, known to confer health benefits for children, is debatable. Suitable physical activity prescriptions for children and adolescents are often specific to the outcome being measured, such as for changes in blood lipids. Consequently, general recommendations have encompassed various dose-response informations (Sallis and Patrick, 1994). Following a meta-analysis of studies, the 1993 Consensus Advisory Committee (Sallis and Patrick, 1994) recommended the appropriate physical activity for adolescents (11-21 year) as:

- Three or more sessions of activity per week that should last 20 min or more and require moderate to vigorous levels of exertion (*Guideline 1*)

- The accumulation of 30 min or more of moderate to vigorous physical activity on most days of the week (*Guideline 2*)

A similar set of "cumulative" guidelines have recently been proposed by the Health Education Authority (1998). Whilst these recommendations provide a "baseline" of activity for adolescents, their application to the dose-response continuum remains debatable. Importantly, similar guidelines have not been determined for pre-adolescents.

2.5.1 The dose-response of physical activity required to provide beneficial changes in chronic disease risk factors and cardiorespiratory fitness

Most chronic disease processes have multi-factorial aetiology (Leon and Norstrom, 1994) associated with several modifiable and non-modifiable risk factors. Non-modifiable factors, such as male gender, increasing age and familial history, contribute to the risk factor profile and are included in the model of Bouchard et al. (1990). Alteration of modifiable, lifestyle-related, risk factors may be the single most effective method of retarding the disease process. Smoking (Bartecchi et al., 1994; Jeremy et al., 1995), hypertension (Berenson et al., 1982), adverse blood lipid profile (Schaefer et al., 1995), and inactivity (Berlin and Colditz, 1990; Malina, 1996), have been associated with increased prevalence of chronic disease. More recently obesity (Bar-Or and Baranowski, 1994) and low levels of cardiorespiratory fitness (Morrow and Freedson, 1994; Paffenbarger and Lee, 1996) have been implicated in the development of chronic diseases.

Whilst being generally free from chronic disease, the components of the "classical" risk factor profile, namely smoking, hyperlipidaemia, hypertension, obesity and low levels of physical activity, have been identified in studies of children. Interactions between these variables require more investigation and the appropriate level of physical activity required to alter risk factors, in a favourable direction, remains equivocal. Importantly, changes in these risk factors, with increasing biological and chronological age, have rarely been assessed, especially in British child populations.

The role of physiological risk factors, in the development of chronic disease, has been well documented for adult populations (Paffenbarger et al., 1986; Berlin and

Colditz, 1990; Paffenbarger and Lee, 1996). Elevated blood pressure, blood lipids and obesity may be related to low levels of physical activity. An appropriate activity prescription designed to promote alterations in these risk factors remains unresolved. For children these relationships are even less clear.

2.5.2 Physical activity and blood pressure

Hypertension is relatively rare in British children. Armstrong et al. (1990b; 1991) and Packer et al. (1995) did not identify the presence of elevated blood pressure in British children. Whilst they provide valuable information on the levels of children's blood pressure, these studies are limited by problems in determining childhood hypertension. As with several other risk factors, criterion cut-off points for adolescents are used to classify the potential risk for pre- and circum-pubertal children. The confounding effects of normal somatic growth may hinder the identification of physiological risk factors. Considerable variation in body size, during the developmental phase, may bias results and provide anomalous blood pressure data (Berenson et al., 1982). Consequently, several different "cut-off" points have been adopted to classify the hypertensive child.

Berenson et al. (1982) reported that the expression of blood pressure in the growing child should be related to body stature, as a measure of body size. During this period of considerable somatic growth applying similar cut-off points, for subjects of differing biological maturity, would appear to be flawed. Differences in body size must be taken into account. Unfortunately, the construction of appropriate cut-off points, accounting for differences in body size, have yet to be determined for the developing child.

The studies of Armstrong et al. (1991) and Packer et al. (1995) commonly failed to include body size terms in their assessment of blood pressure, thereby not addressing changes in blood pressure with increased morphological maturity. The large age-range of the study group used by Packer et al. (1995) would indicate a variety of maturity states and may bias mean group scores. An analysis of smaller age groups would allow for analysis of changes in blood pressure with increasing age, especially without the presence of a maturity indicator.

Other studies of British children's blood pressure levels are often performed upon clinical sub-groups, primarily the chronically diseased (Primrose et al., 1994). Such studies may not truly reflect blood pressure levels in healthy populations leading to a possible bias in results. Cross-sectional studies do not raise concern, with normal values similar to other reported European studies (de Man et al., 1994; Twisk et al., 1995). Interpretation of such results must be treated with caution due to a lack of standardised methodology and appropriate cut-off points.

Evidence to support the role of structured physical activities in altering the blood pressure levels of normotensive adults remains equivocal (Alpert and Wilmore, 1994). This is unsurprising as there is little need to reduce the blood pressure of normotensive subjects. The relatively asymptomatic nature of children presents further problems in identifying an appropriate exercise prescription to alter blood pressure in a favourable direction.

- Empirical studies of the dose-response of physical activity to changes in blood pressure

In a meta-analysis of current literature Alpert and Wilmore (1994) reported no clear association between physical activity and reduced blood pressure in normotensive adolescents. Increased physical activity is recommended as a non-pharmacological intervention for hypertension (Bouchard et al., 1990; Alpert and Wilmore, 1994). Therefore, for normotensive adolescents no recommendations have been made for an appropriate physical activity prescription. Similar recommendations for younger children have yet to be reported. Currently, literature examining the dose-response of physical activity and blood pressure in younger children is extremely rare. Whilst experimental evidence is inconclusive, it appears that exercise that is continuous of duration, and moderate to high in intensity is a prerequisite for reducing blood pressure. A summary of these studies is presented in Table 5.

Table 5. Empirical studies investigating the dose-response of physical activity upon changes in blood pressure.

Study	Subjects	Control group (Y/N)	Intervention	Results
Linder et al., (1983)	50 American boys (11-17 year)	N	Intermittent run/walk exercise, of 60 s duration, at 80% of maximum work capacity for 8 weeks. Additional 60 min of organised invasion games weekly.	No significant changes in systolic or diastolic blood pressure (P>0.05).
Chatterjee and Bandyopadhyay (1990)	41 Indian boys (10-14 year)	Y	12-weeks of continuous running, 3 times weekly for 30 min Exercise intensity between 80% and 85% of maximum.	Significant reductions in systolic and diastolic blood pressure (P<0.01).
Hansen et al., (1991)	69 hypertensive Danish children (9-11 year)	Y	60 min of extra physical education, 3 times weekly for 8 months. An average of 35 min of the lessons with heart rate above 70% of maximum	Significant reductions in systolic and diastolic blood pressure after 8 months (P<0.05). No significant differences after 3 months.
Blessing et al., (1995)	25 partially-sighted American schoolchildren (13 to 18 year)	N	16-weeks of continuous, large muscle group activity for 40 min, 3 times weekly. Exercise intensity equivalent to 90% of maximum.	No significant changes in systolic or diastolic blood pressure (P>0.05).
Leupker et al., (1996)	5106 American children (8 year)	Y	3 -year of enhanced physical education classes. No mention of the exact intervention.	No significant changes in systolic or diastolic blood pressure (P>0.05).

The studies outlined in Table 5 had mixed findings. Reductions in blood pressure were found in two studies were the exercise intensity was in excess of 70% of maximum heart rate for a minimum of 30 min (Chatterjee and Bandyopadhyay, 1990; Hansen et al., 1991). These findings emphasised that reductions in blood pressure may only be achieved using structured, high-intensity exercises. As previously discussed, children's free-living physical activity are not characterised by such patterns. It is doubtful that participating in free-living physical activities may provide a suitable stimulus for reducing blood pressure levels.

Unfortunately, studies investigating the effects of intermittent, or sporadic, physical activities upon blood pressure are rare. The study of Linder et al. (1983), outlined in table 5, provided no evidence for the benefits of intermittent exercise to favourably alter children's blood pressure. Intermittent run/walk exercise, of 60 s duration, at 80% of maximum work capacity was performed for 8 weeks. The use of short duration exercise bouts partially approximates the profile of short "bursts" of activity observed by Bailey et al. (1995). Whilst suggesting that intermittent activities will not provide benefits, the lack of information on the dose-response relationship precludes an outright dismissal. The contribution of free-living, sporadic physical activities to favourable alterations in blood pressure remains to be investigated.

2.5.3 Physical activity and blood lipids

Several consensus statements have outlined different criteria to classify elevated blood cholesterol and lipid sub-fractions (Lipid Research Clinics, 1983; Medical Journal of Australia, 1991; Canadian Consensus Conference, 1992). Many other research groups have utilised arbitrary criteria in assessing elevated blood cholesterol levels. These are often in contrast to consensus committee recommendations. Currently, an appropriate cut-off point for children has yet to be proposed.

The lack of an acceptable criterion "cut-off" for children is not surprising. Elevated levels of blood cholesterol are relatively rare in children. The choice of an appropriate cut-off point for circum-pubertal children is governed by standards used for adolescents. Whilst several studies appear to recommend a uniform total

cholesterol cut-off point for adults (>5.2 mmol.l^{-1}), the problems associated with creating such standards for younger age groups are complex.

Goldbloom (1992) reviewed data from 71 North American cohort studies. They concluded that the effects of multiple laboratories, innumerable testers and poorly maintained equipment would confound reported data. Whether these studies include both clinical and opportunistic health trials is unclear, yet Goldbloom (1992) highlighted a lack of follow-up advice for patients exceeding these cut-off points. Such findings indicate a lack of continuity in defining appropriate cut-off points for children.

Armstrong and co-workers (1990b; 1991), Sporik et al. (1991), Azad et al. (1994) and Morgan et al. (1994) have reported elevated blood cholesterol, and other lipid subfractions, for British schoolchildren. Comparison between these studies is problematic due to the use of innumerable cut-off points, differing measures of various lipid subfractions and study populations. Despite conflicting methodologies, empirical evidence suggests that a small proportion of British children have elevated blood cholesterol, with subsequent elevations in the ratio of TC:HDL-C.

Other assessments of lipid profiles of British schoolchildren are rare, being mostly confined to clinical studies. Information on the lipid levels of children with normal lipid profiles is essential to establish reference standards and allow comparison between studies. Unfortunately, without a consensus recommendation, as to an appropriate lipid profile for younger children, reporting these variables must be considered study-specific at best.

- Empirical studies of the dose-response of physical activity to changes in blood lipids

Physical activity has been shown to influence the levels of serum lipids in adult populations (Tran et al., 1983; Superko, 1991). Empirical dose-response informations on the effects of physical activity on blood lipids of children are less clear. Reported studies of the dose-response of physical activity to favourable alterations in blood lipids of children are limited. Whilst several studies have

investigated such changes in adolescents, younger age children (<11 year) have rarely been examined. A summary of empirical evidence is provided in Table 6.

Results of the studies outlined in Table 6 support consensus opinion that an appropriate physical activity prescription, to alter blood lipids favourably, remains elusive (Armstrong and Simons-Morton, 1994). Armstrong and Simons-Morton (1994) recommended that four 30 min sessions of large muscle group activity per week, at an exercise intensity equivalent to 80% of maximum oxygen uptake ($\dot{V}O_2$ max) would favourably alter the blood lipid profile of adolescents. Calculating the heart rate or $\dot{V}O_2$, reserve will provide a more individualistic approach to determining an appropriate physical activity threshold. Studies that have utilised the heart rate reserve method (Rimmer and Looney, 1997) have addressed the individual difference in baseline and maximal heart rates. The majority of studies continue to use arbitrary percentage of maximal heart rate as their recommended threshold (Linder et al., 1983; Docherty et al., 1990; Blessing et al., 1995). Consistently, these studies fail to account for individual differences in heart rate.

Despite methodological problems, it appears that high-intensity continuous exercise (>75% heart rate reserve or >165 beats.min^{-1}) sustained for training periods in excess of 12 weeks, may provide sufficient stimulus for favourably altering blood lipids. Controlling for the potentially confounding effects of gender, maturity and baseline lipid profile may allow for a more comprehensive analysis of the exercise/lipid dose-response.

Table 6. Empirical studies investigating the dose-response of physical activity upon changes in children's blood lipids.

Study	Subjects	Control group (Y/N)	Intervention	Results
Linder et al., (1983)	50 American boys (11-17 year)	N	Intermittent run/walk exercise, of 60 s duration, at 80% of maximum work capacity for 8 weeks. Additional 60 min of organised invasion games weekly.	No significant alterations in serum lipid or lipoprotein levels (P>0.05).
Savage et al., (1986)	20 American boys (8.3 ± 1.7 years)	Y	Walk/run exercise 3 times weekly for 10 weeks. Duration determined by the time taken to cover a set distance (2.4 km to 4.8 km). Children grouped by exercise intensity, corresponding to 40% (Low) and 75% (High) of $\dot{V}O_2$ max.	Significant decreases in total cholesterol concentrations for the high intensity exercising group (P<0.05). Little change in HDL-C and TC:HDL-C ratio pre- and post-testing (P>0.05).
Docherty et al., (1990)	24 pre-menearchal and 41 post-menearchal American girls	Y	30 min of continuous cycling at 75% of maximum heart rate, 3 times weekly for 12 weeks.	No significant alterations in serum triglycerides, total cholesterol, LDL-C, VLDL-C and HDL-C (P>0.05).
Zonderland et al., (1994)	156 Dutch children aged 10 year on first test occasion. Children from a school without appropriate physical education facilities acted as controls.	Y	Additional 1 1/2 physical education classes per week for 3 year. One afternoon of out- of-school activities every 6 weeks. Exercise intensity determined by the sport participated in, mainly invasion games.	Lipid sub-fractions not significantly altered in boys (P>0.05). Small, yet significant (P<0.05) increases in triglyceride and apoprotein A-I were shown for the girls.
Blessing et al., (1995)	25 partially sighted American schoolchildren (13 to 18 years). Assigned control group was normally sighted children of similar age.	Y	16-wk of continuous, large muscle group activity for 40 min, 3 times weekly. Exercise intensity equivalent to 90% of maximum.	Significant increases in HDL-C (P<0.05). Significant decreases in total cholesterol and TC:HDL-C ratio (P<0.05).
Rimmer and Looney (1997)	25 American adolescents (14-17 year), 14 experimental group subjects and 11 controls.	Y	Aerobic activities including running, dancing and aqua-aerobics performed for ≥30 min, 4 days weekly for 15 weeks. Exercise intensity set at 60% to 85% of heart rate reserve.	Significant decreases in total cholesterol (P<0.05). Non-significant reductions in HDL-C (P>0.05). Children achieved target heart rate thresholds in only 61.5% of training sessions.
Welsman et al., (1997)	35 girls (10.2 ± 0.4 years) in experimental group, 16 girls in control group (10.2 ± 0.4 years)	Y	3 x 20 min sessions of "aerobics" and cycle ergometry weekly for 8 weeks. Training thresholds were set at >16-170 beats.min^{-1}.	Reductions in total cholesterol for training and control groups (P>0.05). Non-significant changes in HDL-C (P>0.05).

When examining the problem of individualised heart rate thresholds, and their effects upon blood lipid levels, the biological maturity of subjects must be alluded to. Levels of blood lipids undergo great change during the adolescent period. The effects of sex-specific hormones to changes in blood lipids have been alluded to (Malina and Bouchard, 1991), yet this relationship has yet to be clearly established. It is clear that these biological changes may see great variance in blood lipids amongst similar chronologically-aged children.

Use of a heterogeneous distribution of subjects, when classified by chronological age, limits the application of findings to a general population. Of those studies outlined in Table 5, only one categorised results by maturity status (Docherty et al., 1990). Zonderland et al. (1994) and Welsman et al. (1997) measured pubertal staging, yet did not include this variable as an independent factor in analysis. The failure to include such a term in analyses may mask important changes during development. Additionally, two studies failed to categorise results by gender, collapsing data to include both boys' and girls' results. Whilst gender differences in blood lipids are not significant during growth (Kemper et al., 1990) failure to partition out the effects of gender from a controlled study design must be considered problematic.

In nearly all studies, the lack of a training effect was attributed to the normal baseline concentrations of blood lipids and lipoproteins before the study. As with blood pressure, children with normal lipid levels subject should not require intervention to alter lipid profile. Information that is more relevant may be found by classifying children as having elevated lipid profiles prior to intervention, thus providing a more suitable "start-point" for subsequent intervention.

From the studies outlined in Table 6 it is apparent that favourable changes in blood lipids will only be gained by performing continuous, high-intensity exercise. As with blood pressure, this exercise prescription will not provide benefits to all groups. Similarly, the free-living physical activity of children is not characterised by such a profile. Studies investigating the contribution of free-living physical activities to changes in blood lipids remain rare. Subsequently, the relationship between physical activity and blood lipids remains unclear for this age group.

2.5.4 Physical activity and body fat

Excessive body fat has been associated with many health problems in both children and adults. Importantly, literature suggests that elevated body fat levels appear to be maintained from adolescence into adulthood. Consequently, the assessment of body fat is fundamental to health studies.

The assessment of British children's body fat is limited by interchangeable methodologies used between studies. Classifying children as being "overweight", using national standards or the BMI, does not account for the contribution of fat- and fat-free mass to overall body size (Armstrong et al., 1990b; 1991; Riddoch et al., 1990; Packer et al., 1995). Studies measuring skinfold thickness of children are similarly limited by a lack of measurement continuity, resulting in the sum of triceps and subscapular skinfold only, used as the indices of body adiposity (Armstrong et al., 1990b; 1991; Riddoch et al., 1990; Packer et al., 1995). Similarly, a failure to identify the contribution of maturity status when measuring body fat, will not account for different rates of fat development in children and adolescents.

- Empirical studies of the dose-response of physical activity to changes in body fat

Consensus recommendations for adolescents emphasise increases in daily energy expenditure to maintain normal levels of body fat (Bar-Or and Baranowski, 1994). With recognised shortcomings in both the measurement of energy expenditure and body fat (Gutin and Manos, 1993), these training studies have no gold standard from which to derive accurate results. Intervention studies often utilise measures of body fat as covariates, whilst the major aim of the study is generally to assess changes in a different dependent variable, such as VO_2 max. As such, few studies are dedicated solely to assessing changes in the fat of children.

Several studies have reported favourable reductions in children's body fat following structured exercise regimen. These studies are summarised in Table 7. Linder et al. (1983), Savage et al. (1986) and Blessing et al. (1995) reported

Table 7. Empirical studies investigating the dose-response of physical activity upon changes in children's skinfold thickness.

Study	Subjects	Control group (Y/N)	Intervention	Results
Linder et al., (1983)	50 American boys (11-17 year)	N	Intermittent run/walk exercise, of 60 s duration, at 80% of maximum work capacity for 8 weeks. Additional 60 min of organised invasion games weekly.	Non-significant reductions in triceps skinfold between test occasion (13.4 mm to 12.7 mm: $P>0.05$).
Savage et al., (1986)	20 prepubescent American boys (8.3 $\pm$ 1.7 years)	Y	Walk/run exercise 3 times weekly for 10 weeks. Duration determined by the time taken to cover a set distance (2.4 km to 4.8 km). Children grouped by exercise intensity, corresponding to 40% (Low) and 75% (High) of $\dot{V}O_2$ max.	Significant decreases in sum of 6 skinfolds between test occasion for low (59 mm to 58 mm) and high (42 mm to 40 mm) exercise groups ($P<0.01$).
Zonderland et al., (1994)	156 Dutch children aged 10 year on first test occasion. Children from a school without appropriate physical education facilities acted as controls.	Y	Additional 1 1/2 physical education classes per week for 3 year. One afternoon of out- of-school activities every 6 weeks. Exercise intensity determined by the sport participated in, mainly invasion games.	Non-significant reductions in sum of 4 skinfolds between test occasion (- 9 mm for boys, -8 mm).
Blessing et al., (1995)	25 partially sighted American schoolchildren (13 to 18 year). Assigned control group was normally sighted children of similar age.	Y	16-wk of continuous, large muscle group activity for 40 min, 3 times weekly. Exercise intensity equivalent to 90% of maximum.	Significant decreases in sum of 4 skinfolds (47 mm to 42 mm: $P<0.05$)

favourable reductions in body fat using continuous exercise with the heart rate elevated above 75% of $\dot{V}O_2$ max or higher ($\geq$ 160 beats.min^{-1} for 10 year old children). As with other coronary heart disease risk factors, an exercise prescription of continuous, high-intensity activity is required for favourable alterations in body fat. Again, the free-living physical activity of children is not characterised by such activity (Armstrong et al., 1990a; 1996; Riddoch et al., 1991; Welsman and Armstrong, 1992; Bailey et al., 1995).

Without a structured exercise programme, any reduction in body fat, through physical activity, will be difficult to attain. Similar physical activity prescriptions have been shown to elicit favourable alterations in blood lipids (Savage et al., 1986; Blessing et al., 1995; Rimmer and Looney, 1997) and blood pressure (Chatterjee and Bandyopadhyay, 1991; Hansen et al., 1991). From such evidence, it appears that changes in the risk factor profile of children can only be attained using structured, continuous physical activities, uncharacteristic of normal patterns of activity.

The findings outlined in Table 6 must be interpreted cautiously. The wide variation in measurement methodologies used to quantify both the physical activity mode and skinfold thickness is again problematic. Little agreement exists as to the most accurate representation of children's adiposity. Whilst the use of a sum of skinfolds is recommended as the best representation of body adiposity (Reilly et al., 1996) the number of skinfolds required is undetermined. The use a single skinfold measurement (Linder et al., 1983) will not provide information as to the regional distribution of body fat in the growing child. Central fat distribution has been associated with increased risk of cardiovascular disease in later life (Bjorntorp, 1988; Gutin and Manos, 1993; DiPietro, 1995). The assessment of both peripheral and central skinfold thickness must, therefore, be considered a fundamental component of body fat measurement, especially during puberty when regional fat patterns become either android or gynoid (Goulding et al., 1996).

In a consensus statement, Reilly et al. (1996) recommended the use of 5 skinfold thickness, at both central and peripheral locations as a representation of subcutaneous adiposity. The use of a thigh skinfold is important, as a significant amount of variance in total body fat has been accounted for by central and peripheral skinfolds (Peters, 1994). Using magnetic resonance imaging (MRI) Peters reported that between 86% and 95% of the variance in total body fat was accounted for by abdominal and thigh skinfolds. Whilst the measurement of 2 or 4 upper body sites has been regularly performed on children (Armstrong et al., 1990b; 1991; 1996; Zonderland et al., 1994; Blessing et al., 1995), performing lower body measurements may be unduly invasive. Information on lower body skinfolds is rarely reported for children, indicating possible problems in performing this measurement. During preliminary studies in our laboratory, children, especially girls, were reluctant to allow lower body skinfold thickness measurements to be performed, emphasising the problems associated with this technique.

When assessing the relationship between physical activity and changes in body fat, biological maturity state must be considered influential. Sex differences in the amount of body fat, and subsequent regional fat distribution, become most apparent during the circum-pubertal period (Malina and Bouchard, 1991; Ogle et al., 1995). The differences are most apparent after 10 years of age (Ogle et al., 1995). Importantly, the major periods of fat deposition during the development period, or "fat waves" appear to occur at around 10-12 years for boys, yet are not as well defined in girls (Ogle et al., 1995).

Savage et al. (1986) controlled for maturity by using prepubescent children only. In the studies of Linder et al. (1983), Zonderland et al. (1994) and Blessing et al. (1995), a maturity term, whilst measured, was not included as a covariate to explain changes in body fat. The contribution of sex-specific hormones to changes in body fat will be manifested in increased levels of girls' fat mass during the circum-pubertal period. Without controlling for maturity status within adolescents, it is not surprising that no significant intervention effect was identified.

In summary, as with other coronary heart disease risk factors the appropriate exercise prescription to favourably alter body fat remains contentious. High intensity, continuous exercise does appear to provide a sufficient stimulus for

reductions in body fat. The contribution of free-living physical activities to such changes remains, again, equivocal.

2.5.5 Physical activity and cardiorespiratory fitness

Levels of physical fitness have been independently associated with chronic disease risk factors in British adolescents (Boreham et al., 1997). An appropriate dose-response of physical activity to promote favourable alterations in children's cardiorespiratory fitness has yet to be determined. For adults, such an exercise prescription involves continuous activity of large muscle groups, 3-5 sessions weekly for 15-60 min, at an intensity of 60-90% of maximum (Rowland, 1995). In children, when performing a similar volume of exercise, improvements in cardiorespiratory fitness are generally of a smaller magnitude (Rowland, 1995).

Several meta-analyses have assessed the cardiorespiratory benefits of structured training in children and adolescents (Rowland, 1985; Payne and Morrow, 1993; Morrow and Freedson, 1994). These meta-analyses revealed inconsistencies in results. Changes in cardiorespiratory fitness were often a function of the experimental design used more so than any direct physiological response. A summary of these studies is presented in Table 8.

Results of these empirical studies generally showed that cardiorespiratory fitness benefits occurred with continuous, high-intensity exercise periods, sustained for several weeks. These findings are similar to those reported for adults (Shephard, 1995). As in the meta-analyses of Rowland (1985), Payne and Morrow (1993) and Morrow and Freedson (1994), inconsistencies occur when similar training protocols fail to elicit training effects of a similar magnitude. Continuous physical activity above the 75% of heart rate maximum threshold ($\geq$ 160 beats.min^{-1}) has been shown to provide cardiorespiratory fitness benefits in some studies (Massicote and MacNab, 1974; Chatterjee and Bandyopadhyay, 1990; Docherty et al., 1990; Shephard and Lavalee, 1993; MacManus et al., 1995; Roberts et al., 1995; Rowland and Boyajian, 1995). These findings have not been replicated in other studies using a similar exercise prescription (Williams et al., 1995; Welsman et al., 1997). This is surprising as both the intensity, duration and intervention period were similar for nearly all studies. Assessing the sample

Table 8. Empirical studies investigating the dose-response of physical activity upon changes in children's cardiorespiratory fitness.

Study	Subjects	Control group (Y/N)	Intervention	Results
Massicote and MacNab (1974)	36 American boys (11-13 years) assigned to training groups upon baseline fitness level	Y	12 min of cycle ergometry, 3 times weekly for 6 weeks. Exercise intensity set at 130-140 beats.min^{-1} (group 1) 150-160 beats.min^{-1} (group 2) 170-180 beats.min^{-1} (group 3)	Maximal aerobic power increased significantly in group 3 only ($P<0.05$). Significant changes in physical work capacity of groups 1 and 2 ($P<0.05$).
Chatterjee and Bandyopadhyay (1990)	41 Indian boys (10-12 years)	Y	12 weeks of continuous running, 3 times weekly for 30 min Exercise intensity approximated 80% to 85% of maximal heart rate, estimated using 220-age equation.	Increases in endurance time (min) and decreases in submaximal heart rate ($P<0.05$). No difference between control and experimental groups.
Docherty et al., (1990)	24 premenearchal and 41 postmenearchal girls.	Y	30 min of cycle ergometry, 3 times weekly for 12 weeks. Exercise intensity set at 75% of maximum heart rate.	Significant increases in peak $\dot{V}O_2$ for both maturity groups and the control premenearchal group ($P<0.01$).
MacManus et al., (1995)	28 prepubertal English girls (9.6 ± 0.5 years)	N	12 weeks of cycle ergometry, 3 times weekly for 20 min at an intensity of 160 to 170 beats.min^{-1} (group 1). 12 weeks of short-duration runs (10 s to 50 s) 3 times weekly for 20 min at an intensity of 160 to 170 beats.min^{-1} (group 2).	Significant increases in the peak $\dot{V}O_2$ of subjects from group 1 ($P<0.01$).
Roberts et al., (1995)	12 boys and 5 girls (12.4 ± 1.1 years)	Y	Adapted "step-aerobics" programmed, 40 min duration, 3 times weekly for 12 weeks. No manipulation of heart rate thresholds.	Significant increases in peak $\dot{V}O_2$ for the test group ($P<0.05$).

Table 8 continued

Shephard and Lavalee (1993)	137 boys and 94 girls (aged 7 years at first intervention)	N	6 years of an additional 60 min of endurance and skill-orientated activities weekly. Measurements taken at yearly intervals. Children sustained an average of 23 to 24 min of activity per lesson. This activity was performed at an average heart rate intensity of 163 beats.min^{-1}.	Small, yet significant increases in maximal aerobic power ($P<0.05$).
Rowland and Boyajian (1995)	24 girls and 13 boys (10.9 to 12.8 years)	Y	12 weeks of aerobic activity, 3 times weekly for 30 min Exercise intensity set at 80% of maximum (approximately 166 beats.min^{-1}).	Significant increases in mean $\dot{V}O_2$ max ($P<0.05$).
Williams et al., (1995)	39 prepubertal boys (10.1 $\pm$ 0.3 years)	Y	Cycle ergometry performed for a minimum of 20 min, 3 times weekly for 8 weeks. Exercise intensity set at 160-170 beats.min^{-1}.	Non-significant increases in peak $\dot{V}O_2$ for both training and control groups ($P>0.05$).
Welsman et al., (1997)	35 girls (10.2 $\pm$ 0.4 years) in experimental group, 16 girls in control group (10.2 $\pm$ 0.4 years)	Y	3 x 20 min sessions of "aerobics" and cycle ergometry weekly for 8 weeks. Training thresholds were set at >160-170 beats.min^{-1}.	Small, non-significant increases in peak $\dot{V}O_2$ between test occasion (1.58 to 1.61 l.min^{-1} for aerobics group, 1.76 to 1.79 l.min^{-1} for cycling group ($P>0.05$).

characteristics, all studies utilised a study group aged 9-13 years, except for the study of Shephard and Lavalee (1993), whose subjects were 7 years of age at the start of their 6-year study. The variety of subject ages used must also reflect upon the variation in maturity status of children in these studies.

Whilst several studies (Table 8) have categorised subjects by maturity status (Docherty et al., 1990; MacManus et al., 1995; Williams et al., 1995), the majority of investigations failed to include a maturity term in analyses. Changes in cardiorespiratory fitness are associated with increased biological age (Rowland, 1990; Malina and Bouchard, 1991; Rowland, 1996). Variations in body size, accentuated during the circum-pubertal period, must be accounted for when assessing cardiorespiratory fitness levels.

Similar problems occur in the common expression of peak $\dot{V}O_2$ in relative terms. The use of linear expressions of cardiorespiratory fitness ($ml.kg.^{-1}min^{-1}$) is not appropriate in growth studies (Winter, 1991; Nevill, 1994). Several training studies have utilised relative expressions of peak $\dot{V}O_2$ to quantify cardiorespiratory fitness (MacManus et al., 1995; Rowland and Boyajian, 1995). Such statistics assume a linear relationship between body size and cardiorespiratory fitness, and are not applicable to the growing child. Similarly, the use of an absolute expression of peak VO_2 ($l.min^{-1}$) also fails to account for differences in body size.

The development of maximal aerobic capacity is limited before puberty (Rowland 1985). During puberty, the development of peak $\dot{V}O_2$ is influenced by a body size-maturation interaction (Armstrong and Welsman, 1994). Malina and Bouchard (1991) cited evidence from the Saskatchewan Longitudinal Growth Study supporting a "critical age" for the development of peak $\dot{V}O_2$. This "age" was equivalent to the peak height velocity for boys. Similar data are not available for girls. Some longitudinal studies have reported that the "critical age" for $\dot{V}O_2$ max occurs during the year of peak height velocity (PHV) for Canadian boys and girls (Beunen and Malina, 1988) and Dutch boys (Kemper et al., 1986), yet one year earlier than PHV for Dutch girls.

In contrast, Falk and Bar-Or (1993) did not find any evidence of the "critical age" for peak $\dot{V}O_2$ development. Using a mixed cross-sectional longitudinal design, the peak aerobic power of pre- (10.9 years), mid- (13.2 years) and late (16.2 years)

pubertal children was measured yearly for 6 years. Absolute peak aerobic capacity increased during each year of testing, but not significantly ($P>0.05$). In this study the expression of aerobic power was again made using relative expressions ($W.kg.^{-1}$) and would fail to reflect the non-linear development of the growing child or adolescent. Despite controlling grouping subjects by pubertal stage, the failure to partition out the effects of body size, in subjects of similar maturational status, may mask changes in peak $\dot{V}O_2$.

Similarly, the use of pubertal staging indices, to classify maturity status, may be flawed. The use of pubertal staging indices, examining secondary sexual characteristics, has been questioned in circum-pubertal children (Laaneots et al., 1995; Beunen, 1996). The maturity of secondary sexual characteristics is non-linear and classifying children using this method is somewhat arbitrary (Malina and Bouchard, 1991). Many studies have used this technique to provide a maturity term for inclusion in analyses (Falk and Bar-Or, 1993; MacManus et al., 1995; Williams et al., 1995). Advanced development of pubic hair may not be related to similar development in breast or genital development (Laaneots et al., 1995) and may skew data if a mean score is taken for several assessment sites. Similarly, the use of a single site may not be reflective of general sexual maturity.

Evidence to support a critical age for aerobic power remains equivocal. Puberty will have a great influence upon cardiorespiratory fitness development. Functional aspects of the cardiorespiratory responses to exercise will change markedly during childhood and adolescence (Cooper, 1994), yet the concept of a critical age remains to be proven. Despite this lack of understanding, it is important for researchers to include some form of maturational analysis in studies of children's peak $\dot{V}O_2$ development. Additionally, such information should be supported by the inclusion of scaled measurements of peak $\dot{V}O_2$ to assess functional changes with age accurately.

It appears that regular, higher-intensity, continuous exercise provides cardiorespiratory fitness benefits for children. An exercise prescription of more than 20 min of continuous, large muscle group exercises, three times weekly, and at an intensity of above 160 $beats.min^{-1}$, may provide cardiorespiratory benefits in circum-pubertal children. This relationship is much clearer for cardiorespiratory fitness benefits than for coronary heart disease risk factors. Unfortunately,

evidence to support changes in cardiorespiratory fitness from performing free-living physical activity remains equivocal.

2.5.6 The appropriate dose-response of physical activity for health and fitness benefits

Empirical evidence suggests that health and fitness benefits may be achieved from three or more weekly sessions of continuous physical activity, lasting a minimum of 20 min, and at an intensity in excess of 75% maximum physical capacity. Such recommendations should be interpreted with caution as variable methodologies and subject groups have been used in these studies. Similarly, a lack of internal control for the confounding effects of biological maturity may confound results and prevent the establishment of an appropriate dose-response of physical activity for health and fitness benefits.

Importantly, recent evidence does not suggest that the "3 x 20 min weekly" prescription is reflective of the habitual physical activity of children (Armstrong et al., 1990a; 1990b; 1991; 1996; Armstrong and Bray, 1992; Riddoch et al., 1991; Al-Hazzaa and Sulaiman, 1991; Sleap and Warburton, 1992; Bailey et al., 1995; MacManus and Armstrong, 1995; Sallis et al., 1995; Pate et al., 1996; Sallo and Silla, 1997). Despite these findings, literature on the relationships between physical activity, fitness and health remains scarce, especially for British child populations. Reported studies examining changes in these factors during growth are even rarer, representing gap in current understanding.

It is important that more study is performed to assess the contribution of free-living physical activities to changes in coronary heart disease risk factors and cardiorespiratory fitness. Our understanding of the effects of such activity upon these variables remains unclear. In light of reported evidence, the use of "classical" physical activity recommendations, such as 3 x 20 min weekly (Sallis and Patrick, 1994), must be considered unattainable by children during free-living. The current study will address the issue of the contribution of physical activity to coronary heart disease risk and fitness. Importantly, any changes in these relationships will also be examined. In the current study the postulated links from the Bouchard et al., (1993) model may be re-examined to assess their application for younger populations.

2.6 Changes in physical activity over time

The framework of Bouchard et al., (1993) provides little information on changes in physical activity over time. As children develop both biologically and socially, the determinants of physical activity participation will change. During normal growth, children may find that the performance of physical tasks will alter. As an example, increases in body fat may hasten a change in activity participation. Similarly, changing social influences, such as the transition from junior to secondary school may influence a child's participation. To provide a more applicable framework for children, the contribution of time must be included.

Whilst cross-sectional studies yield valuable information on physical activity behaviours, identifying the relationships between physical activity, risk factors and health, over time, require longitudinal investigation. Longitudinal studies of physical activity and risk factors are rare. The problems associated with the measurement of physical activity in children have been well addressed in literature (Saris, 1986; Freedson, 1989). The choice of an appropriate instrument is essential. When combined with the confounding effects of normal somatic growth, and the social and environmental milieu surrounding the growing child, it is not surprising that few longitudinal studies yield conclusive results.

Most physiological and cognitive functions follow the same general pattern of development (Malina and Bouchard, 1991). Changes in modifiable lifestyle behaviours are not so well defined. Alterations in physical activity during the growth period will have important implications for future health. Importantly, the relationships between these factors, and other confounding variables, require a complex, multi-disciplinary, measurement approach.

2.6.1 The tracking of free-living physical activity

Tracking refers to the maintenance of a position within a group over time (Shephard, 1996). Children's physical activity has been shown to track only moderately. Whilst statistical support for the tracking of physical activity remains

equivocal, evidence has shown a reduction in physical activity participation with increasing age (van Mechelen and Kemper, 1995). Participation in physical activity decreases between 13 to 18 years (van Mechelen and Kemper, 1995) and may be a precursor to a sedentary adulthood. The reduction in time spent performing physical activity, during the transition from childhood to adulthood, is of concern. Identifying any determinants which result in reduced physical activity participation must be considered a major health objective.

Investigations of the tracking of free-living physical activity are limited to mainland Europe and North America. van Mechelen et al. (1993) reported physical activity data from the Amsterdam Growth Study. Subjects (84 men, 98 women) completed a structured interview at regular intervals between the ages of 13 and 28 year. Free-living physical activity was reported as the metabolic equivalent of activity, with physical activity characterised as being four times the metabolic equivalent (MET). During the study period daily energy expenditure decreased by 42% in males and 17% in females. The most marked decrease occurred between the ages of 13 and 18 years, this decrease only being significant at between 13 and 16 years of age ($r = 0.44$ to 0.58; $P<0.01$). Reductions in physical activity participation were not significantly different between males and females. The longer the between-test interval, the lower the inter-period correlation coefficient ($r = 0.05$ to 0.20; $P>0.05$). These results showed that the greatest modification in physical activity behaviours occurred during adolescence. This clearly identifies an activity reduction "window". Little is known as to whether this reduction is an ongoing process from an earlier age, or whether it is affected by the onset of puberty.

In a continuation of this work, van Mechelen and Kemper (1995) reported the tracking of self-reported physical activity in the Amsterdam cohort into adulthood. Inter-period correlation coefficients were moderate to high between age 13 and 16 year ($r = 0.38$ to 0.64) indicating the relative stability of self-reported physical activity during adolescence. The tracking of physical activity into adulthood was much weaker. Relationships between physical activity at 13 and 21 year were poor ($r = 0.05$ to 0.20). These findings showed that participation in free-living physical activities was unstable over longer periods. Importantly, childhood and adolescent levels of physical activity were unreflective of adult participation.

The findings of van Mechelen and Kemper (1995) contrast with those of Trudeau et al. (1997). They investigated the influence of primary school physical education upon physical activity levels in adulthood. An experimental group of 122 Canadian boys and girls received 5 extra periods of physical education weekly during their six years of primary school education. Questionnaire based surveys were used to assess participation in free-living physical activity at primary school and during their early 20's, although no exact time was given for the adult measure. Their results showed that members of the experimental group were more active than those assigned to non-intervention groups. Despite similar perceived barriers to exercise, the experimental group showed a greater willingness to exercise ($P<0.05$) and a more positive attitude towards exercise ($P<0.05$).

The study of Trudeau and co-workers provides evidence for the beneficial effect of childhood physical activity to formulating positive health behaviours in later life. Whilst providing valuable information, this study utilised a similar questionnaire for both adult and child measurements. Whether children had appropriate levels of cognitive maturity to complete such questionnaires, and the necessary information-processing skills (Baranowski, 1988) remains questionable. No report was made of the instrument used, and until such information is made available, these results should be interpreted cautiously.

Other studies examining the tracking of children's physical activity are very rare. Sallis et al. (1995) reported the relatively poor stability of physical activity in very young children (tracking period 3 to 7 years of age). Inter-period correlation coefficients ranged between $r = 0.09$ to 0.36 for the mean of four days of observation. These findings contrasted those of Pate et al., (1996) who used heart rate monitoring to assess the physical activity of 47 children, aged 3 to 4 years. Subjects were followed over a 3-year period. Inter-period correlation coefficients ranged between $r = 0.53$ to 0.63 ($P<0.0001$), indicating the relatively stability of physical activity during early childhood.

The conflicting results of these two studies emphasise the difficulty associated with the assessment of free-living physical activity. Both study cohorts were well matched for age and demography. This showed that using two methods of physical activity assessment produced very different results. Despite such methodological problems, it is apparent that physical activity participation varies

within similar demographic groups. Variations in the physical activity of differing age groups, and subsequent changes during the life cycle, are less well understood.

Other large-scale longitudinal studies rarely report the tracking of physical activity. These reports often concentrated on relationships between physical activity and other health and fitness variables (Kemper, 1986; Beunen et al., 1992). Moreover, using various recall/diary techniques to assess changes in physical activity is difficult. A more stable method of assessing changes in physical activity behaviours would be to use direct measurements of physical activity, such as heart rate monitoring, used by Pate et al. (1996) or accelerometry. The individual response to physical activity will undoubtably change over time. Using such techniques will compensate for the cognitive immaturity of children in accurately recalling physical activity behaviours. These methods are readily available, socially acceptable and are suited to use in longitudinal studies where resources are often at a premium. Longitudinal studies using these techniques are, however, rare.

In a meta-analysis of longitudinal studies, Malina (1996) reported inter-age correlation's, for self-reported physical activity, ranging between r = 0.05 to 0.54. This study, and those from Finland (Raitakari et al., 1994), Denmark (Andersen and Haroldsdottir, 1993) and the Netherlands (van Mechelen and Kemper, 1995), provide evidence for the low to moderate tracking of physical activity, as measured by retrospective questionnaire methods.

Comparative analysis of these studies is difficult. Evidence suggests that self-reported physical activity does not track. These findings highlight the paradox of physical activity as a behavioural concept. Attempts to quantify physical activity, within this framework, must be doubted when assessing variable methodologies. Tracking of physical activity must remain uncertain due to both the behavioural influence and methodological problems associated with activity assessment.

Whilst the relationship between inactive children and adult inactivity levels appears to be well-accepted, statistical evidence to support this finding is poor. The lack of data on tracking of this variable, specifically within the United Kingdom, represents a gap in current knowledge. Identifying the potential tracking of sedentary lifestyle behaviours has implications for future health status. Such identification will allow

for intervention strategies, aimed at increasing levels of physical activity, to be implemented during crucial periods when attitudes and behaviours are formed.

2.6.2 The determinants of physical activity participation over time

In a meta-analysis, Dishman et al. (1985) assessed the contribution of a myriad of physiological, psychological and sociological factors in modifying the physical activity of adults. This review was particularly strong in separating supervised from unstructured free-living physical activity. Dishman and co-workers reported the influence of intention, personal capabilities, behavioural skills, commitment and reinforcement in modifying physical activity. Knowledge of, attitudes toward and beliefs about health and physical activity interacted with biomedical and personality traits, feelings and lifestyle behaviours, and environments to influence involvement activity. Familial and peer influences, and education were shown to exert an increased probability of influencing physical activity. No evidence was provided to support physiological factors as modifiers of physical activity behaviours.

The influence of parental and peer group influence upon physical activity has been examined in younger subjects. Anderssen and Wold (1992) performed a self-report of physical activity on 498 boys and 406 girls (13.3 $\pm$ 0.3 years). The influence of parents and peers was examined using a self-report questionnaire. Boys averaged 3.6 ($\pm$1.7) periods of physical activity weekly. Girls were significantly less active ($P<0.001$) reporting 2.7 ($\pm$2.0) periods of physical activity weekly. The questionnaire, whilst well correlated with other questionnaire-based measures physical activity, was not validated against direct measures at an appropriate exercise intensity. This lack of construct validity, allied to a single-question assessment technique, raises doubt as to the accuracy of the instrument in accurately determining the free-living physical activity of the group.

Despite such limitations, Anderssen and Wold (1992) found that parental and peer support made a significant contribution to the performance of free-living physical activities ($P<0.05$). These findings support the meta-analysis results of Dishman et al. (1985) and emphasised the importance of an active social environment in promoting the free-living physical activity of adolescents. The use of cross-sectional study design was ineffective in assessing the changes in both physical

activity and its' influences during early adolescence. Longitudinal studies of the changes in physical activity and their determinants, in children, are rare.

Shaw and Eves (1997) examined the psychological and physiological predictors of physical activity in a sample of 63 boys and 60 girls (mean age 11.3 year). Physical activity was assessed using a record of achievement completed by children every school term. Physical education teachers who rated children as active to inactive using a 5-point Likert scale checked the record. Decisional balance scales, rating the positive and negative aspects of exercise were implemented. A "Sport and Exercise Barriers" questionnaire was also completed. Cardiorespiratory fitness levels were predicted from the performance of the 20-m shuttle run test (Leger and Lambert, 1982). Children completed the test battery at 6-month and 1-year intervals.

Results from this study showed that 24% of total variance in physical activity was accounted for by a multiple regression model containing fitness, motivational barriers, sex and decisional balance ($P<0.001$). The relatively small amount of variance accounted for emphasises the contribution of other physical, psychological and sociological variables in explaining the total variance in physical activity. The determination of physical activity, by means of a long-term self-report, will be hindered by the problems associated with recall of activity in children (Baranowski, 1988). From an information processing perspective, the use of a term-long recall of activity will be imprecise. The ability of the child to retrieve information on their physical activity behaviours accurately will be limited for periods in excess of 3 days (Sallis et al., 1996). Importantly, the use of this scale did not assess the intensity of the physical activity performed. Without such information it would be difficult to identify relationships between fitness levels and the amount of physical activity performed.

Despite the limited number of studies, it is apparent that the true determinants of physical activity in children cannot be certain. The social environment appears to have a significant role in influencing children's physical activity participation. Evidence to support such relationships in both the physical and psychological environment is less apparent. The recognised problems associated with the assessment of physical activity would be expected to limit such identification, especially when comparing results to other studies. Similarly, the "piece-meal"

identification of only certain components of a framework examining the health, fitness and activity continuum, will not enlighten relationships between these areas.

The childhood period is important in formulating and emphasising lifestyle related behaviours which may "track" into adult life. Importantly, the prevalence of detrimental health behaviours will be further complicated by the influence of puberty. Similarly, the myriad of biological and sociological changes that are present during puberty, will not be accurately identified using a cross-sectional study design. Longitudinal investigation would allow for accurate analysis of those behaviours that may be maintained into adult life. Their optimal periods of change, and their effects upon subsequent components of the health, physical activity and fitness paradigm will also remain unresolved.

Individual variables of the Bouchard et al., (1993) framework are frequently assessed. Their interactions with other modular components are relatively unknown. Similarly, the considerable problems associated with the longitudinal assessment of physical activity (Kemper, 1986; Saris, 1986; Freedson, 1989), risk factors and psychosocial variables makes such interactions difficult to identify.

No British study has reported longitudinal changes in physical activity, individual risk factors and those psychosocial factors that may affect physical activity participation, health and fitness. Prospective longitudinal research is difficult to implement. Several primary problems have been reported by researchers from other large-scale longitudinal studies (Kemper, 1986) including:

- long-term financial commitment
- techniques become obsolete
- staff and subject attrition
- confounding effects of repeated measurements

Whether the reluctance of investigators to implement non-interventive research is associated with common problems is unclear. Certainly, longitudinal study designs will be subject to many extraneous variables not found in cross-sectional studies. Whilst cross-sectional and secular trend studies provide important baseline data, only longitudinal studies can provide adequate assessment of those changes associated with growth, development and the changing lifestyle.

2.6.3 The risk factor profile - changes over time

The benefits of regular physical activity on the risk factor profile of children remain uncertain. Whilst children are generally free from chronic diseases common in adulthood, elevated levels of blood pressure, blood lipids and body fat have been identified in children. That chronic disease risk factors have been identified in children raises concern as to whether these factors may track into adulthood. If so, intervention aimed at reducing the incidence of childhood risk factors may have important implications for the prevention of disease in later life. Whilst several cross-sectional studies have identified the presence of elevated risk factors in British children (Armstrong et al., 1990b; 1991; Packer et al., 1995), longitudinal information on these changes are scarce.

- Assessing the tracking of variables – methodological issues

A biological variable is said to track if the differences between or within an individual remain constant (Roche, 1997). Tracking will, therefore, relate to the stability of a variable over time. An appropriate statistical method to examine tracking has yet to be agreed upon. Currently, tracking is assessed using an inter-period correlation coefficient (IPC) or the degree of maintenance within calculated percentiles for age.

Correlations between repeated measures are calculated from values for one variable measured in a group of individuals at two ages. The use of IPC's are recommended as the method of when data are available at only two ages (Roche, 1997). When using multiple measurements the correlation between the first data point and the last may indicate tracking. This technique fails, however, to include information on the intermediary data points, correlations between which may not indicate tracking. The analysis of such intermediaries, espeically during growth, is essential. Growth related changes in stature, blood pressure or blood lipids may be masked by using a "before and after" correlation. Consequently, IPC's should be used within an age-to-age matrix to include all periods of growth. Similarly, IPC's may not be considered a general estimate of tracking as longitudinal data rarely, if ever, come from a random sample (Roche, 1997).

Inter-period correlation coefficients will be suitable for bi-variate measurements if the change in measurements is not great. Small changes in blood cholesterol, for example, may be adequately represented by bi-variate IPC's. The tracking of variables where large differences are measured may suffer when using IPC's. Therefore, IPC's should be backed up with some form of secondary analysis, such as centile rankings, to support tracking where variables have large differences over two measurement visits.

2.6.4 Changes in blood pressure with age

Tracking has been assessed using IPC's or the degree of maintenance within calculated percentiles for age. Longitudinal studies of British children's blood pressure are rare. de Sweit et al. (1992) assessed blood pressure values from birth through to 10 years (n=2088), using sphygmomanometer and Doppler ultrasonograph techniques. Results showed increases in blood pressure throughout the growth period, a recognised physiological response with increasing biological age (Tanner, 1962; Malina and Bouchard, 1991). Between 5 and 10 years of age, systolic blood pressure increased from 89 to 94 mmHg, with diastolic pressure increasing from 58 to 62 mmHg. Tracking of blood pressure from early life to the pre-adolescent phase was reported as r= 0.28 at 2 year to 0.59 at 10 year using IPC's.

These findings were similar to the tracking reported by Clarke et al. (1978). In a study of 820 American subjects (initial age 6-12 year), blood pressure was measured yearly over a 6-year period. Blood pressure tracked poorly over the duration of the study ($r = 0.18$ to 0.41; $P>0.05$). Predicted maintenance within upper centiles was low. Only 3% of children would be expected to remain above the 80^{th} centile for systolic blood pressure, with 2% similarly maintaining a high rank for diastolic.

Despite a lack of evidence to support tracking of blood pressure, children were felt to "occupy" a specific part of a blood pressure distribution with increasing age. Therefore, it is not surprising that the tracking of blood pressure was moderate when the effects of normal somatic growth are considered. Clarke and co-workers (1978) did not include a maturation term in analysis. During the pubertal growth spurt, associated with the chronological age-range of subjects, growth rates will

vary between and within subjects. Such variation must necessitate the use of maturity indicators in subsequent analysis. Unfortunately, few studies have used these indicators in analyses.

In investigations of tracking, the use of percentile values may be an equal predictor of adult blood pressure. Berenson et al. (1982) reported that normal blood pressure values for children of 14 years (128/78 mmHg) may be comparable to hypertensive levels in adulthood (170/110 mmHg), if the 95th percentile is followed. As a practical measure of assessing tracking the percentile method may be an efficient predictor of potential risk in adulthood (Roche, 1995). The use of such statistical methods must be deemed effective only when a series of data points are available. Currently, such studies and statistical applications are rare.

Despite little evidence to suggest a large prevalence of the disease in children, essential hypertension is thought to have paediatric origins and may track throughout the life-cycle (Berenson et al., 1982). When the effects of normal biological development were excluded from changes in blood pressure, Berenson et al., (1982) reported no significant difference between levels of blood pressure in developing children (age 6 months-18 years). The tendency for children to maintain their rank may provide evidence for the maintenance of hypertensive profiles during the life cycle. These findings imply the need for screening of blood pressure during the developmental phase as a possible indicator of nypertension during adulthood.

2.6.5 Changes in blood lipids with age.

Moderate degrees of tracking have been reported for whole blood cholesterol levels from childhood to adulthood (Laskarzewski, et al., 1979; Webber et al., 1991; Guo et al., 1993; Bao et al., 1994). There have been few reported studies on the tracking of other lipid sub-fractions in children. This emphasises the difficulty in maintaining longitudinal study designs, especially when using invasive methodologies.

Several studies have investigated the tracking of blood lipids during childhood. Clarke et al. (1978) investigated the changes in the blood lipids of American children over a 6-year period. Six hundred and sixty-two children (aged 5 to 18

years) were measured yearly. Non-fasting total cholesterol measurements were taken at each test occasion. The tracking of total cholesterol was assessed using inter-period correlation coefficients. Correlation coefficients between measures taken at two, four and six year intervals were r = 0.63, 0.63 and 0.61, respectively. When separated by age group the tracking of total cholesterol was relatively similar for all age groups (r = 0.48 to 0.69). After 6-year, 50% of subjects who were initially measured in the highest percentile for total cholesterol maintained that ranking. No assessment of other lipid sub-fractions was made, increasing the possibility of misclassification of the blood lipid profile by using a single-lipid reference (Rimmer and Looney, 1994). Children in this study represented a large variation in chronological age and, it must be assumed, biological age. Despite no attempt to introduce a biological maturity term into the analysis, these results showed that total cholesterol tracked from childhood into adolescence.

These findings were replicated in another study of American children. Laskarzewski et al. (1978) examined the lipid profile of 108 American children (year groups 5 to 12). No report was made of the number of children in each age group, and analysis was performed on the study group as a whole. Observations were made at 1, 2 and 3 year periods. Measurements were taken of non-fasting total cholesterol, HDL-C, triglycerides and low-density lipoprotein cholesterol (LDL-C). Inter-period correlation coefficients were used together with percentile ranks. Total cholesterol and HDL-C were well correlated between test occasion 1 and 4 (rho = 0.65 to 0.80; $P<0.001$ for total cholesterol, 0.53 to 0.60; $P<0.001$ for HDL-C). Of those children who were placed within the highest decile for total cholesterol at test occasion 1, 27% remained in that decile after four years, lower than the maintenance values reported by Clarke et al. (1978). High-density lipoprotein cholesterol levels were tightly aggregated in the upper centile. Between 64% and 82% of children in the upper centile for HDL-C remained there during follow-up.

These values provide further evidence for the tracking of blood lipid concentrations during childhood and adolescence. Again, this study failed to partition out the confounding effects of biological maturity from analysis. From these results, a favourable baseline lipid measurement appears to be essential in maintaining normal lipid levels during this important period of development. Unfortunately, such longitudinal studies continuing into early-adulthood are rarely reported. Similarly, the use of IPC's to determined tracking are problematic given this study

design. Roche (1997) emphasised the problems in using IPC's when the inter-measurement period becomes too great. The higher IPC's reported were for a period of four years. During this period the confounding effects of growth will, surely, have influenced lipid levels. Using an IPC to assess tracking over this period would be inappropriate unless intermediary measurements were taken to assess short-term changes in lipids.

Webber et al. (1991) measured the blood lipids of 1586 American children, from 2 to 14 year, with observations at baseline and 12 year later. Age "bands" from 2-4 year to 13-14 year grouped subjects at first test occasion. A multiple fasting lipid analysis was performed including assessment of HDL-C, total cholesterol, LDL-C, VLDL-C and trigylcerides. Tracking was assessed using inter-period correlation coefficients and percentile values. Correlations for total cholesterol were moderate ($r = 0.58$ to 0.74; $P<0.05$), as were those for HDL-C ($r = 0.35$ to 0.43; $P>0.05$). Examination of percentiles showed that approximately 50% of subjects who had elevated total cholesterol levels at baseline remained in the uppermost quartile after 12 year. For HDL-C, 42% of subjects remained in the upper percentile after the 12-year interval.

The study of Webber and co-workers provides yet more evidence for the moderate tracking of blood lipids during growth. Unfortunately, the previously cited problems of using IPC's over long inter-measurement periods (Roche, 1997) should necessitate caution when interpreting these results.

The higher tracking for total cholesterol was further emphasised by Guo et al. (1993). Serial analysis of plasma lipids (fasting) were performed on 96 subjects aged between 9 and 21 year at first test occasion. The age-range was divided into 2-year segments from 9-11 year to 19-21 year. Following the determination of baseline values, subjects were tested at 4-, 6-, 8-, 10- and 12-year intervals. The tracking of blood lipid variables was determined using inter-period correlation coefficients. Additionally, the probability of adult hypercholesterolaemia, given childhood values, was predicted by assuming a bivariate normal distribution for paired measurements.

Results showed high inter-period tracking of total cholesterol at all intervals ($r = 0.58$ to 0.77). Two year and 12-year tracking were the highest ($r = 0.77$ and 0.72

respectively). Importantly, the tracking coefficients between different age bands did not differ, despite variations in both chronological and biological age. High-density lipoprotein cholesterol concentrations did not track as well as total cholesterol (r = 0.31 to 0.57), with the highest tracking shown for the 4-year interval.

The prediction of high risk at age 19-21-years was greatest for those subjects having elevated total cholesterol (>5.17 mmol.l^{-1}) or low HDL-C (<0.91 mmol.l^{-1}) at the initial test. Potential risk was estimated as being nearly four-fold for both total cholesterol and HDL-C. These results further emphasise the predictive use of childhood total cholesterol levels in estimating the relative risk during adulthood. Importantly, Guo and co-workers provided evidence to suggest that low levels of HDL-C during childhood may lead to similarly low levels during adulthood.

Evidence that low levels of HDL-C during childhood may contribute to low adult levels is of concern. Dietary manipulation is a cardinal intervention for reducing total cholesterol levels (Schaefer et al., 1995). Little empirical evidence exists suggesting the favourable alteration of HDL-C following structured exercise (Blessing et al., 1995). Smoking and body fat have been associated with increased risk of low HDL-C concentrations (Twisk et al., 1995) yet these findings remain to be supported by other studies. How to promote levels of HDL-C remains contentious. The use of an increased volume of high intensity physical activity to raise HDL-C concentrations appears to have limited effects. Without evidence to support such a prescription, an appropriate intervention to elevate HDL-C remains to be proven.

Clarke et al. (1978), Laskarzewski et al. (1979), Webber et al. (1991) and Guo et al. (1993) provided valuable information on the potential tracking of blood lipids. Similar studies, from a European perspective, are very rare. The Amsterdam Growth Study (Twisk et al., 1995) utilised a multivariate, longitudinal analysis of changes in blood lipids. From the age of 13 years, 84 males and 98 females undertook four annual measurements, one at age 21 years and a further assessment at age 27 years. The tracking of total cholesterol and HDL-C were determined using inter-period correlation coefficients and quartile ranks.

As with other reported studies, inter-period correlations for total cholesterol were at their highest between the ages of 13 and 16 years (r = 0.66 to 0.84). The inter-period correlation for total cholesterol, between 13 and 21 years, was also high (r = 0.62 to 0.71). Levels of HDL-C did not track as well as those for total cholesterol (r = 0.61 to 0.70) in agreement with previous literature. Uniquely for a longitudinal study design, the ratio of TC:HDL-C was used as an indicator of overall lipid profile. The TC:HDL-C ratio tracked well (r = 0.70 to 0.79), with inter-period correlations from age 13 to 21 years equivalent to those for total cholesterol (r = 0.61 to 0.74).

Boys who had elevated total cholesterol at the first test occasion were more likely to have similar elevations at age 21 years than girls (67% compared to 39%). Whilst these differences were not apparent for HDL-C concentrations (41% compared to 40%), the percentage of girls who exhibited elevated TC:HDL-C at age 21 years exceeded that of the boys (41% compared to 54%). Twisk and co-workers identified the positive contribution of smoking and body fat to maintaining an elevated blood lipid profile during adulthood. The presence of these factors throughout the adolescent period, coupled with the tracking of an adverse lipid profile, necessitates both identification and intervention during childhood. Despite the Amsterdam study providing evidence for the tracking of blood lipids during adolescence, knowledge of these changes from the pre-pubertal to circum-pubertal periods is limited. From a British perspective the understanding of changes in blood lipids, and many other risk factors, is limited.

- An appropriate cut-off point for elevations in blood lipids

Empirical evidence indicates that total cholesterol, TC:HDL-C, and to a lesser extent HDL-C, levels track from child- to adulthood. These findings are complicated by the lack of criterion standards to show potential risk. No single cut-off point has been provided for children's blood lipids, severely limiting any findings to comparable studies.

The lack of an acceptable criterion "cut-off" for children is not surprising. Relatively low levels of hypercholesterolaemia have been reported for children. When coupled to low levels of chronic disease this may make the determination of such criteria difficult. The choice of an appropriate cut-off point for circum-pubertal children is governed by standards used for adolescents. Whilst several studies

appear to recommend a uniform total cholesterol cut-off point for adults (>5.2 $mmol.l^{-1}$), the problems associated with creating such standards for younger age groups are complex.

Goldbloom (1992) reviewed data from 71 North American cohort studies and concluded that the effects of multiple laboratories, innumerable testers and poorly maintained equipment would only confound previously reported data. Whether these studies include both clinical and opportunistic health trials is unclear, yet Goldbloom (1992) highlighted a lack of follow-up advice for patients exceeding these cut-off points. Such findings must indicate a lack of continuity in defining appropriate cut-off points for children, a finding echoed in British studies investigating blood lipid profiles.

Armstrong et al. (1990b; 1991), used a "cut-off point" of >4.65 $mmol.l^{-1}$ for total cholesterol concentration. Whilst this cut-off point may be considered arbitrary, in view of the variation in criteria espoused by other sources, it provided a baseline for inter-study comparison. Additionally, the use of a single cut-off point does not provide an indication of the "degree" of elevation of blood lipids over recommended levels.

Several consensus bodies have provided multi-level criteria for the assessment of elevated blood cholesterol levels (Boulton et al., 1991; Plaza-Perez, 1991). More recently, the Canadian Consensus Conference on Cholesterol (1992) recommended a tiered system of cholesterol classification to provide a more sensitive indicator of blood lipid concentrations (Table 9). These values were arbitrary for younger subjects (<19 years), yet provide a truly multi-level approach for determining lipid profile. The use of a single reference point will not be sensitive enough to classify the blood lipids of children and adolescents. Variations in maturity status will affect blood lipid profile (Malina and Bouchard, 1991). Therefore, the use of a single reference value may not be particularly accurate but will have great value for health promotion and change.

Table 9. The Canadian Consensus Conference Cholesterol Guidelines.

Source: Horlick (1992).

	CHD risk			
Age (years)	*Normal*	*Borderline*	*High*	*Very high*
	Plasma total cholesterol ($mmol.l^{-1}$)			
<19	<4.0	>4.0	>4.5	>5.0
20-29	<4.5	>4.5	>5.0	>6.0
30-39	<5.0	>5.0	>6.0	>7.0

The Canadian Conference Guidelines do create some ambiguity when subjects total cholesterol measurements "straddle" two classifications. A subject who has a cholesterol value of 4.0 $mmol.l.^{-1}$ may be classified as both normal and borderline. Without clearly establishing the cut-off points for each risk classification, the Canadian criteria should be interpreted with caution. The guidelines provided by the Canadian conference are limited in their application to children. The use of a <19 years category will not account for differences in biological maturity and resultant changes in blood lipids between maturity groups (Malina and Bouchard, 1991). Given the "free-ranging" series of blood lipid cut-off points used in many other studies, and a lack of empirical evidence on an appropriate cut-off point for children, the criteria used by the Canadians would be as useful as any other. Importantly, the Canadian criteria will provide a unique way of assessing blood levels within a multi-level framework. Changes within this framework may then be analysed to provide an estimate of the stability of blood lipid measurements.

The confusion in establishing a population specific cut-off point for total cholesterol levels is further complicated by the influence of other lipid sub-fractions upon the overall lipid profile. The use of total cholesterol alone may lead to the misclassification of subjects as hypercholesterolaemic (Srinivasan and Berenson, 1992). The ratio of total cholesterol, to high-density lipoprotein cholesterol (HDL-C), has been proposed to provide the best estimate of potential risk (Castelli, 1984; Anderson et al., 1992; Armstrong and Simons-Morton, 1994; Rimmer and Looney, 1994). The TC:HDL-C ratio has become a standard measure of potential risk in child studies (Armstrong et al., 1990; 1991; 1992; Eaton et al., 1995),

providing sensitive indices of the contribution of two influential lipid sub-fractions upon overall lipid profile.

Rimmer and Looney (1994) provided the first reported data on the use of TC:HDL-C ratio in predicting hypercholesterolaemia, when compared to total cholesterol measures alone. Fasting blood plasma samples were collected from 102 children aged 15-16 years. These samples were analysed using an enzymatic reference method. Results from this study showed that 21% of all subjects had elevated total cholesterol (>4.5 $mmol.l^{-1}$), with only 2% of subjects classified as hypercholesterolaemic using TC:HDL-C cut-off point of >4.5. These results provide evidence for the potential misclassification of an elevated lipid profile using a total cholesterol measurement alone. Despite such findings the lack of appropriate cut-off points for total cholesterol, HDL-C and TC:HDL-C should promote caution when interpreting these results.

Further confusion exists when the TC:HDL-C ratio alone is used as a measure of elevated cholesterol levels. Elevated HDL-C may "mask" actual levels of total cholesterol that may not accurately reflect potential risk from elevated total cholesterol. These false-positives (total cholesterol risk but no TC:HDL-C risk), may not provide an adequate assessment of lipid profile unless complete descriptive data are provided for each sub-fraction, and are reported accordingly. The measurement of multiple lipid fractions is probably the most effective approach when determining coronary risk in children.

2.6.6 .Changes in body fat with age

Longitudinal studies of changes in British children's body fat are rare. Brodie et al. (1989) analysed the growth of Northern English boys from age 11 to 16 years. Measurements were taken three times yearly for 5 years. Body fat was expressed as the amount of fat contained within the body, derived from four skinfold thicknesses (subscapular, suprailiac, biceps, and triceps) and using regression equations. The maturity status of the children was determined by viewing secondary sexual characteristics (Tanner, 1962). Body fat increased over the 5 years of the study by 3.3 kg (70.2%). Tracking of body fat was calculated using IPC's. Correlation analysis revealed moderate, yet significant, tracking of body fat

during the pubertal growth spurt ($P<0.001$). Results from this study emphasise the relative stability for boy's body fat during the most rapid period of pubertal growth.

These results should be interpreted cautiously due to the use of prediction equations in determining total body fat mass. Hawes (1996) and Reilly et al. (1996) have previously reviewed the limitations of such techniques. Criterion measurements of children's body fat are controversial. The concurrent validity of several techniques is limited by the lack of a current "gold standard" for body fat measurement. Magnetic resonance imaging (Peters, 1994) and dual-energy x-ray absorptiometry (Goulding et al., 1996; Gutin et al., 1996) techniques have been used to quantify the body fat of children. These techniques are at the forefront of body fat assessment, yet are encumbered by cost, social intrusion and access to facilities. Hydro-densitometry does not provide assessment of regional body fat distribution (Goulding et al., 1996) and may not be wholly acceptable for children afraid of submersion. The body mass index (BMI) again provides little information as to the regional distribution of body fat, and consistently fails to differentiate between fat- and fat-free mass components of the body.

Measurements of skinfold thicknesses are the most commonly used technique to assess the regional fat distribution of children. Many authors have converted skinfold thickness into percentage of body fat using regression equations. Several such equations have been developed for estimating the body fat of children (Lohmann et al., 1975; Harsha et al., 1978; Boileau et al., 1985; Slaughter et al., 1988). The use of these regression equations to predict overall body fat will not account for both subcutaneous and internal deposits of fat (Reilly et al., 1996). In the growing child, the effects of the pubertal growth spurt will accentuate these differences.

Without the cost and accessibility of computer generated imaging, it would appear that skinfold thickness would provide the most suitable measure of body fat assessment in the developing child. Whilst evidence suggests that the technique will not accurately identify internal body fat stores (Peters, 1994; Goulding et al., 1996; Gutin et al., 1996), consensus opinion recommends summing several skinfold thickness to provide the best indices of subcutaneous fat (Reilly et al., 1996).

Of several large-scale growth studies, only the Muscatine study, from America, and the Amsterdam growth study have reported evidence for the tracking of skinfold measurements of body fat from childhood into adulthood (Clarke et al., 1978; 1993; Twisk et al., 1995). The 1978 report included only the tracking of the triceps skinfold and did not report changes in body fat into adulthood. The use of a single skinfold in assessing changes in total body fat must be considered flawed. Such a technique will not account for changes in peripheral and central fat deposits and will not be sensitive enough to detect changes in total body fat (Peters, 1994; Goulding et al., 1996; Gutin et al., 1996).

Clarke et al., (1993) investigated changes in the triceps skinfold thickness from childhood into adulthood. Between the ages of 9 and 18 years subjects were measured bi-annually, with subsequent measurements taken at age 23, 28 and 33 years. Tracking of skinfold thickness was assessed using IPC's and the maintenance of subjects within centile ranks. Inter-period correlations for triceps skinfold, from age 9 to 30 years, were moderate, ranging between r = 0.44 to 0.58. Between 40% and 46% of 9-year old subjects maintained their position within the upper centile for triceps skinfold at age 30 years. These findings, whilst limited due to the use of only one skinfold thickness, indicate that peripheral body fat does not track as well as other body size measurements. The BMI tracked well (r = 0.59 to 0.73) with 62% to 65% of subjects maintaining their rank for this variables throughout the development period. Without assessing both central and peripheral body fat sites the study of Clarke et al., (1993) provides only limited information on tracking during the development period. Additionally, the use of IPC's to assess tracking over long inter-measurement intervals has been questioned (Roche,1997). Therefore, caution should be warranted when interpreting these results.

The findings of Clarke et al., (1993) are similar to those of a more comprehensive assessment performed by Twisk et al., (1995) as part of the Amsterdam growth study. This large study of 89 male and 98 female subjects used the sum of 4 skinfolds (subscapular, suprailiac, biceps, and triceps) as an index of body fat.

Inter-period tracking was poor to moderate between the ages 13, 21 and 27-year ($r = 0.22$ to 0.55). The maintenance of subjects above the 75th centile was similar to that reported by Clarke et al., (1993). Of those 13 year olds assessed as being in the highest centile at the first measurement 46% to 52% remained in the highest centile between the ages of 21 and 27 years.

Clarke et al. (1993) and Twisk et al. (1995) provide limited evidence for the tracking of body fat during the transition from child- to adulthood. Changes in the total amount and distribution of fat will be greatly affected by the biological development of the child. Whilst a genetic component has been associated with the increased prevalence of fat (Olowookere, 1992), the aetiology of obesity is primarily related to the failure to regulate food intake. Whilst some evidence does exist to suggest a gene-environment interaction in human obesity (Sorensen, 1997) the paradox between genetics and choice behaviours may make the establishment of tracking coefficients difficult. Certainly, a gene-environment interaction should not be wholly dismissed as a predictor of changing body fat levels in children.

2.7 The health, fitness and activity continuum: psychological influences upon physical activity participation

The model of Bouchard et al. (1993) suggests that participation in physical activity will be because of physical, social and environmental factors. Investigations into the determinants of physical activity, and its relationships with risk factors, have primarily focussed upon physiological variables. The contribution of psychological variables to physical activity participation, whilst included in the consensus model, have rarely been investigated.

The positive benefits of exercise, in promoting acute and chronic psychological well being, are well documented (Dishman, 1990; Bouchard et al., 1993). In a position statement the International Society of Sport Psychology (1992), proposed the potential psychological benefits of regular, vigorous physical activity as:

- reduced state anxiety
- decreased levels of mild to moderate depression
- reduced neuroticism and trait anxiety from long-term exercise
- reduction in various kinds of stress
- beneficial emotional effects

Such findings promote the use of exercise as a non-pharmacological method of promoting positive psychological benefits. Postulated links between psychological constructs and physical activity remain to be identified and proven.

2.7.1 Physical activity and self-perception

The way that children view themselves may undermine their participation sport and physical activities. Self-perception, as a construct, is used as a primary indicator of mental and social life adjustment (Fox, 1992). This may affect all domains of life, especially the physical. Unfortunately, several terms, associated with self-perception, are used interchangeably. This has led to some confusion. *Self-concept* refers to the individual self-description, developing personalised statements into a multi-faceted description of the subject (Fox, 1990). *Self-esteem* describes the person's worth, or good, inherent in his or her self-description (Whitehead, 1995), and is commonly used interchangeably with self-perception, especially within the physical domain. The multi-faceted nature of self-perceptions will be directly affected by components of self-concept and self-esteem. The enhancement of self-esteem, through exercise and physical education programmes, is generally supported for schoolchildren (Gruber, 1986). Unfortunately, the theoretical influence behind this effect is unclear at present (Fox, 1992).

The influence of self-esteem, on personal behaviours, may provide a mediator for participation in and maintenance of physical activity behaviours. Identifying such perceptions, within the physical domain, may provide evidence for the influence of self-esteem on physical activity. This relationship remains to be identified in British child studies.

- Measuring physical self-esteem

The measurement of self-esteem has been confounded by the theoretical ambiguity of previous research. Several models of self-esteem structure have been proposed. Self-esteem, as a uni-dimensional construct, is widely criticised (Fox and Corbin, 1989; Fox, 1990; Whitehead, 1995). The lack of sensitivity of a global term, in distinguishing between the many domains of self-esteem, has led to

the development of multi-dimensional models of self-esteem within the physical domain (Harter, 1985; Fox and Corbin, 1989).

Harter (1985) provided a multi-dimensional approach to global self-esteem measurement, in children, the Self-Perception Profile for Children (SPPC). The use of several domains, such as physical appearance, athletic competence and social acceptance, provides separate measures of competency or adequacy in individual domains and as part of global self-esteem. The SPPC includes five sub-domains, thought to affect global self-esteem. With increasing cognitive ability, characterised by advancing maturity, further sub-domains, such as job competence and romantic appeal, are included. As more domains are appended to the profile (11 for adolescents), identification of the sub-domain becomes less clear. The sub-domains of physical appearance and athletic competence may draw different perceptual responses (Fox, 1992). When relationships between self-esteem and actual physical parameters are being assessed, the physical domain must be considered the most important influence upon activity and exercise behaviours.

The concept of multi-dimensionality has been further adapted to investigate the structural organisation of global self-esteem (Fox, 1990). Recent literature has focused upon the multi-dimensional and hierarchical organisation of global self-perceptions. The hierarchical structure of physical self-esteem represents specific dimensions of the self. These then "feed" into the global construct at apex level (Fox, 1990). Global self-esteem may be modified by self-perception changes at lower levels of the hierarchical structure. Using the hierarchical structure of global self-esteem proposed by Harter (1985), the physical domain consisted of two dimensions physical appearance and athletic competence. Despite acceptance of these dimensions, in affecting apex level global self-esteem, the sensitivity of these dimensions to accurately describe the physical domain have been questioned.

Fox and Corbin (1989) proposed a three-tier hierarchical structure of global self-esteem within the physical domain. Following large-scale (n-1191), questionnaire administration four sub-domains were identified as having discriminate validity to assess the sub-domain level of physical self-worth (sports competence, physical condition, attractive body and physical strength). Additionally, a general physical

self-worth sub-scale was constructed, to provide a general or global measure of self-worth. Factor analysis, using a principal component design, revealed that the four sub-domain scales measured independent, but related, perception constructs within the physical domain (Fox, 1990). The three-tier hierarchical model is outlined at Figure 2.

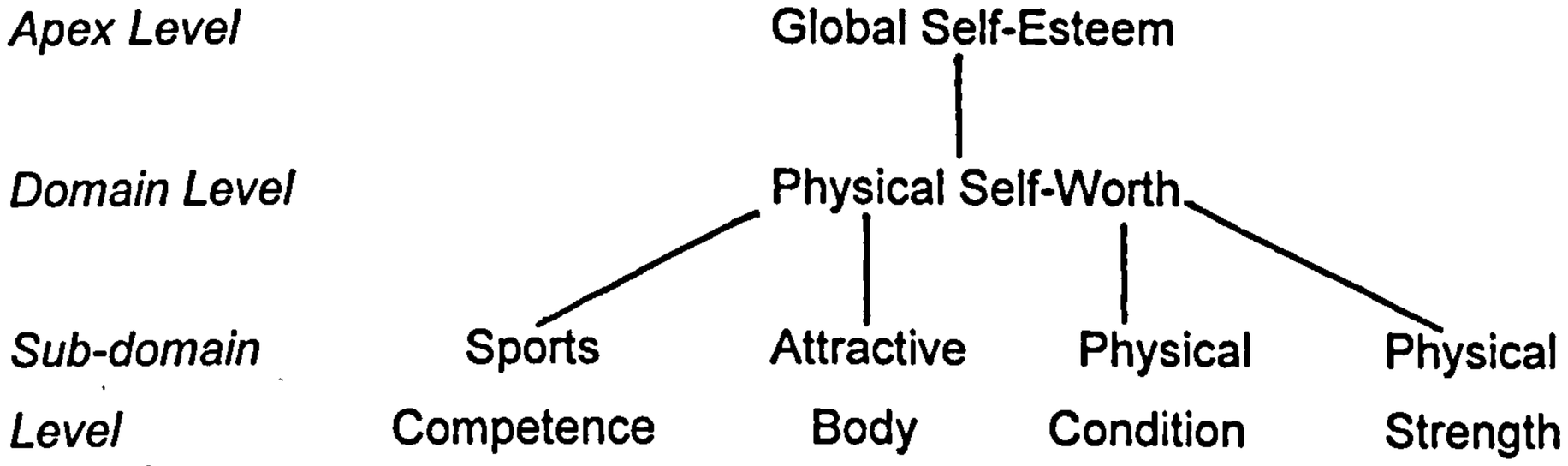


Figure 2. Three-tier hierarchical organisation of self-perceptions. Redrawn from Fox (1990).

The development of the Physical Self-Perception Profile (PSPP) represented a progression in the assessment of the multi-dimensional, hierarchical constructs of self-esteem within the physical domain. The less stable sub-domain level influences may permeate upwards to affect apex level dimensions. Interest in the relationship between physical indicators of health and fitness and global self-esteem has yet to stimulate research into the possible influence of psychological parameters upon health/fitness variables.

Studies using external criteria to validate the sub-domains outlined within a hierarchical self-esteem structure have incorporated indicators of physical fitness. The use of fitness indicators is thought to provide evidence for the concurrent validity of the PSPP sub-scales (Whitehead, 1995). Perceptions of the attractive body may correlate with measurements of body size and composition. Unfortunately, reports of the concurrent validity, using external criteria, are rare.

As an associated study to the current project, Bettinson (1996) used a sample of 86, 6th and 11th grade boys, from the south-east of England. Construct validity of the PSPP was determined using indicators of physical condition (20 m shuttle test - *20 MST*), sports competence (alternate hand-wall toss), physical strength (grip dynamometer) and attractive body (skinfold assessment). Moderate yet significant correlations were reported between physical condition sub-scale and the 20 MST ($r= 0.51$ to 0.61, $P<0.001$). Physical strength and grip test performance were also

correlated (r= 0.52 to 0.61, P<0.001). Physical condition and skinfold test (r= -0.36 to -0.46, P<0.05) and attractive body and skinfold test (r= -0.30 to -0.33, P<0.05) showed lower correlations.

In a similar associated study, Saunders (1996) examined the construct validity of the PSPP in a sample of 9 to 11 year old Liverpool schoolchildren (n= 60). Significant correlations between strength (r=0.33, P<0.05), body attractiveness (r= -0.41, P<0.01), sports competence (r=0.46, P<0.01), and physical conditioning (r=0.52, P<0.01), and appropriate fitness indicators were reported for boys. Girls reported similar findings for body attractiveness (r= -0.50, P<0.01), sports competence (r=0.38, P<0.05), and physical conditioning (r=0.41, P<0.01), yet no correlation was reported between the strength domain and grip strength.

These results are similar to the findings of Whitehead (1995), and provide some evidence for the concurrent validity of the PSPP. Importantly, only two sub-scales (physical strength and physical condition) were related to the appropriate physical test. The lack of standardisation of appropriate fitness tests, hypothetically chosen to approximate the sub-scale being measured, makes comparison between studies difficult. Field testing of physical fitness provides an accessible method of collecting large amounts of data. The use of criterion, laboratory measurements of fitness must be considered as the next progression in determining relationships between fitness and self-esteem parameters.

Whilst promising, these studies assume that children can differentiate between self-perceptions in the physical domain. The initial psychometrics of the instrument were determined using a sample of college-age (≥18 year) subjects (Fox, 1990). In subjects of this age, an level of cognitive maturity is assumed. As such, the PSPP is *population specific* for older age subjects. Psychometric validation must be provided to determine the suitability of the PSPP for children.

Whitehead (1995) used a sample of 7^{th} to 8^{th} grade boys and girls (n=459), to estimate the concurrent validity of an adapted PSPP for younger children. Children completed the adapted PSPP (C-PSPP). A principal component analysis was used to evaluate the factorial validity of the four PSPP sub-scales. Factor rotation was high for all a priori determined sub-scales, with all factors loading above the

0.40 value. When a four factor solution was obliquely rotated, 36% of total variance remained unexplained.

Despite such promising evidence, supporting the earlier cognition of younger children, the study of Whitehead (1995) stands as another example of population specificity. No reported British study has attempted to provide evidence for the factorial content of the PSPP for younger children, representing a gap in current literature. Further population studies are required to assess the suitability of the instrument to identify those sub-domains associated with domain and apex level self-perceptions and self-worth. Additionally, more evidence is required to assess the concurrent validity of such an instrument in measuring sub-scales associated with criterion, external evaluations.

In Whitehead's study, the construct validity of the C-PSPP was established against a battery of fitness tests. Moderate correlations were reported between physical condition and performance of shuttle-run, 50 yard dash and 600 yard run ($r=-0.61$ to -0.69, $P<0.001$ for boys; $r=-0.61$ to -0.70, $P<0.001$ for girls). Lower correlation's were reported between other indicators of fitness (pull-ups, sit-ups, standing long jump and mile run), sub-scales of the PSPP and physical self-worth. The use of predominantly performance-based measures of fitness did not take into account external assessment of body composition variables, associated with the attractive body sub-scale. Similarly, measures of direct strength associated with the physical strength sub-scale were not assessed.

Currently, there are no British reports upon the construct validity of the PSPP using laboratory based measures of fitness. The fact that such measurements have yet to be reported reflects the difficulty in assessing fitness, for large samples of subjects, in a laboratory environment. Similarly, the problems of choosing a standardised methodology to approximate the four PSPP sub-scales have made such assessment difficult. This "criterion" identification of relationships must be considered a logical progression our understanding of the PSPP's validity for children.

2.7.2 The physical self-perceptions of children

Studies examining the physical self-perceptions of children are rare. Problems arise with younger children as they tend to differentiate their self-worth into more complex self-profiles (Whitehead, 1995) related to increased cognitive function. Changes in self-perception must be considered a function of normal development, yet developmental studies of self-perceptions have yet to be reported.

The psychometrics of the PSPP, as reported by Whitehead (1995) provided evidence for its application in the physical domain. Relationships between physical self-perceptions and free-living physical activities are less well understood. Determining such a relationship is fraught with problems. Interchangeable methodologies and variation in the cognitive abilities of the developing child may preclude an adequate assessment from being made. The place of well-defined sub-domains of self-esteem, when associated with free-living behavioural responses may be difficult to ascertain, and is subject to already cited methodological flaws.

Assessing those physical parameters associated with individual sub-scales, during free-living physical activity, is difficult, This creates a situation of opportunistic relationship identification between sub-scales and the chosen measurement of physical activity. The "blind" study of these parameters may yield evidence for the relationship between physical conditioning and sports competence sub-scales and free-living activities of appropriate activity. For the attractive body and physical strength sub-scales, such relationships may be less apparent.

Despite such shortcomings, relationships between physical self-perceptions and free-living physical activities should be investigated. A dearth of literature exists investigating such relationships. A need exists for appropriate research into the psycho-physiological antecedents of physical activity behaviours. This will add to our understanding of an appropriate framework from which to describe the physical activity, health and fitness continuum for children.

2.8 Summary of literature relating to the role of physical activity in the health, physical fitness and physical activity continuum.

Physical activity forms a major component of the holistic model for health (Bouchard et al. 1990). Whilst this model is not wholly appropriate for children their levels of physical activity are postulated to influence health-related fitness, other lifestyle-related factors and general health. Such a model requires restructuring to be more specific for children.

Whilst physical activity is positively related to health, (Paffenbarger and Lee, 1996), researchers have commonly reported low levels of free-living physical activity in adults and children. These findings are particularly worrying as physical activity habits appear to be formulated during childhood (Riddoch and Boreham, 1995; Malina, 1996). Whether such behaviours may be the antecedents of a sedentary adulthood is unclear. Evidence to support the "tracking" of physical activity remains equivocal, primarily due to the lack of a standardised methodology to assess free-living physical activity. Importantly, low levels of children's physical activity must be considered a potential health problem.

Despite the important contribution of physical activity to a multi-disciplinary model of health, relationships between physical activity, fitness and other indicators of health have yet to be established for younger populations. There is little empirical evidence on reductions in the resting blood pressure of normotensive adolescents following structured physical activity programmes (Hansen et al., 1991; Alpert and Wilmore, 1994). Relationships between physical activity and blood lipids in children are similarly unclear. Whilst some authors have reported associations between physical activity and favourable changes in blood lipids (Blessing et al., 1995) general evidence remains equivocal. Small reductions in body fat have been associated with increased physical activity in the general adolescent population (Bar-Or and Baranowski, 1994). Currently, such a relationship, in younger children, remains to be established. Higher intensity continuous physical activities (heart rate >165 beats.min^{-1} for a period >12 min, three times weekly) have been shown to promote cardiorespiratory fitness. Despite these findings, such an exercise prescription appears to be uncharacteristic of the free-living physical activity of children. Regular physical activity is thought to exert a beneficial effect upon mental health and well-being (Calfas and Taylor, 1994; Dishman, 1995).

Currently, few researchers have investigated such relationships in younger children.

Whilst consensus promotes the use of regular physical activity in preventing ill-health during adulthood (Shephard, 1995), investigations of the role of activity in the health of the child are rare. The influence of normal growth and development, and the problems associated with implementing longitudinal studies during the growth period present problems. Longitudinal investigations of chronic disease risk factors, and psychological variables, are important to our understanding of changes in the risk factor profile during growth. Such studies are uncommon to British children.

Whilst there have been several British studies of changes in individual risk factors, no attempts have been made to provide an analysis of changes in the components of the broader health, fitness and physical activity continuum (Bouchard et al., 1990; Shephard, 1995). With such limitations, the need for a framework to examine children's health, fitness and activity represent the primary research aim of the current study. Importantly, the lack of British data on changes in the components of the holistic model, during the growth period, makes the use of a longitudinal study design important. Such a study design will allow for the identification of tracking of risk factors during the circum-pubertal period.

2.9 The major aims of the current study

The current study was designed to provide a psycho-physiological, longitudinal investigation of the physical activity, health and fitness of Liverpool schoolchildren. There have been no reported attempts to establish such relationships in this demography. Consequently, there is a lack of information on the "risk factor profile" of Liverpool schoolchildren. Similarly, British reports of changes in children's physical activity, risk factors and fitness are uncommon.

The hypotheses stated in section 1 were investigated using five individual studies.

Study One: A descriptive analysis of the free-living physical activity of Liverpool schoolchildren.

- Assessing the levels of physical activity of Liverpool schoolchildren.

- Providing information on a baseline heart rate for subsequent assessment of heart rate responses during normal waking hour's physical activity. Using these techniques directly determined heart rate reserve thresholds would be calculated.
- Investigating the suitability of recommended training loads during normal waking hours physical activity, to the dose-response required for health and fitness benefits.

Study Two: Investigating the prevalence of risk factors and levels of cardiorespiratory fitness in Liverpool schoolchildren.

- Providing the first reported descriptive data investigating recognised chronic disease risk factors in Liverpool schoolchildren.
- Measuring cardiorespiratory fitness levels using maximal treadmill testing.
- Partitioning out differences in body size, using allometric scaling techniques, to provide a more sensitive analysis of changes in cardiorespiratory fitness and selected chronic disease risk factors.

Study Three: Assessing changes in physical activity and risk factors using a longitudinal study design.

- Measuring changes in physical activity, risk factors and cardiorespiratory fitness levels over a 12 month period.

Study Four: Identifying relationships between physical activity and risk factors.

- Determining the relationships between physical activity, chronic disease risk factors and fitness in Liverpool schoolchildren.
- Utilising morphological age and chronological age as simultaneous covariates in analysis of risk factors, physical fitness and psychological health.

Study Five: Describing the Physical Self-Perceptions of Liverpool schoolchildren.

- Establishing the validity and reliability of physical self-perception instruments in children, and changes in these responses over a 12 month period.
- Investigating the relationships between physical activity, risk factors and physical self-perceptions.

Results from these studies will provide an insight into the levels of risk among younger Liverpool schoolchildren. Such assessment will provide a baseline for

subsequent estimation of risk using similar aged populations. A multi-disciplinary assessment of the tracking of physical activity and risk factors has yet to be reported for British children. Importantly, the current research will provide a multi-disciplinary approach to the investigation of the health, fitness activity continuum. From these results the conceptual model of Bouchard et al., (1993) will be re-examined. The model does not appear to be wholly applicable for children. Therefore, the current study will reconsider the model specifically for children. A newer framework will then be provided for children as certain links are investigated. Previous British studies have consistently failed to provide such a comprehensive framework, representing a large gap in current understanding.

METHODOLOGY

3.0 Methodology

3.1 Recruitment of subjects

The sampling process was designed to provide a representative sample of children, from the Liverpool area, aged between 9 and 12 years. 'Stage one' involved contacting primary and secondary schools in the local vicinity of the laboratory. Formal letters of introduction were sent to 27 primary schools and 8 secondary schools, of all religious denominations and fund-holding status. Eight primary and three secondary schools expressed interest in the study. A second letter was forwarded to schools from whom there had been no initial response. Schools not responding to the second approach letter were not included in any further recruitment.

Stage two' of the approach involved formal interviews with headteachers to ascertain their degree of assistance. The transition from primary to secondary school education (age 11 - 12 years) would see a dispersion of children to several secondary schools. It was agreed to use several schools for preliminary fitness testing, validation of techniques and informal approach to children by means of health-related fitness sessions in school time. Following these sessions, children were approached to take part in the main study by formal letter (appendix 1).

'Stage three' of the approach involved the distribution of formal approach letters to parents and children. Approximately 700 letters were sent to primary schools (school years 5 and 6), and 500 letters sent to secondary schools (year 7), requesting participants for the study. A total of 245 boys and 216 girls wished to participate in the study.

3.2 Selection of subjects for the study

Quota sampling of subjects used a measure of physical performance, the 20 metre shuttle test (20-MST), first proposed by Leger and Lambert (1982). The use of pre-selection would prevent a bias in highly active individuals being selected for the study. During preliminary testing, and school-based fitness days, an

overwhelming majority of interested children were athletes or competitive team players. Often, non-athletic children were reluctant to participate in testing without great encouragement. By pre-selecting children from between the high- and low-performance percentiles, it was hoped that less athletic children would participate in the study. Pre-selection would see children excluded from the study that fell below the 25th percentile and exceeded the 75th percentile for the 20-MST. Percentile values, for the 20-MST, were calculated from data collected over several years of similar age children in the Merseyside area (n=230 boys, 250 girls).

Subsequently, 157 boys and 76 girls consented to take part in the pre-selection testing. Testing was performed in a sports hall over a period of two weeks. The Multistage Fitness Test cassette (Queens University Belfast, 1988) was used to administer the test. Subjects were withdrawn from the test when:

- volitional exhaustion was indicated
- subjects could not complete two consecutive shuttles within the time allotted

The calculated percentile values for Merseyside schoolchildren are reported in Table 10.

Table 10. Descriptive data for criterion 20-MST performance based upon a sample (n=480), of Merseyside schoolchildren (9-13 years).

	n	Mean (shuttles)	S.D.	Percentile values	25th	50th	75th
Boys	230	61	19		54	68	83
Girls	250	53	14		32	43	52

Following testing, 38 boys (10.5 $\pm$ 1.1 years), and 39 girls (10.2 $\pm$ 1.0 years), met pre-selection criteria. Mean shuttle values varied from those determined to represent the 50th percentile. A large variation in the results of the highest and lowest performance levels would skew results and provide this anomalous result. These subjects then provided informed written consent to take part in the main study. Several other subjects, who expressed an interest in the study and were within criterion selection for the study, withdrew prior to testing. Reasons for

withdrawal included lack of available time, disinterest and no extrinsic reward for participation in the study.

3.3 Research design

Testing was performed between September 1994 and April 1995, for the first test occasion, and September 1995 and April 1996 for the second. Children were re-tested within 4 weeks of the corresponding first test occasion. The longitudinal study design is outlined in Figure 3.

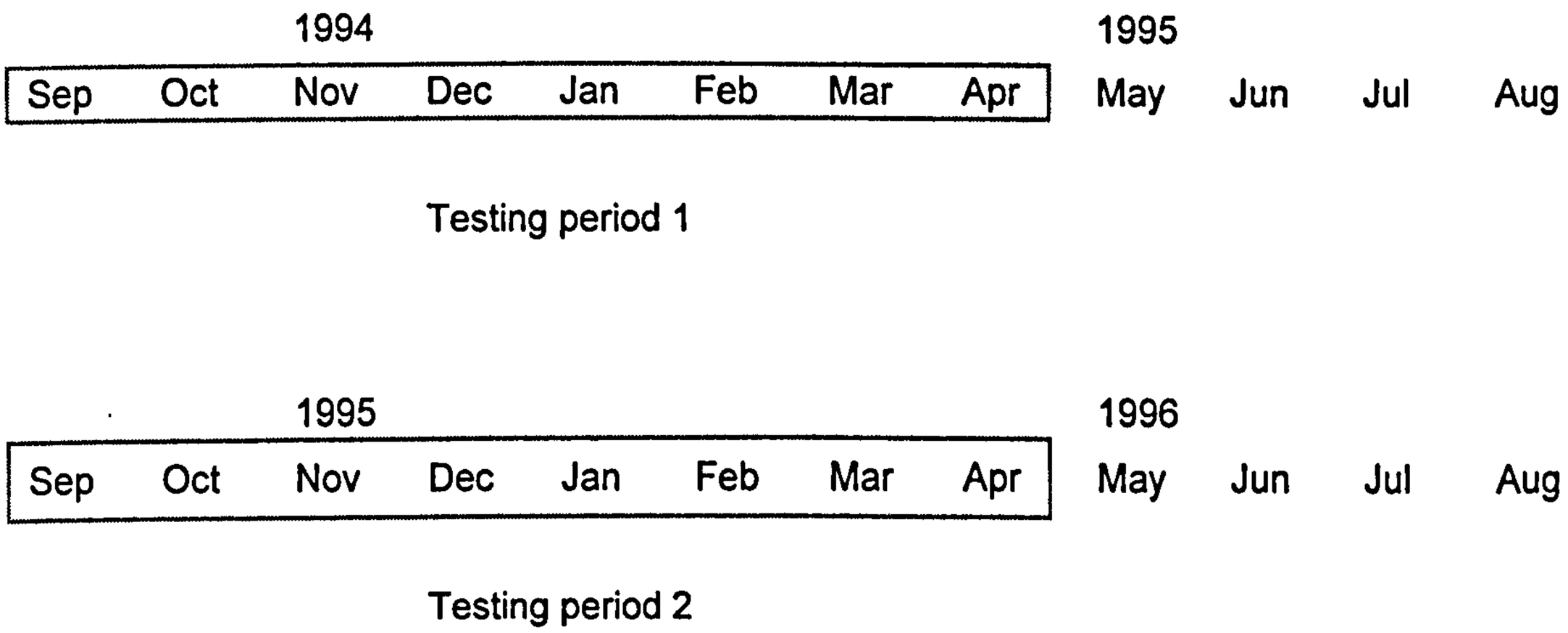


Figure 3. Longitudinal study design.

3.4 Classification of socio-economic status

Subjects were asked to give details of the occupation of the head of household to provide a classification of socio-economic status, using the Registrar General's five-tier classification system (Office of Population and Census Surveys, 1995). Classification required clear definition of manual or non-manual occupations, and of self-employment or company ownership. All children and parents were willing to provide this information.

3.5 Anthropometry

All anthropometric measurements were performed using the guidelines outlined by Lohmann et al. (1988). The choice of these guidelines was to provide a reference set of anthropometric techniques suitable for replication.

- *Stature*

Stature was measured using a wall mounted stadiometer (British Indicators Ltd. Birmingham, England). Subjects were measured without footwear whilst wearing light sports clothing, preferably shorts and T-shirt. Subjects were instructed to stand on a flat surface that was at a right angle to the vertical part of the stadiometer. Heels were placed together and feet angled to around 60 degrees. The scapulae, buttocks and vertical plane of the scapulae were in contact with the vertical part of the stadiometer. The head was aligned in the Frankfort horizontal plane, where the most inferior point of the left orbital margin was at the same level as the left tragion. In the Frankfort plane the line of vision was approximately horizontal and the sagittal plane of the head vertical.

Once in the measurement position the subject was asked to inhale deeply and maintain a fully erect position. Gentle upward pressure was then placed on the manbidular angle. The measurement blade was placed on the superior point of the cranium, with sufficient pressure to compress the hair. Measurement was to the nearest 0.25 cm.

- *Body mass*

Body mass was measured using a beam balance scales (Avery, Birmingham, England). Subjects were measured without footwear and wearing light sports clothing, preferably shorts and T-shirt. The subject stood in the centre of the levelled platform, with weight evenly distributed between both feet, and with arms at the sides. Measurement was taken, to the nearest 0.25 kg, once the beam balance had remained stable for a minimum of 5 seconds.

- *Skinfold measurements - General technique*

Skinfolds were measured using Harpenden callipers (British Indicators Ltd. Birmingham, England). Skinfolds were measured using the technique of Lohmann et al. (1988):

- The thumb and index finger were used to elevate a double fold of skin and adipose tissue approximately 1 cm proximal to the measurement site.
- The fold was raised perpendicular to the surface of the body at the measurement site, with the long axis of the fold parallel to the natural cleavage lines of the skin. The fold was kept elevated until completion of the measurement.
- The calliper was placed over the skinfold where both sides of the skinfold were approximately parallel.
- The measurement was taken after 4 s.

Skinfolds were measured at four sites. Peripherally at the triceps and biceps, and centrally at the subscapular and suprailiac sites. All measurements were performed on the left side of the body, sequentially and in triplicate (Lohmann et al., 1988). The mean of three measurements was recorded, to an accuracy of 0.1 mm.

- *Subscapular skinfold*

The skinfold site was located at the inferior angle of the scapula. The site was located by running fingers inferiorly and laterally along the vertebral border of the scapula until the inferior border was found. The skinfold was measured approximately 45 degrees to the horizontal plane, and within the natural cleavage lines of the skin.

- *Suprailiac skinfold*

The skinfold site was at the mid-axilliary line immediately superior to the iliac crest. An oblique skinfold was grasped posteriorly to the mid-axilliary line, in the natural cleavage lines of the skin. The skinfold was then aligned 45 degrees infero-medially to the horizontal.

- *Biceps skinfold*

The skinfold site was located at the midpoint of the upper arm, measured as the distance between the lateral projection of the acromion process of the scapula and the olecranon process of the ulna. The distance was measured with the arm flexed to 90 degrees, and the mark taken on the lateral side of the upper arm. The skinfold was raised at a point on a vertical line joining the centre of the antecubital fossa and the anterior border of the acromion.

- *Triceps skinfold*

The skinfold was measured at the line used to locate the biceps skinfold. The site of the measurement is taken approximately 1 cm posteriorly to the mid-line of the posterior aspect of the arm, and at the midpoint of the lateral projection of the acromion and the inferior margin of the olecranon process.

- *Sum of Skinfolds*

The sum of skinfolds (SSF) was calculated as:

SSF = Biceps skinfold (BSF) + Triceps (TSF) + Subscapular (SSSF) + Suprailiac (SISF)

The sum of four skinfold thicknesses was then calculated to the nearest 0.1 mm.

3.6 Blood pressure

Blood pressure was measured using a mercurial sphygmomanometer (Accosson, Birmingham, England) with appropriate sized cuffs (bladder covering at least two-thirds of the upper arm) and a binaural stethoscope (Taylor Instruments, Toronto, Canada). Subjects rested for 5 minutes, prior to measurement, in the semi-recumbent position.

Pressures at the systolic point of appearance (Korotkoff I), and diastolic point of muffling (Korotkoff IV), were recorded with average of three measurements and in accordance with the guidelines of Ragg et al., (1980). Measurements were recorded at 1 min intervals, with readings taken to the nearest 2 mmHg.

3.7 Blood lipid profile

Total cholesterol and high density lipoprotein cholesterol were assayed using blood samples placed in the Reflotron II reflectance photometer (Boehringer Mannheim, Mannheim, Germany).

- *Biochemical assaying - criterion technique*

Subjects were seated prior to fingerprick blood collection, or placed in the semi-recumbent position if requested. The finger was immersed in warm water for one minute prior to capillary puncture to help peripheral blood flow. The first droplet of blood was wiped off to prevent excessive collection of blood sap. All skin punctures were performed utilising guidelines outlined in the IM Marsh Human Movement Studies Laboratory ethics document (appendix 2).

- *Whole-blood cholesterol assaying*

Non-fasting total cholesterol (TC) was determined using appropriate reagent strips (Reflotron, Boehringer-Mannheim, Mannheim, Germany). The use of non-fasting samples was necessary, as children could not be expected to fast during the school day. From waking to the time of testing was a period of 9 hours. For children to abstain from food for this period would be both unworkable and unethical. A 30 *ul* sample of fresh capillary blood is collected in a 32 *ul* capillary tube (Reflotron, Boehringer-Mannheim, Mannheim, Germany), a rated volume to ensure sufficient blood collection, even in the case of elevated haematocrit levels above 60% of the total blood sample (Reflotron Reference Manual). Filled capillary tubes were placed in a pipette and discharged immediately onto the reagent strips, and were placed in the Reflotron photometer. If values were obtained outside the Reflotron cholesterol measurement range (2.59 - 12.9 $mmol.l^{-1}$), repeat samples were taken. Further sampling was only performed with the agreement of the child. Repeat samples were taken to provide test-retest reliability analysis.

- *Plasma high-density lipoprotein cholesterol assaying*

Non-fasting high density lipoprotein cholesterol (HDL-C) was determined using appropriate reagent strips (Reflotron, Boehringer-Mannheim, Mannheim,

Germany). The Reflotron photometer was calibrated before HDL-C determination using the Presinorm reference method (Reflotron, Boehringer-Mannheim, Mannheim, Germany). Assaying of HDL-C was performed using blood plasma. Following skin puncture, a 150 *ul* sample of capillary blood was collected in a micro-cuvette (Sarstedt, Numbrecht, Germany). Separation of blood plasma was performed using a laboratory centrifuge. The sample was placed in the centrifuge and spun for 3 min at 4000 $rev.min^{-1}$. A minimum of 32 *ul* of plasma was withdrawn using a capillary tube. Filled capillary tubes were discharged immediately onto a Reflotron HDL-C reagent strip. Reagent strips were then placed in the Reflotron photometer.

If values were obtained outside of the Reflotron HDL-C range
(0.26 - 2.59 $mmol.l^{-1}$), repeat samples were taken, with the agreement of the child. When sufficient blood flow was obtained, repeat samples were taken to assess test-retest reliability.

- *Lipid profile analysis - units of measurement*

The Reflotron reflectance photometer enables the user to choose between conventional (CON; $mg.dl^{-1}$), and SI ($mmol.l^{-1}$), units. In the current study blood lipid concentrations are reported as SI units to allow for comparison with previously reported British studies (Armstrong et al., 1990; 1991; 1992; Morgan et al., 1994).

- *Total Cholesterol to High-Density Lipoprotein Cholesterol ratio*

The ratio of total cholesterol to high-density lipoprotein cholesterol (TC:HDL-C) was calculated using the following formula:

$$\text{TC:HDL-C} = \frac{\text{Total cholesterol}}{\text{High density lipoprotein cholesterol}}.$$

3.8 Blood haemoglobin assaying

Blood haemoglobin assays were performed using the Hemocue B-Haemoglobin photometer (Hemocue, Helsingborg, Sweden). A Hemocue microcuvette was filled

with 10 *ul* of whole blood and inserted into the photometer. Results were reported as conventional units ($g.dl^{-1}$). As relatively small amounts of whole blood were collected, two samples were taken for each subject. The mean of two samples was then calculated. If values were obtained outside of the Hemocue B-Haemoglobin range (0-256 $g.dl^{-1}$) repeat samples were taken, with the agreement of the child.

3.9 Habitual physical activity

The volume, duration and intensity of physical activities were measured using continuous heart rate monitoring (HRM). Monitoring was performed between September and March of each year, approximating the Autumn and Winter seasons.

Subjects were fitted with a short range radio telemeter (Polar Sportstester, Polar, Kempele, Finland), set to record minute by minute heart rate. The lightweight transmitter was attached to the chest using 40 mm foam electrodes (Skintact, Bodycare Products, Kenilworth, England), placed inferiorly to nipple line. Detailed instructions were given not to touch the unit, and the receiver was sealed, using surgical tape, to prevent tampering of control buttons. A contact telephone number was given to parents and children to allow advice to be given to reset the receiver should the recording stop.

Heart rate telemetry systems were fitted in the subjects' home, on three consecutive schooldays. Fitting of HRM systems occurred between 7.30 and 8.45 am, before attending school. The 75 minute "time-window", allowed a maximum of six children to be fitted with HRM systems, and for data to be recovered. Due to the constraints of having only 75 min to perform the monitoring, and to stay within the longitudinal study time-scale, only 24 boys and 27 girls participated in this measurement.

Data were analysed each day using Polar HR Analysis Software 4.0 (Polar, Kempele, Finland), interfaced through a portable computer (Powerbook, Apple MacIntosh). Subjects were asked to record time of retiring to sleep and time of

waking, to provide an analysis of sleep periods. This period was then converted into minutes.

Heart rate thresholds were set at 139 beats.min^{-1}, 60% heart rate reserve (HRR) and 75% HRR. Individualistic HRR thresholds were calculated using the Karvonen (1988) equation:

$$HRR = HR_{sleep} + Int(HR_{max} - HR_{sleep})$$

Where: HR_{sleep} is the lowest 3 recorded heart rates during the sleep period

HR_{max} is the highest recorded heart rate during maximal treadmill exercise testing

Int is the percentage intensity (60%, 75%), expressed as a decimal (0.60, 0.75)

The mean of the lowest three recorded heart rates, during the sleeping period was established to determine HR_{sleep}. Heart rate against time curves were analysed and obvious mechanical artefacts discounted from the assessment of HR_{sleep}. The highest heart rate determined during maximal intensity treadmill exercise (HR_{max}), was also recorded.

Continuous 5,10,15 and 20 min periods, with heart rate elevated above the 139 beats.min^{-1}, 60% HRR and 75% HRR thresholds, were identified from heart rate-time curves, constructed using Polar version 4.0 software (Polar, Kempele, Finland). The cumulative number of minutes spent with heart rate elevated above these thresholds was also calculated.

3.10 Cardiorespiratory fitness

Laboratory assessment of cardiorespiratory fitness was performed using an incremental continuous treadmill test. Subjects were asked to wear appropriate clothing and footwear. All subjects were given a familiarisation period of 5 to 10 min of walking, walk/jogging and running prior to graded exercise testing on the treadmill (Woodway ELG 2, Germany). The test began once the children were confident in using the treadmill and wearing appropriate gas collection equipment. The treadmill protocol chosen was adapted from that of MacManus et al. (1994),

with increments graded according to age group. Table 11 outlines the treadmill protocol used during testing.

Table 11. Treadmill protocol for cardiorespiratory fitness testing.

Workstage			
Time (minutes)	Treadmill speed ($km.h^{-1}$) year 5 children	Treadmill speed ($km.h^{-1}$) year 6 and 7 children	Inclination (%)
0 - 5 (warm up period)	7	8	o
5 - 8 (test period)	8	9	0
8 - 11	8	9	2.5
11-14	8	9	5.0
14 - 17	8	9	7.5
17 - 20	8	9	10

Adaptation of this protocol was performed if the subject:

- Found running at the set speed difficult, or was observed to have difficulties running at that speed
- Complained of difficulty in maintaining a normal running pattern

If either of these factors were observed, the treadmill speed, or bed inclination, was altered to allow the subject to continue testing. Several subjects found the concept of treadmill running a daunting proposition, requiring manipulation of test protocols to achieve compliance. Additional "spotters" were placed around the treadmill to ensure maximum safety during treadmill running.

Subjects were required to clasp a paediatric sized mouthpiece, attached to a low-resistance T-shaped paediatric valve (Hans Rudolph, Kansas City, USA) between their teeth. System resistance was calculated using a water-filled manometer. The maximum resistance measured was less than 5 cm, within limits of acceptability. The mouthpiece was attached to the collection balloons using sealed tubing. Various noseclips were provided, and children were given the choice of noseclip according to comfort and fit. Expired gases were collected in meteorological balloons (Cranlea Medical Electronic, Birmingham, England) during the final 30 s of each workstage. Resistance across the gas collection system was measured using a water manometer.

Breathing frequency was measured by palpitating the neck of the balloon from the first inspiration to the final expiration, during the final 30 s of each workstage. Dilation of the balloon neck approximated the expiration of air during the respiratory cycle.

Heart rate was measured using a short range radio telemeter (Polar Sportstester, Kempele, Finland), set to record at 5 s intervals. The chest strap was placed at the base of the sternum approximately in line with the xiphisternal joint. Data were recorded and interfaced through a computer using Polar version 4.0 software (Polar, Kempele, Finland).

The test was terminated when signs of respiratory distress, dyspnea, ataxic gait and indication by the subject of volitional exhaustion were observed. The attainment of maximal predicted heart rate (220 beats.min^{-1} minus age) was also used as an end-point. End points of exercise are outlined in the IM Marsh exercise laboratory protocols document (Appendix 2), and in accord with those described by Rowland (1993). The run time of subjects was calculated from the start of testing to the cessation of exercise, and rounded up or down to the nearest minute. Whilst not being as accurate as second by second recording time, the use of minute indices would provide a reference for improvements in performance.

Expired gases were analysed for concentrations of oxygen and carbon dioxide using dry-gas analysers (Servomex 470A and 1400, Servomex, Crowborough, England). Expired gases were first passed through a calcium chloride drying agent, contained within the spirometry system. Analysers were calibrated using gases of known concentrations (British Oxygen Corporation, Birmingham, England), representing the low (15% O_2; 2.5% CO_2), and high (21% O_2; 6% CO_2), range. Before calibration gas meters were zeroed using 100% nitrogen. Expired gas concentrations were determined to the nearest 0.1% (O_2), and 0.01% (CO_2).

Gas volume was determined by the manual evacuation of the meteorological balloons through a mechanical dry gas meter (Harvard Apparatus, Edenbridge, England). Dry gas meters were calibrated using a 350 litre gasometer (Tissot,

Warren and Collins, Braintree, England), to produce the following correction equation for all gas volumes:

$$\text{Corrected volume (litres)} = \text{Recorded volume (litres)} \times 1.053 + 0.0426$$

The use of the Tissot spirometer would provide a criterion measurement and allow for accurate volume displacement measurements. Gas volumes were subsequently calculated to the nearest 0.1 litre, and converted from ATPS to STPD following the guidelines of MacDougall et al., (1991).

The laboratory environment was assessed at each test session to provide measurements of ambient temperature, barometric pressure and relative humidity. Barometric pressure was recorded using a barometer (Darton and Co., Watford, England), to the nearest 1 mmHg. Humidity was measured using a hair hygrometer (Fischer, Germany). Measurements were recorded to the nearest 1%. Ambient temperature was recorded using a mercurial thermometer (Gallenkamp, London, England). Temperature recorded to the nearest 0.1^{0} C.

The validity of the test system, to provide accurate measurements of children's peak $\dot{V}O_2$, was assessed using a repeated maximal treadmill test protocol. Using a bag collection system can increase error, as testers must handle the gas twice (measurement phase and collection phase). We wished to compare these measurements with a direct measurement system, which analysed gas once. Peak $\dot{V}O_2$ values were determined using a Sensor Medics 2900Z Gas Analysis system, driven by an IBM microcomputer, providing minute by minute analysis of $\dot{V}O_2$. Five children gave consent to perform a second maximal treadmill test within 7 days of their first, using indirect spirometry. The mean differences in peak $\dot{V}O2$ scores was within 99% agreement limits (1.11 to 2.30 $l.min^{-1}$). Using a Sign Confidence Interval test the highest attainable confidence was achieved between test measurements. These findings emphasised the validity of the meteorological balloon system to accurately record peak $\dot{V}O_2$ when compared to "on-line" spirometry systems.

3.11 Morphological maturity

Maturity status of subjects was assessed using the non-invasive method of Roche et al., (1983). Stature was measured, and an additional 1.25cm added to approximate recumbent length (Roche et al., 1975). Body mass of subjects was taken from previous measurements. Chronological age was calculated as a decimal from the charts of Tanner and Whitehouse (1984). Mid-parent stature was determined by measuring stature of both biological parents. These values were then included in the equation:

$$\text{Mid-parent stature} = \frac{\text{Stature (cm) of father + Stature (cm) of mother}}{2}$$

If direct measurement of parental stature was not possible, reported stature was utilised, with only small increases in the error of prediction (Imrhan et al., 1996). When both biological parents are unavailable, the sex-appropriate average value, for the national population, can be used, though with less accuracy (Roche et al., 1975).

The estimation of predicted adult stature was achieved using regression weights for adjusted stature, body mass, mid-parent stature, chronological age and the regression intercept, derived from the tables of Roche, Weiner and Thissen, for all childhood ages (Roche et al., 1975). Once calculated, these values are incorporated into the equation outlined at Table 12. Constant values are taken from the age specific matrices of reported by Roche et al. (1975). These constants were derived from serial growth studies of the Fels population, an ongoing longitudinal study of over 500 American subjects from birth onwards.

Table 12. Calculation matrix to predict adult stature using the non-invasive method of Roche et al. (1983).

		Reported Regression Weights***		Positive value	Negative value
Recumbent length*	x		=		
Mass	x		=		
Mid-parent stature	x		=		
Skeletal age**	x		=		
Constant					
Total				+	-
Predicted Adult Stature					

*Stature + 1.25 cm to approximate recumbent length

**Decimal for chronological age

***Taken from tables reported by Roche et al. (1975)

Following estimation of predicted adult stature, the percentage of estimated adult stature was calculated using the equation:

$$\frac{\text{predicted adult stature}}{\text{present stature}} \times 100$$

Percentage of estimated adult stature is compared to values for the Fels reference populations (Roche et al., 1983). Values above 3 standard deviations represent higher levels of maturity (Table 13).

Table 13. Percentage of adult stature estimated without skeletal age. Adapted from: Roche et al. (1983).

Chronological age (years)	Boys		Girls	
	Mean	S.D.	Mean	S.D.
9	75.62	1.10	80.97	1.56
10	78.59	1.06	84.47	1.85
11	81.63	1.15	88.09	1.86
12	84.94	1.46	91.98	1.95
13	88.71	1.78	95.36	1.46
14	92.68	1.89	-	-

3.12 Physical self-esteem

Physical self-perceptions were assessed using the Physical Self Perception Profile (PSPP), developed by Fox and Corbin (1989). The instrument is a 30-item scale to assess the sub-domains of sports competence, sports conditioning, physical strength, body attractiveness and a global scale assessing physical self-worth. Children also completed the Physical Importance Profile (PIP), an 8-item measure of the importance placed upon the four sub-domains contained within the PSPP.

- *Psychometrics of the PSPP*

The factorial validity of the PSPP was assessed using a large-scale pilot study (n=139 boys and 134 girls), of Liverpool schoolchildren (age 10.29 $\pm$ 0.75 years, boys; 10.14 $\pm$ 0.72 years, girls). The PSPP was administered during normal school classes. Subjects were instructed in completion of the instrument by a trained tester and given unlimited completion time.

Factor analysis of the four *a priori* determined PSPP sub-scales was performed to determine whether the sub-scales are capable of measuring independent constructs (Fox, 1990). Following the recommendations of Fox (1990), the sub-domain of physical self-worth was conceptualised as a general outcome, resulting from other sub-scales, and was not included in the factor analysis. A principal component analysis, with oblique rotation (Fox and Corbin, 1989; Whitehead, 1995), was performed for the four measured sub-domains. This would allow the four factors to assume a natural geometric space.

- *Administration of the PSPP to the study group*

Participants in the main study completed the PSPP at home. Children were sent the PSPP, together with instruction sheets to provide uniform guidelines as to instrument completion. If questionnaires were not returned, follow up telephone calls were made to ensure reply.

3.13 Data analysis

Data were analysed using several statistical packages. Minitab and SPSS for Windows packages were the most commonly used packages, with support from Microsoft Excel 5.0, StatView 4.0 and Super ANOVA. The Multilevel Regression Modelling Procedures (MLn) package was used when applicable. Heart rate data were assessed using Polar version 4.0 software (Polar, Kempele, Finland).

The mean, standard deviation and range of scores were calculated, for all variables. Descriptive statistics were calculated by gender group and test occasion. The Kolmogrov-Smirnov 1 sample test was used to identify significant differences from a normal distribution. Differences between the means of scores, by gender and test occasion, were tested using a 2 x 2 MANOVA, accounting for between-subject and inter-subject variance. The statistical significance level was set at $P<0.05$.

Pearson product moment correlation coefficients were used to identify relationships between test variables. To ensure the results were normally distributed obvious data "outliers" were re-checked before correlation analysis. The tracking of variables was also examined using Pearson product moment correlation coefficients. Inter-period correlation coefficients (IPC) were determined to assess the stability of a variable over time, and assessed by correlating scores from test occasion 1 with those from test occasion 2. To further assess tracking the maintenance of a score in the upper or lower percentile was determined where appropriate.

A logistical multiple regression analysis was performed to identify the significant contribution of independent variables to physical activity and chronic disease risk factors. Variables were entered into the regression model in the same order for each analyses, with levels of significance set at $P<0.05$. Dependent variables were the cumulative minutes of physical activity performed, blood lipids, blood pressure and sum of skinfold thickness. Independent variables were determined *a priori*, and thought to exert an influence upon the dependent variable. The

coefficient of multiple determination (R^2) was calculated for all variables. This identified the percentage variance accounted for in the regression model.

Cardiorespiratory variables were scaled to account for differences in body size. The special circumstance outlined by Tanner (1949) was calculated to assess the appropriateness of using the ratio scaling expression of peak $\dot{V}O_2$ ($ml.kg.^{-1}min^{-1}$). If the coefficient of variation (CV) for body size divided by the CV for peak $\dot{V}O_2$ equalled the Pearson product moment correlation coefficient (r) then the circumstance was met.

If the circumstance discussed by Tanner was not met peak $\dot{V}O_2$ was scaled allometrically. Power function ratios ($ml.kg.^{exp}.min^{-1}$) were calculated using the techniques outlined by Nevill (1996) and Welsman et al. (1996). The natural logarithm of the body size term (*ln*mass) was entered into a linear regression model against the dependent, performance, variable (absolute peak $\dot{V}O_2$). The slope of the regression line (*b*) was used as the mass exponent. Power function ratios ($ml.kg.^{exp}.min^{-1}$) were calculated using the *b* exponent derived from log-linear regression analyses.

Multi-level regression analysis was performed upon log-linear peak $\dot{V}O_2$ data to identify the significant contribution of independent variables to the performance variable. Age, gender, stature, body mass and a $sex^x age$ interaction term were used as independent variables. The Multilevel Analysis package (MLn) also identified the between-subject and inter-subject variance in peak $\dot{V}O_2$ and subsequent influence of independent variables.

Tester reliability was determined using repeated trials of physiological variables. Coefficient of variance statistics were used to determine percentage of variance in measurement technique. Anthropometric and blood pressure measurements were taken using a repeated measurement protocol, outlined in Appendix 3. Tester reliability for blood lipid measurements were performed using the external criterion

assessment method of Wolfson Ltd. (Birmingham, England) and are included in Appendix 3.

RESULTS

4.1 Anthropometric data - descriptive variables

The chronological age of the boys and girls was significantly different from a normal distribution ($P<0.05$) indicating a skewness towards younger children. The spread of all other test variables were within a normal distribution ($P>0.05$) assessed using a 1-sample Kolmogorov Smirnov test. The chronological age and socio-economic status of the study group are summarised in Table 14. No significant differences ($F_{1,133} = 0.02$; $P>0.05$) were identified between the socio-economic status of the boys and girls.

Table 14. Descriptive data for age and socio-economic status of study group.

		Boys				Girls			
		n=	Mean	S.D.	Range	n=	Mean	S.D.	Range
Age (years)	Visit 1	38	10.2	0.8	9.0 - 11.0	39	9.9	0.8	9.0 - 11.0
	Visit 2	31	11.2	0.8	10.0 - 12.0	29	10.9	0.8	10.0 - 12.0
Socio-economic status*	Visit 1	38	3	1	1 - 4	39	3	1	1 - 5

*Categorised by Registrar Generals Five-Tier Occupational Classification system

Descriptive data for measurements of body size are summarised in Table 15. Boys were not significantly taller ($F_{1,133} = 0.05$; $P>0.05$), or heavier than girls ($F_{1,133} = 0.01$; $P>0.05$), but had a significantly greater percentage of estimated adult stature ($F_{1,133} = 34.09$; $P<0.001$), on both test visits. A significant increase in stature was observed for boys and girls ($F_{1,133} = 17.54$; $P<0.001$). The percentage of estimated adult stature ($F_{1,133} = 30.76$; $P<0.001$), and body mass ($F_{1,133} = 11.36$; $P<0.001$) also increased significantly between test visit. The relative percentage of estimated adult stature was within the normal distribution for reference data of the Fels study population (Roche et al. 1983).

Table 15. Anthropometric variables - descriptive data.

		Boys				Girls			
		n=	mean	S.D.	range	n=	mean	S.D.	range
Stature (m)	Visit 1	38	1.43	0.08	1.33 - 1.66	39	1.43	0.09	1.25 - 1.58
	Visit 2	31	1.50	0.09	1.34 - 1.73	29	1.49	0.11	1.26 - 1.64
Body mass (kg)	Visit 1	38	36.6	7.2	26.0 - 60.8	39	36.6	8.1	23.0 - 57.6
	Visit 2	31	41.6	10.3	30.1 - 69.5	29	42.2	9.7	24.5 - 64.1
% of adult stature	Visit 1	38	84.79	4.41	76.0 - 92.2	39	80.72	3.55	72.1 - 87.4
	Visit 2	31	89.18	4.73	80.6 - 96.1	29	84.07	3.74	78.0 - 90.4

4.2 **Study One**: Habitual physical activity - descriptive data

Boys had a significantly lower heart rate during sleep (HR_{sleep}) than girls during both test visits ($F_{1,66} = 15.03$; $P<0.001$). The HR_{sleep} decreased between test visit for both genders (boys 58 $\pm$ 9 beats.min^{-1} to 55 $\pm$ 5 beats.min^{-1}; girls 65 $\pm$ 5 beats.min^{-1} to 64 $\pm$ 9 beats.min^{-1}) though not significantly ($F_{1,66} = 1.24$; $P>0.05$). No significant differences were observed in the maximal heart rate (HR_{max}) of boys and girls ($F_{1,133} = 2.07$; $P>0.05$). Maximal heart rate increased between test visits, but not significantly ($F_{1,133} = 2.77$; $P>0.05$). The 139 beats.min^{-1} heart rate threshold used in previous studies, was closely approximated by 55% HRR for boys and girls. Directly estimated 60% HRR was signficiantly lower in boys than girls ($F_{1,66} = 7.33$; $P<0.01$), as was the 75% HRR ($F_{1,66} = 4.03$; $P<0.05$). The 60% and 75% HRR thresholds increased slightly between test visit (60% HRR, $F_{1,66} = 0.02$; $P>0.05$: 75% HRR, $F_{1,66} = 0.52$; $P>0.05$). Descriptive heart rate variables are outlined in outlined in Table 16. Patterns of free-living physical activity were assessed using continuous 5, 10, 15 and 20 minute periods with heart rate elevated above the 139 beats.min^{-1}, 60% HRR and 75% HRR thresholds. The number of sustained periods, with heart rate elevated above these thresholds, are outlined in Table 16.

Table 16. Heart rate monitoring variables and calculated heart rate reserve thresholds.

		Boys				Girls			
		n=	mean	S.D.	range	n=	mean	S.D.	range
Average of lowest 3 continuous heart rates ($beats.min^{-1}$)	Visit 1	24	58	9	43 - 88	27	65	5	56 - 78
	Visit 2	13	55	5	47 - 67	19	64	9	47 - 67
Maximal heart rate ($beats.min^{-1}$)	Visit 1	24	199	9	179 - 216	27	201	10	176 - 214
	Visit 2	13	202	7	184 - 214	19	203	7	188 - 217
55% Heart Rate Reserve	Visit 1	24	136	7	124 - 153	27	141	6	123 - 153
	Visit 2	13	137	6	130 - 145	19	140	6	131 - 151
60% Heart Rate Reserve	Visit 1	24	143	7	130 - 159	27	147	6	138 - 157
	Visit 2	13	144	5	137 - 152	19	148	6	129 - 160
75% Heart Rate Reserve	Visit 1	24	164	7	150 - 177	27	168	7	148 - 180
	Visit 2	13	166	6	157 - 175	19	169	5	161 - 177

At the 139 beats.min^{-1} threshold no boy and 3 girls (11.1%), achieved three, or more, continuous 5 min periods with heart rate elevated above this threshold. During test visit 1, 41% of boys failed to attain a single continuous 5 min period of activity with their heart rate elevated above the 139 beats.min^{-1} threshold. At the >75% HRR threshold this value increased to 88%. These values increased to 77% and 92% respectively, during test visit 2. During test visit 1, 52% of girls failed to attain a single continuous 5 min period of activity with their heart rate elevated above the 139 beats.min^{-1} threshold. This percentage increased to 93% at the >75% HRR threshold. These values were similar during test visit 2 (58% and 89% respectively). No child attained the recommended "3 x 20 min" physical activity guidelines (Sallis and Patrick, 1994), during either test visit.

At the 60% HRR threshold one boy (7.7%), and one girl (3.7%), achieved three twenty minute periods of activity during three days of heart rate monitoring. Neither of these children achieved similar periods of activity during other test visits. Results from both test periods showed that only 17% of boys and 15% of girls attained a single 5 min period of activity above the 60% HRR. One boy (7.7%), and one girl (3.7%), achieved three or more 20 min periods of continuous activity above the 75% HRR threshold. Over two test visits 8% to 11% of children attained a single five minute period of activity above the 75% HRR threshold.

Cumulative minutes, with heart rate elevated above the 139 beats.min^{-1}, 60% HRR and 75% HRR thresholds are summarised in Table 16. No significant gender differences were identified in the cumulative minutes of physical activity performed at the 139 beats.min^{-1} ($F_{1,73}$ = 0.06; P<0.14), 60% HRR ($F_{1,73}$ = 0.10; P>0.05) and 75% HRR ($F_{1,73}$ = 0.22; P>0.05). At the 139 beats.min^{-1} threshold non-significant reductions in cumulative minutes of physical activity were observed for boys and girls ($F_{1,73}$ = 0.39; P>0.05). Similar, non-significant reductions were observed at the 60% HRR ($F_{1,73}$ = 0.33; P>0.05) and 75% HRR ($F_{1,73}$ = 0.25; P>0.05).

Table 17. Heart rate monitoring variables; number of children achieving continuous periods of physical activity above the 139 beats.min^{-1}, 60% HRR and 75% HRR thresholds, (figures in brackets represent the percentage of children).

	Continuous activity >139 beats.min^{-1}				Continuous activity >60% HRR				Continuous activity >75% HRR			
Period	Boys		Girls		Boys		Girls		Boys		Girls	
	Visit 1	Visit 2	Visit 1	Visit 2	Visit 1	Visit 2	Visit 1	Visit 2	Visit 1	Visit 2	Visit 1	Visit 2
n=	24	13	27	19	24	13	27	19	24	13	27	19
5 min												
0	10 (42)	11 (85)	14 (52)	11 (58)	18 (75)	10 (77)	21 (77)	16 (85)	21 (88)	12 (92)	25 (93)	17 (89)
1	8 (33)	1 (8)	7 (26)	3 (16)	4 (17)	1 (8)	4 (15)	1 (5)	2 (8)	1 (8)	2 (7)	2 (11)
2	6 (25)	- (0)	3 (11)	5 (26)	1 (4)	2 (15)	1 (4)	1 (5)	1 (4)	- (0)	- (0)	- (0)
>3	- (0)	1 (8)	3 (11)	- (0)	1 (4)	- (0)	1 (4)	1 (5)	- (0)	- (0)	- (0)	- (0)
10 min												
0	19 (79)	10 (77)	24 (89)	18 (95)	22 (92)	13 (100)	24 (89)	16 (85)	23 (96)	13 (100)	27 (100)	18 (95)
1	5 (21)	3 (23)	2 (7)	1 (5)	2 (8)	- (0)	2 (7)	3 (15)	1 (4)	- (0)	- (0)	1 (5)
2	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	1 (4)	- (0)	- (0)	- (0)	- (0)	- (0)
>3	- (0)	- (0)	1 (4)	- (0)	- (0)	- (0)	-	- (0)	- (0)	- (0)	- (0)	- (0)
15 min												
0	23 (96)	12 (92)	27 (100)	18 (95)	23 (96)	13 (100)	24 (89)	18 (95)	24 (100)	13 (100)	27 (100)	18 (95)
1	- (0)	1 (8)	- (0)	1 (5)	1 (4)	- (0)	2 (7)	1 (5)	- (0)	- (0)	- (0)	1 (5)
2	1 (4)	- (0)	- (0)	- (0)	-	- (0)	1 (4)	- (0)	- (0)	- (0)	- (0)	- (0)
>3	-	- (0)	- (0)	- (0)	-	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
20 min												
0	22 (92)	12 (92)	24 (89)	16 (84)	24 (100)	8 (62)	26 (96)	17 (90)	24 (100)	13 (100)	26 (96)	19 (100)
1	- (0)	1 (8)	3 (11)	3 (16)	- (0)	4 (31)	- (0)	2 (10)	- (0)	- (0)	- (0)	- (0)
2	2 (8)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)	- (0)
>3	- (0)	- (0)	- (0)	- (0)	- (0)	1 (7)	1 (4)	- (0)	- (0)	- (0)	1 (4)	- (0)

Figures are the number (percentage) of children achieving 0, 1, 2, >3 periods of continuous activity at different heart rate thresholds

Table 18. Daily cumulative minutes with elevated heart rate - descriptive data.

		Boys				Girls			
		n=	Mean	S.D.	Range	n=	Mean	S.D.	Range
Cumulative minutes with heart rate >139 beats.min^{-1}	Visit 1	24	55	53	6 - 219	27	57	54	6 - 219
	Visit 2	13	45	27	7 - 91	19	46	37	0 - 116
Cumulative minutes with heart rate >60% HRR	Visit 1	24	40	41	1 - 166	27	40	39	2 - 165
	Visit 2	13	36	25	7 - 85	19	33	28	0 - 95
Cumulative minutes with heart rate > 75% HRR	Visit 1	24	10	15	0 - 67	27	9	11	0 - 46
	Visit 2	13	6	10	0 - 34	19	7	8	0 - 22

4.3 **Study Two**: Chronic Disease Risk Factors and Cardiorespiratory Fitness - descriptive data

- *Blood Pressure*

Descriptive data for systolic and diastolic blood pressures are summarised in Table 19. No significant gender differences were identified between systolic blood pressures during either test visit (systolic, $F_{1,133} = 0.01$; $P>0.05$). Diastolic blood pressure was significantly greater for girls during both test visits ($F_{1,133} = 4.49$; $P<0.05$). Significant increases in systolic ($F_{1,133} = 23.43$; $P<0.001$), and diastolic ($F_{1,133} = 49.91$; $P<0.0001$), pressures were observed between test visits. No children exceeded the cut-off point for systolic or diastolic blood pressure.

Table 19. Descriptive data for systolic and diastolic blood pressure.

		Boys				Girls			
		n=	Mean	S.D	Range	n=	Mean	S.D.	Range
Systolic (mmHg)	Visit 1	38	104	9	87 - 121	39	105	10	88 - 130
	Visit 2	31	112	9	98 - 134	29	111	10	97 - 129
Diastolic (mmHg)	Visit 1	38	62	5	54 - 73	39	65	6	52 - 80
	Visit 2	31	71	5	62 - 81	29	72	6	61 - 82

- *Blood Lipid Profile*

Descriptive data for blood lipid concentrations are summarised in Table 20. No significant gender differences were observed for total cholesterol ($F_{1,113}$ = 0.01; P>0.05). Total cholesterol increased by 11% for boys and 9.2% for girls, though not significantly ($F_{1,113}$ = 0.45; P>0.05). Using the three-tier recommendations of the Canadian Cholesterol Conference (1992), 14 boys and 11 girls were classified as borderline (>4.0 $mmol.l^{-1}$), during test visit 1. Of these children, 3 boys and 2 girls exceeded the high "cut-off" point (>4.5 $mmol.l^{-1}$), and 1 girl exceeded the very high classification (>5.0 $mmol.l^{-1}$). During the second test visit 17 boys and 13 girls exceed the borderline recommendation. Eleven boys and 10 girls exceeded the high level, and 8 boys and 7 girls showed total cholesterol levels above the very high classification. One boy exhibited elevated TC (>4.5 $mmol.l^{-1}$), during both test visits.

The high-density lipoprotein cholesterol (HDL-C) of boys was not significantly different from that of the girls ($F_{1,113}$ = 0.32; P>0.05). Boys had a small decrease (-2.0%), in HDL-C between visits whilst the HDL-C of the girls increased (+5.7%). Changes in HDL-C concentrations were not significant between test visit ($F_{1,113}$ = 0.02; P>0.05). The recommended "cut-off" point for HDL-C was below 0.91 $mmol.l^{-1}$, in accordance with the proposals of the Canadian Cholesterol Conference (1992). During the first test visit 7 boys and 10 girls were assessed as having HDL-C below this cut-off point. During the second test visit 7 boys and 4 girls exhibited HDL-C below the reference value. No child had HDL-C values below the 0.91 $mmol.l^{-1}$ "cut-off" point on either of the test visits.

Table 20. Descriptive data for total cholesterol, high-density lipoprotein cholesterol and the ratio of TC:HDL-C*.

		Boys				Girls			
		n=	Mean	S.D.	Range	n=	Mean	S.D.	Range
Total Cholesterol ($mmol.l^{-1}$)	Visit 1	32	3.81	0.60	2.65 - 4.86	32	3.87	0.50	3.15 - 5.10
	Visit 2	30	4.28	0.99	2.61 - 7.90	30	4.26	1.04	2.79 - 6.07
HDL-C ($mmol.l^{-1}$)	Visit 1	32	1.02	0.21	0.69 - 1.49	32	1.01	0.17	0.76 - 1.38
	Visit 2	30	1.00	0.15	0.71 - 1.32	30	1.07	0.25	0.70 - 1.70
TC:HDL-C ratio	Visit 1	32	3.85	0.87	2.10 - 5.60	32	3.93	0.75	2.70 - 6.40
	Visit 2	30	4.33	1.12	2.60 - 7.90	30	4.14	1.25	2.20 - 7.90

*Note that several children refused to give blood samples during testing

The mean TC:HDL-C ratio, for boys and girls, was within the normal range, of 3:0 and 5:0 (Wilmore and Costill, 1994), during both test visits. No significant gender differences were observed for TC:HDL-C ($F_{1,113} = 0.06$; $P>0.05$). The TC:HDL-C ratio did not increase significantly between test visits ($F_{1,113} = 0.06$; $P>0.05$). One boy and 3 girls had TC:HDL-C above 5.0 during the first test visit, with no subject showing similar elevation at the second test visit.

- *Skinfold thickness*

Girls had significantly larger sum of four skinfold thicknesses than the boys during both test visits ($F_{1,133} = 18.63$; $P<0.0001$). Sum of four skinfolds increased significantly between test visits for both boys and girls ($F_{1,133} = 7.90$; $P<0.001$). Skinfold thickness measurements are described in Table 21.

Table 21. Skinfold thickness - descriptive data.

		Boys				Girls			
		n=	mean	S.D.	Range	n=	Mean	S.D.	Range
Subscapular (mm)	Visit 1	38	6.5*	1.8	4.4 - 10.2	39	8.6	3.4	4.8 - 23.2
	Visit 2	31	7.2*	3.3	4.0 - 18.5	29	10.2	4.0	5.0 - 20.4
Suprailliac (mm)	Visit 1	38	7.8*	4.5	3.0 - 23.2	39	11.1	4.5	3.6 - 22.0
	Visit 2	31	10.9	7.2	3.0 - 28.5	29	12.9	5.9	5.2 - 29.2
Biceps (mm)	Visit 1	38	5.9**	2.2	3.0 - 11.6	39	7.0	2.2	4.6 - 14.2
	Visit 2	31	6.0*	1.9	3.1 -11.0	29	7.9	3.1	3.3 -15.2
Triceps (mm)	Visit 1	38	10.1**	3.6	3.6 - 18.4	39	12.5	4.6	5.4 - 22.4
	Visit 2	31	11.5**	3.8	4.2 - 19.8	29	13.9	5.1	7.0 - 34.0
Sum (mm)	Visit 1	38	30.3**	10.3	15.3 - 59.8	39	38.7	11.3	21.2 - 66.0
	Visit 2	31	35.5**	13.5	17.3 - 79.1	29	44.7	14.4	22.9 - 77.8

*Significant gender difference at $p<0.01$ level

**Significant gender difference at $p<0.05$ level

- *Cardiorespiratory Fitness - descriptive data*

Descriptive data for cardiorespiratory fitness variables are summarised in Table 22. Boys had higher absolute peak $\dot{V}O_2$ during both test visits ($F_{1,133} = 4.27$; $P<0.04$). Absolute peak $\dot{V}O_2$ increased between test visits (+19.1% for boys and +17.5% for girls), though not significantly ($F_{1,133} = 2.47$; $P>0.05$). Minute ventilation did not differ significantly between boys and girls ($F_{1,133} = 2.45$ $P>0.05$), yet increased significantly (+21% for boys and +25% for girls) between test visit ($F_{1,133} = 31.9$; $P<0.001$). Boys had a significantly greater run time ($F_{1,133} = 13.5$; $P<0.001$) and run time increased significantly for boys and girls between test visit ($F_{1,133} = 3.89$; $P<0.05$).

Table 22. Cardiorespiratory fitness - descriptive data.

		Boys				Girls			
		n=	mean	S.D.	range	n=	mean	S.D.	range
Peak $\dot{V}O_2$ ($l.min^{-1}$)	Visit 1	38	1.49	0.39	0.84 - 2.51	39	1.37	0.36	0.70 - 2.14
	Visit 2	31	1.84	0.44	1.20 - 3.28	29	1.66	0.38	0.92 - 2.41
Maximal heart rate ($beats.min^{-1}$)	Visit 1	38	199	9	179 - 216	39	201	10	176 - 214
	Visit 2	31	202	7	184 - 214	29	203	8	188 - 217
Minute ventilation ($l.min^{-1}$)	Visit 1	38	40.8	11.2	20.1 - 68.6	39	39.1	11.6	18.7 - 66.7
	Visit 2	31	52.1	10.5	34.1 - 82.2	29	49.8	10.4	35.3 - 77.7
Run time (min)	Visit 1	38	14	3	9- 19	39	12	3	5- 19
	Visit 2	31	17	3	8- 24	29	13	3	7- 20

- *Statistical modelling of cardiorespiratory fitness measurements*

Descriptive data for cardiorespiratory fitness were modelled using the techniques outlined by Nevill (1996) and Welsman et al. (1996). The special circumstance of Tanner (1949) was not met during either test visit (Table 23), indicating a non-linear ratio between peak $\dot{V}O_2$ and body mass. These findings made the use of simple ratio scaling ($ml.kg.^{-1}min^{-1}$) inappropriate for the expression of peak $\dot{V}O_2$ in the current study group.

Table 23. Application of the Tanner (1949), special circumstance to cardiorespiratory fitness and body mass data, between gender and visits.

		Boys	Girls
Coefficient of variance between highest recorded $\dot{V}O_2$ and body mass	Visit 1	0.75	1.19
	Visit 2	1.03	0.99
Pearson r = value	Visit 1	0.67	0.65
	Visit 2	0.74	0.71

To compensate for the non-linearity of growth data, peak $\dot{V}O_2$ was scaled in relation to body mass, and incorporated into the allometric equation:

$$y = ax^b$$

where: a = constant multiplier, b = exponent

The allometric equation was adjusted to include the natural logarithms of the physiological and body size terms to give:

$$\ln y = \ln a + b \ln x$$

The peak $\dot{V}O_2$ term (ln *y*), was regressed onto the body mass term (ln *x*), to linearise non-linear relationships. The anti-log of ln a identified the constant multiplier in the allometric equation (Nevill, 1996), with the numerical exponent being the slope of the line. Following identification of the b exponent, power function ratios were calculated by dividing the absolute value of peak $\dot{V}O_2$ by mass raised to the appropriate exponent (Welsman et al. 1996), where:

$$y \cdot m^{b}$$

where m = mass.

Exponents for the body size term were calculated for all subjects during both testing periods, and for individual gender groups. Exponents and constant values, predicted for the allometric model, are summarised in Table 24.

Table 24. Constants and exponents determined from the allometric scaling of highest recorded $\dot{V}O_2$ and body size (mass).

		All Subjects		Boys		Girls	
		Visit 1	Visit 2	Visit 1	Visit 2	Visit 1	Visit 2
Exponent	Mean	0.88	0.77	0.89	0.80	0.88	0.74
	S.E. ±	0.11	0.09	0.16	0.13	0.15	0.13
Constant	Mean	4.07	4.58	4.09	4.39	4.04	4.73
	S.E. ±	0.39	0.35	0.57	0.47	0.52	0.47

Power function ratios, expressed as adjusted ml.kg.$^{-b}$ min^{-1} values, are summarised in Table 25.

Table 25. Adjusted peak $\dot{V}O_2$ values using power function exponents to partition out differences in body mass.

		Boys		Girls	
		Visit 1	Visit 2	Visit 1	Visit 2
Power Function Exponent	Mean	0.89	0.80	0.88	0.74
	S.E. ±	0.16	0.13	0.15	0.13
Adjusted peak VO_2 value (ml.kg.^{exp}min^{-1})	Mean	62.74	104.5	57.69	93.60
	S.E. ±	1.97	2.84	1.70	2.67

When the influence of body mass were partitioned out, no significant difference was identified between the peak $\dot{V}O_2$ of boys and girls ($F_{1,133} = 0.25$; $P>0.05$). Changes in adjusted peak $\dot{V}O_2$,between test visit, were significant ($F_{1,133} = 8.09$; $P<0.01$).

Boys had higher, but not significant, blood haemoglobin concentrations than girls ($F_{1,113}$ = 0.35;P>0.05) during both testing periods (Table 26). Small, non-significant ($F_{1,113}$ = 0.01; P>0.05) reductions in blood haemoglobin were observed between test visits (boys -0.3%, girls -0.6%).

Table 26. Descriptive data for blood haemoglobin measurement.

		Boys				Girls			
		n=	Mean	S.D.	Range	n=	Mean	S.D.	Range
Haemoglobin	Visit 1	32	130	11	113 -155	30	127	13	109 - 154
($mg.l.^{-1}$)	Visit 2	30	126	11	108 -154	27	125	8	107 - 140

4.4 Study Three: The tracking of physical activity and chronic disease risk factors

- *Physical activity variables*

Inter-period correlation coefficients between the number of sustained periods of physical activity (5, 10, 15 and 20 min), at pre-determined heart rate thresholds, and test visit were poor for all variables (r = <0.22; P>0.05). Poor to moderate correlation coefficients were identified between cumulative minutes of activity at all heart rate thresholds (Table 27). A significant relationship was identified for cumulative minutes of activity, at the 75% HRR, for boys.

Table 27. Tracking correlation coefficients for heart rate variables.

		Cumulative minutes with heart rate>139 beats.min^{-1}	Cumulative minutes with heart rate >60% HRR	Cumulative minutes with heart rate >75% HRR
Cumulative minutes with heart rate >139% HRR	Boys	.18		
	Girls	.09		
Cumulative minutes with heart rate >60% HRR			.14	
			-.01	
Cumulative minutes with heart rate >75% HRR				.65*
				.05

*Significant at P<0.01 level

- *Anthropometric variables*

Significant inter-period tracking coefficients were identified for stature, body mass and the percentage of estimated adult stature (P<0.01). These inter-period correlation coefficients are summarised in Table 28.

Table 28 Tracking correlation coefficients for anthropometric variables

		Stature	Body Mass	% of adult stature
Stature	Boys	0.92*		
	Girls	0.96*		
Body Mass			0.94*	
			0.97*	
% of adult stature				0.96*
				0.94*

*Significant at P<0.01 level;

- Chronic disease risk factors

- *Blood Pressure*

The tracking of boys' blood pressure was signficant between test visit for systolic (r = 0.83; P<0.01) and diastolic (r = 0.46; P<0.01) pressures. Similarly, girls' systolic (r = 0.88; P<0.01) and diastolic (r = 0.78; P<0.01) blood pressures tracked significantly between test visit.

- *Skinfold Thicknesses*

The sum of four skinfold thickness' was shown to track moderately for girls and highly for boys, both tracking correlation coefficients being significant (P<0.01). Tracking of the sum of four skinfolds was in excess of those for individual skinfolds for boys, although similar to individual skinfolds for girls. Inter-period correlation coefficients for skinfold thicknesses are summarised in Table 29.

Table 29. Tracking correlation coefficients for skinfold thickness.

		Subscapular	Suprailiac	Biceps	Triceps	Sum of four skinfolds
Subscapular	Boys	0.65*				
	Girls	0.39**				
Suprailiac			0.68*			
			0.55*			
Biceps				0.64*		
				0.41*		
Triceps					0.52*	
					0.44**	
Sum of four skinfolds						0.79*
						0.51*

*P<0.01 **P<0.05

- *Blood Lipid Profile*

Low, yet significant, tracking of total cholesterol values was identified for boys and girls (boys r = 0.36; P<0.05, girls r = 0.39: P<0.05). No significant correlation coefficients were identified for HDL-C and the ratio of TC:HDL-C for boys and girls (r= 0.14 - 0.19; P>0.05). The tracking of blood lipid variables is described in Table 30.

Table 30. Tracking correlation coefficients for blood lipid concentrations.

		Total Cholesterol	HDL-C	TC:HDL-C
Total Cholesterol	Boys	0.36**		
	Girls	0.39**		
HDL-C			0.14	
			0.14	
TC:HDL-C				0.17
				0.19

**Significant at P<0.05 level

- *Cardiorespiratory fitness variables*

Absolute ($l.min^{-1}$) peak $\dot{V}O_2$ was shown to track highly for girls ($r = 0.85$; $P<0.01$) and moderately for boys ($r = 0.66$; $P<0.01$). Adjusted peak $\dot{V}O_2$ ($ml.kg.^{exp}min^{-1}$) did not track signficantly for boys (boys $r = 0.36$; $P>0.05$), but was moderately signficiant for girls ($r = 0.69$; $P<0.01$). Moderate, but significant, tracking of minute ventilation (boys $r = 0.54$; $P<0.01$, girls $r = 0.62$; $P<0.01$) and run time (boys $r = 0.51$; $P<0.01$, girls $r = 0.48$; $P<0.01$) was also identified.

4.5 **Study Four**: Identifying relationships between physical activity and risk factors.

Relationships between risk factors and physical activity were assessed using cumulative minutes of physical activity. Results are summarised at Tables 31, 32 and 33. Examination of the complete correlation matrix for boys reveals few correlation's exceeding the $r = 0.20$ value. Data from test visit 2 revealed significant correlations between activity at the 139 $beats.min^{-1}$ (Cum_{139}) and body mass ($r = -0.49$; $P<0.05$), sum of four skinfolds ($r = -0.60$; $P<0.05$) and diastolic BP ($r = 0.42$; $P<0.05$).

Table 31. Relationships between cumulative minutes of physical activity at the 139 beats.min^{-1} threshold, anthropometric variables, risk factors and cardiorespiratory fitness.

		Boys	Girls
Stature	Visit 1	0.10	-0.11
	Visit 2	0.27	-0.16
Body Mass		0.02	-0.17
		-0.49	-0.03
% Adult Stature		0.05	-0.41**
		0.03	-0.14
Sum of Skinfolds		-0.07	-0.35
		-0.60**	0.01
Systolic BP		0.19	-0.16
		-0.35	0.09
Diastolic BP		-0.26	-0.33
		0.60**	-0.11
Total Cholesterol		0.07	0.27
		0.26	0.18
HDL-C		-0.21	0.07
		-0.44	0.16
TC:HDL-C		0.24	0.17
		-0.02	0.18
Adjusted peak $\dot{V}O_2$		0.31	-0.04
		0.01	-0.23

**Significant at P<0.05 level

At the 60% HRR threshold (Cum_{60}), significant relationships were identified with body mass (r = -0.48; P<0.05), sum of skinfolds (r = -0.62; P<0.05) and HDL-C (r = -0.45; P<0.05) during test visit 2. Significant relationships were identified between cumulative minutes of activity at the 75% HRR (Cum_{75}) and sum of skinfolds during test visit 2 (r = -0.38; P<0.05).

Table 32. Relationships between cumulative minutes of physical activity at the 60% HRR threshold, anthropometric variables, risk factors and cardiorespiratory fitness.

		Boys	Girls
Stature	Visit 1	0.02	-0.11
	Visit 2	-0.25	-0.05
Body Mass		-0.01	-0.13
		-0.48	0.06
% Adult Stature		0.04	-0.42**
		0.07	-0.06
Sum of Skinfolds		-0.10	-0.35
		-0.62**	0.05
Systolic BP		0.16	-0.14
		-0.33	0.12
Diastolic BP		-0.24	-0.30
		0.60**	-0.02
Total Cholesterol		0.11	0.21
		0.22	0.14
HDL-C		-0.20	-0.01
		-0.45	0.15
TC:HDL-C		0.25	0.26
		-0.06	0.16
Adjusted peak $\dot{V}O_2$		0.33	-0.05
		0.02	-0.15

**Significant at P<0.05 level

For girls a significant correlation was identified between physical activity at the Cum_{139} threshold and the percentage of adult stature during test visit 1 (r = -0.41; P<0.05). During test visit 2 relationships were identified between Cum_{60} and percentage of adult stature (r = -0.42; P<0.05), and diastolic BP (r = -0.35; P<0.05). Activity at the Cum_{75} threshold was correlated with percentage of adult stature (r = -0.43; P<0.05), during test visit 1, with no relationships identified during test visit 2. Adjusted peak $\dot{V}O_2$ values ($ml.kg.^{exp}min^{-1}$) were poorly correlated with activity at all heart rate thresholds (P>0.05).

Table 33. Relationships between cumulative minutes of physical activity at the 75% HRR threshold, anthropometric variables, risk factors and cardiorespiratory fitness.

		Boys	Girls
Stature	Visit 1	-0.06	-0.12
	Visit 2	-0.03	0.20
Body Mass		-0.13	-0.16
		-0.18	0.17
% Adult Stature		0.08	-0.43**
		-0.28	0.07
Sum of Skinfolds		-0.29	-0.30
		-0.38	0.01
Systolic BP		-0.06	-0.17
		-0.19	0.10
Diastolic BP		-0.32	-0.30
		0.01	0.14
Total Cholesterol		0.15	0.07
		0.10	0.14
HDL-C		-0.14	0.01
		-0.31	0.33
TC:HDL-C		0.23	0.10
		0.18	-0.19
Adjusted peak $\dot{V}O_2$		0.34	-0.05
		0.18	0.26

**Significant at P<0.05 level

The multiple regression analysis incorporated all results, irrespective of gender group (Table 34). Gender, anthropometric, blood lipid and cardiorespiratory fitness measurements did not significantly account for variance in physical activity at any HRR threshold during either test visit (P>0.05). The independent variables used in the multiple regression model only accounted for between 4.4% and 8.4% of the total variance in cumulative minutes physical activity. Including both the percentage of estimated adult stature and measured stature did not affect the model significantly. This was despite both of these measurements including measured stature.

Table 34. Multiple regression analysis with cumulative minutes of free-living physical activity used as dependent variables, and gender, biological age, test visit, anthropometric variables and cardiorespiratory fitness used as independent variables.

	Dependent variables					
Independent variables	Cumulative minutes of activity >139 beats.min^{-1}		Cumulative minutes of activity >60% HRR		Cumulative minutes of activity >75% HRR	
	T	Significance of T	T	Significance of T	T	Significance of T
Gender	-0.65	0.14	-1.20	0.12	-1.43	0.39
Test visit	-0.08	0.51	-0.09	0.23	-0.47	0.16
Stature	-0.19	0.94	-0.03	0.92	0.57	0.64
Body Mass	0.33	0.84	0.26	0.97	0.13	0.57
% of Adult Stature	-1.26	0.74	-1.45	0.79	-1.40	0.90
Sum of Skinfolds	0.50	0.21	0.53	0.15	0.73	0.17
Adjusted Peak $\dot{V}O_2$	0.37	0.62	0.57	0.59	1.16	0.46
Statistics						
F	0.41		0.53		0.83	
Sig. F	0.89		0.81		0.57	
R^2	4.4%		5.6%		8.4%	

- Relationships between chronic disease risk factors and cardiorespiratory fitness

Analysis of correlation matrices, outlining relationships between risk factors and anthropometric variables, revealed a sporadic pattern of relationship. Few relationships were significant during both test visits, and these relationships are described below. The complete correlation matrices are provided in Appendix 4.

- *Skinfold Thicknesses*

Sum of skinfolds (SSF) was significantly related to body mass (r = 0.70 and 0.73; P<0.01) and stature (r = 0.50; P<0.05), for boys during both test visits. Girls' body mass was significantly related to the sum of skinfolds (r = 0.52 and 0.81; P<0.01). Moderate, yet significant, relationships were also identified between sum of skinfolds and systolic blood pressure, for boys (r = 0.38 and 0.41: P<0.05) and girls (r = 0.34

and 0.31: P<0.05), during both test visits. Total cholesterol concentrations were negatively related to the sum of skinfolds, for boys, during both test visits (r = -0.33; P<0.05).

- *Blood Pressure*

Systolic blood pressure (SBP) was positively related to stature (boys, r = 0.53 and 0.58; P<0.01: girls, r = 0.53 and 0.56; P,0.01) and body mass (boys, r = 0.48 and 0.40; P<0.01: girls, r = 0.58 and 0.53; P,0.01) on both test visits.

- *Blood Lipid Profile*

Total cholesterol (TC) concentrations were significantly related to stature for all test groups (boys, r = -0.46; P<0.01; girls, r = -0.41; P<0.05) except for girls during test visit 1 (r = -0.28). The TC of boys was moderately related to SSF during both test visits (r = -0.33; P<0.05). Relationships between TC and other risk factors were poorly represented. The ratio of TC:HDL:C was significantly related to TC concentrations (P<0.01), for all test groups and by test visit.

- *Cardiorespiratory Fitness*

Adjusted peak $\dot{V}O_2$ ($ml.kg.^{exp}min^{-1}$) was significantly related to stature (girls r = 0.46; P<0.05) and the ratio of TC:HDL-C (girls r = -0.39; P<0.05) during test visit 2. No other variables were significantly related to adjusted peak VO_2.

To further assess the significant contribution of simultaneous covariates, to peak $\dot{V}O_2$, multilevel regression modelling procedures (MLn) were used. Chronological age, gender and the natural logarithms of body mass and stature were used as covariates, and modelled against peak $\dot{V}O_2$ using two levels of hierarchical observation (between visits and between individuals). The fitted model (Table 35) showed the significant contribution of stature and body mass to changes in peak $\dot{V}O_2$

(P<0.05), and identified the contribution of changing body size to increased cardiorespiratory fitness.

Table 35. Fitted parameters (± SEE) when predicting changes* in peak $\dot{V}O_2$ using stature, body mass, chronological age and gender as simultaneous covariates.

Explanatory variables	Estimate	± SEE
Constant	-9.515	2.425
Log_e (mass)	0.424	0.159
Log_e (stature)	1.690	0.572
Gender	-0.091	0.039
Age	0.033	0.025
Gender*Age interaction	-0.011	0.030

*Significance level established at twice ± SEE

- Multiple regression analysis applied to coronary heart disease risk factors

A multiple logistical regression analysis was performed with blood lipid concentrations (total cholesterol and HDL-C), blood pressure and sum of four skinfolds used as dependent variables. Measurements of morphological age, body size, physical activity and cardiorespiratory fitness were used as independent variables. Results of the multiple regression analysis are summarised in Table 36.

Selected independent variables accounted for 16% of cumulative variance in total cholesterol (P>0.05). No independent variable accounted for a significant amount of variance (P>0.05). The selected variables significantly accounted for 28.4% of variance in HDL-C (P<0.05). Estimated percentage of adult stature (P<0.01) and stature (P<0.05) were significant predictors of HDL-C. Approximately 14.2% of cumulative variance in the TC:HDL-C ratio was explained by the selected variables (P>0.05).

Table 36. Multiple regression analysis with blood lipids, blood pressure and sum of four skinfolds used as dependent variables, and gender, anthropometric variables, cumulative minutes of physical activity and cardiorespiratory fitness used as independent variables.

	Dependent variables											
Independent variables	TC:HDL-C Ratio		Total Cholesterol		Systolic BP		HDL Cholesterol		Diastolic BP		Sum of Four Skinfolds	
	t	P<	t	P<	t	P<	t	P<	t	P<	t	P<
Gender		*		*		*		*	3.10	0.003	4.40	0.001
Test visit		*		*	2.91	0.01		*	2.49	0.02		*
Stature		*		*	2.12	0.05	-2.43	0.02		*	-2.91	0.01
Body Mass		*		*		*		*		*	7.99	0.001
% adult stature	-2.16	0.04		*		*	2.75	0.02		*		*
Sum of skinfolds		*		*		*		*		*		*
Adjusted peak $\dot{V}O_2$		*		*		*		*		*		*
Cumulative min >139		*		*		*		*		*		*
Cumulative min >60 HRR		*		*		*		*		*		*
Cumulative min >75 HRR		*		*		*		*		*		*
Statistics												
F	0.85		0.95		2.81		2.10		4.74		16.58	
Sig. F	0.55		0.40		0.01		0.05		0.01		0.001	
(R^2)	15.3%		16.3%		23.8%		30.0%		44.5%		64.8%	

*Significance values of P>0.05 removed for clarity

Of those variables measured the estimated percentage of adult stature accounted for a significant amount of cumulative variance. The cumulative variance explained for systolic blood pressure was significant (23.8%; $P<0.05$). Test visit ($P<0.01$) and stature ($P<0.05$) accounted for significant amounts of variance in systolic blood pressure. Levels of diastolic blood pressure were significantly accounted for by the selected variables (44.5%; $P<0.001$). Gender ($P<0.05$), test visit ($P<0.05$) and cumulative minutes of activity above the 139 beats.min^{-1} threshold ($P<0.05$) accounted for significant amounts of variance in diastolic BP.

The selected variables accounted for a signficant amount of cumulative variance in the sum of four skinfolds (64.8%; $P<0.001$). Gender ($P<0.001$), stature ($P<0.01$) and body mass ($P<0.001$) accounted for signficant amounts of variance when entered into the model. When individual heart rate thresholds alone were included in the final model no significant alteration was observed. Therefore, the final model retained physical activity at the three heart rate thresholds as indepdendent variables. Similarly, Including both the percentage of estimated adult stature and measured stature did not affect the model significantly.

4.6 **Study Five**: Physical Self-Perceptions

- *Preliminary validation study*

Significant gender differences were observed between all sub-scales, except for sports competence, in the preliminary validation study (n=139 boys, 134 girls). Boys had significantly greater perceptions of physical conditioning ($F_{1,266} = 4.82$; $P<0.05$) attractive body ($F_{1,266} = 8.12$; $P<0.01$) physical strength ($F_{1,266} = 5.63$; $P<0.05$) and physical self-worth ($F_{1,266} = 11.11$; $P<0.001$). Girls had greater perceptions of sports competence, but differences were not significant ($F_{1,266} = 1.41$; $P>0.05$) Descriptive data for the preliminary validation study are summarised in Table 37.

Table 37. Descriptive data for preliminary validation study, PSPP sub-scales.

Sub-scale	n=		Age (years)	Sports Competence	Physical Conditioning	Attractive Body	Physical Strength	Physical Self-Worth
Boys	139	Mean	10.3	14.7	18.1	16.7	17.3	16.8
		S.D.	0.8	2.7	3.6	3.1	3.4	3.6
Girls	134	Mean	10.1	15.1	17.1	15.4	16.3	15.6
		S.D.	0.7	2.7	3.2	3.8	3.7	2.8

- *Factor Analysis of the PSPP*

Results from the principal components factor analysis are shown in Table 38. The construction of the PSPP specifies a four-factor solution to the factorial analysis. Eigenvalues of 1.5 and higher, for boys and 1.6 and higher, for girls were identified for the four-factor solution. This solution accounted for 44.0% and 45.7% of total variance for boys and girls respectively.

Physical strength showed factor loadings above 0.30 for all items, with no cross-loading within other scales. Complete loading was also shown for the physical condition scale, but with two items cross-loading across the sports competence and attractive body scales. The attractive body scale had four factors loading above 0.30, with two items cross-loading with sports competence and physical conditioning scales. Loadings for the sports competence sub-scale were less clear, with only three items loading above 0.30, and one item cross loading with physical strength.

Physical strength was observed to load, for all items above 0.30, with no cross-loading for girls only. The attractive body scale also loaded across all six items, but with cross-loading on the condition and sports competence scales. Four items loaded above 0.30 for the sports competence scale, with no cross-loading. The physical conditioning sub-scale loaded on only three items, with two items cross-loading with the sports competence sub-scale.

Table 38. Principal components factor loadings for PSPP items – preliminary validation study.

Subscale		Male				Subscale		Female			
		Factor						Factor			
	Item	1	2	3	4		Item	1	2	3	4
Condition	2	.44			(.52)	Attractive Body	3	.64			
	7	.53	(.47)				8	.54	(.31)		
	12	.65					13	.33	(.68)		
	17	.57					18	.56			
	22	.41					23	.50	(.56)	(.36)	
	27	.47					28	.63			
Sports Competence	1		.69			Physical Con	2		.48		
	6						7		.43		
	11		.44				12				
	16		.44	(.37)			17		.64		
	21						22			(.47)	
	26						27			(.49)	
Physical Strength	4			.80		Sport Comp	1			.45	
	9			.67			6			.75	
	14			.50			11			. 68	
	19			.35			16				
	24			.41			21				
	29			.31			26			.63	
Body	3				.69	Strength	4				.65
	8	(.36)	(.35)		.37		9				.57
	13						14				.74
	18				.57		19				.54
	23						24				.77
	28				.68		29				.65
Statistics											
Eigenvalue		7.1	2.3	1.9	1.5			7.5	2.3	1.9	1.6
% Variance		24.5	7.8	6.5	5.2			25.8	7.8	6.6	5.4
Cumulative % Variance		24.5	32.3	38.8	44.0			25.8	33.6	40.2	45.7

- *Physical Self-Perceptions within the study group*

Descriptive statistics for the four sub-scales, and the overall scale of physical self-worth, are summarised in Table 38. Boys had higher perceptions of physical self-worth ($F_{1,133}$ = 1.41; P>0.05), physical condition ($F_{1,133}$ = 0.04; P>0.05) and attractive body ($F_{1,133}$ = 0.06; P>0.05). Girls had greater self-perceptions of physical strength ($F_{1,133}$ = 2.10; P>0.05), with no significant gender difference observed for sports competence ($F_{1,133}$ = 0.29; P>0.05).

Table 38. Descriptive statistics for PSPP subscales between test visits.

		n=		Sports Competence	Physical Conditioning	Attractive Body	Physical Strength	Physical Self-Worth
Boys	Visit 1	34	Mean	1.95	2.35	3.06	2.83	2.77
			S.D.	0.33	0.35	0.65	0.56	0.50
	Visit 2	28	Mean	2.33	3.07	2.86	2.99	2.98
			S.D.	0.51	0.58	1.21	0.59	0.56
Girls	Visit 1	32	Mean	2.30	2.45	2.91	2.71	2.63
			S.D.	0.41	0.58	0.60	0.66	0.37
	Visit 2	25	Mean	2.12	2.95	2.38	2.81	2.68
			S.D.	0.53	0.57	0.59	0.55	0.77

Relationships between the four sub-domains and domain level physical self-worth (PSW) are summarised in Figures 4 and 5. Physical self-worth was signficantly related (P<0.05) to the attractive body and physical strength subscales, for boys and girls, during both test visits. The physical conditioning subscale was signficantly related to PSW only during test visit 2 (P<0.001).

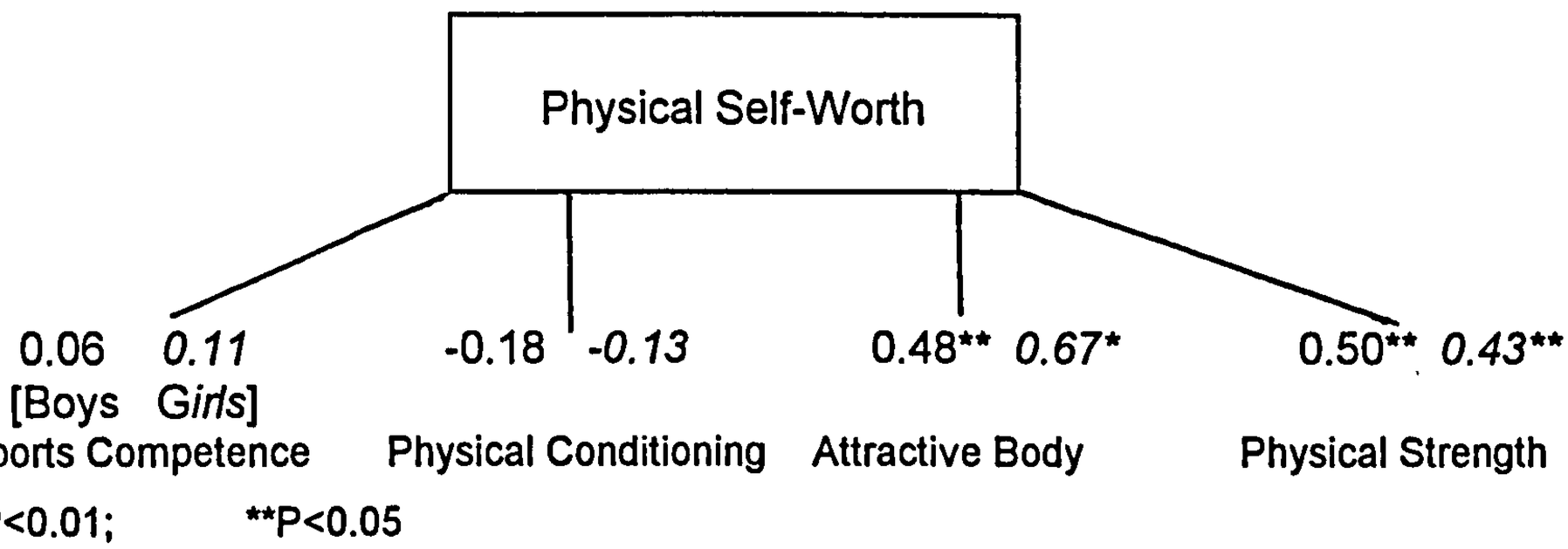


Figure 4. Relationships between PSPP subscales and Physical Self-Worth - Visit 1

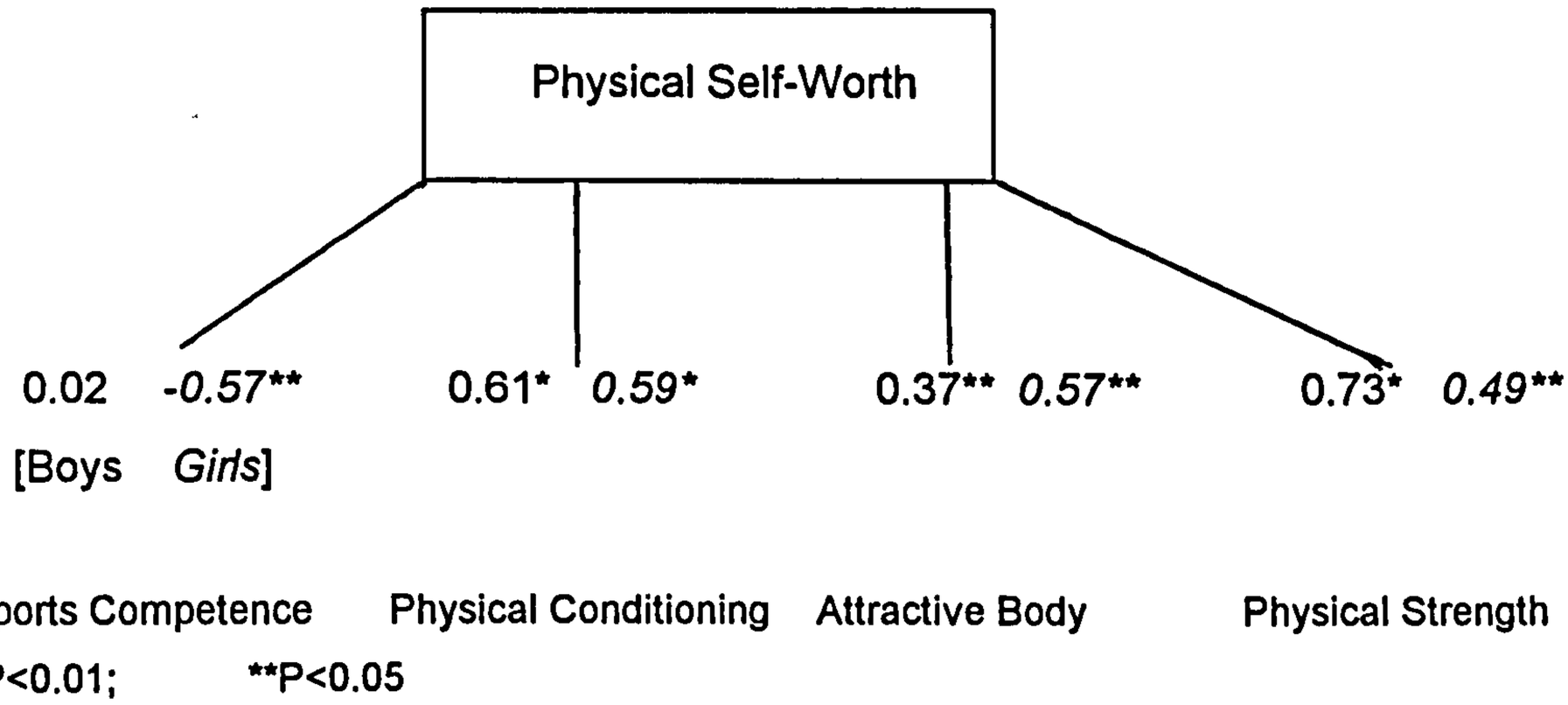


Figure 5. Relationships between PSPP subscales and Physical Self-Worth - Visit 2.

Changes in physical self-perceptions, between test visits, were significant for the attractive body subscale only ($F_{1,133}$ = 18.33; P<0.0001). Changes in sports competence ($F_{1,133}$ = 3.06; P>0.05), physical conditioning ($F_{1,133}$ = 0.04; P>0.05), and physical strength ($F_{1,133}$ = 1.76; P>0.05), were non-significant. Boys displayed improved self-perceptions of sports competence (+6.3%), attractive body (+2.8%), and physical strength (+12.8%). Girls showed improved self-perceptions of attractive body (+12.8%), physical strength (+9.7%), and physical self-worth (+7.5%). Reduced perceptions of physical condition (-20.7%), and physical self-worth (-0.2%), were observed for boys. Girls showed reduced perceptions of sports competence (-2.3%), and physical condition (-16.9%).

Changes in physical self-perceptions were measured using inter-period correlation coefficients (Table 39). Significant inter-period correlation coefficients, for boys and girls, were only observed for the physical strength sub-scale (P<0.01). Physical conditioning appeared to track signficantly for girls (P<0.01)and the attractive body scale also tracked signficantly for boys (P<0.01).

Table 40. Inter-period correlation coefficients for PSPP sub-scales.

		Sports Competence	Physical Conditioning	Attractive Body	Physical Strength
Sports Competence	Boys	0.03			
	Girls	0.14			
Physical Conditioning			-0.29		
			-0.55*		
Attractive Body				0.42*	
				0.33	
Physical Strength					0.54*
					0.45*

*P<0.01

Descriptive statistics for the PIP sub-scales are presented in Table 40.

Table 41. Descriptive statistics for PIP subscales between test visits.

		n=		Sports Competence Importance	Physical Conditioning Importance	Attractive Body Importance	Physical Strength Importance
Boys	Visit 1	34	Mean	3.01	3.02	2.87	3.00
			S.D.	0.81	0.74	0.70	1.04
	Visit 2	28	Mean	3.22	2.97	2.93	2.86
			S.D.	0.83	0.73	0.78	0.72
Girls	Visit 1	32	Mean	2.96	2.79	2.77	2.86
			S.D.	0.78	0.77	0.83	1.04
	Visit 2	25	Mean	3.04	2.88	2.84	2.72
			S.D.	0.72	0.81	0.92	1.01

On test visit 1 boys placed greater importance upon all sub-scale items than girls, though not signficantly ($F_{1,133}$ = 0.34 to 1.29; P>0.05). The girls perception of importance increased for all sub-scales except for physical strength, whilst boys placed increased importance upon sports competence and attractive body. Between visit changes in PIP items were non-significant (Sports Competence $F_{1,133}$ = 0.64; P>0.05, Physical Conditioning $F_{1,133}$ = 0.02; P>0.05, Attractive Body $F_{1,133}$ = 0.39; P>0.05, Physical Strength $F_{1,133}$ = 0.44; P>0.05).

Relationships between PIP and PSPP sub-scales were poor (Figure 6). Inverse relationships were identified between sports competence and the importance of sports competence during both test visits. Other relationships were positive, yet of a lower magnitude.

	Sports Competence Importance		Physical Conditioning Importance		Attractive Body Importance		Physical Strength Importance	
	Visit 1	Visit 2						
Boys	-0.29	-0.17	0.20	0.18	0.31	0.21	0.04	0.41
Girls	*-0.36*	*-0.17*	*0.20*	*0.18*	*0.34*	*0.24*	*0.04*	*0.41*
	Sports Competence		Physical Conditioning		Attractive Body		Physical Strength	

Figure 6. Relationships between PSPP and PIP items.

- Relationships between physical activity and physical self-perceptions

Relationships between physical self-perceptions and cumulative minutes with elevated heart rate, are summarised in Table 42. Only one signficant correlation was identified, between self-perceptions of physical conditioning and activity at the Cum_{75} thresholds, for boys during test visit 2 ($r = -0.64$; $P<0.05$). Other relationships were of a low to moderate magnitude, and non-significant ($P>0.05$). Physical self-worth was poorly related to all heart rate variables during both test visits.

Table 42. Pearson Product Moment correlation coefficients: cumulative minutes of activity with elevated heart rate and PSPP sub-scales.

		Subscale									
		Sports Competence		Physical Conditioning		Attractive Body		Physical Strength		Physical Self-Worth	
		Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Cumulative minutes with heart rate >139 beats.min^{-1}	Visit 1	-0.37	-0.04	0.09	-0.16	0.12	0.02	0.06	0.22	0.08	-0.09
	Visit 2	-0.01	0.27	0.29	0.08	0.25	0.16	-0.23	-0.27	-0.34	0.13
Cumulative minutes with heart rate >60% HRR	Visit 1	-0.33	-0.05	0.03	-0.21	-0.06	0.03	0.14	0.16	0.09	-0.10
	Visit 2	0.07	0.27	-0.33	-0.01	0.27	-0.01	0.21	-0.27	-0.31	-0.09
Cumulative minutes with heart rate >75% HRR	Visit 1	-0.21	-0.22	-0.14	-0.31	-0.02	0.01	0.27	0.10	0.22	-0.13
	Visit 2	0.43	0.21	-0.64**	0.15	-0.05	-0.32	-0.25	-0.26	-0.03	-0.07

**Significant at P<0.05 level

- Relationships between physical self-perceptions and selected physiological variables

The construct validity of the PSPP was tested using theoretically appropriate sub-domains and physiological variables. The sum of four skinfolds (SSF) was not significantly related to the attractive body sub-scale on both test visits ($P>0.05$). Relationships between the SSF, other PSPP sub-scales and the domain level of Physical Self-Worth were also poor.

Adjusted peak $\dot{V}O_2$ ($ml.kg^{exp}min^{-1}$) was negatively related to the physical conditioning sub-scale, for boys and girls, on both test visits ($P>0.05$). Significant inverse relationships were identified between peak $\dot{V}O_2$ and the perceptions of an attractive body for girls, during both test visits ($r = -0.38$ and -0.59; $P<0.05$). There were relationships between adjusted peak $\dot{V}O_2$ and sports competence ($r = 0.43$; $P<0.05$) during test visit 2 for boys. A significant inverse relationship ($r = 0.39$; $P<0.05$) was also identified between adjusted peak $\dot{V}O_2$ and PSW during test visit1 for boys ($r = -0.42$; $P<0.05$). A complete correlation matrix is provided in Table 43.

Table 43. Pearson product moment correlation coefficients for PSPP subscales and selected physiological variables.

		Sum of four skinfolds (mm)		Adjusted peak $\dot{V}O_2$ ($ml.kg.^{exp}min^{-1}$)	
		Boys	Girls	Boys	Girls
Sports Competence	Visit 1	-0.03	0.17	0.03	-0.20
	Visit 2	-0.23	0.15	0.43*	0.05
Physical Conditioning	Visit 1	0.09	0.23	-0.10	0.04
	Visit 2	0.10	-0.05	-0.23	-0.08
Attractive Body	Visit 1	0.06	0.08	-0.30	-0.38**
	Visit 2	0.05	-0.23	0.25	-0.59*
Physical Stength	Visit 1	0.15	-0.11	-0.11	-0.16
	Visit 2	0.17	-0.23	-0.16	-0.15
Physical Self-Worth	Visit 1	0.07	0.14	-0.16	-0.42**
	Visit 2	-0.29	-0.36	0.39**	-0.39

*Significant at $P<0.01$ level ** Significant at $P<0.05$ level

DISCUSSION

5.0 Discussion

This study investigated the influence of physical activity on risk factors and fitness in Liverpool schoolchildren. Importantly, our study attempted to analyse changes in these factors during an important period of growth. To examine the hypotheses outlined in section 1.0, five studies were performed (Section 2.9). From these studies, and their acceptance or rejection of the hypotheses, a child-specific framework of the links between physical activity, health and fitness would be proposed.

5.1 Study One: Habitual Physical Activity

Assessment of the physiological response to activity used directly determined heart rate reserve (HRR) thresholds. In the current study, the lowest three heart rates during sleep (HR_{sleep}) were approximately 20 beats.min^{-1} lower than in previous studies of similarly aged children (Durant et al., 1992). The resting heart rate in these studies was measured whilst the subject was awake. The influence of transient physiological, chronological, environmental and emotional responses may confound measurement of a true basal heart rate using this technique (Freedson, 1989; Malina and Bouchard, 1991). Our findings support the use of heart rate measurement during sleep as a measure of baseline heart rate and a closer index of basal metabolic rate. Subsequently, our calculated HRR, at 60% and 75% intensities, were lower than previously reported values (Stratton, 1996), and therefore provide a lower baseline for subsequent heart rate elevations during activity.

The use of the HRR will account for changes in baseline and maximal heart rates during the growth period. A progressive decrease in basal heart rate was observed between test visits. This represented the pattern of change expected for children during development (Malina and Bouchard, 1991). Maximal heart rates (HR_{max}) were similar to those reported in other studies of children (Welsman and Armstrong, 1992; Al-Hazzaa and Sulaiman, 1993; Armstrong et al., 1996).

Maximal heart rate should decline with increasing age (Malina and Bouchard, 1991), yet small increases in HR_{max} were observed between test visit. Whilst a 12 month period may not be sufficient to identify significant changes in heart rate, the measured increases in HR_{max} appear to be mediated by the greater endurance of children during the second test visit. Significant increases in run time are associated with a myriad of factors. Changes in running economy, running gait, physical conditioning or motivation may aid in a better run performance.

Directly estimated 60% and 75% HRR were significantly lower for boys than girls during the first test visit. The 60% and 75% HRR thresholds were lower than those outlined by Stratton (1996). This is not surprising as the resting heart rates used were considerably higher than our results (25 - 30 beats.min^{-1}). The use of arbitrary HR_{max} (200 beats.min^{-1}) may not be reflective of the range of heart rates observed during maximal exercise testing. In our study, several children were observed to have a high HR_{max} at the cessation of exercise testing (214 to 217 beats.min^{-1}). Similarly, several children also had final heart rates below that expected for age during maximal testing. Although the range of maximal heart rate scores were high (38 beats.min^{-1} for boys, 30 beats.min^{-1} for girls) the mean group HR_{max} was equal to the age expected range. It is likely that some had difficulty in reaching a true peak $\dot{V}O_2$, and subsequent HR_{max}.

Motivation has been cited as a reason for the non-attainment of peak $\dot{V}O_2$ in children (Rowland, 1992; Armstrong and Welsman, 1997). Armstrong and Welsman (1997) allude to the problem of an apparently maximal exercise test representing a true peak in children. They suggest that such uncertainty may be alleviated by adequate laboratory habituation. Similarly, a supramaximal "verification phase" may answer the question of attaining a true peak. The use of such verification should be of interest to future researchers using child populations (MacDougall et al., 1991).

The measurement of HR_{sleep} was problematic. During the sleeping period, 95% of children had some data loss. The short-range telemetry system was limited when measuring minute-by-minute heart rate during sleeping. Future researchers must consider the use of other precautions to prevent loss of data, such as other methods of securing electrodes and receivers. The choice of the most appropriate series of heart rates, representing basal metabolism, was problematic. The periods of initial rest and final stages of sleep may be influenced by many confounding variables. Ambient temperature (Hebestreit and Bar-Or, 1995), sleep disturbance (Freedson, 1989) and illness (Freedson, 1989) may affect the physiological responses of the body. Similarly, myocardial adaptations during growth may see variations in individual basal heart rate, possibly creating a bias in calculating mean group results over the 12 month period.

To compensate for these periods of possible "distortion" the first hour of the sleep period and the hour before waking were not analysed. Subsequently, the averages of the lowest 3 consecutive heart rates represented the HR_{rest} value. Information supporting the use of this sequence to reflect baseline heart rate is scarce. This is especially noticeable when using short-range heart rate telemetry systems. Future researchers may wish to establish the concurrent validity of this method against a criterion heart rate measurement, such as ECG. This has yet to be reported for children during sleep. From such studies, an appropriate sequence of heart rates may be recommended to represent baseline heart rate.

At the 60% and 75% HRR, our results generated heart rate thresholds above the pre-determined 139/140 and 159/160 $beats.min^{-1}$ used in previous studies activity (Armstrong et al., 1990; 1991; 1996; Armstrong and Bray, 1991; Riddoch et al., 1991; Welsman and Armstrong, 1992; Al-Hazzaa and Sulaiman, 1993; Gilbey and Gilbey, 1995). Subsequently, the assessment of children's physical activity patterns accounted for individual differences in basal and maximal heart rates, and the degree of deflection from baseline during free-living activities.

- *Patterns of habitual physical activity*

Results from the current study emphasised the low levels of free-living physical activity among younger Liverpool school children. Children rarely attained the "3 x 20 min per week" prescription of physical activity (Sallis and Patrick, 1994; Health Education Authority, 1998), and no child achieved these recommendations during both test visits.

These findings are consistent with other reported British studies using heart rate monitoring (Armstrong et al., 1990; 1991; 1996; Armstrong and Bray, 1992; Riddoch et al., 1991; Welsman and Armstrong, 1992). Similarly, children from America (Durant et al., 1992), Saudi Arabia (Al-Hazzaa and Sulaiman, 1993), Singapore (Gilbey and Gilbey, 1995), Hong Kong (MacManus and Armstrong, 1995) and Finland (Sallo and Silla, 1997) failed to meet the "3 x 20 min" criteria recommended by Sallis and Patrick (1994).

Continuous activities of 5 to 10 min duration were attained more often than activities of 20 min or more. This finding has been commonly reported other studies (Armstrong et al., 1990; 1991; 1996; Armstrong and Bray, 1992; Riddoch et al., 1991; Welsman and Armstrong, 1992; Gilbey and Gilbey, 1995; Sallo and Silla, 1997). Results from the current study identified the lower attainment of >5 min periods of activity than other British studies. Only 8% to 11% of children in the study group achieved more than 3 periods of continuous activity of 5 min duration, compared to 9% to 91% of children, from other studies.

Comparison with other studies is problematic. Differing age groups, recording times, and measurement tools have been used in other studies of heart rate monitoring, making comparison difficult. The contribution of weekend physical activity to the overall activity profile of children was not measured in the current study. Whilst some empirical evidence suggests a significant increase in weekend physical activity against that for a weekday (Gavarry et al., 1996) no significant

differences have been reported by the majority of heart rate studies (Armstrong et al., 1990; DuRant et al., 1992; Gilbey and Gilbey, 1995; Sallo and Silla, 1997). This is similarly reported in direct observation studies (Sleap and Warburton, 1992).

Other variables may influence the measured differences in physical activity. The Exeter-group studies of Armstrong and co-workers were performed upon children from the Southwest of England. The demography of this area may influence physical activity participation. Children from our study were primarily from a suburb of Liverpool, with relatively spacious street layout and an adequate availability of "green space". Whether residing in more terraced residential areas, characteristic of the children from the Anfield area would create a difference in activity participation remains to be proven. Residence in a highly terraced area may see a greater capacity for personal interaction with other children who live nearby. In a more suburban area, such as that for the majority of children in our study, children may often live up to several hundred metres from each other. This could influence possible interactions between children and subsequent performance of group-based physical activity. Again, such a relationship remains to be identified.

Irrespective of methodological problems, when our data are analysed in relation to the consensus recommendations of Sallis and Patrick (1994) Liverpool children do not attain the volume of physical activity needed for health and fitness benefits. The apparently sedentary nature of these children may be masked, however, when using continuous periods to quantify physical activity. Accumulating 30 min of moderate to vigorous physical activity daily has been advocated as beneficial to health (Sallis and Patrick, 1994; Health Education Authority, 1996). Results from the current study show that school children attained this recommendation far more readily, especially at lower heart rate thresholds ($\leq$ 60% HRR). At the lower heart rate thresholds, the cumulative minutes of physical activity were more than that recommended for boys and girls, during both visits. The performance of physical activities above the higher 75% HRR was uniformly low. Children

consistently failed to meet consensus recommendations at this threshold.

Despite problems in expressing the cumulative minutes of physical activity, used by other studies, the failure of children to perform free-living activities at higher heart rate intensities is commonly reported (Armstrong et al., 1990; 1991; 1996; Welsman and Armstrong, 1992; Al-Hazzaa and Sulaiman, 1993; Gilbey and Gilbey, 1995; Sallo and Silla, 1997). Whilst an appropriate dose-response of physical activity remains debatable, continuous higher intensity activities are thought to be the main stimuli for health and fitness benefits (Bouchard et al., 1990; Sallis and Patrick, 1994; Shephard, 1996). Using the cumulative minutes index for comparison, Liverpool school-children performed similar amounts of free-living physical activity as children from the south-west of England (Armstrong et al., 1990a; 1990b; 1991; Welsman and Armstrong, 1992), Estonia (Sallo and Silla, 1997). They also performed only slightly less activity than Saudi Arabian boys (Al-Hazzaa and Sulaiman, 1993) did.

Recent evidence has supported a sporadic pattern to children's free-living physical activity (Sleap and Warburton, 1992; Bailey et al., 1995). The lack of continuous periods of physical activity, measured in the current study, coupled with children attaining cumulative minutes recommendations, support a physical activity pattern consisting of these shorter activity "bursts". Current heat rate monitoring devices preclude the investigation of such bursts during long-duration physical activity assessment. The logistical constraints of using multiple recording systems currently make such assessment extremely difficult. Until a more sensitive measure of heart rate is made available, the attainment of cumulative minutes of physical activity recommendations may be the best indicator of such short-duration "bursts".

The dose-response of physical activity for cardiorespiratory benefits is characterised by continuous duration, high-intensity exercise (Massicote and Macnab, 1974; Chatterjee and Bandyopadhyay, 1990; Docherty et al., 1990; Shephard and Lavalee, 1993; MacManus et al., 1995; Roberts et al., 1995;

Rowland and Boyajian, 1995). Our results, in agreement with other studies, show that children do not perform sufficient physical activity to elicit cardiorespiratory fitness benefits.

A similar physical activity prescription (3 x 20 min weekly) has been proposed for favourable alterations in chronic disease risk factors (Alpert and Wilmore, 1994; Armstrong and Simons-Morton, 1994; Bar-Or and Baranowski, 1994). Again, results indicate that children do not perform sufficient free-living physical activity to elicit favourable health benefits.

Whilst these results suggest that children attained recommended cumulative minutes of physical activity, albeit at lower intensity heart rate thresholds, the large range of scores between subjects raised further questions. Boys accumulated between 1 and 219 min of activity above the 139 beats.min^{-1} and 60% HRR thresholds, whilst girls ranged between 0 and 219 min during both test periods. Several children greatly exceeded 30 min of daily physical activity, whilst approximately 25% of boys and 15% of girls did not accumulate the recommended physical activity prescription. It is apparent that a disparity occurs for physical activity performed by low and high active children. Currently, little empirical evidence supports the influence of high levels of free-living, sporadic, physical activity in conferring health and fitness benefits for children. Such investigation is a direction for future research.

During three consecutive days of monitoring most children experienced at least 1-d when they accumulated 30 min of activity above the 139 beats.min^{-1} threshold. That some children may have achieved consensus recommendations on one day, and failed to attain any activity above pre-determined heart rate thresholds on another, highlights the between-day instability of children's physical activity. A preliminary reconsideration of our data did not reveal significant differences in the cumulative amount of physical activity performed over three schooldays ($P>0.05$). With our evidence indicating a great variation between high-activity and low-activity days, investigation into the between day variability of cumulative minutes

of physical activity requires further analysis. Importantly, the 3 days of monitoring may not be sufficient to adequately identify inter-day variance in physical activity. The recommendations of Sallis et al., (1995) where that 3-14 days of monitoring would be needed for heart rate monitoring to be reliable and valid. Extending the monitoring period would be both costly and in need of more tester-hours. Such commitment is rarely reported in longitudinal studies. Without such study designs information on inter-day variance remains to be adequately reported.

- *The determinants of free-living physical activity*

When incorporated into a multiple stepwise regression analysis gender did not account for significant variance in the cumulative minutes of physical activity. Boys are commonly reported as being more active than girls are (Armstrong et al., 1990; 1991; 1996; Armstrong and Bray, 1992; Welsman and Armstrong, 1992; Riddoch et al., 1992; Sleap and Warburton, 1992). Further research is required to establish the approximate period when the gender differential becomes significant, and positively influences participation in physical activity. However, the gender difference was observed when establishing the HRR thresholds. Such findings suggest that heart rate responses during rest and exercise are different for boys and girls.

When analysed using logistical regression gender, morphological maturity, cardiorespiratory fitness and body fat did not account for a significant amount of variance in cumulative physical activity at any heart rate threshold. Sallis et al., (1995) postulated that the majority of variance in physical activity may be attributed to transient factors, predominantly of an environmental nature. Factors such as weather patterns, seasonal variations and climate remain to be assessed when evaluating patterns of physical activity in children.

Anderssen and Wold (1992) provided support for the influence of parental and peer group support in changing physical activity behaviours. These are only two of several possible variables contained within the environmental myriad. Our

research design did not measure environmental or sociological influences. Whilst providing a psycho-sociological analysis of the determinants of children's physical activity, our model did not include social and environmental influences. Such measurements will provide yet more potentially confounding variables, which may explain children's participation in free-living physical activities. It is clear that physical activity participation is a multi-faceted construct. This may not be explained by measuring the components of social, environmental, physical or psychological domains individually.

- Applying the findings of Study One to a newer framework for physical activity health and fitness

In the model provided by Bouchard et al., (1993), reproduced at Figure 1, structured exercise forms a major component of total physical activity. The free-living physical activity of school children is different to that of adults. Even during the school day, continuous duration activity does not form an integral component of children's physical activity. The model of Bouchard and co-workers therefore requires restructuring before being applied to children.

Liverpool children performed a pattern of moderate intensity (<60% HRR) physical activities lasting less than 5 min. This included activities performed during the normal school day. The components of school day physical activity would include free movement, free play, formal exercise, physical education and competitive sports (Malina, 1997). Within these definitions would fall all components of physical activity, whether it be skateboarding, soccer or walking. Subsequently, any model should reflect both structured and unstructured physical activities (Figure 7).

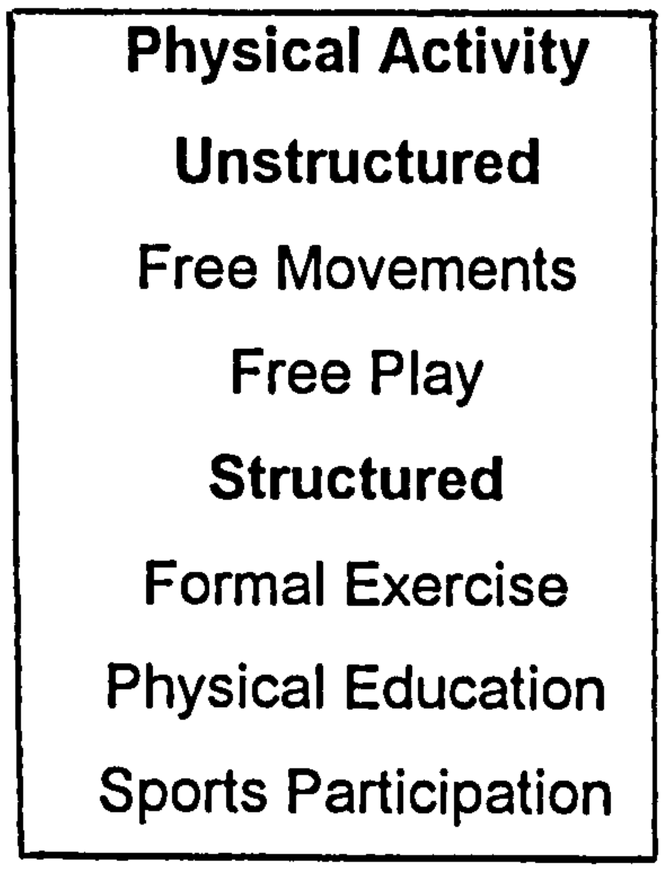


Figure 7. The components of physical activity applied specifically to children.

Assessing such a multi-component scheme must include information on the volume and tempo of such physical activity. Researchers must appreciate that children's physical activity is not characterised by continuous duration, high intensity exercise. Therefore, any framework should include an understanding of the sporadic nature of children's physical activity.

To assess these components presents problems. A criterion method of physical activity assessment cannot be supported. Therefore, assessment of the mode, intensity, duration and frequency of physical activity, as recommended by Bouchard et al., (1993) will require a combination of techniques. Heart rate monitoring, questionnaire and direct observation may cover all eventualities, but will be manpower intensive and costly. Heart rate monitoring and questionnaire recall may provide the most accessible two-component method of assessing physical activity. However, the concerns raised earlier when using 3-day or 7-day recall must warrant caution when choosing such methods.

5.2 Study Two: The prevalence of chronic disease risk factors and the levels of cardiorespiratory fitness in Liverpool school children

5.2.1 Blood Pressure

Blood pressure levels in the current study do not raise concern and are similar to

previously reported British, European and American data (Clarke et al., 1978; Armstrong et al., 1990b; 1991; Hansen et al., 1991; Packer et al., 1995). As expected, the growth of these subjects was comparable to elevations in blood pressure (Malina and Roche, 1983; Malina and Bouchard, 1991; Kemper, 1995; Rowland, 1996).

Anatomical changes are thought to provide the initial stimulus for elevations in blood pressure (Hansen, 1995). With increasing body size the peripheral vascular resistance would also increase (Hansen, 1995). Whilst the aetiology of increased blood pressure remains uncertain, internal changes in myocardial contractility, cardiac output and anatomical size will be related to increased body size. The expression of stature will provide a simple method of estimating relative body size. Systolic blood pressure was significantly related to stature and body mass during both test visits. These relationships emphasise the linear growth of body size and the vascular system during childhood, before the pubertal growth spurt (Malina and Bouchard, 1991).

Relationships between blood pressure and other physiological variables were sporadic. The sum of four skinfolds was significantly related to systolic blood pressure for boys during both test visits. These relationships were of a similar magnitude to those of other child studies (Bazzano et al., 1993). Whilst the relationship between blood pressure and elevated body fat has been identified for adults (Wilmore and Costill, 1994) such relationships have yet to be conclusively proven for children and adolescents. Greater body adiposity will place greater strain upon the functional vasculature, and so may increase peripheral resistance.

Cardiorespiratory fitness was significantly associated with systolic blood pressure for boys and girls during both test visits. Increased vascular function will be a major determinant of changes in cardiorespiratory fitness during the development period. Whilst heart rate remains stable during childhood and adolescence (Malina and Bouchard, 1991), increases in cardiac output will be mediated by

improvements in stroke volume. A positive relationship between systolic blood pressure and increased cardiac output, a principle recognised in children (Rowland, 1996), may be inferred from our results.

Using multi-level modelling procedures, changes in systolic blood pressure were significant between test visits. This reflects that as children grow blood pressure will increase. Whether the relationship between vascular pressure and body size remains during later adolescence requires resolution. Differences in the relative body size of similar aged subjects may "mask" these relationships until the relative stability of late adolescence is attained. Partitioning out differences in body size may provide a clearer pattern of relationship for blood pressure and body size. The scaling of systemic vascular pressure requires further investigation.

5.2.2 Blood Lipid Profile

Using the multi-level criterion standards of the Canadian Consensus Conference on Cholesterol (1992), mean values for total cholesterol were within normal limits (<4.0 $mmol.l.^{-1}$), during test visit one. Measurements taken during the second test visit placed boys and girls within the "borderline" classification (4.0 - 4.5 $mmol.l.^{-1}$). This was despite less than 50% of boys and girls falling within this value. It is important to recognise the effect of very high total cholesterol scores (>5.0 $mmol.l.^{-1}$), in skewing mean data. During visit two, 8 boys (27%), and 7 girls (26%), exceeded the very high classification for total cholesterol, representing a large variation in data distribution. Importantly, the Canadian Consensus recommendations have an "overlap" in classifying risk levels. If a child has a mean cholesterol value of 4.0 $mmol.l.^{-1}$ they may be classified as both normal and borderline. It would be more effective if these borders were defined clearly. A borderline classification should be definite, 4.1 to 4.5 $mmol.l.^{-1}$. Similarly, high total cholesterol levels should be defined as 4.6 to 5.0 $mmol.l.^{-1}$.

An appropriate cut-off point for children can only be determined using large-scale studies of the relationship between lipids and health status. Without such studies,

a criterion cut-off will remain elusive, Consequently, the assessment of potential lipid risk will continue in a "piece-meal" fashion. Similarly, using a single cut-off point will not provide evidence for variation in measurements over time. The maintenance of a subject within a low, borderline or high classification may provide a useful alternative to correlation coefficients or percentiles to assess the tracking of lipids. The multi-level classification system used in our study provides at least some evidence for variation in lipid measurements between and within subjects.

Mean total cholesterol values, were similar to British studies of similar aged children (Armstrong et al., 1990; 1991; de Swiet et al., 1992; Azad et al., 1994; Morgan et al., 1994). They were also lower than for other children from the south-west of England (Sporik et al., 1991). International results were also similar, most noticeably during test visit 1 (Suter and Hawes, 1993; Zonderland et al., 1994; Kemper, 1995; Anding et al., 1996).

One child had elevated total cholesterol values during both test visits. Four children who had elevated total cholesterol during the first test visit did not have similar elevations during the second test period. Similarly, five children who had normal total cholesterol values during test visit 1 showed elevations to risk-related thresholds during the second test session. These findings emphasise both the limitations of espoused criterion thresholds, and the considerable variation in total cholesterol values over the 12-month period. This variation may be primarily associated with dietary intake of cholesterol, and resultant changes in plasma cholesterol levels (Schaefer et al., 1995). Evidence to support changes in cholesterol levels with increased dietary cholesterol intake, must be considered important for future researchers.

Multiple regression analyses indicated no significant relationships between anthropometric, lifestyle and fitness variables, and total cholesterol levels. Body size, morphological age, body adiposity and cardiorespiratory fitness variables accounted for 16% of the cumulative variance in total cholesterol, though not

significantly. These findings have implicated the greater contribution of non-modifiable factors, such as gender and genetic predisposition, and other lifestyle variables in influencing children's total cholesterol level. Dietary composition, stressful lifestyle behaviours and non-modifiable risk factors must be thought to exert independent influences upon blood lipid levels. In future, researchers may wish to include these variables into a more multi-dimensional analysis. Similarly, the total cholesterol measurements taken in our study were non-fasting samples. The question of fasting versus non-fasting samples, for children, remains unresolved. Simons-Morton and Armstrong (1994) suggested that differences between fasting and non-fasting samples were not problematic in interpreting adolescent's total cholesterol. When collection times are late afternoon as ours were, it may be a problem to ask children to fast for the whole schoolday.

High density lipoprotein cholesterol values were consistently lower in our group than in children from other British studies (Armstrong et al., 1990; 1991; Sporik et al., 1991; Azad et al., 1994; Morgan et al., 1994). They were within the recommended cut-off points (>0.91 $mmol.l.^{-1}$), of the Canadian Consensus Conference (1991), during both test visits. Girls had higher HDL-C during the second visit. The influence of sex-specific hormones, in explaining differences in lipoprotein sub-fractions, remains to be clearly identified. Morphological age appears to be related to increases in HDL-C (Sporik et al., 1991; Webber et al., 1991; Armstrong et al., 1992; Guo et al., 1993; Morgan et al., 1994). This may suggest the influence of male and female sex hormones. Boys had a greater morphological age than girls did; yet, levels of HDL-C were lower. These findings are further confounded as morphological age accounted for a significant amount of variance in HDL-C when entered into a multiple logistical regression analysis.

The TC:HDL-C ratio was significantly related to morphological maturity. The significance of TC:HDL-C ratio will be mediated by the level of HDL-C measured. The significant contribution of these variables is, again, difficult to explain. The confounding effects of internal tissue physiology, diet and genetic predisposition would be thought to exert independent influences upon HDL-C, and subsequent

TC:HDL-C ratio. Importantly, the cumulative variance explained by anthropometric, cardiorespiratory fitness, physical activity and sex was significant for HDL-C concentrations (28.4%; $P<0.05$). It appears that a combination of factors will influence HDL-C levels. These findings must necessitate a multi-disciplinary study design when assessing the influences on HDL-C levels in children.

5.2.3 Body fat

Girls had significantly greater adiposity than boys did during both test visits. Sum of skinfolds, triceps and subscapular skinfolds were similar to those from other British studies (Armstrong et al., 1990; 1991; 1996; MacManus et al., 1994; McVeigh et al., 1995). Despite similar stature and body mass, children in the current study had higher individual and sum of four skinfolds than children from the Northern Ireland (Riddoch et al., 1990). Liverpool children's sum of four skinfold thicknesses was elevated when compared to the Northern Irish sample. Liverpool school children's sum of four skinfold thickness' approximated the 50th percentile identified for older children in the Amsterdam Growth Study, at 13 years of age (Kemper, 1995; Twisk et al., 1995).

Several British studies have used the sum of triceps and subscapular skinfolds to provide an index of body adiposity. When results were similarly adjusted, the sum of two skinfolds were akin to those reported by Armstrong et al., (1991; 1996). The sum of two skinfolds for boys were 2% lower than those reported by Armstrong and co-workers during test visit 1, and 3% higher during test visit 2. Girls in the current study had a greater sum of two skinfolds during both test visits than their counterparts from Exeter (4.1% at test visit 1 and 4.7% at test visit 2).

Liverpool children's body fat was similar to that reported by some British studies (Armstrong et al., 1991; 1996; MacManus et al., 1994; McVeigh et al., 1995) yet higher than that reported for others (Riddoch et al., 1990). Comparison with the Northern Irish study would be the most appropriate as they utilised the sum of the

same four skinfolds in their analysis. Despite being of similar stature and body mass to their Northern Irish counterparts, Liverpool children had a higher sum of four skinfolds. Children in the current study were slightly younger than those from Northern Ireland during test visit one, yet a larger sum of four skinfolds was identified. As the Northern Ireland survey did not use an indicator of somatic maturity in their analyses, the contribution of growth on body fat remains unknown in this study. Children of this age (≥ 11 years) will undergo some growth associated with the pubertal spurt. Subsequently, relationships between body fatness and the changing fat free mass will be altered.

Poor, non-significant, relationships were identified between sum of skinfolds and adjusted peak $\dot{V}O_2$, although it is important to note that not all children reached a peak. The inverse relationship between sum of skinfolds and cardiorespiratory fitness is well reported in literature (Armstrong et al., 1991; 1996; Payne and Morrow, 1993; Suter and Hawes, 1993; Kemper, 1995). Our results showed relationships of a smaller magnitude than previous studies. These findings may reflect the myriad of biological changes observed during the early-pubertal period. Whilst increases in body size are associated with increased cardiorespiratory function (Malina and Bouchard, 1991) these potentially beneficial changes may masked by the increased fat-mass of girls and increased fat-free mass of boys.

Gender differences in body fat were also identified in the multiple regression analysis as was body size. Changes in body size will contribute to increased adiposity, as expected during the circum-pubertal period. The inclusion of a specific measurement of morphological age did not significantly contribute to changes in body fatness. Using a predictive measure of morphological maturity, such as the Roche and co workers technique, would not provide data on the biological processes occurring within. Including a maturity term in the multiple regression model did not account for significant variance in the sum of skinfolds. Ultimately, sex-specific hormones will contribute to changes in body fatness during the circum-pubertal period (Roemmich et al., 1997).

When entered into a logistical regression analysis gender, body mass and stature explained significant variance in the sum of four skinfolds. In the complete regression model, a combination of anthropometric measurements, morphological maturity, cardiorespiratory fitness and free-living physical activity accounted for 60% of total variance in the sum of four skinfolds. These findings indicated that, whilst significant, a large amount of variance remains to be explained.

Appropriate nutrition is thought to be the most influential environmental factor associated with biological development (Rowland, 1996) with dietary manipulation regarded as a primary lifestyle intervention to retard the processes leading to increased body fatness. In the current study the measurement of dietary intake was not performed. Preliminary studies of physical activity recall questionnaires found that children were unable or uninterested to complete these questionnaires accurately, or completely. Similar problems could occur for dietary recall questionnaires. Without a direct assessment of dietary intake, the measurement of an important predictor of body fatness was not completed. Other factors such as genetic disposition are not thought to be predictors of elevated body fatness in adults (Sorenson, 1997). Consequently, their application to the pattern of children's body fatness remains to be identified.

5.2.4 Cardiorespiratory fitness

Absolute peak $\dot{V}O_2$ values, expressed as $l.min^{-1}$, were lower than those previously reported for British children of similar age (Armstrong et al., 1991; 1995; MacManus et al., 1994; Welsman et al., 1995; Winsley et al., 1995). Likewise, the peak $\dot{V}O_2$ of the study group, expressed in absolute or relative terms, was lower than similarly aged subjects from Canadian (Mirwald and Bailey, 1986), North American (Savage et al., 1986) and Dutch (Kemper, 1995) studies. Liverpool school-children had absolute peak $\dot{V}O_2$ values similar to those of subjects from Saudi Arabia (Al-Hazzaa and Sulaiman, 1993) and younger American children (7 to 9 years of age; Rogers et al., 1995).

Partitioning out differences in body size provided a more accurate measure of the

cardiorespiratory fitness of the growing child. Relative peak $\dot{V}O_2$ (ml.kg.$^{-1}$ min.$^{-1}$) failed to meet the special circumstance of Tanner (1949), and emphasised the non-linear growth of cardiorespiratory fitness in these children. Higher body mass, facilitated by elevated fat-mass, has detrimental effects upon the maximal cardiorespiratory fitness levels of children (Rowland, 1990; Parizkova, 1996). The child with a greater fat-mass will be disadvantaged in exercise requiring the manipulation of the body against gravity. It is assumed that the fatter child will be outperformed by their lean counterparts during maximal treadmill exercise. Children from the present study had similar, or slightly greater, skinfold thickness measurements than comparable study populations (Armstrong et al., 1990; 1991; 1996; MacManus et al., 1994; McVeigh et al., 1995). Despite similarities in body fatness Liverpool school children had lower peak $\dot{V}O_2$ values using both absolute values and allometric adjustments.

Children from the current study were heavier than national averages and this may be manifested in the lower peak $\dot{V}O_2$ values. Allometric modelling supported non-linear growth by identifying mass exponents of 0.88 for girls and 0.89 for boys during the first test visit. During the second test visit mass exponents were lower (0.80 for boys, 0.74 for girls). These values were above the mass$^{0.67(2/3)}$ exponent used to express the fitness of animals of different sizes (Astrand and Rohdal, 1986; Nevill and Holder, 1994). Our results confirmed that, in circum-pubertal children, peak $\dot{V}O_2$ values were not proportional to mass$^{0.67}$, nullifying the application of geometric similarity in the growing child.

Mass exponents ranging between 0.37 to 0.92 have been reported for children (Rogers et al., 1995; Welsman et al., 1996). Our results showed mass exponents consistently above the 0.74 value, yet reducing over time. Such reductions have been previously reported (Armstrong and Welsman, 1994). These findings suggest that from pre-puberty to adulthood peak $\dot{V}O_2$ will change with increases in body size. However, this increase is less than proportional to the change in body sizes (Armstrong and Welsman, 1994). Only one study of children has reported mass exponents close to the mass$^{2/3}$ thought to represent linear proportions and

growth (Schmidt-Nielson, 1984). In studies of children, the mass$^{2/3}$ exponent may not be applicable due to non-linear segmental development of the subjects. Such wide variation in mass exponents further supports the argument that peak $\dot{V}O_2$ does not increase in direct proportion to body mass. The Amsterdam Growth Study (Kemper, 1995) used such an expression in reporting serial growth data during puberty and through to adulthood. Our results indicate that application of the mass$^{2/3}$ exponent, to peak $\dot{V}O_2$ data, may be flawed.

Whilst the mass exponents identified in the current study provided evidence for the non-linear relationship between peak $\dot{V}O_2$ and body mass, multi-level modelling procedures were used to assess the contribution of simultaneous covariates upon changes in peak $\dot{V}O_2$. Results identified the significant contribution of both body mass and stature to changes in peak $\dot{V}O_2$ during the circum-pubertal period. When fitted to a multi-level regression model, changes in stature had a greater contribution to peak $\dot{V}O_2$ development than body mass.

The contribution of stature to developmental changes in aerobic power has been reported previously (Nevill, 1994). The inclusion of stature within the allometric equation must be advised for future research. Recent reports have shown that when mass is used as a covariate the mass exponent is reduced to 0.71 (Armstrong and Welsman, 1997). The 0.71 value was not significantly different from the mass$^{2/3}$ exponent thought to represent linear proportions and growth (Schmidt-Nielson, 1984). These findings support that to represent normal growth; peak $\dot{V}O_2$ should be scaled using both body mass and stature as covariates. Importantly, the reduction in the allometric scaling exponent for body mass reflects that growth and peak $\dot{V}O_2$ are not developing at a linear rate, as expected in children (Welsman et al., 1996).

Gender differences in peak $\dot{V}O_2$ were significant when using multi-level modelling procedures. These results are different to the non-significant gender differences identified for absolute peak $\dot{V}O_2$ alone. Our results indicate that gender differences in maximal cardiorespiratory fitness will be partially accounted for by

changes in stature and body mass. Other factors such as differences in fat-free mass have been associated with sex-specific differences in peak $\dot{V}O_2$ (Malina and Bouchard, 1991). Such factors will be influential when discussing sex differences.

Allometrically adjusted peak $\dot{V}O_2$ values were lower for Liverpool school children than for similar aged British and American children (Armstrong et al., 1995; Rogers et al., 1995; Welsman et al., 1996). These findings must be interpreted cautiously as several different allometric exponents have been used to scale peak $\dot{V}O_2$ data from this and other studies. Rogers et al., (1995) scaled body mass by 0.75 and 0.67, whilst Welsman et al., (1996) scaled by mass $^{0.67}$, despite calculating an exponent close to mass$^{0.80}$. As our mass exponents were generally higher, it is unsurprising that our scaled peak $\dot{V}O_2$ values were lower. This was due to the smaller mass exponent resulting in a higher peak $\dot{V}O_2$ value.

The mass exponents of girls, during the second test visit, were closer to the 0.75 exponent proposed by Kleiber (Nevill, 1994), based upon the concept of elastic similarity. The $^{0.75}$ exponent is generated from zoological studies of animals, often associated with disproportionate increases in specific musculature. These findings would appear to support the changes in body dimensions observed during puberty.

Rogers et al., (1995) used the mass exponent 0.75 to allometrically scale peak $\dot{V}O_2$ data. They reported adjusted peak $\dot{V}O_2$ values of +35 to +60 ml.min^{-1} when compared to our girls at test visit two. These differences were echoed for our boys (+24 to +66 ml.min^{-1}) during both test visits. When the potentially confounding effects of body mass were removed from analysis it was apparent that Liverpool school children have a lower level of cardiorespiratory fitness than children from other studies. The reason for this difference is difficult to explain. Liverpool school children were similarly inactive, slightly taller and heavier and have comparable levels of body fat as similarly aged British school children. A reason for the lower peak $\dot{V}O_2$ values observed may be associated with true maximal performance. Most children achieved an age associated maximal heart rate. It is difficult to assume that all children achieved such performance. The mean values for peak

$\dot{V}O_2$ and heart rate may have included some scores from less than peak performances, thus skewing data. A confirmatory verification phase must be considered essential for future researchers. Using such a protocol would help to identify a true peak performance. Further research should be performed to assess the differences in pre- and post-verification peak $\dot{V}O_2$ measurements.

Low levels of blood haemoglobin will limit the transference of oxygen from lungs to the tissues (Yip and Dallman, 1996). Blood haemoglobin levels were within normal limits for this age group (Yip and Dallman, 1996). Liverpool school-children had haemoglobin levels only slightly lower than those reported by other British studies (Armstrong et al., 1991; 1995; 1996). Whilst low haemoglobin levels may contribute to poor cardiorespiratory fitness, no direct evidence exists examining this relationship in children. Evidence suggests that chronic exercise result in depleted iron stores in adults (Yip and Dallman, 1996). Our mean group results did not cause concern as to a haemoglobin deficiency in Liverpool school children.

Children in the current study were classified as having a mean group increase in morphological status between test visit. Consequently, increases in body size, blood volume and functional capacity require sufficient haemoglobin to compensate for the effects of rapid somatic growth (Willows et al., 1993; 1995). As no relationships were identified between blood haemoglobin and scaled peak $\dot{V}O_2$, the contribution of this variable to the low levels of cardiorespiratory fitness remain questionable.

Differences in peak $\dot{V}O_2$ have been attributed to the differential growth rates of cardiorespiratory fitness and body size variables (Mirwald and Bailey, 1986). Relationships between peak $\dot{V}O_2$ and body size variables were poor for boys and moderate for girls. Contrastingly, when entered into a multiple regression analysis the significant contribution of both stature and body mass terms to changes in peak $\dot{V}O_2$ was revealed. Evidence to support the similarity of timing for the peak velocity of body size and peak $\dot{V}O_2$ has been provided (Mirwald and Bailey, 1986;

Kemper, 1995). Such findings provide further evidence for the significant contribution of body size to explain changes in cardiorespiratory fitness during growth.

Whilst our results emphasise the regional differences in British children's peak $\dot{V}O_2$, evidence to support the deleterious effect of low levels of cardiorespiratory fitness upon health remains equivocal. A "risk level" of below 35 $ml.kg^{-1}min^{-1}$ for boys and 30 $ml.kg^{-1}min^{-1}$ for girls has been proposed (European Paediatric Work Physiology Group, 1986). Importantly, the relatively "silent" chronic disease profile of children makes direct estimation of potential relationships difficult. Our results showed that 24% of boys and 13% of girls failed to attain these recommendations during test visit 1. These percentages reduced by test visit 2 when 8% of boys and 4% of girls failed to meet the recommended minimum levels. When the effects of body size were partitioned out, no child failed to meet the minimum criteria for peak $\dot{V}O_2$. Such findings further emphasise the inappropriate use of ratio scaled peak $\dot{V}O_2$ to describe the cardiorespiratory fitness of the growing child.

- *Non-physiological determinants of cardiorespiratory fitness*

Performance measures, such as run time, did not significantly contribute to changes in peak $\dot{V}O_2$. Such findings echo previous literature which recognise the independent contribution of running ergonomics to maximal treadmill performance (Rowland, 1990). Gender differences in oxygen delivery mechanics may be evident during pre-puberty (Rowland, 1990). It appears more likely that the boy's peak performance will be affected by their motivation and running economy. Running economy is shown to improve with age (Rowland, 1996), yet the determinants of this change is unclear at present. Certainly the evolution of running economy in children will be facilitated by a combination of improved muscular dynamics and running mechanics. Further research is warranted to provide evidence for such a link in children, and to assess the relative contribution to improved cardiorespiratory fitness with age.

The boys and girls who did participate in structured sports may be expected to have a greater potential for running performance, manifested in greater run times. Their familiarity with running ergonomics would allow for more productive testing and more reflective results. However, the ability of the child to continue to exercise, whether through a combination of fatigue, motivation or extrinsic factors, such as competition, requires further investigation. Similarly, these findings were produced through speculative questioning only. Such findings should be interpreted accordingly.

- Applying the findings of Study Two to a newer framework for physical activity health and fitness

In the model of Bouchard et al., (1993) risk factors are categorised within the morphological (body fat), cardiorespiratory (blood pressure) and metabolic (blood lipids) components. By including these variables in the framework, their relationships with physical activity and health will be assessed.

As most children are free from coronary heart disease, the question remains as to the need to include the risk factor profile in the framework. Literature indicates that the root of certain adult risk factors extends back to childhood (Lever and Harrap, 1992; Hansen, 1997). Whilst a childhood risk factor profile may not provide evidence for potential risk per se, as a predictive tool it will have benefits. Given current physical activity recommendations, children in the current study were almost uniformly inactive. Several children had elevated levels of total cholesterol, and children were generally overfat when compared to other British studies. Therefore, despite the lack of chronic disease in these children the components of the risk factor profile are in evidence.

The early identification of adverse risk factors would allow an appropriate intervention to be made. In the current study, three children were advised to seek GP referral in light of elevated total cholesterol. Such opportunistic risk factor identification may be useful as a preventative health measure for children. It would therefore be prudent for such risk factors to be included in any framework

of children's physical activity, fitness and health.

Figure 8 illustrates a framework that targets risk factor identification within the context of health-related fitness. Other components of health related fitness, such as muscular endurance, speed or motor co-ordination factors may also be important. As the current study did not measure such factors, it is imprudent to include them in a newer framework. However, their contribution to overall fitness should not be underestimated.

Muscular fitness is recognised as an important component of physical work capacity (Bouchard et al., 1994). Whilst helping in the performance of physical activities muscular fitness may also be important for normal hormonal and substrate metabolism (Bouchard et al., 1994). Relationships between muscular fitness and metabolism may have implications for lipid levels. Exercise has been shown to have beneficial effects on lipoprotein profiles (Blessing et al., 1995), yet information on the contribution of muscular fitness to such benefits remains to be reported. As an extension of the current work, the contribution of these variables to the framework should be measured.

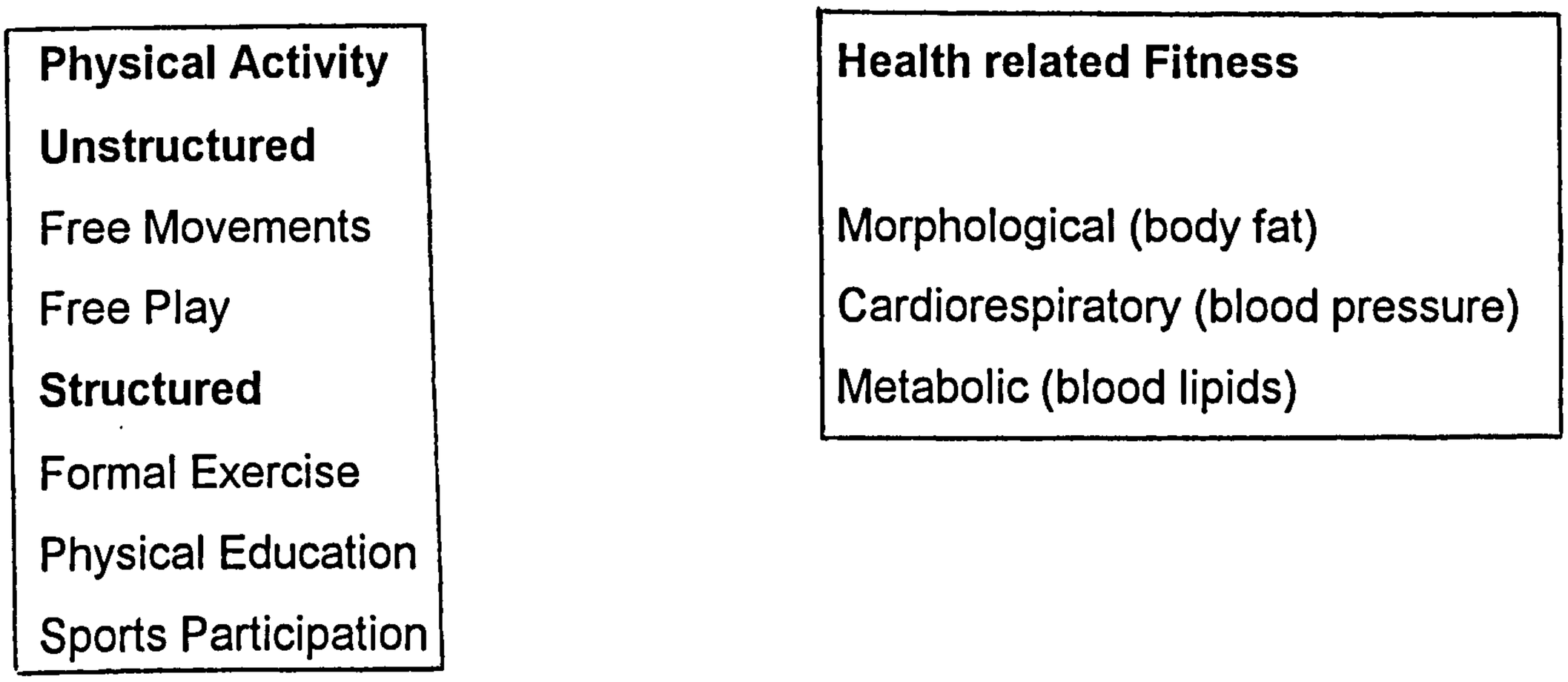


Figure 8. The revised framework for children's physical activity health and fitness – Physical Activity and Health Related Fitness.

The framework at Figure 8 currently represents little more than two lists of variables. For the framework to become "applied" the interpretation of our findings

relating to links between physical activity, health and fitness is required, especially during development.

The newer framework now includes information on physical activity and health-related fitness. Changes in these factors during growth were investigated during study three. Postulated links between factors were investigated in study four. Such information has rarely been provided during growth. Given the biological and sociological milieu surrounding children during growth it is essential to include such interpretation in the revised framework.

5.3 **Study Three**: The tracking of physical activity and chronic disease risk factors

- *Physical activity*

Children consistently failed to achieve continuous periods of physical activity of more than five minutes duration. The number of children achieving a single, continuous 20-min period of physical activity was low. Fourteen percent of girls and nine percent of boys achieved just one 20-min period. No child achieved the recommended "3 x 20 min" prescription for adolescents (Sallis and Patrick, 1994). No child who achieved a 20-min period during test visit 1 achieved a similar period of activity at test visit 2. Children also failed to reproduce the shorter periods of continuous physical activity between test visit. Inter-period correlation coefficients for continuous periods of physical activity were difficult to construct due to the poor attainment of these periods during both test visits. These changes were not statistically different (see Section 4.2). Our results also showed that the cumulative minutes of activity above the 75% HRR threshold remained low during both test visits. These findings again emphasised that children do not readily perform free-living physical activities at the higher heart rate thresholds.

These reductions in physical activity participation contrasted with previously reported literature. van Mechelen et al., (1993) reported that decreases in physical activity were most marked between age 13-18 years. Such findings were

confirmed by Twisk et al., (1995), who reported that the greatest reduction in total physical activity occurred during adolescence (13-16 year). Our data reveals that this initial change occurs at an earlier age and emphasise the importance of measuring change in activity behaviours during the circum-pubertal period. This is especially true when associated with social changes such as the education transition.

Why the reduction in physical activity occurs is debatable. The current study consisted of many children making the transition from primary to secondary education. This is a period of great change in both peer group, surroundings and the availability of activity resources. This change may be implicated in the reduction of cumulative minutes of activity during the study period. Interviews with several children revealed that the change of school associated with the education transition contributed to a reduction in extra-curricular physical activities, through both interest and provision of facilities.

That the transition of education seemingly affects physical activity and is a cause for concern. At primary school children often had a greater availability of resources than their secondary school counterparts. From our observations during school visits, this was manifested in more gymnasium space, green-field sites and available staff. A combination of these factors enabled children to participate in regular extra-curricular activities. During the second test visit, children who had made the transition from primary to secondary often complained of a lack of extra-curricular activities at their new schools. For two girls, the lack of an after school soccer club led to their total withdrawal from any form of physical activity outside of structured physical education lessons. Similarly, the physical activity performed by children during physical education lessons does not appear to be of a sufficient volume to promote health and fitness benefits (Stratton, 1996; Malina, 1997). The reduction in extra-curricular activities at secondary school level requires investigation. It appears that this period contributes greatly to observed reductions in children's physical activity participation. Unfortunately, the effects of this "window" remain to be assessed.

The contribution of environmental and sociological factors should be alluded to. It is naive to think that poor weather will reduce physical activity participation. Children were often observed performing physical activities in the foulest of weathers. Variations in physical activity during inclement weather should be investigated, as this may be yet another confounding variable. Similarly, the contribution of child safety should be recognised. Given a current social climate of potential child risk, it is unsurprising that parents are reluctant to allow their children to play alone or with few friends. Parental attitudes towards child safety may provide another component of a predictive model for children's physical activity participation. Again, such information remains to be reported. Other confounding social and environmental variables, such as the logistics of physical activity participation and finance, must exert some influence. Again, future researchers should address these issues when investigating the determinants of children's physical activity.

Physiological determinants did not significantly contribute to reductions in physical activity participation. Few studies have reported changes in the predictors of physical activity over time. Shaw and Eves (1997) reported that a myriad of psychological factors, gender and baseline fitness levels accounted for 24% of the total variance in physical activity behaviours over a 1-year period. These results support our findings that baseline fitness levels and gender do not contribute significantly to physical activity participation. They further emphasise the multi-factorial nature of the determinants of children's physical activity.

Tracking correlation coefficients were low for the cumulative minutes of activity at the 139 beats.min.$^{-1}$ and 60% HRR thresholds. Only one significant tracking correlation was identified, for the cumulative minutes with heart rate elevated >75% HRR for boys. This showed the relative instability of low levels of boys physical activity performed at higher heart rate thresholds. Children appear unable to perform higher levels of physical activity consistently during childhood.

The use of inter-period correlation coefficients has provided the majority of tracking information for physical activity and risk factors (Kemper et al., 1995; Roche, 1997). This technique provides a tool for comparison with other studies. For information on variables, showing relatively little variation this technique may be fundamentally sound. When a parameter is measured which may show great variance, such as physical activity, the use of the technique becomes less viable. Table 44 is composed of a hypothetical data set assessing the cumulative minutes of physical activity performed by children at two test visits.

Table 44. Hypothetical data set for cumulative minutes of physical activity performed at 12-month intervals.

Cumulative minutes of physical activity	
Visit 1	Visit 2
2	22
4	44
6	66
8	88
10	111
12	122
14	144
16	166
18	188
20	222

Using an inter-period correlation coefficient the tracking for this variable was highly significant ($r = 0.98$; $P<0.01$). This statistical finding indicates that physical activity tracked between test visit, maintaining its stability over time. When viewing this data set it is apparent that the volume of physical activity performed was anything but stable, increasing greatly between test occasion. Question must be raised about the relevance of the IPC to assess the stability of a variable over time. This is especially true for a variable such as physical activity which, as our findings show, may vary considerably over time.

Given this problem a correct statistical method must be sensitive enough to measure the stability of test variables. Using percentile values would allow for changes in a variable to be assessed in respect to its maintenance within a

certain rank. From our results it is obvious that children consistently failed to perform physical activities at the higher intensity thresholds (>75% HRR). This would surely indicate that low levels of high-intensity physical activity will remain stable over time, and so would track.

Given the apparent instability of heart rate monitoring over time, question must be raised as to the validity of this method for longitudinal studies. Decreases in baseline heart rate, with increasing age, are generally linear (Rowland, 1996). Our results showed a high correlation between the lowest three consecutive heart rates measured during the sleep period between test occasion, emphasising the linear decrease in basal heart rate. During free-living physical activities such relationships will be subject to both myocardial adaptations and the choice of physical activity behaviours. The failure of physical activity to track may reflect the choice nature of participation over time. The pattern of physical activity will change over time, as will the cardiovascular response. When the myriad of confounding variables, such as illness, ambient temperature, myocardial adaptation to training state and transient emotional state are considered, it is not surprising that the heart rate response to physical activity fails to track.

The choice of the system was based on the social acceptability of the unit for long-term physiological monitoring. Other methods were less acceptable due to size or discomfort. Additionally, the heart rate system enabled information to be gathered on the volume of physical activity performed at one-minute intervals, a level of precision unmatched by other physiological systems.

Such information is contradictory when we consider that a low level of physical activity appears to be stable during growth. This necessitates the choice of an appropriate method of statistical analysis to assess changes in physical activity behaviours. Movement within centile ranks would appear to be the most appropriate method at this time.

Until a criterion measurement of physical activity assessment is provided, it appears that some form of multi-instrument activity measurement must be used. Such an approach may provide a technique for establishing the construct validity of heart rate in the free-living environment. Rarely has this been investigated.

Comparison with other studies is further complicated by the uniformly young age-groups used (<8 years). Researchers have suggested that physical activity tracks moderately during early childhood (Sallis et al., 1995; Pate et al., 1996). Currently, little information exists examining the important changes in physical activity during late-childhood/early-adolescence. Results from the current study indicate that the period immediately prior to, and during the onset of, puberty may be a crucial for the formation, and change, in physical activity participation. Further research is required to identify the antecedents of physical activity within this age group, and the reasons for change during the early adolescent period, such as the movement from primary to secondary education.

Despite inconclusive tracking evidence, low levels of physical activity, during both test visits, are of concern. Whilst it is difficult to support an "inactive child - inactive adult" supposition using a 1-year longitudinal study design, our results showed the total amount of moderate to vigorous physical activity performed remains low or begins to reduce between test visit. Further research is required to encompass the important periods of change in activity patterns, namely primary schooling, primary to secondary education transition and post-secondary school periods.

- *Blood Pressure*

Tracking of systolic and diastolic blood pressures was significant in all groups except for the diastolic blood pressure of the boys. Increases in blood pressure were also statistically significant over the 12-month period (see Section 4.3). This would indicate a linear relationship between chronological age, normal growth and vascular function. The tracking coefficients in the current study are higher than those reported by Clarke et al., (1978) and de Swiet et al., (1992).

Unfortunately, using only two data points in the current study may "mask" changes shown in longer duration studies.

The tracking of blood pressure has been reported in studies of adolescents (Roche, 1997). This retrospective analysis of data from the Fels longitudinal study used pairwise IPC's to assess tracking. As previously discussed, the use of two data points is not sufficient to assess the stability of physical activity over time. Blood pressure is subject to less variation than a physical activity behaviour. We may, therefore, expect the IPC to be more applicable in this situation. Our results indicated that blood pressure increased over 12-months, but the variable did track. This would indicate that blood pressure measurements tracked over 12-months, despite the increase. Such evidence may suggest the canalisation of blood pressure in accordance with increased somatic growth.

Changes in blood pressure reflected the increases in body size expected during this period of growth. Retrospective analysis of our results showed that mean blood pressure values remained close to the 50th percentile when such values were constructed. This again emphasised the relative stability in blood pressure, and shows that this variable does not increase disproportionately during growth (Malina and Bouchard, 1991). It is obvious that changes in blood pressure mirror changes in stature, as expected. The continuation of measurements past 12-months is needed to fully assess these changes during growth. This is especially important, as children in the current study cannot be said to have entered the most rapid period of growth.

- *Blood Lipids*

Our use of Canadian (1992) criteria was based upon the need for a multi-level classification of relative risk. Given the problematic nature of using two data points in IPC's, the stability of blood lipids, within these bands, could be assessed.

The lipid profile of the children did not change significantly over the 12-month test period (see Section 4.3). Children's total cholesterol increased between test visit, yet these values failed to maintain their ranking within these "bands". When a single reference level was used (High $\geq$ 5.5 mmol.l.$^{-1}$) the tracking of total cholesterol improved. Only one boy had total cholesterol levels above this value during both test visits. Similar results was identified in HDL-C measurements with no child having HDL-C values below recommended cut-off points during both test visits. These findings contrast those of Porkka et al., (1991), who found that tracking coefficients over less than 1-year were generally stronger than those from longer studies. Tracking coefficients from the current study were lower than other reported longitudinal studies (Clarke et al., 1978; Laskarewski et al., 1979; Omura et al., 1991; Porkka et al., 1991; Webber et al., 1991).

Maintenance of total cholesterol values above the 95th percentile has been used to describe tracking of adverse blood lipid profile (Clarke et al., 1978; Laskarewski et al., 1979; Webber et al., 1991). When similar percentile values were established for the current study group, one boy was shown to have total cholesterol values above the 75th percentile, during both test visits. No child was shown to have total cholesterol above the 95th percentile or HDL-C below the 5th percentile during either test visit. These findings showed that percentile ranking, to assess the tracking of blood lipids, provides a valuable technique in determining potential risk. This is especially important when using only two data points. Caution should be emphasised when interpreting these findings due to the small sample size used.

Tracking of the TC:HDL-C ratio was also poor. Again, the problems associated with appropriate classification of elevated lipid profile have resulted in the TC:HDL-C ratio rarely being used. The use of TC:HDL-C, in assessing possible risk, is recognised as providing the only easily administered method of preventing mis-classification of blood lipid profile (Rimmer and Looney, 1994). As part of health screening, for potential chronic disease risk, analysing both total cholesterol and HDL-C is considered the best method. By analysing multiple lipid

sub-fractions, the possibility of erroneous reporting of lipid sub-fractions in younger populations would be reduced (Rimmer and Looney, 1994).

Despite the poor tracking of lipid sub-fractions, our results showed increasing total cholesterol and HDL-C concentrations over time. These results emphasise the normal developmental pattern of total cholesterol during childhood. Total cholesterol concentrations increase throughout the period of adolescent growth (Laskarewski et al., 1979; Webber et al., 1991) and our results show similar increases. With only two data points used in analysis predictions for future total cholesterol levels would be difficult. The contribution of other lifestyle variables, to measured increases in total cholesterol, may have important implications for subsequent lifestyle intervention.

Results showed that one boy had elevated total cholesterol above recommended cut-off points during both test visits. No child had elevated TC:HDL-C or lowered HDL-C outside of Canadian consensus (1992) recommendations during both test visits. Given the significant tracking of total cholesterol, it appears that the poor tracking of TC:HDL-C is mediated by the relative stability of HDL-C concentrations.

- *Body Fat*

The poor stability of sum of skinfolds measurements over time was shown in our study. Tracking correlation coefficients would be expected to decrease during the pubertal growth spurt. Similarly, these increases were shown to be significantly different over the 12-month test period (see Section 4.3). This period is when the deposition of subcutaneous fats are most pronounced (Roche, 1997). The rapid increase in fat-free mass by male adolescents is representative of increased secretions of gonadal steroid hormones (Rogol, 1994). Gender differences in fat-mass during the pubertal period are facilitated by increases in oestrogen's (oestradiol and progesterone), associated with enhanced accumulation of fat throughout the female body (Malina and Bouchard, 1991). Inter-period correlation coefficients for our subjects reflect that girls skinfold thickness' are relatively

unstable between test visit. These findings would be consistent with literature, and support increases in girl's adiposity with increasing biological age (Clarke et al., 1978; Malina and Bouchard, 1991; Clarke and Lauer, 1993). Again, the use of two data points to determine stability, by IPC, is problematic, and caution should be advised when interpreting this statistic.

Results from the current study moderately support the likelihood that elevated adiposity during childhood may reflect similar adiposity levels during later periods of growth and development. The confounding effects of puberty would be expected to alter inter-period relationships, emphasising caution when interpreting these results as possible indicators of adult body fatness. When entered into the multiple regression analysis morphological maturity status did not significantly contribute to changes in body fat. Children in our study are not thought to have entered the most rapid period of growth. Consequently, the contribution of morphological maturity in the multiple regression equation was not significant.

Appropriate lifestyle intervention, from an early age, is regarded as essential in retarding the development of adiposity during the adolescent period. A combination of dietary manipulation and physical activity are important lifestyle intervention's, aimed at retarding the processes leading to increased adiposity. Whether such intervention, performed during childhood, would prevent possible adult adiposity remains to be proven. Moderate tracking of skinfold thickness indicates an unstable increase in adiposity with increased chronological age. Whilst this finding would be expected during growth, our findings are not sufficient to predict future patterns of adiposity from childhood levels.

- *Cardiorespiratory Fitness*

The growth-related changes in peak $\dot{V}O_2$ identified in our study conform to previous literature (Malina and Bouchard, 1991; Welsman et al., 1996; Armstrong and Welsman, 1997). Our results provide information as to the tracking of allometrically adjusted peak $\dot{V}O_2$ values.

Adjusted peak was anything but stable over time, yet increases in allometrically scaled peak $\dot{V}O_2$ were not significantly different over the 12-month test period. (see Section 4.3). This suggests that the biological milieu during growth will promote non-linear changes in peak $\dot{V}O_2$. Whilst a mass exponent is required to normalise growth-related data, the contribution of other variables, such as haemoglobin, lean muscle mass and stature should not be discarded. Within our analyses, the contribution of stature to changes in peak $\dot{V}O2$ was significant. Stature should be included in allometric equations of peak $\dot{V}O2$ (Nevill, 1994; Welsman et al., 1996). A multivariate approach, including these variables, is essential to further tracking studies. Similarly, IPC's should not be used unless a series of data points are available.

- Applying the findings of Study Three to a newer framework for physical activity, health and fitness

The newer framework so far includes a descriptive analysis of physical activity and the health-related fitness of children. When dealing with children the effects of physical and social development must be considered important. Bouchard et al. (1993) has alluded to developmental changes across the life cycle. An actual growth component was not included in their model.

The biological milieu surrounding the growth of children must be accounted for. Cost, logistics, validity and ethical constraints encumber many methods of maturity assessment. Some form of maturity indicator must be included in analysis, especially involving circum-pubertal children.

In the current study, the contribution of maturity state to tracking was not significant. The heterogeneous distribution of children's maturity identified during our study will make such inferences difficult to support. Certainly, for lipids and body fat increased maturity is thought to influence these variables. Unfortunately, the study design, and subject groups, used in our study have precluded such an assessment being made with any statistical strength. Despite this, within a framework for children's physical activity, health and fitness a development term

should be included. This term should include both physical and social aspects of development. Such an inclusion would allow for the contribution of development to be made, and the influence on the continuum assessed. Importantly, the newer framework may be tested to determine possible tracking of physical activity, health and fitness variables across the life cycle.

Developmental factors are included in the revised framework at Figure 9. These developmental factors provide the first postulated link with physical activity and health related fitness in the newer framework.

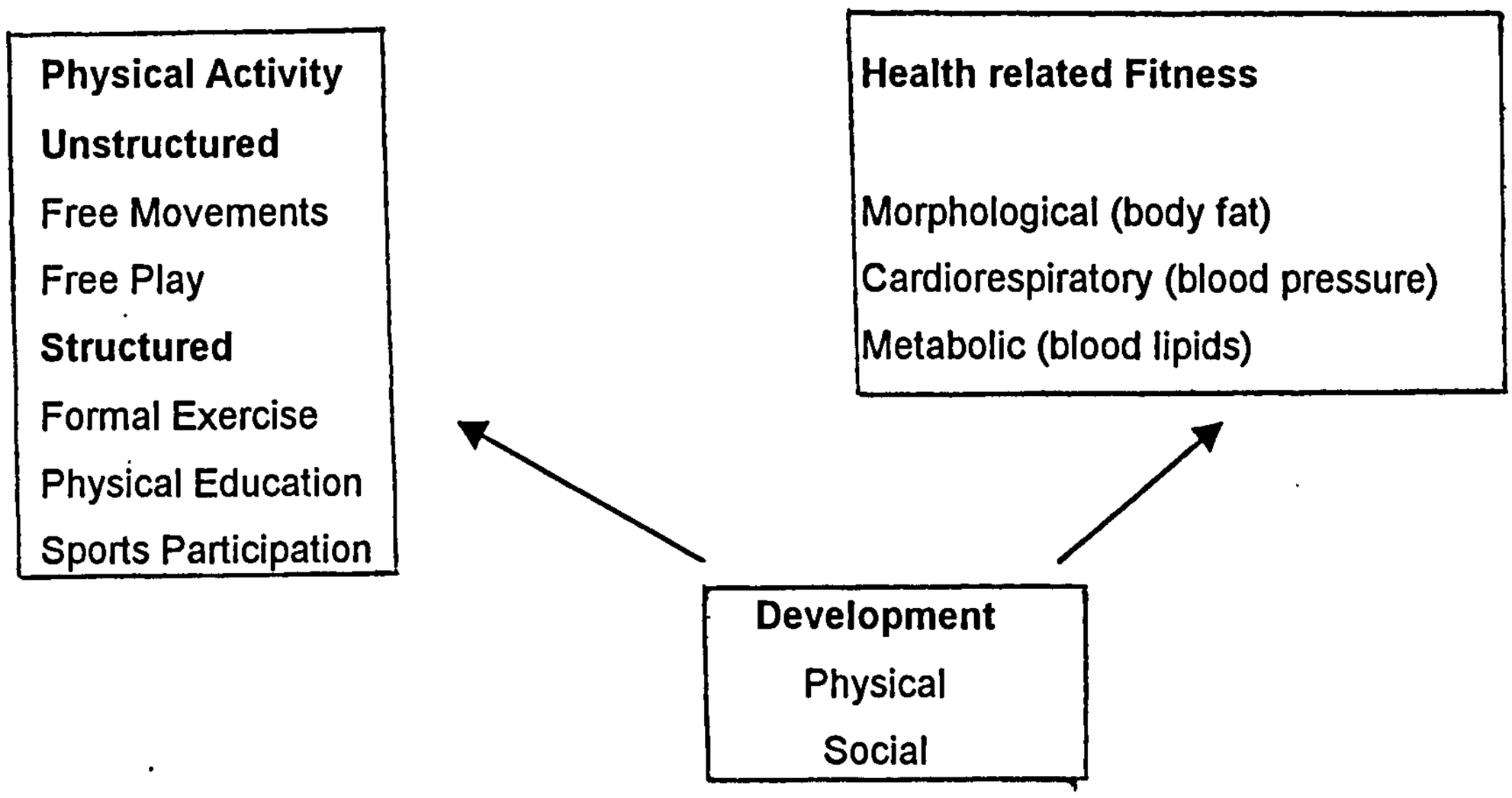


Figure 9. The revised model for children's physical activity health and fitness – the contribution of development.

5.5 **Study Four**: Relationships between habitual physical activity and chronic disease risk factors

Free-living physical activities did not contribute to the risk factor profile or cardiorespiratory fitness during either test visit. The failure of physical activity behaviours or health-related fitness to track further complicates the determination of such relationships,

- *Relationships between free-living physical activity and blood pressure*

Physical activity at all heart rate thresholds was poorly related to blood pressure. This poor relationship echoed previous literature (Alpert and Wilmore, 1994; Hansen, 1991, 1997; Bouchard et al., 1994; Andersen, 1995). Our results provided limited evidence for the influence of free-living physical activities on children's blood pressure. The instability of children's physical activity patterns, coupled with relatively stable blood pressure measurements over time, provide inconclusive evidence for a physical activity/blood pressure relationship. In controlled training studies, few significant relationships have been identified. It is doubtful that uncontrolled, free-living physical activity would contribute significantly to changes in vascular pressure in children. These changes appear to be primarily growth related.

The logistical regression analysis showed that cumulative minutes of activity, at all heart rate thresholds, did not account for significant amounts of cumulative variance in systolic and diastolic blood pressure. When incorporated into a larger model, using body size, morphological maturity, body fat, cardiorespiratory fitness and blood lipid variables, 26% of variance in systolic blood pressure and 45% of variance in diastolic pressure were significantly accounted for. Despite explaining a significant amount of variance in blood pressure, over 50% of total variance have yet to be explained. With increasing body size the peripheral vascular resistance also increases (Hansen, 1995). Partitioning out differences in body size may clarify the relationship between physical activity and blood pressure. Such scaling has rarely been reported for children, and represents a logical progression in statistical modelling of children's blood pressure.

Increased chronological age contributed significantly to changes in systolic and diastolic blood pressure. Increases in chronological age are associated with increases in both biological age and body size. Such findings are emphasised by the significant contribution of stature to changes in the systolic blood pressure of boys. Given the similarity in stature and body mass, the relationship between

blood pressure and stature is less clear in the girls.

High levels of adiposity have been implicated in the emergence of adult hypertension. The contribution of adiposity to elevated blood pressure cannot be clearly defined from the data in this study. Further investigation may wish to address this problem.

- *Relationships between habitual physical activity and blood lipid profile*

Poor relationships were identified between the cumulative minutes of physical activity and TC measurements. Low, yet significant relationships were identified between cumulative minutes of activity at the 60% HRR threshold and HDL-C for boys, during test visit two. Previous experimental evidence, allied to the low statistical power of the current study, makes it likely that such relationships are fallacious or could have been stronger. The problematic nature of physical activity recording will certainly limit such findings. This problem places emphasis on identifying a true criterion method of physical activity assessment for use in such inferential analysis. Additionally, other confounding variables, such as dietary influence, non-fasting blood sampling and the problems associated with defining adverse blood lipid levels must be considered influential.

Continuous duration activities, at or above 80% of maximum heart rate, have been associated with favourable alterations in blood lipids (Thorland and Gilliam, 1981; Superko, 1991; Armstrong and Simons-Morton, 1994; Blessing et al. 1995). Using these thresholds, the free-living physical activities of children in the current study were not of a sufficient duration or intensity, to promote favourable alterations of blood lipids. These findings confirmed previous consensus statements for adolescents (Armstrong and Simons-Morton, 1994) with the relationship between physical activity and blood lipids remaining unclear.

- *Relationships between free-living physical activity and body fat*

Our results showed that free-living physical activity, at all heart rate thresholds, does not contribute significantly to changes in body adiposity. Such findings are not surprising given the maturity status of these children. Puberty will see a myriad of biological, social and environmental changes, which contribute to both the performance of free-living physical activity and changes in body adiposity. The contribution of sex-specific hormones to body adiposity is well understood, and accounts for great changes in fatness during puberty (Roemmich et al., 1997). Changes in social environment, schooling, peer group, dietary habits, and parental influence may all affect physical activity participation. Subsequently, levels of body adiposity are mediated by a combination of physical activity and the biological, sociological and environmental milieu surrounding puberty. Importantly, a combination of increased physical activity and alteration of dietary habits has been proposed to alter the body fat levels of both adults and children. The inclusion of estimates of dietary intake must be included in future research to provide a complete assessment of the possible predictors of changes in body fat.

Our findings suggest that physical activity was not related to body fat during the 12-month study period. The volume of physical activity performed by Liverpool schoolchildren does not appear suitable to promote favourable levels of body fat. Structured exercise alone appears to be a sufficient stimulus for changes in body fat (Bar-Or and Baranowski, 1994). As previously reported, the vast majority of children do not perform this type of physical activity. Further investigation is required to see if unstructured physical activities, at a variety of exercise intensities, are sufficient to promote favourable alterations in body fat. Importantly, the measurement of physical activity remains problematic and such limitations should be alluded to when reporting findings.

- *Relationships between free-living physical activity and cardiorespiratory fitness*

Adjusted peak $\dot{V}O_2$ did not make a significant contribution to the performance of

physical activities when entered into a logistical regression analysis. Whilst continuous duration, high-intensity exercise has been shown to promote changes in peak $\dot{V}O_2$, our findings confirmed a poor relationship between these variables. Similarly, children's cardiorespiratory fitness level was not a significant predictor of physical activity.

These findings suggest that children's participation in physical activities were not affected by their level of fitness. Whether low-fit children participate in more or less physical activity is contentious. Our findings further disprove that the more active child is the fitter. When we consider that improvements in peak $\dot{V}O_2$ are only mediated by long-term, high intensity exercise (Morrow and Freedson, 1994), it is unsurprising that no relationship was identified. Children do not perform a sufficient volume of physical activity to facilitate such improvements.

The term's physical activity and fitness are used interchangeably, often erroneously. Classifying a child as high- or low-fit is therefore questionable. The child with higher fitness level may perform less physical activity than a low-fit child would. This suggests that physiological differences may be better predictors of cardiorespiratory fitness than physical activity. Our results indicated that stature contributed significantly to increasing peak $\dot{V}O_2$. Other variables, such as lean muscle mass, respiratory capacity and haemoglobin level, contribute to peak $\dot{V}O_2$. It is important when assessing the relationship between fitness level and physical activity, to account for these potentially confounding variables. Future researchers should include some form of multivariate modelling to account for these variables.

Our findings indicate that physical activity participation is irrespective of cardiorespiratory fitness level. As our study utilised a pre-selection criteria to provide a normally distributed sample, we do not know if children from the lower performance levels would have been more physically active. The children who performed the most physical activity were often those who competed in structured sports or exercise. Importantly, these children often performed little additional physical activity on days when they did not compete. This indicates that children

will perform physical activities irrespective of fitness level. Fitter children may find the demands of physical activity easier, yet baseline fitness level will not influence the participation of the less-fit child. Physical activity participation, outside of structured exercise, is a choice behaviour. Children will perform physical activity irrespective of level of cardiorespiratory fitness.

- Applying the findings of Study Four to a newer framework for physical activity, health and fitness

The volume of free-living physical activity performed by children in this study was not sufficient to facilitate changes in the risk factor profile or cardiorespiratory fitness. The model of Bouchard et al. (1993) indicates that physical activity will be associated with health-related fitness and subsequent health. Our findings suggest that free-living physical activities are not significantly related to these factors. Within the definition of physical activity in the newer framework formal exercise may contribute to such changes, but only if an adequate frequency and intensity of activity is performed (Sallis and Patrick, 1994).

Despite this poor relationship, the question of physical activity measurement should again be raised. As with all test variables the lack of criterion physical activity measurement will hinder the interpretation of results. Physical activity must be considered a complex bio-behavioural action. Physiological responses, as measured using heart rate techniques, will not reflect the choice behavioural nature of physical activity. Again, some form of multi-instrument methodology is required to adequately assess physical activity. As previously discussed, heart rate monitoring will provide information on the volume and tempo of physical activity performed. Such information is important in determining the relationship between physical activity and other physical variables.

That children's physical activity is not related to health-related fitness should not preclude this relationship from being espoused within a newer framework. The quantity of empirical evidence assessing the dose-response of sporadic free-living activity to health-related fitness is minimal. Whilst the current volume of children's physical activity is insufficient to promote health-related fitness benefits, empirical

support is needed to remove or include such activity within the framework. Reductions in body fat have been reported following such an exercise prescription (Linder et al., 1983). This factor alone should promote a controlled study to investigate this dose-response for children.

Additionally, the contribution of development should be included in future studies. Increasing physical development will see an alteration in health-related fitness of children. Our findings support the transition from primary to secondary school as being influential on children's physical activity behaviours. When assessing the relationships between physical activity and health related fitness, it is important to include the influence of social and physical development. Therefore, a multi-disciplinary approach to all components of the newer framework is essential when determining these relationships. The model of Bouchard et al., (1993) suggests that physical activity, health-related fitness and health can influence each other. As we have identified, the level of fitness does not influence physical activity participation and vice-versa. An updated framework is provided at Figure 10.

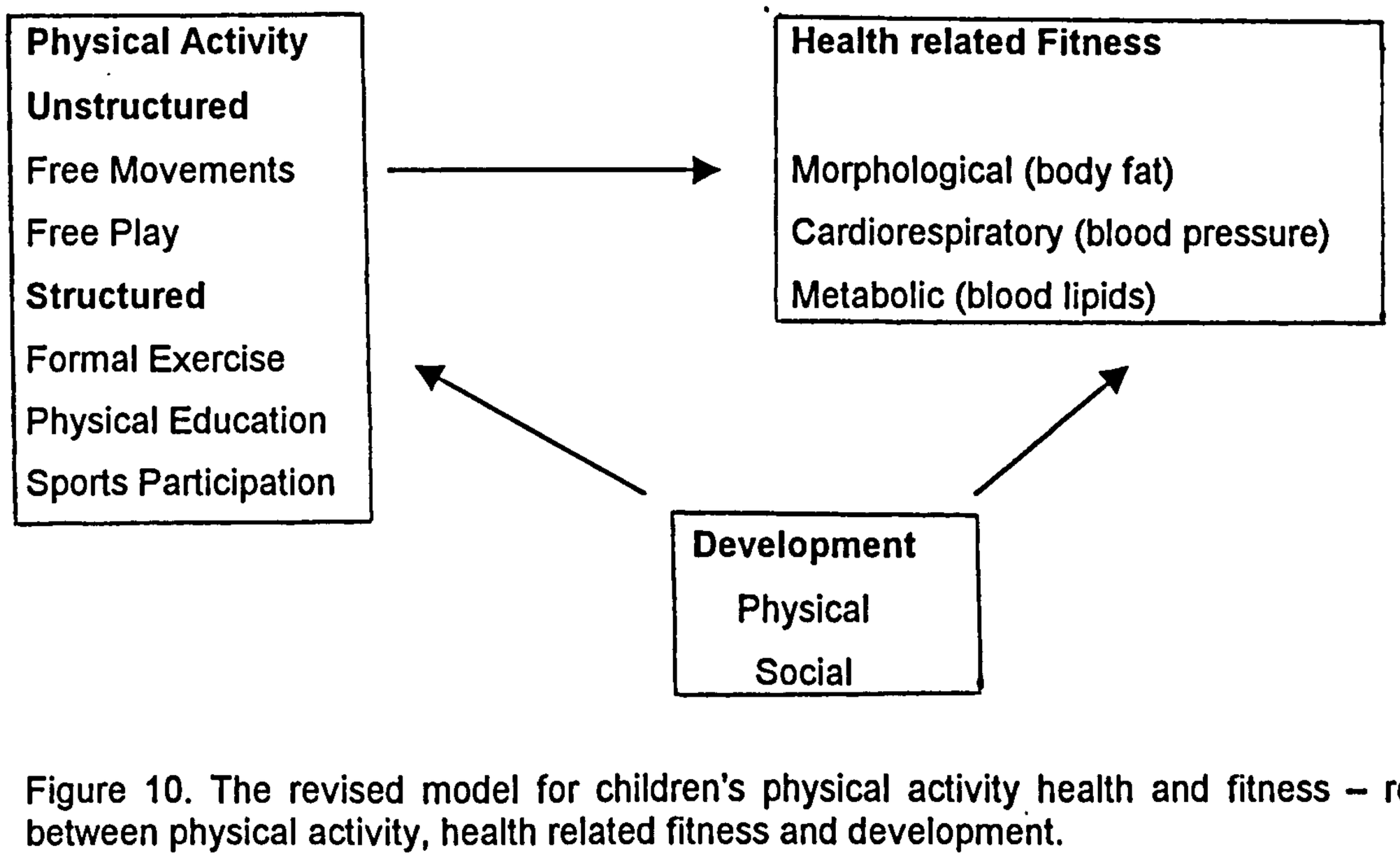


Figure 10. The revised model for children's physical activity health and fitness – relationships between physical activity, health related fitness and development.

5.5 **Study Five**: Physical self-perceptions

- *Factor analysis and structure of the PSPP*

The principal components factor analysis revealed poor psychometrics for the PSPP. The anticipated factor loadings were only evident for two sub-scales for boys (physical conditioning, physical strength) and girls (attractive body, physical strength). This did not support that the four sub-domains measured independent physical self-perceptions. Additionally, the factor solution explained 44% of variance for boys and 46% for girls. Items that cross-loaded for boys did not for girls and further emphasise the problematic factor structure of the PSPP in this sample of Liverpool school-children. Our results show that much of the content of physical self-perceptions was accounted for by factors other than the four PSPP sub-domains.

These findings are in opposition to those reported by Whitehead (1995) for a population of slightly older children (11-12 years). Adaptations to the original PSPP, designed to make the instrument easier to understand, did not help in improving the factor structure. Whitehead's (1995) C-PSPP used similar changes in wording, yet resulted in a better factor structure. The older cohort used in the study of Whitehead may be indicative of greater cognitive functioning and subsequent ability to differentiate between self-perceptions.

The physical self-perceptions of younger children are less clear than for older children. Comparison of our data with those of Whitehead (1995) shows a "window" whereby the conceptualisation of physical self-perceptions becomes clearer. Whether this "window" is related to changes in maturity is an intriguing question. Further research appears warranted to identify the approximate period of change in the physical self-perceptions of children.

The validity of the PSPP is questioned for the current study group. Without a secondary factor analysis, performed upon the same children at an older age,

subsequent PSPP measurements were likely to be weakened (Fox, *personal communication, 24 Feb 97*). The use of the strongest items identified from the factorial analysis was suggested by Fox (*personal communication, 24 Feb 97*). With this "cleaning" our findings revealed a three-item solution to the sports competence sub-scale for boys and the physical conditioning sub-scale for girls. Those three items alone were used for subsequent analysis, and repeated for other sub-domains, to provide a stronger factor structure to an already weakened instrument.

- *Physical self-perceptions within the study group*

Comparison with sum of sub-scale values is difficult due to the inferior factor structure found for children in this age group. It was decided to include only those sub-scale items with the required factor structure in analysis, thus preventing comparison with several studies who have used sum of sub-scale items as their scoring system (Bettinson, 1996; Saunders, 1996). Individual item values saw boys with greater perceptions of physical conditioning, attractive body, physical strength and physical self-worth.

Boys seemingly placed great importance upon physical strength, confirming societal expectations of masculinity. These results are common in many studies using the PSPP (Fox and Corbin, 1989; Whitehead, 1995; Welk et al., 1995; Bettinson, 1996; Saunders, 1996) and reinforce the gender stereotype of the "stronger male" (Scraton, 1992). The perception of an attractive body was more significant for boys than girls during both test visits these findings are replicated by other studies (Fox and Corbin, 1989; Whitehead, 1995; Welk et al., 1995; Bettinson, 1996; Saunders, 1996). That boys have greater self perceptions of strength and the attractive body is emphasised by their responses to the Perceived Importance Profile (PIP). Boys placed greater importance upon the strength and body sub-scales than girls, yet these two sub-scales were the least important of the four used in the PSPP.

Boys and girls placed greatest importance upon sports competence, closely followed by physical conditioning. Why children perceived the sports competence sub-domain so strongly is unclear. Fox (1994) reported that 12-year old children tended to relate global self-esteem to appearance factors rather than athletic competence. Other studies similarly failed to associate athletic competence with overall self-esteem (Whitehead, 1995). Liverpool children appear to perceive sports competence more importantly than appearance or physical capacity.

Participation in structured sports may influence perceptions of competence and self-esteem (Ommundsen, 1997). With such expectancies, reductions in perceived competency and subsequent persistence in participation may result from negative experiences (Ommundsen, 1997). The fear of failure, or looking awkward during sports and activities, may influence children's participation in physical activity. Certainly, the child who is not as proficient at certain skills may not feel inclined to participate for fear of embarrassment, however this remains to be investigated.

How children perceive and differentiate between physical self-perceptions must be questioned. The factor analysis revealed that only the physical strength sub-scale provided the required psychometric factor structure to warrant its inclusion in the PSPP for boys and girls of this age. A further factor analysis, performed upon the same population at a 1-year interval, would have greatly enhanced our understanding of the change "window" whereby self-perceptions become more stable. Longitudinal results showed that perceptions of physical strength and physical conditioning increased with age, whilst perceptions of the attractive body decreased. Within the limits of our construct analysis, these findings provided evidence for the changing physical self-perceptions of children with age. The components of self-worth are thought to become more differentiated with increased maturity (Fox, 1994; Whitehead, 1995). As children mature they perceive the physical self more, and are able to rate themselves according to physical abilities (Fox, 1994).

There is little reported literature investigating changes in physical self-perceptions. The instability of self-perceptions over time was emphasised by the poor to moderate inter-period correlation coefficients. Only the physical strength sub-scale tracked significantly for boys and girls. Whilst the poor psychometrics of the instrument may weaken statistical findings, self-perceptions are changing with age. Highly significant changes in physical conditioning and attractive body sub-scales emphasise the underlying change in cognitive ability of the child and highlight the need for further research to be performed to determine the appropriate periods of change in physical self-perceptions.

- *Relationships between physical self-perceptions and habitual physical activity*

Relationships between the PSPP sub-scales and cumulative minutes of physical activity were poor. A single significant inverse relationship, between physical conditioning and activity at the Cum_{75} threshold, was identified for boys during test visit 2. Decreases in the cumulative minutes of physical activity appear to be related to increased perceptions of physical conditioning. Whilst the construct validity of the PSPP has been confirmed using appropriate physical fitness tests (Fox, 1990; Whitehead, 1995; Bettinson, 1996) relationships between the sub-scales and free-living physical activities are less clear. The wording of the PSPP used in the current study, and those of Whitehead (1995) and Bettinson (1996), used physical activity specific statements. Re-wording of the instrument, with emphasis upon unstructured free-living physical activities, may provide a basis for improved correlation coefficients between the PSPP sub-scales and free-living physical activities. Additionally, the lack of a criterion measurement of physical activity may also weaken such relationships.

With limitations in both the method of activity assessment and factorial validity of the PSPP it is not surprising that few significant relationships were identified. When the construct validity of the instrument was tested, using appropriate physiological tests, no evidence for such validity was found.

Despite such limitations, these findings outline the frailty of the PSPP in

accurately measuring the physical self-perceptions of younger age children. Physical self-perception differentiation emanates from the early-adolescence (Fox, 1992) and emphasis should, again, be placed upon researching the changes in both physical self-perceptions and factorial content of the PSPP.

- *Evidence for the construct validity of the PSPP*

Sum of four skinfolds was not significantly correlated with the attractive body sub-domain during either test visit, for boys or girls. Similar results were shown for other sub-domains and the physical self-worth scale. Relationships between allometrically scaled peak $\dot{V}O_2$ and physical conditioning were also not significant. The attractive body sub-scale correlated significantly with peak $\dot{V}O_2$ for girls on both test visits. Other sub-domains showed a sporadic pattern of moderate relationships.

Our findings did not provide evidence for the construct validity of the PSPP in the sub-domains of attractive body and physical conditioning. The construct validity of the instrument as a whole must remain debatable as no physical measures of sports competence or physical strength were performed. These findings are in contrast to those of Whitehead (1995) and Bettinson (1996) who identified significant relationships between physical conditioning and a multi-stage shuttle run test. Skinfold thickness measurements were similarly unrelated in the study of Bettinson (1996) but not measured in Whitehead's study.

These findings support the limited psychometric strength of the PSPP. Bettinson (1996) used the same instrument as this current study, and a similarly weak factor structure may have occurred. Future researchers may wish to use the adapted C-PSPP of Whitehead (1995) which has been shown to have adequate psychometric properties for younger children.

- Applying the findings of Study Five to a newer framework for physical activity health and fitness

Any inferences on physical self-perceptions and physical activity are tainted by the poor psychometric properties of the PSPP for children of this age. Whilst an adequate factor solution was created, the findings of this study should be interpreted cautiously.

The model of Bouchard et al., (1993) proposed that those personal attributes, such as personality characteristics and motivation, would shape the lifestyle of a person. Our results showed that in children of this age physical activity was not influenced by physical self-perceptions. Despite these limitations, the contribution of physical self-perceptions should not be excluded from any framework for children. With increased cognitive development, the perceptions of the physical self may improve. This would be manifested in an improved factor structure (Fox and Corbin, 1989). Therefore, a newer framework should allude to the contribution of psychological variables as mediators of performance. Motivation may contribute to the performance of physical activity. Whether intrinsic motivation or some form of extrinsic reward will influence performance should be investigated. Other factors such as personality have been under-reported for children and should be examined.

SYNTHESIS OF RESULTS AND CONCLUSIONS

6.0 Synthesis of results and conclusions

Results from the current study supported previous literature, and emphasised the low levels of Liverpool schoolchildren's physical activity. Children very rarely performed free-living physical activities of a sufficient volume to elicit a favourable alteration in health and fitness. Their failure to attain consensus recommendations does not provide a true reflection of their participation in physical activities. The "3 x 20 min weekly" edict does not reflect the true pattern of children's physical activity. As most empirical evidence suggests that such a dose-response is required for health and fitness benefits, the free-living physical activities of children will not contribute to this. Similarly, attaining cumulative minutes recommendations of 30 min (Sallis and Patrick, 1994) and up to 60 min daily (Health Education Authority, 1996) does not appear to be attainable.

Within the consensus model of Bouchard et al. (1993) physical activity has important implications for the health-related fitness, health and morbidity of adults. Our results indicate that the contribution of children's free-living physical activities, within such a continuum, is negligible. Physical activity and health-related fitness are not strongly correlated for children and adolescents (Malina, 1997). Our results support this, and point to the contribution of other factors as important determinants of levels of physical activity and health-related fitness.

Our newer framework sees a physical activity and health-related fitness continuum similar to that provided by Bouchard et al. (1993). Importantly, the specific children's physical activity components have been included. This inclusion represents an understanding that endurance-based training will favourably alter the health-related fitness of children and adolescents. If the volume of physical activity is sufficient, then these alterations may occur. Unfortunately, without an adequate stimulus to perform such activity these alterations may be difficult to attain.

It is inaccurate to suggest that children are sedentary. The free-living physical activity of these schoolchildren is characterised by the accumulation of sporadic

bursts of activity. The accumulation of these bursts enabled children to attain a recommended volume of physical activity (Sallis and Patrick, 1994) albeit at the lower heart rate thresholds. As little empirical evidence supports the use of short-duration physical activities in favourably altering health and fitness, question is raised as to the value of such a prescription. Why, if such a prescription does not provide benefits, is it continually recommended? Certainly, the use of an "any exercise is good exercise" argument is relevant. If children were to perform even a small amount of physical activity, then the potential for a "knock-on" effect may be accentuated. A small amount of activity may lead to participation in a longer bout as both experience and enjoyment increase. If such a "knock on" where to be promoted, educators must also emphasise the potentially deleterious effects of exercise. In the chronically diseased child, such as with asthmatics or obese children, exertion may result in hazardous bronchoconstriction (Bar-Or, 1997). Therefore, it is essential for health promoters to recognise underlying chronic conditions, and adapt physical activity programmes accordingly.

The stimulus for this "knock-on" effect must come from within the school or peer environment. The available time for free-play in school is potentially high. Morning breaks, lunch breaks and, for some, afternoon breaks provide an ideal opportunity for physical activity. At one school we visited, a series of basketball hoops and soccer goals provided an ideal stimulus for team games. Rarely were these facilities unused during play periods. If such facilities where made available then the potential for a "knock-on" could be great. If, by using such facilities, the child were stimulated to join an extra-curricular club then a possible health intervention would have been made. This is of course dependent upon the volume of physical activity performed at such a club. Currently, a dearth of information exists on the effects of playtime physical activity on health and fitness. Similarly, the contribution of extra-curricular clubs to health and fitness remains unresolved. With this potential for extra-physical activity, at very little cost to time or resources, researchers should investigate the potential health and fitness benefits of such activity.

With the potential for such activity readily available, other determinants of physical activity must be included in a newer framework. The physical and social development of children has been included. Information on changes in children's physical activity is scarce. What little information that exists confirms our findings that children's physical activity is low, yet unstable. The assumption that a physically active child will be a physically active adult is cannot be supported from our findings. Our results show that the accumulation of physical activity is decreasing, whilst continuous duration activities are characterised by their absence. Physical activity should be viewed as a bio-behavioural process. As the child develops, both physical and social influences may influence participation. This was partially explained when children suggested that the transition from school had a major impact on their potential for physical activity participation. This social factor should be included in any future longitudinal assessment. Currently, little reported information exists examining this obviously influential period of social development.

The bio-behavioural nature of physical activity performance, allied to possible links with health-related fitness, is included in the newer framework (Figure 9). Additionally, the contribution of social and physical development is also included.

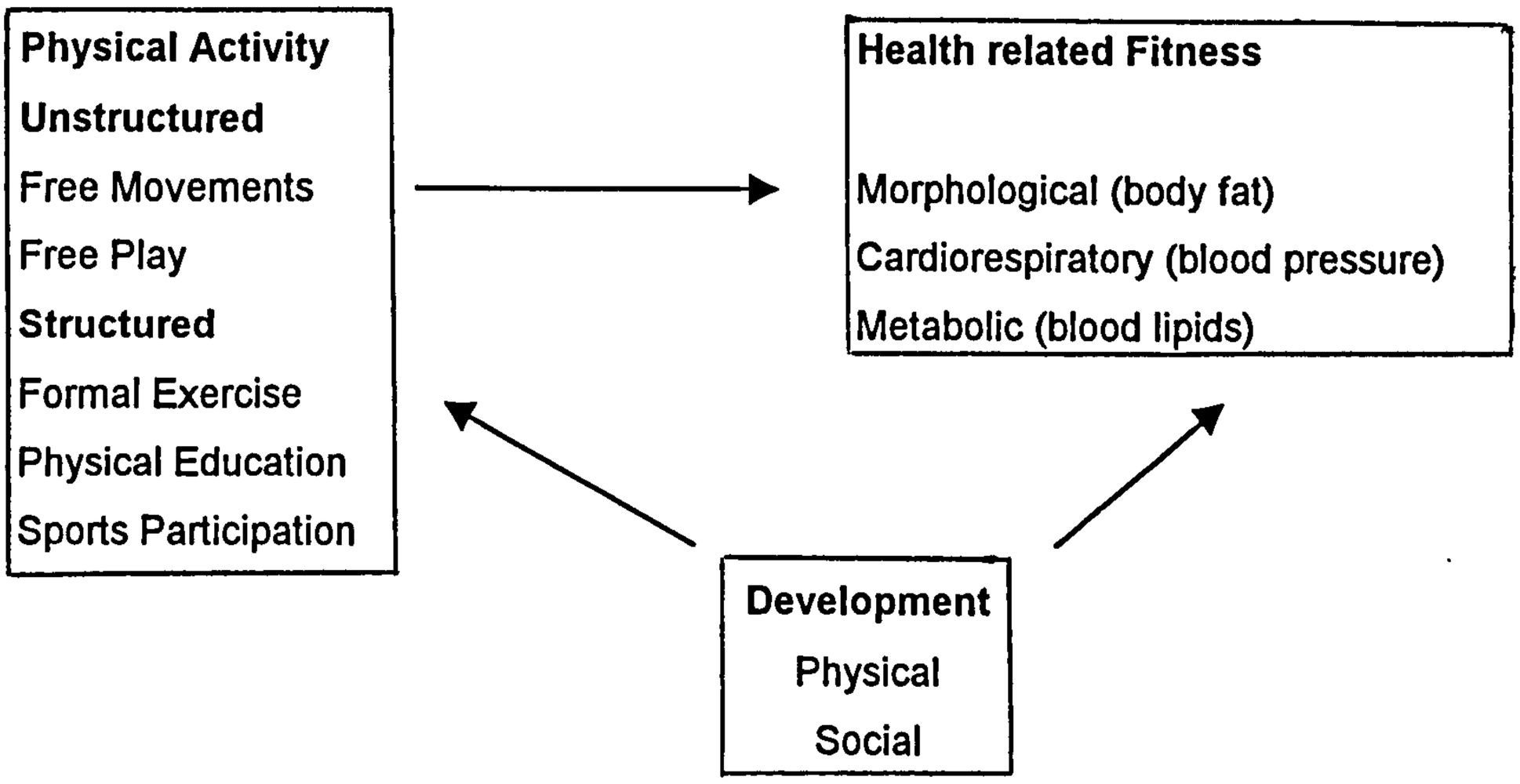


Figure 9. The revised model for children's physical activity health and fitness – relationships between physical activity, health related fitness and development.

Our results showed that children's physical activity participation decreased with increasing chronological and morphological age. These findings were particularly worrying as they show a reduction in physical activity participation at an earlier age than previously reported (van Mechelen and Kemper, 1995). As they grow older, children performed less and less physical activity. Why this reduction occurred remains unclear. From our results, physiological and psychological variables did not contribute significantly to the performance of free-living physical activities. Given previous literature, a combination of physiological, psychological, sociological and environmental variables would appear to provide the best "solution" to explaining the predictors of free-living physical activity in schoolchildren. Currently, such a multi-disciplinary study has yet to be performed, and represents a research need.

The change from primary to secondary education may have implications for the reduction in free-living physical activity. This "education transition" appears to exert a major influence upon children's physical activity participation both in and out of school. Some children were required to travel for longer periods to reach their secondary schools, thus limiting time for extra-curricular activities and home-based physical activity. The use of public transport or private vehicles may also influence time and participation in activities. Such areas must be examined further.

Other potentially confounding variables, such as peer group influence, resource availability and demographic variation, require similar investigation. During informal interviews children often spoke of the "kudos" in denigrating participation in organised sports and physical activities. Such comments imply that being "sporty" is in some-way not "cool". As organised sporting activities alone would appear to provide a sufficient stimulus for health, educators must attempt to promote physical activity and sports participation as both credible and fun. Making organised games less regimented may make them more socially acceptable by children who perceive them as being "un-cool." Information on such influences remains scarce and requires further investigation.

These findings warrant the inclusion of sociological influence within the framework. Peer and parental influences are shown to influence children's physical activity levels (Anderssen and Wold, 1992). This influential variable be included, and would be thought to influence physical activity participation (Figure 11). Importantly, this relationship must be considered two-way. If peer group would influence physical activity participation, then activity mode may contribute to the type of children who the individual would become associated. The child playing soccer alone in an urban environment should expect some form of interaction with other children as they take an interest. Similarly, the child who shows an aptitude for a form of physical activity may influence the parent or guardian to promote that activity as a recreational mode for the child.

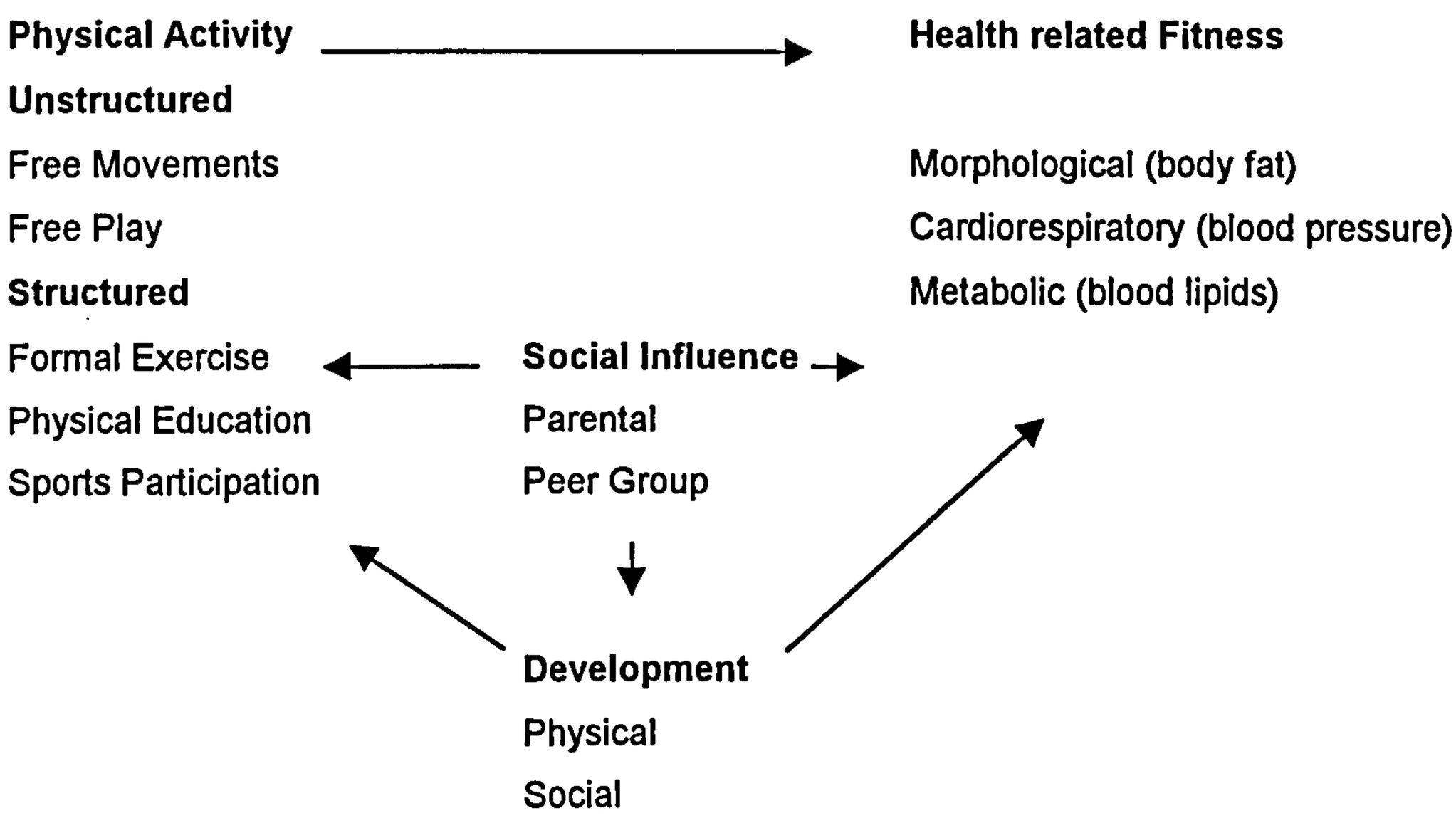


Figure 11. The newer framework including relationships with social influence – peer group and parental.

The risk factor profile of Liverpool schoolchildren did not raise concern. Whilst the prevalence of elevated body fat, blood lipids and blood pressure were identified, very few children maintained high levels of risk during both test occasions. Despite these risk factors being generally within normal limits several children did display elevations at both baseline and during the second test occasion. These findings suggest that the promotion of a low baseline measurement is essential in

reducing elevated risk during development. Children should be encouraged to maintain healthier lifestyles in respect to diet, alcohol and tobacco misuse, and to perform activities that are more physical. Favourable alterations in lifestyle will provide a non-pharmacological method of reducing potential risk during childhood and adolescence, and will have implications for adult health.

Despite the low prevalence of these risk factors, they should be included within the health-related fitness domain. Our findings found that children, who had elevated levels of a risk factor during one test visit, appeared to maintain that level during the second. This was especially noticeable for the sum of four skinfolds. The physical development of the child will see great variance in risk factors. Whilst relationships between these factors and physical activity remain to be identified, their change during development should necessitate their inclusion in any framework of the physical activity and health-related fitness continuum.

Within health-related fitness, the contribution of cardiorespiratory fitness has yet to be conclusively proven. We did not show any relationship between habitual physical activity and cardiorespiratory fitness. From our results, it is clear that levels of free-living physical activity will not provide a sufficient stimulus for aerobic fitness benefits. The inclusion of this variable within the new framework is therefore difficult. We assume that "fit" children are more physically active, yet this assumption remains unproven (Malina, 1997). Similarly, we found no indication that the fitter children performed more physical activity. Therefore, a physiological response (peak $\dot{V}O_2$) will not be related to a bio-behavioural one (physical activity). The problems of monitoring physical activity have been well reported. Allied to the potentially confounding effects of genetic disposition, it is unsurprising that no relationship was found.

If we hypothesise some form of "knock-on" effect from any volume of physical activity, then we may see an increase in cardiorespiratory fitness through a similar effect. If the child can perform activity that is more physical then the hope would be that continued enthusiasm for such activity could lead to an increased volume, commensurate with increases in fitness. Again, we must see evidence for this

"knock-on" to promote its use as a non-pharmacological method of improving levels of health-related fitness.

From our studies, it appears that physical activity, risk factors and fitness are influenced by a myriad of physical and social variables. The contribution of psychological variables to this continuum is included in the model of Bouchard et al. (1993). From our results, it is clear that physical self-perceptions were not related to physical activity levels. The poor psychometric properties of the PSPP in this group of children led to the use of a much adapted instrument. When coupled with no criterion method of physical activity assessment the poor relationship is unsurprising.

This lack of a relationship could be confirmed or altered if further studies were performed on older groups of children. Using multi-instrument methods of physical activity assessment could enhance this. Older children should have greater cognitive maturity, thus enabling increased validity for the PSPP. Coupled with a multi-instrument physical activity assessment future researchers may find the evidence for such a relationship that was lacking in our results.

Given a lack of supporting evidence, the contribution of physical self-perceptions to a newer framework cannot be included. This should not suggest that physical self-perceptions might not influence physical activity. Increased perceptions of a child's physical conditioning, for example, may well have implications for the performance of longer duration physical activities, commensurate with health-related fitness benefits. Motivation has been cited as influential upon children's physical activity and fitness (Ommundsen, 1997). These factors remain to be adequately investigated for free-living physical activity. As with physical self-perceptions, the measurement of motivation will be subject to cognitive interpretation. Again, this leads to a problem of when to implement such studies for children. Without factor analyses of motivation inventories similar problems may occur. Certainly, psychological aspects should be investigated and may yet be highly significant, yet our evidence does not support the inclusion of these variables in our newer framework at present. However, the contribution of

psychological variables should not be under-estimated. Physical activity is thought to influence cognitive function and psychosocial outcomes in adults (Bouchard et al., 1993), yet such evidence is scarce for children and adolescents. Psychological variables would seem to represent a "great unknown" in the physical activity, health and fitness continuum. Consequently, despite a lack of empirical evidence from our study a generalised term for psychological variables is included in the model, although the type of variable and their relationships to the continuum remain to be proven.

In a meta-analysis, Ommundsen (1997) emphasised the contribution of motivation and goal achievement theory in mediating exercise behaviours. Such findings must, therefore, necessitate the inclusion of psychological variables within a newer framework. Importantly, a variety of psychological variables should be investigated in relation to exercise and physical activity. Given the limitations of both physical activity and psychological measurement techniques, for children of this age, we may not determine such relationships using current technology. However, psychological variables should be included in the framework to account for a potentially confounding variable. Importantly, investigators should look for a cause and effect of psychological variables on physical activity behaviours, more so than a simple correlation analysis.

The newer framework now includes the contribution of social, psychological and physical variables to physical activity and health-related fitness. Major gene effects have been suggested as affecting physiological responses (Sorenson, 1997). Genetic differences interact constantly with cellular tissues to control cell responses related to environmental demands (Bouchard and Shephard, 1993). Therefore, the low levels of physical activity observed in our study may be precursors for some biological response, such as reduced bone mineralisation (Blimkie and Kriemler, 1997). The contribution of genetics to the physical activity and health continuum should be considered for health related fitness indicators alone. Given current knowledge, it is doubtful that genetic disposition would influence physical activity, a behavioural facet.

- The newer framework for physical activity and health-related fitness

The construction of this newer framework attempted to describe the links between physical activity and health-related fitness, and the confounding variables, which may influence such a continuum. The completed framework is outlined in Figure 12.

Important differences with the Bouchard et al. (1993) model include the interaction between these two areas and general health. The framework of Bouchard and co-workers alludes to the physical activity continuum leading to changes in the wellness, morbidity and mortality of the individual. As children are generally free from chronic illnesses, including such terms may not be wholly specific to this population. Far better would be to include the prevalence of elevated levels of coronary heart disease risk factors as a component of overall health. This would give some indication of potentially adverse health status, and may be monitored using an opportunistic risk factor identification. Such monitoring could be easily implemented during school-based health days or fitness testing sessions, such as those used in our pilot work.

The proposed framework for children is shown at Figure 12. Children's physical activity, whilst not being directly related to health-related fitness, may be influential if enough of a "health stimulus" can be generated. This would point to the contribution of health educators in promoting physical activity during both school and home time. Whilst the promotion of physical activity has been a mainstay of Health Education Authority policy, the lack of attainment suggests that this advice may be ignored". The "3 x 20 min" recommendation is virtually impossible for children to attain, even during school time. Similarly, accumulating 30 min or 60 min of activity daily is also difficult for these children. Accumulating shorter periods of physical activity, characteristic of children's physical activity patterns may provide an answer for health promotion. Unfortunately, without empirical evidence to support the dose-response of this activity, recommending it as an appropriate prescription remains speculative. Without this empirical support, current guidelines appear to suggest that any form of physical activity will

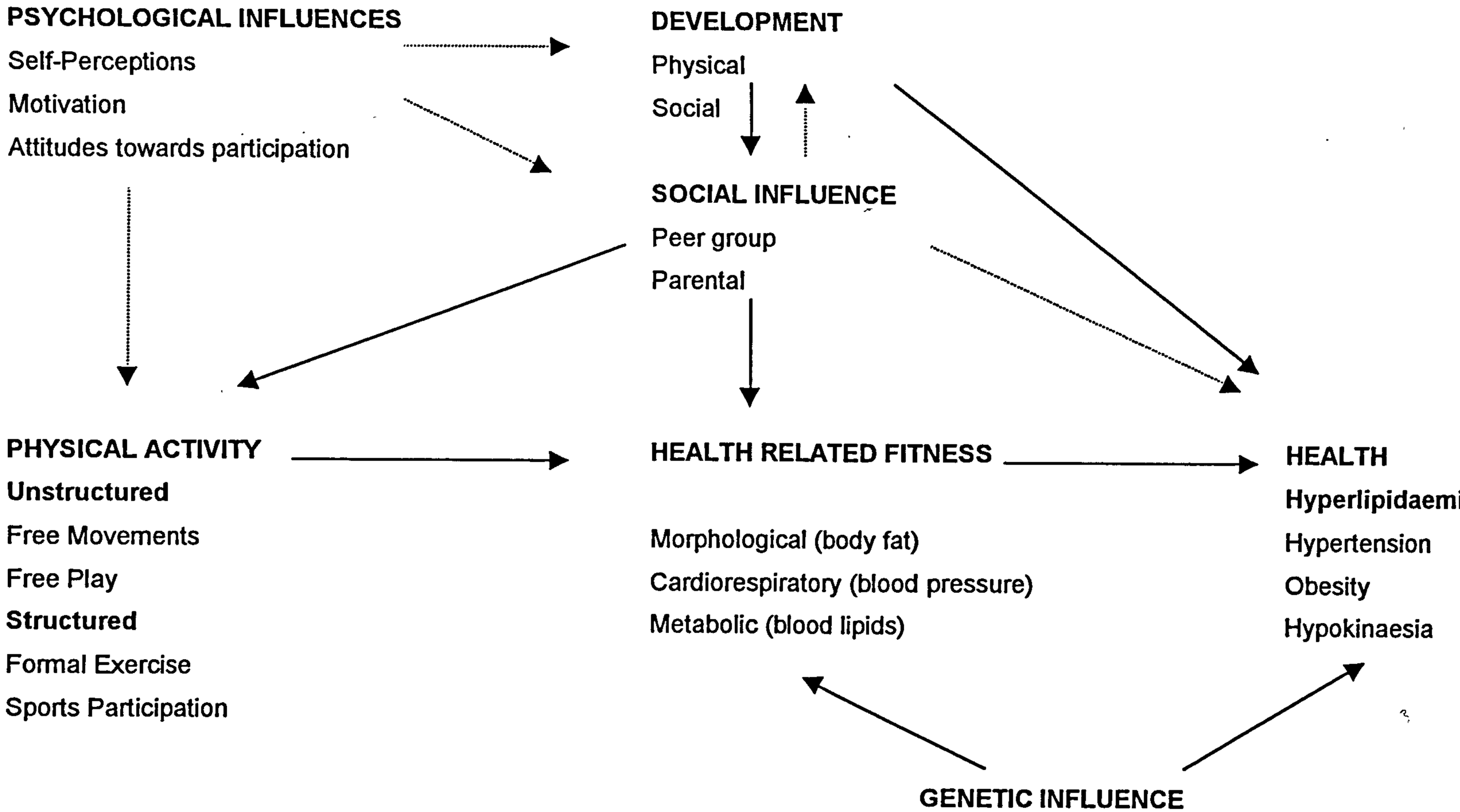


Figure 12. The newer framework for children's physical activity and health-related fitness.

should be investigated, as a reduction appears to occur in such provision between primary and secondary education. The long-term implications for children's health are great. If the child can get the "activity habit" early, then there is some hope of that child remaining active during the life cycle. Unfortunately, evidence to support the "active child-active adult" supposition remains elusive. What is clear is that the transition between schools is a stimulus for altering physical activity participation, and should be investigated further.

As a final component of the finished model, our understanding of the determinants of children's physical activity remains unclear. A combination of physical, psychological and sociological variables will affect such participation, yet remain to be identified. Without criterion methods of assessing physical activity, allied to measures of physical, psychological and sociological variables. Therefore, a question mark hangs over our understanding of a completed model of the children's physical activity, health and fitness continuum. This "grey area" continues to be investigated, yet remains far from resolution.

In conclusion, the hypotheses outlined in section 1.0 were not supported. Children did not perform a sufficient volume of physical activity to mediate changes in risk factors and fitness, thus disproving hypothesis one. Similarly, physical self-perceptions were not influenced by physical activity participation.

Hypothesis two suggested that physical activity, risk factors, fitness and physical self-perceptions would remain stable during development. Our results indicated that body fat tracked over 12 months, leading to the supposition that elevated levels of adiposity may be observed during the development period. Other variables did not track as well, emphasising the unique social and physical milieu within which younger children are subjected to just before the pubertal growth spurt. In interpreting these findings, a possible measurement error should be identified. This is due to using inter-period correlation coefficients to assess tracking.

The newer framework identifies that children's physical activity is composed of individual areas related to school- and home-based activities. This activity will be influenced by a myriad of social and environmental factors, which will alter with age. Whilst not being sufficient to promote health-related fitness benefits whatever physical activity children perform should be encouraged. This may generate a "health stimulus", leading to an increase in physical activity volume. Only through the promotion of school and home-based activities can this be secured. Coronary heart disease risk is low for Liverpool children. This does not raise concern at present. However, studies such as this should be treated as opportunistic risk assessments, and may subsequently allow for a "lowering" of risk, by health professionals, during development. Psychological variables were not thought to influence physical activity participation in this population, and hence were removed from the final framework.

The framework at Figure 12 provides only a small indication of the many physical, social and environmental factors, which surround children's development. Several of the links have yet to conclusively proven, and much work remains to be done to provide support for such a children's framework. It is hoped that this framework may provide a stimulus for future research, which will investigate changes in this framework during children's development. Such multi-disciplinary longitudinal investigations remain rare, and continue to be a research need.

RECOMMENDATIONS FOR FUTURE RESEARCH

7.0 Recommendations for further study

Results from the current study pose several questions as to the physical activity, health and cardiorespiratory fitness of Liverpool schoolchildren, and changes in these variables during development. Primarily, further research should incorporate longitudinal study designs. Such studies will enable the understanding of changes in physical activity, fitness and health to be identified.

The main areas for further study, identified from our results, should be:

Physical Activity

- Further longitudinal investigation of changes in the free-living physical activity of schoolchildren during development.
- The use of other methods of physical activity assessment, in conjunction with heart rate monitoring, to provide a more accurate assessment of the pattern, mode and volume of activity performed during waking hours.
- Developing a multi-level threshold approach in the assessment of physical activities.
- An investigation of the determinants of physical activity incorporating biological, environmental, psychological and sociological factors, and changes in these factors during development.
- Longer duration studies to assess the stability of physical activity, health and fitness over time.

Risk Factors

- Longitudinal investigations into the stability of the risk factor profile in British schoolchildren.
- More evidence to support the use of recommended cut-off points to express potential risk in children.
- The use of other lifestyle factors, such as dietary composition, to explain unaccounted variance in regression models.

- Using more accurate measures of biological maturity as covariates in explaining the risk factor profile.

Cardiorespiratory Fitness

- Determine appropriate mass exponents from allometrically adjusted models.
- Use other covariates, such as stature in these models.
- Examine the tracking of allometrically adjusted cardiorespiratory fitness.

Physical Self-Perceptions

- Assess changes in the factorial structure of the PSPP instrument during development.
- Provide evidence for the construct validity of the PSPP using appropriate laboratory-based techniques.
- Further examine the relationships between physical self-perceptions, physical activity, health and fitness.

The changes in physical activity, health and fitness during development are complex. Multi-disciplinary, longitudinal study designs are the best method of assessing such changes during the transition from childhood into adulthood. The dearth of literature currently available, especially for British children, prevents a complete understanding of such changes a this time.

BIBLIOGRAPHY

8.0 References

Ailhaud, G., Guy-Grand, B., Lafontan, M. and Ricquier, D. (1992) Obesity in Europe 1991. John Libbey, London, England.

Al-Hazzaa, H.M. and Sulaiman, M.A. (1993) Maximal oxygen uptake and daily physical activity in 7 to 12 year old boys. Paediatric Exercise Science 5: 357-365.

Alpert, B.S. and Wilmore, J.H. (1994) Physical activity and blood pressure in adolescents. Paediatric Exercise Science 6: 361-380.

American College of Sports Medicine (1991) Guidelines for Exercise Testing and Prescription, (4th Edition). Lea and Febiger, Philadelphia, USA.

Andersen, L.B. (1995) Tracking of VO_2 max., strength and physical activity from teenage to adulthood. In: Exercise and Fitness: Benefits and Risks. XVIII Symposium of European Group of Paediatric Work Physiology: Abstracts. Odense University, Odense, 1995, p. 60.

Andersen, L.B. and Haraldsdottir, J. (1995) Coronary heart disease risk factors, physical activity and fitness in young Danes. Medicine and Science in Sports and Exercise 27: 158-163.

Anderssen, N. and Wold, B. (1992) Parental and peer influences on leisure-time physical activity in young adolescents. Research Quarterly for Exercise and Sport 63: 341-348.

Anderson, R.H. McCartney, F.J. Shwinbourne, E.A. and Tynan, M. (1987) Paediatric Cardiology Vol.1. Churchill Livingstone, London.

Anderson, K.M., Wilson, P.W.F., Odell, P.M. and Kannel, W.B. (1992) An updated coronary risk profile - a statement for health professionals. In: Cholesterc' and coronary heart disease: The great debate. Gold, P., Grover, S. and Roncari, D.A.K. (Eds.). Parthenon Publishing Group, Carnforth, England. p: 8-14.

Anding, J.D., Kubena, K.S., McIntosh, W.A. and O'Brien, B. (1996) Blood lipids, cardiovascular fitness, obesity and blood pressure: the presence of potential coronary heart disease risk factors in adolescents. Journal of the American Dietetic Association 96: 238-242.

Armstrong, N., Balding, J., Gentle, P. and Kirby B. (1990a) Patterns of physical activity among 11-16 year old British schoolchildren. British Medical Journal 301: 203-205.

Armstrong, N., Balding, J., Gentle, P. and Kirby B. (1990b) Estimation of coronary risk factors in British schoolchildren: a preliminary report. British Journal of Sports Medicine 24: 61-65.

PAGE
NUMBERS
CUT OFF
IN
ORIGINAL

Armstrong, N. and Bray, S. (1991) Physical activity patterns defined by continuous heart rate monitoring. Archives of Disease in Childhood 66: 245-247.

Armstrong, N., Balding, J., Gentle, P. and Kirby B. (1991) Cardiopulmonary fitness, physical activity patterns and selected coronary heart disease risk factor variables in 11-16 year old children. Paediatric Exercise Science 3: 219-228.

Armstrong N. (1992) New Directions in Physical Education. Human Kinetics Publishers, Champaign, USA.

Armstrong, N. and Simons-Morton, B. (1994) Physical activity and blood lipids in adolescents. Paediatric Exercise Science 6: 381-405.

Armstrong, N. and Welsman, J. (1994) Assessment and interpretation of aerobic fitness in children and adolescents. Exercise and Sports Science Reviews, 22, 435-476.

Armstrong, N., Kirby, B., MacManus, A. and Welsman, J. (1995) Aerobic fitness and physical activity patterns among prepubescents. In: Exercise and Fitness: Benefits and Risks. XVIII Symposium of European Group of Paediatric Work Physiology: Abstracts. Odense University, Odense, 1995, p. 51.

Armstrong, N. Kirby, B. MacManus, A. and Welsman, J. (1995) Aerobic fitness of prepubescent children. Annals of Human Biology 22: 427-441.

Armstrong, N., MacManus, A., Welsman, J. Kirby, B. (1996) Physical activity patterns and aerobic fitness among prepubescents. European Physical Education Review 2: 19-29.

Armstrong, N. and Welsman, J. (1997) The assessment and interpretation of aerobic fitness in children and adolescents: an update. In: Exercise and Fitness - Benefits and Risks. Froberg, K., Lammert, O., Hansen, H. and Blimkie, C.J.R. (Eds.). Odense University Press, Odense, Denmark. p: 173.

Ashton, J. (1987) Indicators and Targets for Health for All in the Mersey Region. Liverpool University Press, Liverpool, England.

Astrand, P.O. and Rodahl, K. (1986) Textbook of Work Physiology, (3rd edition). McGraw-Hill, New York, USA.

Atkinson, G. and Reilly, T. (1995) Sport, Leisure and Ergonomics. E & FN Spon, London, England.

Azad, K., Court, S., Parkin, J.M., Laker, M.F. and Alberti, K.G. (1994) Lipid levels in schoolchildren in North East England: effects of feeding and age. Annals of Clinical Biochemistry 31: 233-239.

Aznar, S., Batty, G.D. and Riddoch, C. (1995) Caltrac validation studies reporting level of agreement. In: Exercise and Fitness: Benefits and Risks. XVIII Symposium of European Group of Paediatric Work Physiology: Abstracts. Odense University, Odense, 1995, p. 132.

Aznar, S. and Riddoch, C. (1995) Validation of a physical activity diary in children. In: Exercise and Fitness: Benefits and Risks. XVIII Symposium of European Group of Paediatric Work Physiology: Abstracts. Odense University, Odense, 1995, p. 52.

Bailey, R.C., Olson, J., Pepper, S.C., Porszasz, J., Barstow, T.J. and Cooper, D.M. (1995) The level and tempo of children's physical activity: An observational study. Medicine and Science in Sports and Exercise 27: 1033-1041.

Ballor, D.L., Burke, L.M., Knudson, D.V., Olson, J.R. and Montoye, H.J. (1989) Comparison of three methods of estimating energy expenditure: Caltrac, heart rate and video analysis. Research Quarterly for Exercise and Sport 60: 362-368.

Bao, W., Srinivasan, S.R., Wattingey, W.A. and Berenson, G.S. (1994) Persistence of multiple cardiovascular risk clustering related to syndrome X from childhood to young adulthood. The Bogalusa Heart Study. Archives of Internal Medicine, 154, 1842-1847.

Bar-Or, O. and Baranowski, T. (1994) Physical activity, adiposity and obesity among adolescents. Paediatric Exercise Science 6: 348-361.

Bar-Or, O. (1997) Safe exercise for the child with a chronic disease. In: Exercise and Fitness - Benefits and Risks. Froberg, K., Lammert, O., Hansen, H. and Blimkie, C.J.R. (Eds.). Odense University Press, Odense, Denmark. p: 15.

Baranowski, T. (1988) Validity and reliability of self-report measures of physical activity: an information processing perspective. Research Quarterly for Exercise and Sport 59: 314-327.

Bartecchi, C.E., MacKenzie, T.D. and Schrier, R.W. (1994) The human cost of tobacco use. New England Journal of Medicine 330: 907-912.

Behrman, R.E. Vaughan, V.C. and Nelson, W.E. (1983) Nelson Textbook of Paediatrics (12th Edition). W.B. Saunders and Company, London.

Bennett, N., Dodd, T., Flatley, J., Freeth, S. and Boiling, K. (1995) Health Survey for England 1993: Series HS no.3. HMSO, London, England.

Berenson, G.S., Voors, A.W., Frank, G.C. and Webber, L.S. (1982) Studies of blood pressure and dietary sodium intake in children in semi-rural Southern United States: The Bogalusa Heart Study. In: The role of salt in cardiovascular hypertension. Fregly, M.J. and Kare, M.R. (Eds.). Academic Press, London, England. p: 82-96

Text cut off in original

Berlin, J.A. and Colditz, G.A. (1990) A meta-analysis of physical activity in the prevention of coronary heart disease. American Journal of Epidemiology 132: 612-628.

Bettinson, S.P. (1996) Self-esteem and physical education: an investigation into the Physical Self Worth of eleven and sixteen year old males. Unpublished Dissertation, Liverpool John Moores University, Liverpool, England.

Beunen, G.P. and Malina, R.M. (1988) Growth and physical performance relative to the timing of the adolescent spurt. Exercise and Sports Science Reviews 16: 503-540.

Beunen, G.P., Malina, R.M., Renson, R., Simons, J., Ostyn, M. and Leferve, J. (1992) Physical activity and growth, maturation and performance: a longitudinal study. Medicine and Science in Sports and Exercise 5: 576-585.

Beunen, G.P. (1996) Physical growth, maturation and performance. In: Kinanthropometry and Exercise Physiology Laboratory Manual: Tests, procedures and data. Eston, R. and Reilly, T.(Eds.). E&FN Spon, London, England. p: 56-60.

Binkhorst, R.A., Kemper, H.C.G. and Saris, W.H.M. (1985). Children and Exercise XI. Human Kinetics Publishers, Champaign, USA.

Bjorntorp, P. (1988) The associations between obesity, adipose tissue distribution and disease. Acta Medica Scandinavia 723: S121-S134.

Black, A.E., Coward, W.A., Cole, T.J. and Prentice, A.M. (1996) Human energy expenditure in affluent societies: an analysis of 574 doubly-labelled water measurements. European Journal of Clinical Nutrition 50: 72-92.

Blackburn, G.L. and Kanders, B.S. (1994) Obesity: Pathophysiology, Psychology and Treatment. Chapman-Hall, London, England.

Blair, S. Barlow, C.E. and Kohl, H.W. (1993) Change in physical fitness and all-cause mortality in apparently healthy men. Medicine and Science in Sports and Exercise 25: S75 (Abstract).

Blair, S. (1993) The 1993 C.H. McCloy Research Lecture: Physical activity, physical fitness and health. Research Quarterly for Exercise and Sport 64: 365-376.

Blair, S.N. (1995) Exercise prescription for health. Quest 47: 338-353.

Blessing, D.L., Keith, R.E., Willford, H.N., Blessing, M.N. and Barksdale, J.A. (1995) Blood lipid and physiological responses to endurance training in adolescents. Paediatric Exercise Science 7: 192-202.

Blimkie, C.R. and Kriemler, S. (1997) Bone mineralisation patterns during childhood: relationship to fractures and fracture risk. In: Exercise and Fitness - Benefits and Risks. Froberg, K., Lammert, O., Hansen, H. and Blimkie, C.J.R. (Eds.). Odense University Press, Odense, Denmark. p: 111.

Boileau, R.A., Lohman, T.G. and Slaughter, M.H. (1985) Exercise and body composition of children and youth. Scandinavian Journal of Sports Science 7: 17-27.

Boreham, C.A.G., Twisk, J.W. and van Mechelen, W. (1997) Relationships between aerobic fitness and coronary heart disease risk factors in adolescents. Medicine and Science in Sports and Exercise 29: S14 (Abstract).

Bouchard, C., Shephard, R.J., Stephens, T., Sutton, J.R. and McPherson, B.D. (1990) Exercise, Fitness and Health: A Consensus of Current Knowledge. Human Kinetics Publications, Champaign, USA.

Bouchard, C., Shephard, R.J. and Stephens, T. (1993) Physical Activity, Fitness and Health. Consensus Statement. Human Kinetics Publications, Champaign, USA.

Bouchard, C. and Shephard, R.J. (1993) The Model and Key Concepts. In: Physical Activity, Fitness and Health. Consensus Statement. Bouchard, C., Shepard, R.J. and Stephens, T. (Eds.). Human Kinetics Publications, Champaign, Ill. p: 11-20.

Bouchard, C. (1994) The Genetics of Obesity. CRC Press, Boca Raton, USA.

Boulton, T.J., Seal, J.A. and Magarey, A.M. (1991) Cholesterol in childhood: how high is OK? Recommendations for screening, case-finding and intervention. Medical Journal of Australia 154: 847-850.

Bray, M.S., Morrow, J.R., Pivarnik, J.M. and Bricker, J.T. (1992) Caltrac validity for estimating caloric expenditure with children. Paediatric Exercise Science 4: 166-179.

Bray, M.S., Wong, W.W., Morrow, J.R., Butte, N.F. and Pivarnik, J.M. (1994) Caltrac versus calorimeter determination of 24-h energy expenditure in female children and adolescents. Medicine and Science in Sports and Exercise 26: 1524-1530.

Breeze, E., Maidment, A., Bennett, N., Flatley, J. and Carey, S. (1994) Health Survey for England 1992: Series HS no.2. HMSO, London, England.

Brewer, J., Ramsbottom, R. and Williams, C. (1988) The Multistage Fitness Test: A Progressive Shuttle Run Test for the Prediction of Maximal Oxygen Uptake. National Coaching Foundation, Leeds, England.

Brodie, D., Atkinson, P.J., Buckler, J.M.H., Burkinshaw, L., Laughland, A. and Reed, G.W. (1989) A longitudinal study of the growth of boys from 11 to 16 years of age. In: Children and Exercise XIII. Oseid, S. and Carlsen, K-H. (Eds.). Human Kinetics Publishers, London. p: 122-126.

Bunc, V. (1995) A simple assessment of cardiovascular fitness in children. In: Sport, Leisure and Ergonomics. Atkinson, G. and Reilly, T. (Eds.). E & FN Spon, London, England. p: 161-166.

Byrne, K.P. (1991) Understanding and Managing Cholesterol: A Guide for Wellness Professionals. Human Kinetics Publishers, Champaign, Illinois, USA.

Calfas, K.J. and Taylor, W.C. (1994) Effects of physical activity on psychological variables. Paediatric Exercise Science 6: 406-423.

Canadian Fitness and Lifestyle Research Institute (1990) Technical Report no. 9107-2135-1013. Canadian Fitness and Lifestyle Research Institute, Gloucester, Canada.

Castelli, W.P. (1984) Epidemiology of coronary heart disease: the Framingham study. American Journal of Medicine, Symposium 4-12.

Chatterjee, S. and Bandyopadhyay, A. (1993) Effect of continuous slow-speed running for 12 weeks on 10-14 year old Indian boys. British Journal of Sports Medicine 27: 179-185.

Child Growth Foundation. (1993) United Kingdom cross-sectional reference data. Harlow Printing, South Shields.

Clarke, W.R., Schrott, H.G., Leaverton, P.E., Connor, W.E. and Lauer, R.M. (1978) Tracking of blood lipids and blood pressures in school age children: The Muscatine Study. Circulation 58: 626-634.

Clarke, W.R. and Lauer, R.M. (1993) Does childhood obesity track into adulthood? Critical Reviews in Food Science and Nutrition 33: 423-430.

Cooper, D.M. (1994) Evidence for the mechanisms of exercise modulation of growth - an overview. Medicine and Science in Sports and Exercise 26: 733-740.

Cox, B.D. (1993) The Health and Lifestyle Survey: Seven Years On. Health Promotion Trust, London, England.

de Man, S.A., Andre, J.L., Bachmann, H., Grobbee, D.E., Ibsen, K.K., Laaser, U., Lippert, P. and Hofman, A. (1994) Blood pressure in childhood: pooled findings of six European studies. Journal of Hypertension 9: 109-114.

de Swiet, M., Fayers, P. and Shinebourne, E.A. (1992) Blood pressure in the first ten years of life: the Brompton study. British Medical Journal 304: 23-26.

Department of Health (1991a) The Health of the Nation. HMSO, London, England.

Department of Health (1991b) Dietary Reference Values for Food Energy and Nutrients for the United Kingdom. HMSO, London, England.

Department of Health (1992) The Health of the Nation: Summary of Main Findings. HMSO, London.

Department of Health (1994) The Health of the Nation: Obesity - A Report from the Nutrition and Physical Activity Taskforces. HMSO, London.

Department of Health (1994) Nutritional Aspects of Cardiovascular Disease. Report on Health and Social Subjects. HMSO, London.

DiPietro, L. (1995) Physical activity, body weight and adiposity: An epidemiological perspective. Exercise and Sports Science Reviews 23: 275-304.

Dishman, R.K. (1985) Medical psychology in exercise and sport. Medical Clinics of North America 69: 123-143.

Dishman, R.K. (1990) Determinants of participation in physical activity. In: Exercise, fitness and health: A consensus of current knowledge. Bouchard, C., Shepard, R.J., Stephens, T., Sutton, J.R. and McPherson, B.D. (Eds.). Human Kinetics Publications, Champaign, Ill. p: 360-364.

Dishman, R.K. (1995) Physical activity and public health: mental health. Quest 47: 362-385.

Docherty, D., Gaul, C.A. and Wenger, H.A. (1990) Exercise and the young female: maturational differences in the responsiveness to aerobic training. In: Canadian Fitness and Lifestyle Research Institute, Technical Report no. 9107-2135-1013. Canadian Fitness and Lifestyle Research Institute, Gloucester, Canada.

Durant, R.H., Baranowski, T., Davis, H., Rhodes, T., Thompson, W.O., Puhl, J., Greaves, K.A. and Rhodes, T. (1992) Reliability and variability of heart rate monitoring in 3-, 4- and 5-year old children. Medicine and Science in Sports and Exercise 24: 265-271.

Durant, R.H., Baranowski, T., Davis, H., Rhodes, T., Thompson, W.O., Puhl, J., Greaves, K.A. and Rhodes, T. (1993) Reliability and variability of indicators of heart rate monitoring in children. Medicine and Science in Sports and Exercise 25: 389-395.

Eaton, C.B., Lapane, K.L., Garber, C.E., Assaf, A.R., Lasater, T.M. and Carleton, R.A. (1995) Physical activity, physical fitness and coronary heart disease risk factors. Medicine and Science in Sports and Exercise 27: 340-346.

Emons, H.J.G., Groenenboom, D.C., Westerterp, K.R. and Saris, W.H.M. (1992) Comparison of heart rate monitoring combined with indirect calorimetry and the doubly-labelled water method for the measurement of energy expenditure in children. European Journal of Applied Physiology 65: 99-103.

Eston, R. and Reilly, T. (1996) Kinanthropometry and Exercise Physiology Laboratory Manual: Tests, procedures and data. E&FN Spon, London, England.

Expert Panel of the National Cholesterol Education Programme. (1988) Report of the National Cholestrol Education Programme Expert Panel on detection, evaluation and treatment of high blood cholesterol in adults. Archives of Internal Medicine 148: 36-39.

Falk, B. and Bar-Or, O. (1991) Longitudinal changes in peak aerobic power and anaerobic mechanical power of circumpubertal boys. Paediatric Exercise Science 5: 318-331.

Floyd, J.F. (1990) A public health perspective on physical fitness: the role of self-perception. In: The Physical Self-Perception Profile manual. Fox, K.R. (Ed.). Northern Illinois University, USA.

Fox, K.R. and Corbin, C.B. (1989) The physical self-perception profile: Development and preliminary validation. Journal of Sport and Exercise Psychology 11: 408-430.

Fox, K.R. (1990) The Physical Self-Perception Profile manual (PRN Monograph). Northern Illinois University, USA.

Fox, K.R. (1992) Physical education and development of self-esteem in children. In: New Directions in Physical Education. Armstrong, N. (Ed.). Human Kinetics Publishers, Champaign, Ill.

Fox, K.R. (1994) Research perspectives on children's competence and achievement in physical education and sport. British Journal of Physical Education 25: 21-22.

Freedson, P. (1989) Field monitoring of physical activity in children. Paediatric Exercise Science 1: 8-18.

Garrow, J.S. (1988) Obesity and Related Diseases. Churchill-Livingstone, London, England.

Gavarry, O., Bernard, T., Giacomoni, M., Seymat, M., Euzet, J-P. and Falgairette, G. (1996) Habitual physical activity from a weeks heart rate monitoring in teenagers. In: European College of Sports Sciences, Abstracts. University of Nice Sophia-Antipolis, France. p: 708-709.

Gilbey, H. and Gilbey, M. (1995) The physical activity of Singapore primary school children as estimated by heart rate monitoring. Paediatric Exercise Science 7: 26-35.

Gilson, N.D., Cooke, C.B., Mahoney, C.A., Golby, J. and Starkey, S.A. (1997) Heart rate monitoring, self-report and diary analysis: A comparison of methods in the assessment of children's physical activity. Journal of Sports Sciences 15: 52-53 (Abstract).

Goldbloom, R.B. (1992) Children's health and the cholesterol/fat issue. In: Cholesterol and coronary heart disease: The great debate. Gold, P., Grover, S. and Roncari, D.A.K. (Eds.). Parthenon Publishing Group, Carnforth, England. p: 80-86.

Goulding, A., Taylor, R.W., Gold, E. and Lewis-Barned, N.J. (1996) Regional body fat distribution in relation to pubertal stage: a dual-energy x-ray absorptiometry study of New Zealand girls and young women. American Journal of Clinical Nutrition 64: 546-551.

Gruber, J.J. (1986) Physical activity and self-esteem development in children: a meta-analysis. American Academy of Physical Education Papers 19: 30-48.

Guo, S., Beckett, L., Chumlea, W.C., Roche, A.F. and Siervogel, R.M. (1993) Serial analysis of plasma lipids and lipoproteins from individuals 9-21 years of age. American Journal of Clinical Nutrition 58: 61-67.

Gutin, B. and Manos, T.M. (1993) Physical activity in the prevention of childhood obesity. Annals of the New York Academy of Sciences 699: 115-126.

Gutin, B., Litaker, M., Islam, S., Manos. T., Smith, C. and Treiber, F. (1996) Body composition measurement in 9-11 year old children by dual-energy x-ray absorptiometry, skinfold thickness measurements and bio-impedence analysis. American Journal of Clinical Nutrition 63: 287-292.

Gyarfas, I. (1992) Cardiovascular disease: the worlds public enemy number one. World Health 4: 5.

Hansen, H.S., Froberg, K., Hydlebrandt, N. and Nielsen, J.R. (1991) A controlled study of eight months of physical training and reduction of blood pressure in children: the Odense schoolchild study. British Medical Journal 303: 682-685.

Hansen, H.S. Hypertension in children and the role of physical activitv. In: Exercise and Fitness: Benefits and Risks. XVIII Symposium of European Group of Paediatric Work Physiology: Abstracts. Odense University, Odense, 1995, p. 29.

Hansen, H.S. (1997) Hypertension in children and the role of physical activity. In: Exercise and Fitness - Benefits and Risks. Froberg, K., Lammert, O., Hansen, H.S. and Blimkie, C.J.R. (Eds.). Odense University Press, Odense, Denmark. p: 91.

Harsha, D.W., Frerichs, R.R. and Berenson, G.S. (1978) Densitometry and anthropometry of black and white children. Human Biology 50: 261-280.

Harter, S. (1985) Manual for the Self-Perception Profile for Children. University of Denver, Colorado.

Hawes, M.R. (1996) Human body composition. In: Kinanthropometry and Exercise Physiology Laboratory Manual: Tests, procedures and data. Eston, R. and Reilly, T.(Eds.). E & FN Spon, London, England. p: 26-30.

Haymes, E.M. and Byrnes, W.C. (1993) Walking and running energy expenditure estimated by Caltrac and indirect calorimetry. Medicine and Science in Sports and Exercise 25: 1365-1369.

Health Education Authority (1995) Health Update no.5: Physical Activity. Health Education Authority, London, England.

Health Education Authority (1998) Young and Active: Young people and health enhancing physical activity - evidence and implications. Health Education Authority, London, England.

Hebestreit, H. and Bar-Or, O. (1995) Climate related overestimation of energy expenditure from heart rate in children. In: Exercise and Fitness: Benefits and Risks. XVIII Symposium of European Group of Paediatric Work Physiology: Abstracts. Odense University, Odense, 1995, p. 97.

Hills, A.P. and Wahlqvist, M.L. (1994) Exercise and Obesity. Smith-Gordon, London, England.

Horlick, L. (1992) Canadian Consensus Conference on Cholesterol (CCCC). In: Cholesterol and coronary heart disease: The great debate. Gold, P., Grover, S. and Roncari, D.A.K. (Eds.). Parthenon Publishing Group, Carnforth, England. p: 110-114.

Imrhan, S.N., Imrhan, V. and Hart, C. (1996) Can self-estimates of body weight and height be used in place of measurements for college students? Ergonomics 39: 1445-1453.

International Society of Sport Psychology (1992) Physical activity and psychological benefits: a position statement from the International Society of Sport Psychology. Journal of Applied Sports Psychology 4: 94-98.

Janz, K.F., Witt, J. and Mahoney, L.T. (1995) The stability of children's physical activity as measured by accelerometry and self-report. Medicine and Science in Sports and Exercise 27: 1326-1332.

Jeremy, J.Y. (1994) Smoking and vascular defence mechanisms. Journal of Smoking Related Disorders 5: 49-54.

Jones, A. (1991) Peak aerobic power in intensively trained young athletes related to puberty. Journal of Sports Sciences 9: 418-419 (Abstract).

Karvonen, M.J. (1988) Heart rate and exercise intensity during sports activities. Sports Medicine 5: 303-312.

Kemper, H.C.G. (1986) Longitudinal studies on the development of health and fitness and the interaction with physical activity of teenagers. Paediatrician 13: 52-59.

Kemper, H.C.G., Nels, J., Verschuur, R. and Storm-van Essen, L. (1990) tracking of health and risk indicators of cardiovascular diseases from teenage to adult: Amsterdam Growth and Health Study. Preventative Medicine 19: 642-655.

Kemper, H.C.G. (1995) The Amsterdam Growth Study: A Longitudinal Analysis of Health, Fitness and Lifestyle. HK Sports Science Monograph Series, Volume 6. Human Kinetics Publications, Champaign, USA.

Klesges, L.M. and Klesges, R.C. (1987) The assessment of children's physical activity: a comparison of methods. Medicine and Science in Sports and Exercise 19: 511-517.

Klimis-Tavantzis, D.J. and Wolinsky, I. (1996) Nutritional concerns of women. Wolinsky, I. and Klimis-Tavantzis, D.J.(Eds.). CRC Press, Boca Raton, USA.

Laaneots, L. Karelson, K. Smirnova, T. and Viru, A. (1995) Exercise induced hormonal responses in pubescent girls. In: Exercise and Fitness: Benefits and Risks. XVIII Symposium of European Group of Paediatric Work Physiology: Abstracts. Odense University, Odense, 1995, p. 46.

Laporte, R.E., Montoye, H.J. and Caspersen, C.J. (1987) Assessment of physical activity in epidemiologic research: problems and prospects. Public Health Reports 100: 131-146.

Laskarzewski, P., Morrison, J., deGroot, I., Kelly, K.A., Mellies, M.J., Khoury, P. and Glueck, C. (1979) Lipid and lipoprotein tracking in 108 children over a four year period. Paediatrics 64: 584-591.

Leger, L.A. and Lambert, J. (1982) A maximal multi-stage 20-m shuttle run test to predict VO_2 max. European Journal of Applied Physiology 49: 1-12.

Leger, L. and Thivierge, M. (1988) Heart rate monitors: validity, stability and functionality. Physician and Sports Medicine 16: 143-151.

Leon, A.S. and Norstrom, J. (1995) Evidence for the role of physical activity and cardiorespiratory fitness in the prevention of coronary heart disease. Quest 47: 311-319.

Linder, C.W., DuRant, R.H. and Mahoney, O.M. (1983) The effect of physical conditioning on serum lipids and lipoproteins in white male adolescents. Medicine and Science in Sports and Exercise 15: 232-236.

Lohman, T.G., Boileau, R.A. and Massey, B.H. (1975) Prediction of lean body mass in young boys from skinfold thickness and body weight. Human Biology 47: 245-262.

Lohmann, T. Roche, A. and Martorell, M. (1989) The Anthropometric Standardisation Reference Manual. Human Kinetics Publishers, Champaign, Ill.

Luepker, R.V., Perry, C.L., McKinlay, S.M., Nader, P.R., Parcel, G.S., Stone. E.J., Webber, L.S., Elder, J.P., Feldman, H.A., Johnson, C.C., Kelder, .H. and Wu, M. (1996) Outcomes of a field trial to improve children's dietary patterns and physical activity. The Child and Adolescent Trial for cardiovascular Health. CATCH collaborative group. Journal of the American Medical Association 275: 768-776.

McArdle, W.D., Katch, F.I. and Katch, V.L. (1991) Exercise Physiology: Energy, Nutrition and Human Performance (3rd edition). Lea and Febiger, London, England.

McVeigh, S.K., Payne, A.C. and Scott, S. (1995) The reliability and validity of the 20-meter shuttle test as a predictor of peak oxygen uptake in Edinburgh school children, age 13 to 14 years. Paediatric Exercise Science 7: 69-79.

MacConnie, S.E., Gilliam, T.B., Geenan, D.L. and Pels, A.E. (1982) Daily physical activity patterns of prepubertal children involved in a vigorous exercise program. International Journal of Sports Medicine, 3, 202-207.

MacDougall, J.D., Wenger, H.A. and Green, H.J. (1991) Physiological Testing of the High Performance Athlete. (2nd edition). Human Kinetics Publishers, Champaign, Illinois, USA.

MacManus, A., Williams, C.A. and Armstrong, N. (1995) The effect of two different training programmes on the peak VO_2 of prepubescent girls. Medicine and Science in Sports and Exercise 26: S583 (Abstract).

MacManus, A. and Armstrong, N. (1995) Physical activity patterns of Hong Kong Chinese primary schoolchildren. In: Exercise and Fitness: Benefits and Risks. XVIII Symposium of European Group of Paediatric Work Physiology: Abstracts. Odense University, Odense, 1995, p. 88.

Malina, R.M. and Roche, A.F. (1983) Manual of Physical Status and Performance in Childhood: Vol.2, Physical Performance. Plenum, New York, USA.

Malina, R.M. and Bouchard, C. (1991) Growth, Maturation and Physical Activity. Human Kinetics Publishers, Champaign, Ill.

Malina, R.M. (1996) Tracking of physical activity and physical fitness across the lifespan. Research Quarterly for Exercise and Sport 67: S48-S57.

Malina. R.M. (1997) Activity and fitness of youth: are they related? Do they track? In: Exercise and Fitness - Benefits and Risks. Froberg, K., Lammert, O., Hansen, H. and Blimkie, C.J.R. (Eds.). Odense University Press, Odense, Denmark. p: 161.

Massicote, D.R. and MacNab, R.B.J. (1974) Cardiorespiratory fitness adaptations to training at specified intensities in children. Medicine and Science in Sports and Exercise 6: 242-246.

Mattews, C.E. and Freedson, P.S. (1995) Field trial of a three dimensional monitor: comparison with self-report. Medicine and Science in Sports and Exercise 27: 1071-1078.

Mirwald, R.L. and Bailey, D.A. (1986) Maximal Aerobic Power: A Longitudinal Analysis. Sports Dynamics, Canada.

Morgan, D.A. Boreham, C. Grant, G.W. Savage, J.M. and Straint, J.J. (1994) Influences of plasma total and high density lipoprotein cholesterol in 12 and 15 year old schoolchildren from Northern Ireland. British Association of Sports and Exercise Sciences, abstract. University of Aberdeen.

Morrow, J.R. and Freedson, P.S. (1994) The relationship between habitual physical activity and aerobic fitness in adolescents. Paediatric Exercise Science 6: 315-329.

National Cholesterol Education Programme (1992) Report of the expert panel on blood cholesterol levels in children and adolescents. Paediatrics 89: 525-571.

Nevill, A.M. (1996) Validity and measurement agreement in sports performance. Journal of Sports Sciences 14: 199.

Nevill, A.M., Ramsbottom, R. and Williams, C. (1992) Scaling physiological measurements for individuals of different body size. European Journal of Applied Physiology 65: 110-117.

Nevill, A.M. and Holder, R.L. (1994) Modelling maximum oxygen uptake-a case-study in non-linear regression model formulation and comparison. Applied Statistics 43: 653-666.

Ogle, G.D., Allen, J.R. and Humphries, I.R.J., Lu, P.W., Briody, J.N., Morley, K., Howman-Giles, R. and Cowell, C.T. (1995) Body composition assessment by dual-energy x-ray absorptiometry in subjects aged 4-26 y. American Journal of Clinical Nutrition 61: 746-753.

O'Hara, N.M., Baranowski, T., Simons-Morton, B.G., Wilson, B.S. and Parcel, G.S. (1989) Validity of the observation of children's physical activity. Research Quarterly for Exercise and Sport 60: 42-47.

Olowookere, J.O. (1992) The bioenergetics of obesity syndrome. World Review of Nutrition and Dietetics 70: 132-170.

Ommundsen, Y. (1997) Sport for Children and Youth: Motivational aspects. In: Exercise and Fitness - Benefits and Risks. Froberg, K., Lammert, O., Hansen, H.S. and Blimkie, C.J.R. (Eds.). Odense University Press, Odense, Denmark. p: 229.

Omura, T., Takizawa, Y., Kojima, S., Funaki, S., Sawabe, K., Takauwa, K., Ono, Y., Kishi, M., Yamazaki, T., Iida, M. et al. (1991) A five year follow-up study on blood pressure and serum cholesterol in junior high school children. Nippon Koshu Eisei Zasshi 38: 417-424.

Oseid, S. and Carlsen, K-H. (1989) Children and Exercise XIII. Human Kinetics Publishers, London.

Packer, M., Wharton, C.Y. and Edwards, D.F. A cross-sectional survey of health-related fitness in British schoolchildren aged 11 to 16 years. In: Exercise and Fitness: Benefits and Risks. XVIII Symposium of European Group of Paediatric Work Physiology: Abstracts. Odense University, Odense, 1995, p. 90.

Paffenbarger, R.S., Hyde, R.T., Wing, A.L. and Hsieh, C. (1986) Physical activity, all-cause mortality and longevity of college alumni. New England Journal of Medicine 314: 605-613.

Paffenbarger, R.S., Blair, S.N., Lee, I.M. and Hyde, R.T. (1992) Measurement of physical activity to assess health effects in free-living populations. Medicine and Science in Sports and Exercise 25: 60-70.

Paffenbarger, R.S. and Lee, I-M. (1996) Physical activity and fitness for health and longevity. Research Quarterly for Exercise and Sport 67: 11-28.

Parizkova, J. (1996) Nutrition, Physical Activity and Health in Early Life. CRC Press, London, England.

Pate, R.R. Baranowski, T. Dowda, M. and Trost, S.G. (1996) Tracking of physical activity in young children. Medicine and Science in Sports and Exercise 28: 92-96.

Payne, V.G. and Morrow, J.R. (1993) Exercise and VO_2 max in children: a meta-analysis. Research Quarterly for Exercise and Sport 64: 305-313.

Peters, D.M. (1994) Body fatness and fat distribution in children and adolescents - cause for concern? British Journal of Physical Education 25: 18-19.

Plaza-Perez, I. (1992) Report on cholesterol levels of Spanish children and adolescents. Group of experts of Spanish societies of arteriosclerosis, cardiology, paediatrics, nutrition and preventative medicine. Review of Spanish Cardiology 44: 567-585.

Porkka, K.V., Viikari, J.S. and Akerblom, H.K. (1991) Tracking of serum HDL-cholesterol and other lipids in children and adolescents: the Cardiovascular Risk in Young Finns Study. Preventative Medicine 20: 713-724.

Powell, K.E. Thompson, P. Caspersen, C.J. and Kendrick, J.S. (1987) Physical activity and the incidence of coronary heart disease. Annual Review of Public Health 8: 253-287.

Primrose, E.D., Savage, J.M., Boreham, C.A., Gran, G.W. and Strain, J.J. (1994) Cholesterol screening and family history of vascular disease. Archives of Disease in Childhood 71: 239-242.

Raitakari, O.T., Porkka, K.V.K., Taimela, S., Telama, R., Rasanen, L. and Vikari, J.S.A. (1994) Effects of persistent physical activity and inactivity on coronary risk factors in children and young adults. American Journal of Epidemiology 140: 195-205.

Reilly, T., Maughan, R.J. and Hardy, L. (1996) Body fat consensus statement of the steering groups of the British Olympic Association. Sports Exercise and Injury 2: 46-49.

Riddoch, C.J. (1990) The Northern Ireland Fitness Survey - 1989. Queens University, Belfast.

Riddoch, C., Mahoney, C., Murphy, N., Boreham, C. and Cran, G. (1991) The physical activity patterns of Northern Irish schoolchildren ages 11-16 years. Paediatric Exercise Science 3: 300-309.

Riddoch, C.J. and Boreham, C.A.G. (1995) The health-related physical activity of children. Sports Medicine 19: 86-102.

Rifkind, B.M. and Segal, P. (1983) Lipid Clinics Research Programme reference values for hyperlipidaemia and hypolipidaemia. Journal of the American Medical Association 250: 1869.

Rimmer, J.H. and Looney, M.A. (1994) A preliminary study of misclassification of blood cholesterol levels in an adolescent population. Research Quarterly for Exercise and Sport 65: 382-385.

Rimmer, J.H. and Looney, M.A. (1997) Effects of an aerobic activity program on the cholesterol levels of adolescents. Research Quarterly for Exercise and Sport 68: 74-79.

Roberts, S.O., Robergs, R.A., Stolarczyk, L., Mermier, D., Maes, R., Scales, R. and Griffin, S. (1994) Effects of combined step aerobic and resistance training in children on cardiorespiratory endurance and strength. Medicine and Science in Sports and Exercise 26: S83 (Abstract).

Roche, A.F., Wainer, H. and Thissen, D. (1975) The RWT method for the prediction of adult stature. Pediatrics 56: 1026-1033.

Roche, A.F. Tyleshevski, F. and Rogers, E. (1983) Non-invasive measurements of physical maturity in children. Research Quarterly for Exercise and Sport 54: 364-371.

Roche, A.F. (1995) Tracking in body composition and risk factors for cardiovascular disease from childhood to middle age. In: Exercise and Fitness: Benefits and Risks. XVIII Symposium of European Group of Paediatric Work Physiology: Abstracts. Odense University, Odense, 1995, p. 28.

Roche, A.F. (1997) Tracking in body composition and risk factors for cardiovascular disease from childhood to middle age. In: Exercise and Fitness - Benefits and Risks. Froberg, K., Lammert, O., Hansen, H.S. and Blimkie, C.J.R. (Eds.). Odense University Press, Odense, Denmark. p:79.

Roemmich, J.N., Clark, P.A. and Rogol, A.D. (1997) Growth and hormone release in children and adolescents: are they altered by athletic training? In: Exercise and Fitness - Benefits and Risks. Froberg, K., Lammert, O., Hansen, H.S. and Blimkie, C.J.R. (Eds.). Odense University Press, Odense, Denmark. p: 49.

Rogers, D.M.,Turley, K.R., Kujawa, K.I., Harper, K.M. and Wilmore, J.H. (1995) Allometric scaling factors for oxygen uptake during exercise in children. Paediatric Exercise Science 7: 12-25.

Rogol, A.D. (1994) Growth at puberty: interaction of androgens and growth hormone. Medicine and Science in Sports and Exercise 26: 767-770.

Round, J.M., Nevill, A.M., Honor, J. and Jones, D.A. (1996) The role of testosterone in explaining the developmental differences in strength between boys and girls. In preparation.

Rowland, T.W. (1985) Aerobic response to endurance training in prepubescent children: a critical analysis. Medicine and Science in Sports and Exercise 17: 493-497.

Rowland, T.W. (1990) Exercise and Children's Health. Human Kinetics Publishers, Champaign, Ill.

Rowland, T.W. (1991) "Normalising" maximal oxygen uptake, or the search for the holy grail. (per kg). Paediatric Exercise Science 3: 95-102.

Rowland, T.W. (1993) Does peak VO_2 reflect VO_2 max in children? Evidence from supramaximal testing. Medicine and Science in Sports and Exercise 25: 689-693.

Rowland, T.W. (1995) Performance fitness in children as a model for fatigue, or, what good is allometry, anyway? Paediatric Exercise Science 7: 1-4.

Rowland, T.W. and Boyajian, A. (1995) Aerobic response to endurance training in children. Medicine and Science in Sports and Exercise 26: S583 (Abstract).

Rowland. T.W. (1996) Developmental Exercise Physiology. Human Kinetics Publishers, Champaign, USA.

Rowland, T.W. (1997) The aerobic trainability of athletic and non-athletic children. In: Exercise and Fitness - Benefits and Risks. Froberg, K., Lammert, O., Hansen, H.S. and Blimkie, C.J.R. (Eds.). Odense University Press, Odense, Denmark. p: 193.

Ruiz Jiminez, M.A., Adnan, R., Zafra Mezuca, J., Fernandez Garcia, J.R. and Pavon Lebrero, R. (1996) Prevalence of arterial hypertension, hypercholesterolaemia, hyperlipaemia and obesity in 1652 children and adolescents in Cadiz. Nutrition Abstracts and Reviews 66: 372 (Abstract).

Rutenfranz, J. (1986) Longitudinal approach to assessing maximal aerobic power during growth: the European experience. Medicine and Science in Sports and Exercise 18: 270-275.

Rutenfranz, J., Mocellin, R. and Klimt, F. (1986) Children and Exercise XII. Human Kinetics Publishers, Champaign, USA.

Sallis, J.F., Patterson, T.L., McKenzie, T.L. and Nader, P.R. (1986) Family variables and physical activity in pre-school children. Journal of Developmental and Behavioural Paediatric 9: 57-61.

Sallis, J.F., Patterson, T.L., Buono, M.J. and Nader, P.R. (1988) Relation of cardiovascular fitness and physical activity to cardiovascular disease risk factors in children. American Journal of Epidemiology 127: 933-941.

Sallis, J.F., Buono, M.J., Roby, J.J., Micale, F.G. and Nelson, J.A. (1993) Seven day recall and other physical activity self-reports in children and adolescents. Medicine and Science in Sports and Exercise 25: 99-108.

Sallis, J.F. and Patrick, K. (1994) Physical activity guidelines for adolescents: Consensus statement. Paediatric Exercise Science 6: 302-314.

Sallis, J.F., Berry, C.C., Broyles, S.L., McKenzie, T.L. and Nader, P.R. (1995) Variability and tracking of physical activity over 2 yr in young children. Medicine and Science in Sports and Exercise 27: 1042-1049.

Sallo, M. (1995) Simultaneous assessment of habitual physical activity with a questionnaire, heart rate monitor and motion accelerometer in 6-8 year old children. In: Exercise and Fitness: Benefits and Risks. XVIII Symposium of European Group of Paediatric Work Physiology: Abstracts. Odense University, Odense, 1995, p. 50.

Sallo, M. and Silla, R. (1997) Physical activity with moderate to vigorous intensity in pre-school and first-grade schoolchildren. Paediatric Exercise Science 9: 44-54.

Saris, W.H.M., Noordeloos, A.M., Ringnalda, B.E.M., Van't Hof, M.A. and Binkhorst, R.A. (1985) Reference values for aerobic power of healthy 4 to 18 year old Dutch children. In: Children and Exercise XI. Binkhorst, R.A., Kemper, H.C.G. and Saris, W.H.M. (Eds.). Human Kinetics Publishers, Champaign, Ill. p: 210-214.

Saris, W.H.M. (1986) Habitual physical activity in children: Methodology and findings. Medicine and Science in Sports and Exercise 18: 253-263.

Saunders, S. (1996) A study to investigate the Physical Self-Perceptions of children 9-11 years. Unpublished Dissertation, Liverpool John Moores University, Liverpool, England.

Savage, M.P., Petratis, M.M., Thompson, W.H., Berg, K., Smith, J.L. and Sady, S.P. (1986) Exercise training effects on serum lipids of prepubescent boys and adult men. Medicine and Science in Sports and Exercise 18: 197-204.

Schaefer, E.J., Lichtenstein, A.H., Lamon-Fava, S., McNamara, J.R. and Ordovas, J.M. (1995) Lipoproteins, nutrition, ageing and artherosclerosis. American Journal of Clinical Nutrition 61: 26-40.

Schmidt-Nielsen, K. (1984) Scaling: Why is Animal Size so Important? Cambridge University Press, Cambridge, England.

Scraton, S.J. (1986) Gender and girls in PE. The implications for practice. British Journal of Physical Education 4:

Shaw, A. and Eves, F. (1997) Predictors of physical activity in children: A longitudinal study. Journal of Sports Sciences 57: (Abstract).

Shephard, R.J. and Lavallee, H. (1993) Impact of enhanced physical education in the prepubescent child: Trois Rivieres revisited. Paediatric Exercise Science 5: 177-189.

Shephard, R.J. (1994) Aerobic Fitness and Health. Human Kinetics Publishers, Champaign, USA.

Shephard, R.J. (1995) Physical activity, fitness and health: the current consensus. Quest 47: 288-303.

Shephard, R.J. and Bouchard, C. (1996) Associations between health behaviours and health related fitness. British Journal of Sports Medicine 30: 94-101.

Simmonds, G., Aznar, S., Barnes, K., Christopher, M., Goldberg, J. and Riddoch, C.J. (1995) The health related physical activity of children. In: Exercise and Fitness: Benefits and Risks. XVIII Symposium of European Group of Paediatric Work Physiology: Abstracts. Odense University, Odense, 1995, p. 52.

Simons-Morton, B.G., Taylor, W.C. and Huang, I.W. (1994) Validity of the physical activity interview and Caltrac with preadolescent children. Research Quarterly for Exercise and Sport 65: 84-88.

Slaughter, M.H., Lohman, T.G., Boileau, R.A., Horswill, C.A., Stillman, R.J., Van Loan, M.D. and Bemben (1988) Skinfold equations for estimation of body fatness in children and youth. Human Biology 60: 709-723.

Sleap, M. and Warburton, P. (1992) Physical activity levels of 5-11 year old children in England as determined by continuous observation. Research Quarterly for Exercise and Sport 63: 238-245.

Sorenson, T.I.A. (1997) Genetic and environmental factors related to the development of obesity in youngsters. In: Exercise and Fitness - Benefits and Risks. Froberg, K., Lammert, O., Hansen, H.S. and Blimkie, C.J.R. (Eds.). Odense University Press, Odense, Denmark. p: 37.

Sporik, R., Johnstone, J.H. and Cogswell, J.J. (1991) Longitudinal study of cholesterol values in 68 children from birth to 11 years of age. Archives of Disease in Childhood 66: 134-137.

Spurr, G.B. and Reina, J.C. (1990) Daily pattern of %VO_2 max and heart rates in normal and undernourished schoolchildren. Medicine and Science in Sports and Exercise 22: 643-652.

Srinivasan, S. and Berenson, G.S. (1992) Serum lipids and lipoprotein in children. Paediatric Annals 21: 220-223.

Stratton, G. (1996) Children's heart rates during physical education lessons: A review. Paediatric Exercise Science 8: 215-233.

Superko, H.R. (1991) Exercise training, serum lipids and lipoprotein particles: is there a change threshold? Medicine and Science in Sports and Exercise 23: 677-685.

Suter, E. and Hawes, M.R. (1993) Relationship of physical activity, body fat, diet and blood lipid profile in youths 10-15 years. Medicine and Science in Sports and Exercise 25: 748-754.

Tanner, J.M. (1949) Fallacy of per-weight and per-surface area standards, and their relation to spurious correlation. Journal of Applied Physiology 2: 1-15.

Tanner, J.M. (1962) Growth at adolescence. Blackwell Scientific Publications, London.

Tanner, J.M. and Whitehouse, R.H. (1984) Growth and development: a book of reference charts: Tanner-Whitehouse standards. Castlemead, London, England.

Torun, B., Davies, P.S.W., Livingstone, M.B.E., Paolisso, M., Sackett, R. and Spurr, G.B. (1996) Energy requirements and dietary energy recommendations for children and adolescents 1 to 18 years old. European Journal of Clinical Nutrition 50: S37-S81.

Tran, Z.V., Weltman, A., Glass, G.V. and Mood, D.P. (1983) The effects of exercise on blood lipids and lipoproteins: a meta-analysis of studies. Medicine and Science in Sports and Exercise 15: 393-402.

Trieber, F., Musante, L., Hartdagan, S., Davis, H., Levy, M. and Strong, W. (1989) Validation of a heart rate monitor with children in laboratory and field settings. Medicine and Science in Sports and Exercise 21: 338-342.

Trudeau, F., Laurencelle, L., Tremblay, J., Marchand, A., Rajic, M. and Shephard, R.J. (1997) Tracking of physical activity from daily primary school physical education to adult life. Medicine and Science in Sports and Exercise 29: S13 (Abstract).

Tsanakas, J., Bannister, O., Boom, A. and Milner, R. (1986) The Sports Tester, a device for monitoring the free running test. Archives of Disease in Childhood 61: 912-914.

Twisk, J., Kemper, H.C.G. and Snel, J. (1995) Tracking of cardiovascular risk factors in relation to lifestyle. In: The Amsterdam Growth Study. HK Sport Science Monograph Series Volume 6. Kemper, H.C.G. (Ed.) Human Kinetics Publishers, Champaign, Ill. p: 66-72.

van Mechelen, W., Kemper, H.C.G., Twisk, J., Snel, J., Post, G.B. and Welten, D. (1993) Tracking of habitual physical activity from 13-28 years of age. Medicine and Science in Sports and Exercise 25: S122 (Abstract).

van Mechelen, W. and Kemper, H.C.G. (1995) Habitual physical activity in longitudinal perspective. In: The Amsterdam Growth Study: A longitudinal analysis of health, fitness and lifestyle. Kemper, H.C.G. (Ed.). Human Kinetics Publications, Champaign, Ill. p: 73-80.

Verschuur, R. and Kemper, H.C.G. (1985) Habitual physical activity in Dutch teenagers measured by heart rate. In: Children and Exercise XI. Binkhorst, R.A., Kemper, H.C.G. and Saris, W.H.M. (Eds.). Human Kinetics Publishers, Champaign, Ill. p: 40-44.

Wajciechowski, J.A., Gayle, R.C., Andrews, R.L. and Dintiman, G.B. (1991) The accuracy of radio telemetry heart rate monitoring during exercise. Clinical Kinesiology 45: 9-12.

Walker, A. (1990) Applied human nutrition for food scientists and home economists. Ellis Horwood, London, USA.

Walker, A. (1990) Diet and coronary heart disease. In: Applied human nutrition for food scientists and home economists Walker, A.(Ed.). Ellis Horwood, London, USA.

Webb, W.B. (1982) Biological rhythms, sleep and performance. John Wiley and Sons Ltd. Chichester, England.

Webber, L.S., Srinivasan, S.R., Wattingey, W.A. and Berenson, G.S. (1991) tracking of serum lipids and lipoproteins from childhood to adulthood: The Bogalusa Heart Study. American Journal of Epidemiology, 133, 884-899.

Welsman, J.R. and Armstrong, N. (1992) Daily physical activity and blood lactate indices of aerobic fitness in children. British Journal of Sports Medicine 26: 228-231.

Welsman, J.R., Armstrong, N., Nevill, A.M., Winter, E.M. and Kirby, B.J. (1996) Scaling peak VO_2 for differences in body size. Medicine and Science in Sports and Exercise 28: 259-265.

Welsman, J.R., Armstrong, N. and Kirby, B.J. (1997) Scaling the aerobic fitness of overfat children. Journal of Sports Sciences 15: 34 (Abstract).

Welsman, J.R., Armstrong, N. and Withers, S. (1997) Responses of young girls to two modes of aerobic training. British Journal of Sports Medicine 31: 139-142.

Whitehead, J.R. (1995) A study of children's physical self-perceptions using an adapted physical self-perception profile questionnaire. Paediatric Exercise Science 7: 132-151.

Williams, C.A., Armstrong. N. and Powell, J. (1995) The effects of continuous and interval training programmes on the anaerobic and aerobic performance of prepubertal boys. In: Exercise and Fitness: Benefits and Risks. XVIII Symposium of European Group of Paediatric Work Physiology: Abstracts. Odense University, Odense, 1995, p. 70.

Willows, N.D., Grimston, S.K., Roberts, D., Smith, D.J. and Hanley, D.A. (1995) Iron and hematological status in young athletes relative to puberty: A cross-sectional study. Paediatric Exercise Science 5: 367-376.

Willows, N.D., Grimston, S.K., Smith, D.J. and Hanley, D.A. (1995) Iron and hematological status among adolescent athletes tracked through puberty. Paediatric Exercise Science 7: 253-262.

Wilmore, J.H. and Costill, D.L. (1994) Physiology of Sport and Exercise. Human Kinetics Publishers, Champaign, Ill.

Winsley, R.J. Armstrong, N. and Welsman, J.R. (1995) MRI determined thigh volume and the demonstration of a plateau in oxygen uptake during maximal aerobic exercise in prepubescent girls. In: Exercise and Fitness: Benefits and Risks. XVIII Symposium of European Group of Paediatric Work Physiology: Abstracts. Odense University, Odense, 1995, p. 71.

Winter, E.M. (1992) Scaling: partitioning out differences in size. Paediatric Exercise Science 4: 296-301.

Winter, E.M. and Nevill, A.M. (1996) Scaling: adjusting for differences in body size. In: Kinanthropometry and Exercise Physiology Laboratory Manual. Eston, R. and Reilly, T. (Eds.). E&FN Spon, London, England. p; 160-166.

Wolinsky, I. and Klimis-Tavantzis, D.J. (1996) Nutritional Concerns of Women. CRC Press, Boca Raton, USA.

World Health Organisation (1981) WHO Global strategy for "Health for all by the year 2000". WHO, Geneva.

World Health Organisation (1990) Study group on diet, nutrition and prevention on non-communicable diseases. Diet, nutrition and prevention of chronic diseases: report of a WHO study group (Technical Report Series 797). WHO, Geneva.

Ziegler, E.E. and Filer, L.J. (1996) Present Knowledge in Nutrition. ILSI Press, Washington, USA.

Yip, R. and Dallman, P.R. (1996) Iron. In: Present Knowledge in Nutrition. Ziegler, E.E. and Filer, L.J.(Eds.). ILSI Press, Washington, USA.

Zonderland, M.L., Erich, W.B.M., Kortlandt, W. and Erkelens, D.W. (1994) Additional physical education and plasma lipids and apoproteins: A 3-year intervention study. Paediatric Exercise Science 6: 128-139.

APPENDICES

Appendix 1

Example of approach letter to children and parents, including written informed consent form

Liverpool John Moores University

Mr S. Atkins,
Holmefield House,
Liverpool John Moores
University,
Barkhill Road,
Liverpool,
L17 6BD.

Date: 6 Jun 94

Tel: 051 231 5261.

Dear parent,

Your child ..... has been chosen to take part in the laboratory based phase of our study into the health and fitness of Merseyside schoolchildren. Testing will be based at the Exercise Science laboratory at the IM Marsh campus in Barkhill Road, off Aigburth Road. The testing will consist of a 1 to 2 hour testing period with the following tests being performed:

1. A treadmill run test during which expired gas samples will be collected and heart rate monitored. This test will last between 8 and 20 minutes dependent upon the level of fitness of your child. Whilst we would like this test performed to a state of voluntary exhaustion your child is free to retire at any point.

2. A strength test that will require your child to lift a pre-tensioned bar a short distance. This test will be repeated three times and we encourage children to lift to their maximal limits. As with all test's safety will be of paramount importance and any risk of injury will be eliminated by the use of correct technique and supervision.

3. A series of skinfold measurements using spring loaded calipers with measures being taken from the waist, arms, calf, and central back. in addition height and weight measures will also be recorded.

Executive Director | Professor Jennifer Lalto

Webster Street Liverpool L3 2l

Road Liverpool L17 6BD

4. A series of blood samples that require very small samples of blood to be taken from the fingertip by means of a rapid pinprick that is quite painless. These samples will enable assessment to be made of blood cholesterol and haemoglobin levels.

The testing will take place, where possible, during the early evening, and if you are unable to attend the appointment given please could you contact myself as soon as possible to arrange an alternative appointment. Transport, if required, will be provided, and if this service is required please could you let me know prior to the testing session.

Once again may we thank both you and your child for your invaluable help in this project and hope that you can support the project for the full three year period.

Yours faithfully,

Steve Atkins BA (Hons.)

Liverpool John Moores University

Mr S. Atkins,
Room M111,
Liverpool John Moores University,
Barkhill Road,
Liverpool,
L17 6BD.

Tel: 0151 231 5239/5244

Date: 7 Feb 96

Dear parent and child,

Thank you very much for taking part in our major study investigating the activity and fitness of Merseyside schoolchildren. Over the past few years we have gathered some superb information which. when published, will provide the first reported measurements of fitness and health in Liverpool schoolchildren. physiological testing is now completed and to aid in the final data collection we are asking both children and parents to complete some simple questionnaires.

The children's questionnaires are the same as those posted to you last year and assess your feelings about your physical self and your motivation for fitness activities. I enclose complete instructions as to how to complete each questionnaire and hope you can complete them to enable a full set of results to be gained.

The parents questionnaire will provide information as to the economic background of the group, via information as to occupation of head of household. Such information is routinely gathered during the course of large scale investigations and provides invaluable information as to the background of subjects tested. This information will be treated in complete confidence and your help would be gratefully appreciated.
As a final test measurement we are also assessing the possibility of measuring parents height to give an idea as to the estimated stature of the children at adulthood. This analysis is invaluable in providing data as to the maturity state of children. If you are agreeable we would ask that you fill in the consent form attached to the parents questionnaire and I will contact you to make arrangements. This simple testing will be performed in your home at any time (weekends or evenings), and takes a couple of minutes. I hpe it will not inconvenience you too much.

I hope that you and your child will be able to complete these questionnaires and return them in the prepaid envelope. I also enclose two free swim passes for the IM Marsh pool as a final token of our appreciation at your help in our project.

Once again, many thanks for your help in our project over the last few years, and best wishes for the future. If you have any queries regarding testing please call on the above number.

Yours faithfully,

Steve Atkins

Executive Director | Professor Jennifer Latto

Liverpool John Moores University

School of Education and Community Studies.

"The Health and Physical Activity of Merseyside Schoolchildren."

Form of Consent.

Consent Form (a)

I agree to my child..... participating in a research project, concerned with the physical activity and physical fitness levels of children, the nature of which has been explained to me by letter.

I have been informed of the experimental procedures that will be utilised and understand that my child will be asked to undertake several measures of physical and psychological fitness including:

1. Endurance measured by a multiple shuttle run test.
2. Strength measured by handgrip dynamometry.
3. Body composition assessed by skinfold and height/weight measures.
4. A questionnaire to assess attitude towards physical activity and self esteem.

If selected I also do/ do not* agree to my child undertaking laboratory based measures to assess several physical measures including:

1. A treadmill running test to measure aerobic fitness.
2. A single lift strength test.
3. Skinfold and skeletal measures of body composition.
4. Blood cholesterol measures involving a simple finger prick blood sample.
5. A visual assessment of body development performed by a specialist from the Alder Hey Growth Unit

The results will be stored on computer and will be completely confidential to the researchers.

I also understand that my child will be free to leave the study at any time.

Signed.....(Parent/Guardian)

Date.....

Consent Form (b)

.....agree to participate in the study described. the nature of which has been clearly explained to me. I understand the involvement of myself to the study and that I may leave the study at any time.

Signed.....(Subject/Child)

Date.....

Appendix 2

Copy of laboratory ethics document for the IM Marsh Human Performance Laboratory

Exercise and Health Science Laboratory - IMMarsh Site.
Ethics Document

1.0 Preamble

Much of the work undertaken on human subjects in at the exercise science laboratory at the I.M.Marsh site involves students. All the techniques used in the laboratory are "minor procedures " as defined by Liverpool JMU ethics committee guidance document (December 1991). All laboratories are necessary parts of student courses related to the physiology of exercise, and serve to develop key concepts in the understanding of the physiological mechanisms that control body functions during exercise. Such measurements may involve sub-maximal or maximal tests, all subjects volunteer to take part.

In addition to student work, there have been numerous requests from athletic groups in the North-West for fitness assessment and monitoring, and the laboratory would like to service these needs wherever possible. Many of the techniques used are consistent between exercise laboratories involved in exercise physiology, and thus many of the standard techniques used at I.M.Marsh will be identical to those used in sports science laboratories situated in the Mountford building at Liverpool JMU.

The laboratory is well equipped for the majority of exercise testing, and currently operates within working standards and practices set by the British Association of Sports Sciences (BASS 1988; appendix 1). This document includes the majority of procedures that are used in the laboratory and should be referred to if greater detail than that included in sections 5.0 and 6.0 is required.

Other groups of individuals likely to visit the laboratory and be involved in exercise testing are schoolchildren. There are numerous requests fron schools to visit the laboratory. School groups that do visit (and have visited the lab for many years) are those that teach Physical Education and Sports Studies to GCSE or "A" level standard, and do not have the facilities to teach practical laboratories in exercise physiology.

The nature of the teacher education course directly involves children, and part of the National curriculum for Physical Education is related to health related exercise. Health related exercise programmes in school include field tests of fitness, and student groups regularly visit schools as part of their professional experience, some of these visits to schools involve fitness testing of children. Other student courses (e.g. growth and development) also involve bringing children into the laboratory for

anthropometrical measurement. Data is used by students to interpret somatic growth, and is used by schoolteachers for a variety of educational purposes.

The specialist expertise in the laboratory staff revolves around paediatric exercise and the laboratory director has previous experience in working with the Coronary Prevention in children group in Exeter University. The laboratory is aiming to direct more of its research work into this area in the future. Such specificity also complements the work from the other exercise science laboratory at Sports Science. Many of the tests used with adults are similar to those used on children. The laboratory requires guidance on whether the procedures included in this document will also provide approval for use with all age groups.

2.0 Health and Safety

The laboratory was visited by the University health and safety officer in January of this year, and was generally reported to be in sound and operable condition. The report did however offer a range of recommendations to the laboratory, especially those related to particular facilities which did not meet H&S requirements. The school is endeavouring to fit the necessary facilities over Easter, with work already being costed by estates to develop a safe work area for the management and disposal of blood samples. All other requirements regarding the Working equipment regulations act (1993) the health and safety at work act (1974) have been met.

The current document has been written in response to ethics committee requests for details of work undertaken at the lab, and is written in accordance with sections 1 to 16 of the ethics committee guidelines.

3.0 Students

(i) All students will sign a consent form on arrival in the first year of their course and are healthy volunteers as defined by the Royal College of Physicians (1986).
(See appendix 2)

(ii) All students volunteer to take part in class/group practical work and are under no obligation to do so.

(ii) Students may withdraw from the practical or stop during the practical at any time if they so wish.

4.0 Professional guidelines

In addition the exercise science laboratory adheres to the following guidelines for professional practice in exercise laboratory's (Wenger, MacDougall and Green 1990, Larsson 1976, Heyward 1990). Such guidelines screen for conditions before and during exercise. End points for exercise are also noted.

Preventative conditions pre-exercise

1) Evidence of infection, illness, or a high temperature.

2) Atypical responses at the end of a five minute rest period in the reclining position, such as :-

a) Heart rate 100 bpm or above.

b) Respiratory rate 40 bpm or above.

c) Systolic blood pressure 170 mm Hg or above.

d) Diastolic blood pressure 100 mm Hg or above.

e) Abnormal electrocardiogram.

3) Atypical responses while standing after the period of reclining rest, such as :-

a) Heart rate less than reclining or more than 20 bpm above reclining.

b) Diastolic blood pressure less than reclining, or more than 30 mm Hg above reclining.

c) Abnormal electrocardiogram.

d) Tendency towards fainting or dizziness.

Preventative conditions during exercise

1) Volitional (invisible) end-points

a) Signal from the subject that he/she is unwilling to continue.

b) Complaint of discomfort, fatigue or illness.

c) Distress, irritation or anxiety.

d) Palpitations, chest pressure, or pains of anginal pattern referred to shoulder, arm, jaw, teeth or ear.

e) Insistent stitch in side or breathlessness

f) Light-headedness, dizziness, drowsiness, syncope, faintness, nausea, headache, lethargy, weakness, or unwell feeling.

g) Claudication (discomfort or pain in legs)

h) Pounding or throbbing of pulse felt in the head

i) Muscle weakness, cramping, twitching, spasm, ache or pain

j) Cold sweating

5.0 Blood Sampling Procedures

These procedures are in accordance with Liverpool John Moores University Guidelines

(i) The experimenter must wear disposable gloves, a Laboratory coat and protective glasses with brow and side protection.

(ii) The subjects fingertip is washed and cleansed with a sterile wipe.

(iii) The fingertip is punctured with an Autolet, using a sterile lancet and platform and the first two or three drops of blood wiped away using a tissue.

(iv) The blood sample is taken by capillary action using a capillary tube or cuvette.

(v) The capillary tube is loaded into an injection syringe. The blood sample is injected directly into the YSI lactate analyser, or injected onto a test strip which is loaded into the Reflotron cholesterol analyser.

(vi) If B-haemoglobin is being assayed the cuvette is loaded into the Hemacue analyser.

(vii) Any spots of blood are wiped up immediately using a sodium hypochlorite disinfectant containing 2% available chlorine, or with Cidex, activated glutaraldehyde solution.

(viii) Lancets capillaries and any other sharp objects are discarded into a "Sharps" container labelled "sharps bio-hazard."

(ix) Contaminated materials (eg. gloves, tissues, test strips etc) are discarded into disposal bags labelled bio-hazard.

(x) Liquid waste from the YSI lactate analyser is mixed with Cidex to render safe.

(xi) All waste is immediately placed into a biohazard container supplied and removed by Rentokil once every 3 months

(xii) Work areas, instruments and equipment used are sprayed with a sodium hypochlorite disinfectant containing 2% available chlorine, or with Cidex and wiped.

2) <u>Subjective (visible but not measurable) end points</u>

a) Ataxic gait, unco-ordinated movements, trembling, shakiness, tremor awkwardness, unsteadiness, wavering or faltering, inability to maintain rhythm.

b) Dyspnea (shortness of breath) or hyperpnea (dis-proportionate hyperventilation, laboured or rapid breathing)

c) Cyanosis (blueing of lips or nail beds)

d) Change in colour of face to ashen or pale

e) Vomiting

f) Weakness of voice, postural slumping or reduction of vigour

g) Mental confusion, disorientation, inattention, lethargy, visual disturbances.

h) Expression of distress or anxiety

i) Diminished pulse

j) Clammy skin

3) <u>Objective (measured end-points)</u>

a) Sub maximal target end points for a subject population aged (18 - 35 years). Work with older or younger subjects must be closely supervised by a member of the academic staff of the Laboratory.

Heart rate	170 bpm
Systolic blood pressure	240 mm Hg
Diastolic blood pressure	130 mm Hg
Respiration rate	55 bpm

b) Physiological indices of exercise limits :

i) Oxygen uptake plateaus

ii) Respiratory quotient rises above unity

iii) Ventilatory equivalent increases abnormally

iv) Sharp rise in oxygen pulse (heart rate / oxygen uptake)

v) Sharp rise in time-tension index (heart rate x systolic blood pressure

vi) Systolic blood pressure becomes stabilised or does not rise in proportion to exercise loading

vii) Pulse pressure decreases

(6.0) Procedures used in the Exercise Science Laboratory at I.M.Marsh.

All procedures used in the laboratory are "minor procedures" as defined in Appendix II of the ethics committee guidance document (December 1991).

(a) Anthropometry/Body Composition

(1) Anthropometrical measurements.

Heights, weights, muscle girths, skinfold measures, bone and body widths.

Equipment used is detailed as follows:-
Harpenden skinfold calipers - units millimeters, 0 - 20mm
Huidplooidikte meter - units millimeters, 0 - 80mm
Holtain Bicondyle verniers - units millimeters, 0 - 140mm
Harpenden Anthropometers - units 0-2000mm

(2) Assessment of body composition using bio-impedance E-Z Comp 1500.

Equipment used is detailed as follows:-
Test current less than 1 mA,
Test frequency 50 kHz,
power source 9v DC battery
Add details of technique

(b) Cardiovascular measures

(1) Measuring heart rate

(i) Heart rate telemetry

The sport tester PE4000 heart rate telemetry system is made up of two sections:-
(a) A transmitter which is attached to the chest by an elastic chest strap or self adhesive electrodes.
(b) A receiver wristwatch, which is strapped to the wrist. The receiver may store minute by minute heart rate data for up to 33 hours continuously.
The instrument is a socially acceptable monitoring instrument and has been successfully used in the field with both adults and children. The method is probably the most popular global method for assessing heart rate both in lab and field.

(ii) Cardiometers

Cardiometers are used during whole class practicals to monitor heart rate from a 2 lead ECG pick up pad.

Command and tunturi heart rate monitors are used to measure heart rate from electronic light sensors which are fixed to the ear lobe.

(2) Blood pressure.

Blood pressure is measured both manually using mercury sphygmomanometers, and automatically using electronically sensed sphygmomanometers (Boso-tron). Korotkoff pulses are picked up using a larged bell stethoscope during manual blood pressure readings. Stethoscopes are not required during automatic readings.

(3) Capillary blood sampling

(i) Haemoglobin.

Using Haemocue photoelectric system - B-Hemoglobin Phoeometer, Hemocue, AB Angelholm Sweden.

A small 20ul fingertip blood sample is collected into a microvette which is then inserted into an automated photoelectric instrument which assesses levels of B- haemoglobin. Samples are usually taken in duplicate.

Management of capillary blood sampling is as described in section 5.0 of this document

(ii) Whole blood lactate using

YSI Sport 1500 Lactate Analyser

YSI Incorporated, Yellow Springs, Ohio, USA.

Whole blood lactate may be collected off exercising individuals undertaking a particular exercise test (normally, cycling, running or rowing). Each sample is collected into a 25ul capillary tube or microvette, and normally analysed within 5 minutes using a YSI whole blood lactate analyser. Samples are usually taken in duplicate at the end of each phase of the exercise test. Approximately 10-16 blood samples may be taken from any one exercise test.

Management of capillary blood sampling is as described in section 5.0 of this document

(iii) · Reflotron reflectance photometer - Bohringer Ltd, Lewes, East Sussex.
15 dry chemistry assays.
Whole blood is normally collected in 30 ul capillary tubes. The bloos is then injected onto an enzymatic strip which is inserted into the machine, which uses its photoelectric cell to assay the amount of whole blood cholesterol on the strip. Larger samples of blood (150 ul) may be taken into a microvette, and spun down to separate red blood cells and plasma. using a centofuge. Blood lipids such as triglycerides may then be assayed using the same technique to that previously mentioned.
Management of capillary blood sampling is as described in section 5.0 of this document

(ix) Glucometer II - Ames Division, Miles Laboratories, Indiana, USA.
The glucometer uses a strip method as that decribed above. However this machine is dedicated to assaying whole blood glucose only and is commonly used by individuals with diabetes mellitus.

(4) Electrocardiogram
Up to 12 lead ECG available. 3/4 leads normally used to assess PQRST complexes.

Equipment used is detailed as follows:-
ECG - FX- 1201, Fukunda Denshi Co Ltd
Protective class: according to IEC 601-1 (class I, type CF)
Leads: standard 12-lead
Input impedence: Greater than 50MΩ (at 10Hz)
Pace pulse detection: according to IEC 601-1
Patient auxillary current: less than 10nA
Input circuit protection: Defibrillator protection, original patient cable included.

(c) Measuring aerobic capacity and power.

(i) Max VO2's

Individuals are asked to run, cycle or row, at a range of progressively increasing workloads until voluntary exhaustion sets in. All subjects wear mouthpieces which are linked by flexible tubing to low resistance Salford valves. Noseclips are also worn, as well as a sport tester PE4000 to monitor heart rate once every 5 or 15 seconds during the test.

End points of exercise are observed as in section 4.0

(ii) Sub-max VO2's

These tests estimate efficiency of the cardiorespiratory system. They are based upon a linear relationship between heart rate and oxygen uptake at submaximal levels. Heart rate is assessed using one of the methods mentioned above, and tests are usually undertaken using cycle ergometers or step up benches.

Equipment used for VO2 testing:-

Woodway treadmill ELG2

Monark Ergometer - Model 818E

Oxygen Analyser, Servomex Model 570A, range 0 - 100% O_2

Carbon Dioxide Analyser, Servomex Model PA404, range 0 - 10% CO_2

Dry gas meter, Harvard

Morgan Exercise Test Monitor -

Data deck processor

Cardioscope

Carbon dioxide analyser - model 801R, range 0 - 15% CO_2

Oxygen analyser - model 500d, range 0 -100% O_2

(d) Measures of Anaerobic capacity

(i) Measures of strength using dynamometry.

Subjects are required to provide maximal exertion for 3 seconds.

Equipment used is detailed as follows:-

Harpenden Handgrip Dynamometer, units 0-100 Kg

Takei Back & Leg Dynamometer, units 0-300 Kg

Nissen Back & Leg Dynamometer, units 50 - 1000kg x 10Kg

(ii) Measures of power using Wingate test or Cunningham speed test.

Subjects are required to cycle or run with maximal effort for between 30 and 60 seconds.

Equipment used is detailed as follows:-
Woodway treadmill ELG2
Monark Ergometer Model 90 664
Monark Ergometer Model 814E

(iii) Measures of alactic running power

Margaria-Kalamen stair test
Sprint test between infra-red light beams

Equipment used is detailed as follows:-
Pacesetter automatic telemetric timing system.
Switchmats and automatic timer.

(e) Measures of flexibility

Measurement of joint angles using goniometers or Leighton flexmeter.

Equipment used is detailed as follows:-
Leighton flexometer.
Goniometers

(f) Body temperature regulation experiments.

Body temperature is assessed during exercise under various controlled conditions. Surface probes are used to measure skin temperature. Aural probes are used to estimate core temperature and are fitted into the ear.

NB Rectal probes are never used in body temperature regulation experiments

Equipment used is detailed as follows:-
Edale Thermistors - Edale Instruments Ltd Cambridge, surface probes and aural probes.

(g) Measurements of lung volumes using spirometry

Lung volume and efficiency are measures using dynamic spirometry techniques.

All mouthpieces used are disposable and are discarded into plastic bags ewhich are sealed and disposed of as normal waste.

Equipment used is detailed as follows:-

Vitalograph Spirometer - Linearised Dry Wedge Bellows - Vitalograph Ltd, Buckingham.

References

Fraleigh, W. P. (1993). Codes of Ethics: Functions, Form and Structure, Problems and Possibilities. Quest, 45, (1), pp 13-21.

Kroll, W. (1993). Ethical Issues in Human Research. Quest, 45, (1), pp 32-44.

Berger, B.G. (1993). Ethical Issues in Clinical Settings: A Reaction to Ethics in Teaching, Advising, and Clinical services. Quest, 45, (1), pp 106-119.

Martens, R. (1993). Business, Ethics, and the Physical Activity Field. Quest, 45, (1), pp 120-132.

Rowland, T.W. (1993). Pediatric Laboratory Exercise Testing: Clinical Guidelines Human Kinetics Publishers.

Heyward, V.H. (1991). Advanced Fitness Assessment and Prescription (Second Edition). Human Kinetics Publishers.

MacDougall, Wenger and Green (1991). Physiological Testing of the High Performance Athlete. Human Kinetics.

Hale, T. et.al. (1988). Guidelines for the Assessment of the Elite Competitor. British Association of Sports Sciences.

Lohman, T. and Slaughter (1991). Anthropometric Standardisation Manual. Human Kinetics.

Liverpool John Moores University Ethics Committee Guidelines.

Appendices

(1) BASS guidelines

(2) Consent and medical history form for students.

(3) Consent form for children participating in Research experiments.

SAFETY PROCEEDURES FOR USE OF MOUTHPIECES

Mouth pieces are disinfected by soaking in Cidex, rinsed with boiled water_and put in a bucket labelled " Disinfected Mouthpieces".

The subject should collect a disinfected mouthpiece from the bucket using tongs.

Mouthpieces should be removed from the apparatus by each subject at the end of each experiment and placed in a bucket labelled "Used Mouthpieces".

Used Mouthpieces, nose clips, valves and breathing tubes are washed using a Sodium hypochlorite solution. Mouthieces are returned to soak in Cidex for 10 hours.

MISSING PAGES REMOVED ON INSTRUCTION FROM THE UNIVERSITY

Appendix 4

Correlation matrices for chronic disease risk factors - boys and girls on test occasion 1 and 2

Pearson Product Moment correlation coefficients between physiological variables - male visit 1

	Stature	Body mass	PAS (%)	Sum Skinfolds	SBP	DBP	Hgb	Total Cholesterol	HDL-C	TC.HDL-C	VO_2	Maximal heart rate	Minute ventilation	Run Time
Stature		.83*	.08	.50*	.53*	13	42*	-.46*	08	-.37**	.10	.31**	.43*	.09
Body Mass			.23	.73*	.48*	.08	.31**	-.49*	.22	-.53*	.07	.35**	.52*	-.03
PAS (%)				.16	- 13	- 14	-.24	-.24	.01	-.15	.03	.33**	04	.05
Sum Skinfolds					.38**	-.08	.30	- 33**	28	-.45*	.06	.31**	.43*	- 08
SBP						.38**	.23	-.22	.06	.19	-.07	.02	.28	-.01
DBP							-.12	.07	-.26	.24	.24	-.01	.07	.08
Hgb								-.43*	.09	-.32**	-.10	-.18	-.01	.03
Total cholesterol									.04	.59*	-.01	-.24	-.10	-.09
HDL-C										-.75*	-.18	-.28	-.05	-.45*
TC.HDL-C ratio											.05	.08	-.05	.27
VO_2												.44*	.51*	.53*
Maximal heart rate													.37**	.27
Minute ventilation														.37**
Run time														

* Significant at $p<0.01$ level
** Significant at $p<0.05$ level

Pearson Product Moment correlation coefficients between physiological variables - female visit 1

	Stature	Body mass	PAS (%)	Sum Skinfolds	SBP	DBP	Hgb	Total Cholesterol	HDL-C	TC.HDL-C	VO_2	Maximal heart rate	Minute ventilation	Run Time
Stature		78*	.57*	.15	.56*	.48*	08	- 28	-.27	05	.31	.04	.53*	.06
Body Mass			.49*	.52*	.58*	.55*	32**	- 20	-.33**	.30	.07	-.02	.48*	-.17
PAS (%)				.24	.45*	.42*	-.01	-.14	- 25	.12	.26	-.03	.32**	.03
Sum Skinfolds					.34**	47*	62*	.23	-.03	23	-.16	.03	.08	-.29
SBP						.67*	.06	.18	-.49*	.58*	.24	-.03	.47*	-.09
DBP							.45*	.12	-33**	.40*	.20	-.16	.23	-.35**
Hgb								-.01	.23	- 10	-.14	-.01	-.08	-.41*
Total cholesterol									23	.52*	-.11	-.26	-.05	-.22
HDL-C										-.70*	.03	.01	-.10	.25
TC.HDL-C ratio											-.12	-.26	-.11	-.45*
VO_2												.15	.70*	.46*
Maximal heart rate													.33**	.53*
Minute ventilation														58*
Run time														

* Significant at $p<0.01$ level
** Significant at $p<0.05$ level

Pearson Product Moment correlation coeeficients between physiological variables - male visit 2

	Stature	Body mass	PAS (%)	Sum Skinfolds	SBP	DBP	Hgb	Total Cholesterol	HDL-C	TC.HDL-C	VO_2	Maximal heart rate	Minute ventilation	Run Time
Stature		0.33**	06	50*	53*	13	42*	-.46*	08	07	-.01	.12	.63*	-.09
Body Mass			06	.81*	.40*	- 06	27	18	- 15	.23	- 09	-.08	62*	-.36**
PAS (%)				- 03	-.37**	- 41*	- 34**	- 01	23	-.10	- 18	.23	.04	.07
Sum Skinfolds					31**	12	11	-.33**	- 13	.37**	- 15	.20	.51*	-.43*
SBP						.32**	.24	.07	- 05	.05	- 16	.17	.41*	.08
DBP							.34**	27	.09	.18	-.02	.13	.06	.14
Hgb								11	-.01	.10	- 23	-.21	01	-.44*
Total cholesterol									.14	.82*	- 01	- 20	-.10	-.50*
HDL-C									-.43	02	.20	-.04	16	
TC HDL-C ratio										- 21	-.45*	- 07	-.57*	
VO_2											.18	60*	.37**	
Maximal heart rate												32**	.56*	
Minute ventilation													16	
Run time														

* Significant at p<0.01 level
** Significant at p<0.05 level

Pearson Product Moment correlation coefficients between physiological variables - female visit 2

	Stature	Body mass	PAS (%)	Sum Skinfolds	SBP	DBP	Hgb	Total Cholesterol	HDL-C	TC HDL-C	VO_2	Maximal heart rate	Minute ventilation	Run Time
Stature		.88*	.60*	41*	58*	29	12	-.41*	03	-.33**	.23	- 01	63*	-.08
Body Mass			.60*	70*	53*	14	23	- 05	.25	- 07	-.04	.02	.55*	-.22
PAS (%)				30	42*	28	- 13	- 32**	- 15	-.17	.41*	.14	.19	.04
Sum Skinfolds					41*	05	48*	- 08	- 48*	.25	-.19	.12	.25	- 30
SBP						.44*	.23	-.14	.65*	-.14	-.10	.08	.30	-.18
DBP							.23	- 11	-.06	04	.07	.21	.09	.05
Hgb								.05	-.36**	.30	.34	-.05	.19	-.05
Total cholesterol									.23	.68*	-.12	.12	-.08	.13
HDL-C										-.50*	.20	.04	-.15	-.24
TC HDL-C ratio											-.29	.01	-.10	-.08
VO_2												10	54**	.28
Maximal heart rate													.03	47*
Minute ventilation														07
Run time														

* Significant at p<0.01 level
** Significant at p<0.05 level

Appendix 5

The Physical Self Perception Profile and instructions for completion by children

Questionnaire 2.

What I Am Like

ame_____ Age_____ Grade_____ Boy / Girl

SAMPLE SENTENCE

Really True for me	Sort of True for me				Sort of True for me	Really True for me
		Example				
☐	☑	Some kids would rather play outdoors in their spare time	BUT	Other kids would rather watch T.V.	☐	☐
☐	☐	Some kids do very well at all kinds of sports	BUT	Other kids *don't* feel that they are very good when it comes to sports.	☐	☐
☐	☐	Some kids *don't* feel that they are very physically fit	BUT	Other kids feel that they always have excellent physical fitness.	☐	☐
☐	☐	Some kids feel that they have a good-looking (fit-looking) body compared to other kids	BUT	Other kids feel that compared to most, their body *doesn't* look so good.	☐	☐
☐	☐	Some kids feel that they are stronger than other kids of their age	BUT	Other kids feel that they *lack* strength compared to others of their age.	☐	☐
☐	☐	Some kids are *proud* of themselves physically	BUT	Other kids don't have much to be proud of physically.	☐	☐
☐	☐	Some kids wish they could be a lot better at sports	BUT	Other kids feel that they are good enough at sports.	☐	☐
☐	☐	Some kids try to take part in energetic physical exercise whenever they can	BUT	Other kids try to *avoid* doing energetic exercise if they can.	☐	☐

Really True for me	Sort of True for me				Sort of True for me	Really True for me
☐	☐	Some kids think that it's *hard* to keep their bodies looking fit and in good shape	BUT	Other kids find it easy to keep their bodies looking in good shape.	☐	☐
☐	☐	Some kids think that they have stronger muscles than other kids their age	BUT	Other kids feel that they have weaker muscles than other kids their age.	☐	☐
☐	☐	Some kids are *happy* with how they are and what they can do physically	BUT	Other kids are *unhappy* with how they are and what they can do physically.	☐	☐
☐	☐	Some kids think they could do well at just about any new sports activity they haven't tried before	BUT	Other kids are afraid they might *not* do well at sports they haven't ever tried.	☐	☐
☐	☐	Some kids *don't* usually have much fitness and endurance	BUT	Other kids always have lots of fitness and endurance.	☐	☐
☐	☐	Some kids think that their bodies *don't* look so good in just shorts and a T-shirt	BUT	Other kids feel that their body looks fine dressed in just shorts and a T-shirt.	☐	☐
☐	☐	When strong muscles are needed, some kids are the *first* to step forward	BUT	Other kids are the *last* to step forward when strong muscles are needed.	☐	☐
☐	☐	Some kids *don't* feel very confident about themselves physically	BUT	Other kids really feel good about themselves physically.	☐	☐
☐	☐	Some kids feel that they are *better* than others their age at sports	BUT	Other kids *don't* feel they can play so well.	☐	☐
☐	☐	Some kids feel *uneasy* when it comes to exercising for fitness	BUT	Other kids feel confident when it comes to doing fitness exercises.	☐	☐
☐	☐	Some kids feel that they are *often* admired for their fit, good-looking bodies	BUT	Other kids feel that they are *rarely* admired for the way their bodies look.	☐	☐

Really True for me	Sort of True for me				Sort of True for me	Really True for me
☐	☐	Some kids *lack* confidence when it comes to strength activities	BUT	Other kids are very confident when it comes to strength activities.	☐	☐
☐	☐	Some kids have a positive feeling about themselves physically	BUT	Other kids feel somewhat negative about themselves physically.	☐	☐
☐	☐	In games and sports some kids usually *watch* instead of play	BUT	Other kids usually *play* rather than just watch.	☐	☐
☐	☐	Some kids feel confident about being able to do enough exercise to stay very fit	BUT	Other kids *don't* feel at all confident about doing enough exercise to keep fit.	☐	☐
☐	☐	Some kids think that compared to others their bodies *don't* look in good shape physically	BUT	Other kids feel that their bodies look in great shape compared to others.	☐	☐
☐	☐	Some kids think that they are strong, and have good muscles compared to other kids their age	BUT	Other kids feel that they are weaker, and *don't* have such good muscles as other kids their age.	☐	☐
☐	☐	Some kids wish that they could feel better about themselves physically	BUT	Other kids *always* seem to feel good about themselves physically.	☐	☐
☐	☐	Some kids *don't* do well at new outdoor games	BUT	Other kids are good at new games right away.	☐	☐
☐	☐	Some kids think that they can always do more exercise than other kids their age	BUT	Other kids feel that they *couldn't* do as much exercise as other kids their age.	☐	☐
☐	☐	Some kids are very *happy* about the appearance of their bodies	BUT	Other kids wish that their bodies looked in better shape.	☐	☐
☐	☐	Some kids feel that they are *not* as good as others when physical strength is needed	BUT	Other kids feel that they are among the *best* when physical strength is needed.	☐	☐
☐	☐	Some kids are very *satisfied* with themselves physically	BUT	Other kids are often *dissatisfied* with themselves physically.	☐	☐

	Really True for me	Sort of True for me				Sort of True for me	Really True for m
1.	☐	☐	Some kids are often *unhappy* with themselves	BUT	Other kids are pretty *pleased* with themselves.	☐	☐
2.	☐	☐	Some kids *don't* like the way they are leading their life	BUT	Other kids *do* like the way they are leading their life.	☐	☐
3.	☐	☐	Some kids are *happy* with themselves as a person	BUT	Other kids are often *not* happy with themselves.	☐	☐
4.	☐	☐	Some kids *like* the kind of person they are	BUT	Other kids often wish they were someone else.	☐	☐
5.	☐	☐	Some kids are very *happy* being the way they are	BUT	Other kids wish they were *different*.	☐	☐
6.	☐	☐	Some kids are *not* very happy with the way they do a lot of things	BUT	Other kids think the way they do things is *fine*.	☐	☐
	☐	☐	Some kids have really enjoyed their hand-ball lessons	BUT	Other kids didn't like playing handball much at all	☐	☐
	☐	☐	Some kids really liked their handball teacher	BUT	Other kids didn't like the handball teacher much	☐	☐
	☐	☐	Some kids don't like taking part in PE lessons	BUT	Other kids really love taking part in PE lessons	☐	☐
	☐	☐	Some kids enjoy playing all kinds of sports	BUT	Other kids don't enjoy playing sports much at all	☐	☐

HOW IMPORTANT ARE THESE THINGS TO HOW YOU FEEL ABOUT YOURSELF AS A PERSON?

Really True for me	Sort of True for me			Sort of True for me	Really True for me
☐	☐	Some kids think it's important to be good at sports	BUT	Other kids *don't* think how good you are at sports is that important.	☐ ☐
☐	☐	Some kids *don't* think that being well trained for fitness and endurance is important to how they feel about themselves	BUT	Other kids think that being well trained for fitness and endurance is *very* important.	☐ ☐
☐	☐	Some kids think it's important to have a good looking (fit looking) body in order to feel good about themselves	BUT	Other kids *don't* think that having a good looking body is very important at all.	☐ ☐
☐	☐	Some kids feel that being physically strong is *not* all that important to how they feel about themselves as a person	BUT	Other kids feel that it's *very* important to be physically strong.	☐ ☐
☐	☐	Some kids *don't* think doing well at athletics is that important to how they feel about themselves as a person	BUT	Other kids feel that doing well at athletics is important.	☐ ☐
☐	☐	Some kids think that having the ability to do lots of vigorous exercise is very important to how they feel about themselves	BUT	Other kids *don't* feel it's all that important to be able to do lots of vigorous exercise.	☐ ☐
☐	☐	Some kids *don't* think that having a body which looks in good physical shape is very important to how they feel about themselves as a person	BUT	Other kids feel that it's *very* important to keep their bodies looking in good physical shape.	☐ ☐
☐	☐	Some kids think that having strong muscles is *very* important to how they feel about themselves	BUT	Other kids feel that it's *not* all that important to have strong muscles.	☐ ☐

Instructions for completion of children's questionnaires.

These questionnaires will tell us about how you feel about physical activities, sports and yourselves. All your answers will be stored confidentially.

Questionnaire 1

1. The question will ask your feelings about physical activities.

2. Answer by circling the number (one to five) which most suits you.
One is for you not agreeing with the question, five is for totally agreeing with the question.

3. Only fill in one answer for each question.

4. Once you have completed the questionnaire please put your name and date of birth on the back.

Questionnaire 2

1. The question will consist of two separate statements asking about activities.

2. Choose one statement which best tells us about yourself.

3. Decide whether the statement is really true for you or only sort of true for you and tick the box, (the questionnaire has an example for you.

4. Please tick only one box for each question, and don't forget to write your name and address on the top of each questionnaire.

Thank you very much for completing these questionnaires.

Appendix 6

Questionnaire to assess the socio-economic status of the head of children's household, using the Registrar General 5-tier classification

Parents questionnaire 1

Classification of Employment of Head of Household
(all information contained herein will be treated in strictest confidence)

Job Title/Occupation .....

Manual or non-manual occupation .....

Self-employed **Yes / No**

(If YES please state with or without employees) **With / Without**

2. Would you agree to a tester attending your home to assess the height of biological parents: YES/NO

If YES please give your telephone number and a guide as to when parents would be available

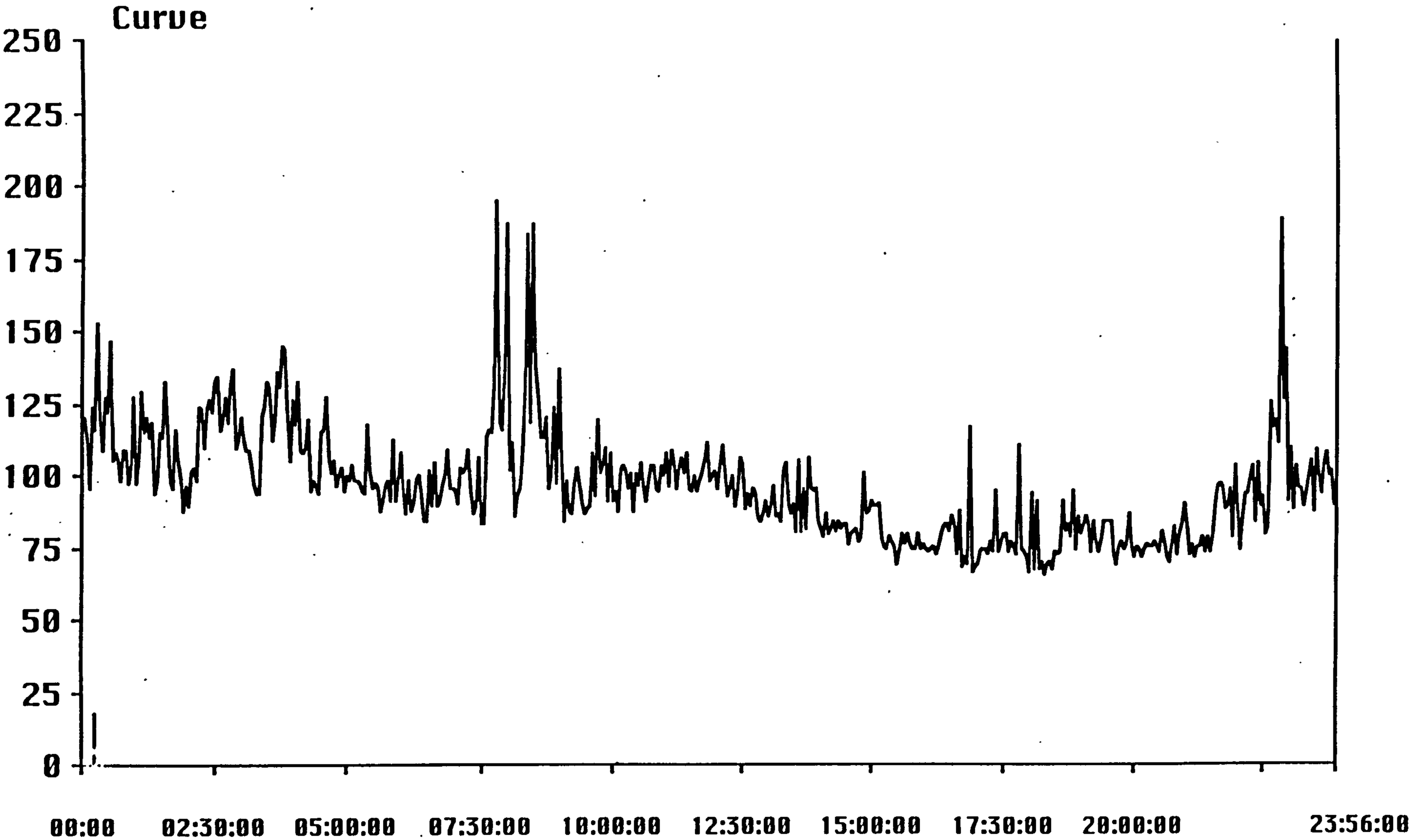
TEL:..... Suitable times .....

If NO please could you state the approximate height of parents

.....

Appendix 7

Sample 24-hour heart rate/time curve generated using Polar Version 4.0 Software (Polar, Kempele, Finland)


Curve
250
225
200
175
150
125
100
75
50
25
0
00:00
02:30:00
05:00:00
07:30:00
10:00:00
12:30:00
15:00:00
17:30:00
20:00:00
23:56:00

Appendix 8

Copy of raw data for physiological measurements generated using Minitab Software

	ID	Gender	Visit no	Ht	Wt	PAS	SSF	SBP	DBP	TC	HDL	VO2ADJ	HGB	CUN139
1	1	1	1	134.0	34.50	82	28.4	105	60	4.11	1.44	50	*	44
2	1	1	2	*	*	*	*	*	*	*	*	*	*	*
3	2	1	1	134.0	29.90	87	20.9	100	65	2.79	0.67	56	*	*
4	2	1	2	*	*	*	*	*	*	*	*	*	*	*
5	3	1	1	142.0	33.90	81	30.1	88	65	4.58	1.00	71	139	*
6	3	1	2	145.5	35.50	83	37.1	120	78	5.01	1.10	108	128	*
7	4	1	1	140.0	30.50	81	30.6	102	60	3.59	0.67	49	132	*
8	4	1	2	144.0	39.50	85	38.3	112	73	4.38	0.95	71	132	*
9	5	1	1	135.0	26.00	80	23.1	88	55	3.44	1.03	46	134	*
10	5	1	2	142.0	30.10	84	23.0	104	62	4.64	1.02	79	138	30
11	6	1	1	141.5	33.00	82	21.2	120	65	4.86	1.02	41	122	72
12	6	1	2	145.5	35.10	86	20.9	114	80	5.07	1.32	109	122	110
13	7	1	1	136.0	32.00	79	32.4	112	68	4.33	0.94	69	128	13
14	7	1	2	141.5	34.50	81	29.6	119	69	3.00	0.91	100	130	*
15	8	1	1	133.0	34.00	85	22.5	86	59	*	*	48	*	*
16	8	1	2	140.5	36.60	89	25.7	99	71	*	*	93	*	33
17	9	1	1	135.5	39.50	87	39.8	102	61	3.65	1.14	57	117	42
18	9	1	2	139.0	38.20	90	48.4	111	70	3.22	1.22	91	120	80
19	10	1	1	142.5	40.00	81	36.6	102	59	3.88	1.05	86	119	37
20	10	1	2	147.5	46.70	86	43.3	113	69	5.01	0.89	93	118	*
21	11	1	1	146.5	35.50	81	33.5	103	60	*	*	59	*	*
22	11	1	2	*	*	*	*	*	*	*	*	*	*	*
23	12	1	1	143.8	33.20	83	22.4	107	63	4.37	1.05	55	*	*
24	12	1	2	*	*	*	*	*	*	*	*	*	*	*
25	13	1	1	146.0	35.00	83	22.5	105	62	3.81	1.49	56	139	128
26	13	1	2	148.0	34.50	86	27.9	117	72	5.07	1.20	107	136	40
27	14	1	1	145.0	36.70	85	21.4	100	52	4.10	1.00	73	110	*
28	14	1	2	147.5	41.20	88	32.4	98	70	5.08	0.93	124	112	*
29	15	1	1	140.5	30.00	88	37.9	102	65	4.47	0.79	74	119	*
30	15	1	2	147.0	38.00	91	37.4	118	72	4.68	1.08	99	117	*
31	16	1	1	137.0	27.00	83	24.3	103	51	4.52	1.10	64	113	7
32	16	1	2	143.5	31.00	86	26.9	110	65	4.16	0.77	84	115	26
33	17	1	1	138.0	33.80	83	44.1	112	59	4.27	1.17	56	130	131
34	17	1	2	145.0	39.00	87	49.6	116	68	5.01	1.02	80	124	*
35	18	1	1	156.0	47.50	88	46.2	117	54	3.37	1.10	69	141	215
36	18	1	2	157.0	47.80	91	44.3	112	68	3.61	0.98	105	130	74
37	19	1	1	143.0	30.50	87	17.5	103	54	4.01	0.85	76	136	*
38	19	1	2	146.5	33.80	92	25.0	109	68	4.04	1.02	109	121	*
39	20	1	1	150.5	36.00	87	25.1	119	63	3.20	0.78	58	133	*
40	20	1	2	156.5	37.70	88	17.3	122	69	4.35	0.95	90	129	*
41	21	1	1	133.5	33.00	92	20.4	89	73	*	*	53	*	39
42	21	1	2	138.5	34.85	96	33.7	113	77	5.14	0.84	76	*	*

	ID	Gender	Visit no	Ht	Wt	PAS	SSF	SBP	DBP	TC	HDL	VO2ADJ	HGB	CUM139
43	22	1	1	152.0	38.30	88	25.6	101	59	3.65	1.25	62	*	77
44	22	1	2	*	*	*	*	*	*	*	*	*	*	*
45	23	1	1	156.4	43.00	82	38.6	111	60	*	0.85	52	*	10
46	23	1	2	*	*	*	*	*	*	*	*	*	*	*
47	24	1	1	144.0	31.00	76	18.0	107	69	*	*	81	*	13
48	24	1	2	*	*	*	*	*	*	*	*	*	*	7
49	25	1	1	135.0	26.00	77	28.8	95	59	4.31	1.00	66	121	*
50	25	1	2	147.5	35.00	80	32.5	117	71	4.00	1.10	104	119	*
51	26	1	1	135.0	32.00	90	28.8	96	58	4.67	0.90	57	125	20
52	26	1	2	140.0	35.50	95	23.2	103	62	2.88	1.79	52	122	17
53	27	1	1	144.5	37.00	91	36.6	108	61	2.61	1.40	118	127	39
54	27	1	2	156.5	48.00	95	38.1	115	57	3.66	1.31	58	117	*
55	28	1	1	144.3	36.00	89	29.0	105	66	4.42	0.98	88	127	*
56	28	1	2	152.5	39.00	95	28.6	126	81	4.20	1.16	65	129	*
57	29	1	1	156.5	41.20	92	37.0	105	61	3.59	1.10	90	119	14
58	29	1	2	162.0	48.90	96	47.2	109	68	2.69	1.14	66	116	19
59	30	1	1	166.0	46.50	85	36.4	103	65	2.89	0.82	93	140	*
60	30	1	2	173.5	51.50	89	47.2	110	69	2.65	0.71	62	147	*
61	31	1	1	159.5	60.80	80	45.4	121	61	4.32	1.01	110	148	*
62	31	1	2	168.5	69.50	81	65.4	129	64	3.02	0.84	48	148	*
63	32	1	1	143.0	52.00	86	59.8	113	56	3.89	1.36	74	125	24
64	32	1	2	148.5	62.00	88	46.4	112	63	4.40	1.02	59	128	73
65	33	1	1	142.0	33.50	78	19.4	102	73	3.51	0.96	96	125	26
66	33	1	2	148.5	37.50	82	25.1	117	73	3.40	0.83	94	129	37
67	34	1	1	151.5	40.00	91	33.8	95	62	3.83	0.98	89	125	14
68	34	1	2	167.5	42.70	95	32.3	109	77	4.50	1.20	51	134	*
69	35	1	1	142.0	45.00	91	31.0	100	61	3.82	1.00	83	*	*
70	35	1	2	146.5	53.50	95	28.8	112	69	*	*	46	*	*
71	36	1	1	142.0	30.80	80	15.3	101	63	3.23	1.18	79	125	13
72	36	1	2	145.0	32.40	86	22.6	110	66	3.57	1.00	65	125	91
73	37	1	1	149.0	31.50	89	16.7	98	58	4.00	0.78	93	133	*
74	37	1	2	163.0	32.50	94	24.5	105	80	*	*	49	131	*
75	38	1	1	146.5	54.10	87	48.7	111	68	7.90	1.10	71	*	*
76	38	1	2	151.5	68.60	92	79.1	134	79	3.22	0.99	57	*	*
77	39	2	1	138.0	34.80	81	47.4	99	61	*	*	*	*	57
78	39	2	2	*	*	*	*	*	*	*	*	*	*	8
79	40	2	1	131.0	29.50	76	29.2	99	59	*	*	*	*	*
80	40	2	2	*	*	*	*	*	*	4.08	1.38	50	135	*
81	41	2	1	132.0	29.50	76	35.6	90	69	5.97	1.20	99	132	71
82	41	2	2	139.5	32.50	79	35.5	120	75	4.07	1.00	51	141	17
83	42	2	1	158.0	33.20	77	48.5	109	65	3.80	0.88	105	142	*
[illegible]	[illegible]	2	2	164.0	34.00	80	55.8	118	72	3.15	1.15	61	122	*

	ID	Gender	Visit no	Ht	Wt	PAS	SSP	SBP	DBP	TC	HDL	VO2ADJ	HGB	CUH139
85	43	2	1	131.0	45.00	78	34.7	109	57	3.70	1.67	112	126	*
86	43	2	2	134.0	46.30	86	35.7	116	64	4.56	1.35	60	125	*
87	44	2	1	138.5	28.80	77	36.2	88	52	5.88	1.10	96	128	65
88	44	2	2	142.0	32.40	80	47.3	97	63	4.10	0.98	59	121	22
89	45	2	1	148.0	28.20	72	36.5	103	56	4.87	1.44	107	123	197
90	45	2	2	155.0	30.00	78	31.2	108	65	3.54	0.76	61	127	16
91	46	2	1	135.0	43.00	80	22.5	108	68	4.91	1.05	105	128	*
92	46	2	2	141.5	49.00	86	60.3	112	65	4.50	0.92	67	112	*
93	47	2	1	135.2	29.50	79	44.8	117	61	5.30	1.17	100	119	76
94	47	2	2	143.0	36.30	82	47.0	129	76	4.32	1.12	59	114	74
95	48	2	1	124.5	27.00	83	36.8	110	63	3.50	1.29	109	114	*
96	48	2	2	126.0	31.40	85	22.9	121	72	*	*	49	*	*
97	49	2	1	130.0	23.00	72	24.8	97	59	2.44	1.00	86	*	43
98	49	2	2	134.0	24.50	79	31.7	100	67	3.21	1.10	51	115	65
99	50	2	1	137.5	27.80	80	30.1	103	59	3.73	1.04	84	121	51
100	50	2	2	145.5	29.70	82	29.8	110	63	*	*	56	*	77
101	51	2	1	143.0	46.00	80	48.5	88	57	3.59	0.92	92	*	115
102	51	2	2	148.0	50.50	83	72.3	98	73	4.47	1.15	57	133	*
103	52	2	1	130.0	37.00	79	52.8	130	61	5.53	1.20	95	133	*
104	52	2	2	137.0	43.70	83	52.8	120	80	*	*	50	*	*
105	53	2	1	132.0	33.10	78	44.4	88	60	*	*	49	*	37
106	53	2	2	*	*	*	*	*	*	*	*	*	*	*
107	54	2	1	150.0	28.50	79	33.3	130	63	*	*	59	*	*
108	54	2	2	*	*	*	*	*	*	*	*	*	*	*
109	55	2	1	136.0	36.50	77	42.0	101	71	*	*	49	*	*
110	55	2	2	*	*	*	*	*	*	*	*	*	*	*
111	56	2	1	134.0	35.50	81	50.6	97	65	*	*	58	130	61
112	56	2	2	142.5	37.20	84	47.2	100	76	3.56	0.88	123	132	*
113	57	2	1	137.0	31.50	77	34.0	120	58	4.43	0.98	58	*	*
114	57	2	2	148.0	36.80	79	45.0	123	71	3.47	1.14	108	*	*
115	58	2	1	149.0	32.00	80	34.0	104	66	*	*	57	138	24
116	58	2	2	154.5	41.00	82	37.8	105	75	3.92	1.24	97	142	24
117	59	2	1	157.5	42.90	83	66.0	102	73	2.79	0.91	71	129	7
118	59	2	2	161.0	49.90	88	54.9	121	82	3.51	1.13	125	134	54
119	60	2	1	147.0	43.50	83	43.6	117	57	2.90	1.04	64	127	219
120	60	2	2	149.0	54.50	86	63.0	107	70	4.26	1.18	138	124	96
121	61	2	1	147.0	34.50	79	26.0	117	62	4.13	1.12	62	116	54
122	61	2	2	149.5	37.75	81	33.0	115	70	3.58	1.08	100	114	79
123	62	2	1	152.0	34.50	83	28.8	125	60	6.07	1.70	57	129	*
124	62	2	2	159.5	39.80	87	36.5	95	62	4.10	1.10	121	131	*
125	63	2	1	154.0	38.00	86	26.1	99	68	3.76	1.23	32	134	19
126	63	2	2	162.5	42.00	89	30.2	103	72	4.23	0.97	74	132	106

	ID	Gender	Visit no	Ht	Wt	PAS	SSF	SBP	DBP	TC	HDL	VO2ADJ	HGB	CUM139
127	64	2	1	158.0	57.60	84	60.4	104	67	4.88	0.80	46	116	37
128	64	2	2	162.0	64.10	89	72.2	97	70	3.41	0.77	105	131	3
129	65	2	1	158.0	45.30	85	40.2	100	70	3.50	0.98	58	113	*
130	65	2	2	165.0	55.70	90	77.8	105	60	3.59	0.84	77	130	*
131	66	2	1	136.0	44.80	81	29.0	110	57	*	*	58	*	*
132	66	2	2	*	*	*	*	*	*	*	*	*	*	*
133	67	2	1	140.0	27.70	80	25.1	103	76	*	*	38	*	13
134	67	2	2	*	*	*	*	*	*	*	*	*	*	116
135	68	2	1	146.5	29.40	82	21.2	104	64	5.10	0.80	60	*	*
136	68	2	2	*	*	*	*	*	*	*	*	*	*	*
137	69	2	1	135.0	55.30	81	63.8	103	70	4.00	1.00	49	*	*
138	69	2	2	*	*	*	*	*	*	*	*	*	*	*
139	70	2	1	134.0	29.50	85	41.2	103	64	4.12	1.26	53	*	28
140	70	2	2	*	*	*	*	*	*	*	*	*	*	8
141	71	2	1	148.0	32.50	81	32.7	112	64	3.18	0.77	53	111	19
142	71	2	2	155.0	35.00	86	44.2	114	70	3.26	0.80	51	113	*
143	72	2	1	150.5	36.00	87	30.0	92	72	4.32	0.90	61	136	40
144	72	2	2	157.0	41.60	89	29.0	126	80	3.89	*	102	125	0
145	73	2	1	148.0	43.60	83	43.8	105	79	3.42	1.02	90	*	41
146	73	2	2	156.0	49.80	87	36.0	113	79	2.92	0.98	142	*	6
147	74	2	1	152.0	40.40	85	34.0	111	76	3.33	*	65	110	10
148	74	2	2	157.0	47.80	90	44.1	116	67	5.62	0.70	118	123	*
149	75	2	1	148.2	44.30	86	49.9	101	68	3.68	0.96	79	*	*
150	75	2	2	155.5	50.00	89	54.0	100	65	3.00	1.17	106	141	17
151	76	2	1	156.0	38.00	83	45.3	105	77	3.45	0.78	69	136	17
152	76	2	2	162.0	46.00	86	39.2	115	71	*	1.12	119	124	38
153	77	2	1	156.0	49.20	84	35.2	103	79	3.96	0.91	42	123	*

	CUH60	CUH75	TCHDL
1	38	10	2.85417
2	*	*	*
3	*	*	4.16418
4	*	*	*
5	*	*	4.58000
6	*	*	4.55455
7	*	*	5.35821
8	*	*	4.61053
9	*	*	3.33981
10	27	6	4.54902
11	64	0	4.76471
12	97	16	3.84091
13	9	0	4.60638
14	*	*	3.29670
15	*	*	*
16	28	4	*
17	35	0	3.20175
18	70	27	2.63934
19	36	9	3.69524
20	*	*	5.62921
21	*	*	*
22	*	*	*
23	*	*	4.16190
24	*	*	*
25	113	61	2.55705
26	20	9	4.22500
27	*	*	4.10000
28	*	*	5.46237
29	*	*	5.65823
30	*	*	4.33333
31	1	0	4.10909
32	13	0	5.40260
33	92	13	3.64957
34	*	*	4.91177
35	166	67	3.06364
36	66	34	3.68367
37	*	*	4.71765
38	*	*	3.96078
39	*	*	4.10256
40	*	*	4.57895
41	21	4	*
42	*	*	6.11905

	CUM60	CUM75	TCHDL
43	43	1	2.92000
44	*	*	*
45	2	0	*
46	*	*	*
47	10	0	*
48	7	0	*
49	*	*	4.31000
50	*	*	3.63636
51	17	6	5.18889
52	15	0	1.67909
53	33	7	1.86429
54	*	*	2.79389
55	*	*	4.51020
56	*	*	3.62069
57	11	0	3.26364
58	15	0	2.35965
59	*	*	3.52439
60	*	*	3.73239
61	*	*	4.27723
62	*	*	3.59524
63	17	0	2.86029
64	60	20	4.31373
65	20	1	3.65625
66	29	10	4.09639
67	11	4	3.90816
68	*	*	3.75000
69	*	*	3.82000
70	*	*	*
71	8	0	2.73729
72	85	0	3.57000
73	*	*	5.12821
74	*	*	*
75	*	*	7.18182
76	*	*	3.25253
77	46	6	*
78	5	0	*
79	*	*	*
80	*	*	2.95652
81	46	7	4.97500
82	21	0	4.07000
83	*	*	4.31818
84	*	*	2.73913

	CU160	CU175	TCHDL
85	*	*	2.21557
86	*	*	3.37778
87	48	15	5.34545
88	9	0	4.18367
89	165	46	3.38194
90	14	6	4.65789
91	*	*	4.67619
92	*	*	4.89130
93	56	9	4.52991
94	54	10	3.85714
95	*	*	2.71318
96	*	*	*
97	31	15	2.44000
98	36	1	2.91818
99	40	7	3.58654
100	52	9	*
101	81	21	3.90217
102	*	*	3.88696
103	*	*	4.60833
104	*	*	*
105	18	1	*
106	*	*	4.32353
107	*	*	*
108	*	*	*
109	*	*	*
110	*	*	*
111	50	13	*
112	*	*	4.04545
113	*	*	4.52041
114	*	*	3.04386
115	18	9	*
116	19	2	3.16129
117	2	0	3.06593
118	47	19	3.10619
119	136	30	2.78846
120	67	18	3.61017
121	33	6	3.68750
122	55	22	3.31481
123	*	*	3.57059
124	*	*	3.72727
125	13	0	3.05691
126	73	7	4.36082

	CUM60	CUM75	TCHDL
127	26	1	6.10000
128	1	0	4.42857
129	*	*	3.57143
130	*	*	4.27381
131	*	*	*
132	*	*	*
133	9	5	*
134	95	17	*
135	*	*	6.37500
136	*	*	*
137	*	*	4.00000
138	*	*	*
139	15	3	3.26984
140	5	0	*
141	12	0	4.12987
142	*	*	4.07500
143	32	5	4.80000
144	0	0	*
145	31	4	3.35294
146	27	10	2.97959
147	4	0	*
148	7	0	8.02857
149	*	*	3.83333
150	11	4	2.56410
151	30	10	4.42308
152	0	0	*
153	*	*	4.35165

Appendix 9

Copy of raw data for psychological measurements generated using SPSS/PC+ Software

	id	age1	sc1	pc1	ab1	st1	ps1	sc2	pc2	ab2	st2	ps2
1	1.00	10.00	1.00	1.00	3.00	3.00	4.00	4.00	1.00	4.00	2.00	4.00
2	2.00	9.00	1.00	1.00	4.00	4.00	3.00	4.00	1.00	4.00	4.00	4.00
3	3.00	11.00	1.00	1.00	4.00	4.00	3.00	4.00	1.00	4.00	4.00	3.00
4	4.00	11.00	1.00	1.00	2.00	4.00	4.00	4.00	4.00	4.00	1.00	4.00
5	5.00	11.00	1.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
6	6.00	9.00	1.00	2.00	3.00	4.00	3.00	3.00	1.00	3.00	4.00	3.00
7	7.00	11.00	1.00	2.00	4.00	3.00	2.00	3.00	2.00	4.00	4.00	3.00
8	8.00	11.00	1.00	2.00	2.00	3.00	3.00	3.00	1.00	4.00	2.00	2.00
9	9.00	10.00	1.00	2.00	3.00	2.00	2.00	3.00	3.00	3.00	3.00	2.00
10	10.00	11.00	1.00	1.00	3.00	4.00	4.00	2.00	4.00	4.00	3.00	3.00
11	11.00	9.00	1.00	2.00	3.00	3.00	3.00	4.00	1.00	4.00	4.00	3.00
12	12.00	9.00	1.00	1.00	2.00	2.00	2.00	3.00	1.00	3.00	1.00	1.00
13	13.00	9.00	1.00	2.00	3.00	3.00	2.00	3.00	2.00	4.00	3.00	2.00
14	14.00	9.00	1.00	2.00	4.00	4.00	4.00	4.00	1.00	4.00	3.00	3.00
15	15.00	9.00	1.00	1.00	3.00	4.00	2.00	1.00	1.00	1.00	3.00	2.00
16	16.00	9.00	1.00	2.00	2.00	1.00	4.00	3.00	2.00	1.00	4.00	3.00
17	17.00	9.00	1.00	1.00	2.00	3.00	3.00	4.00	4.00	3.00	1.00	4.00
18	18.00	9.00	1.00	2.00	1.00	3.00	2.00	4.00	2.00	2.00	1.00	4.00
19	19.00	10.00	1.00	2.00	2.00	4.00	4.00	4.00	1.00	2.00	4.00	3.00
20	20.00	10.00	1.00	1.00	2.00	2.00	4.00	4.00	1.00	4.00	4.00	3.00
21	21.00	10.00	1.00	1.00	4.00	3.00	3.00	4.00	4.00	4.00	3.00	4.00
22	22.00	11.00	1.00	1.00	2.00	3.00	4.00	3.00	2.00	4.00	3.00	3.00

	sc3	pc3	ab3	st3	ps3	sc4	pc4	ab4	st4	ps4	sc5	pc5
1	1.00	1.00	3.00	3.00	4.00	4.00	3.00	3.00	3.00	4.00	4.00	4.00
2	2.00	2.00	3.00	3.00	4.00	4.00	3.00	4.00	2.00	4.00	4.00	4.00
3	1.00	1.00	4.00	4.00	4.00	4.00	3.00	4.00	2.00	4.00	4.00	4.00
4	1.00	2.00	4.00	1.00	2.00	4.00	2.00	2.00	3.00	4.00	2.00	4.00
5	2.00	2.00	3.00	3.00	3.00	4.00	4.00	4.00	1.00	4.00	3.00	4.00
6	1.00	2.00	3.00	4.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	4.00
7	1.00	2.00	4.00	3.00	3.00	3.00	3.00	4.00	2.00	3.00	3.00	4.00
8	2.00	2.00	3.00	4.00	3.00	3.00	3.00	4.00	2.00	3.00	3.00	4.00
9	2.00	1.00	3.00	4.00	1.00	3.00	2.00	3.00	2.00	3.00	3.00	2.00
10	1.00	1.00	4.00	3.00	3.00	4.00	4.00	3.00	3.00	4.00	4.00	4.00
11	1.00	2.00	4.00	4.00	3.00	4.00	3.00	4.00	3.00	3.00	3.00	4.00
12	1.00	2.00	2.00	4.00	2.00	4.00	3.00	4.00	2.00	4.00	3.00	4.00
13	2.00	2.00	3.00	3.00	2.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00
14	1.00	2.00	4.00	3.00	4.00	4.00	3.00	3.00	3.00	3.00	4.00	4.00
15	3.00	4.00	3.00	2.00	2.00	3.00	2.00	2.00	3.00	2.00	3.00	1.00
16	2.00	4.00	4.00	2.00	3.00	4.00	2.00	4.00	1.00	3.00	2.00	2.00
17	2.00	1.00	1.00	2.00	3.00	2.00	3.00	1.00	4.00	1.00	3.00	1.00
18	2.00	4.00	2.00	2.00	3.00	2.00	4.00	2.00	1.00	1.00	2.00	4.00
19	1.00	4.00	2.00	2.00	2.00	2.00	3.00	1.00	1.00	2.00	4.00	1.00
20	1.00	2.00	4.00	2.00	3.00	4.00	3.00	4.00	2.00	4.00	4.00	4.00
21	1.00	2.00	4.00	3.00	3.00	4.00	4.00	4.00	3.00	4.00	4.00	4.00
22	1.00	2.00	4.00	2.00	3.00	3.00	3.00	1.00	1.00	4.00	4.00	4.00

	ab5	st5	ps5	sc6	pc6	ab6	st6	ps6	sc21	pc21	ab21	st21
1	4.00	3.00	4.00	4.00	1.00	4.00	3.00	4.00	1.00	3.00	3.00	4.00
2	4.00	4.00	4.00	4.00	1.00	4.00	4.00	3.00	1.00	4.00	4.00	4.00
3	4.00	3.00	3.00	4.00	1.00	3.00	4.00	4.00	1.00	4.00	4.00	3.00
4	4.00	2.00	4.00	2.00	2.00	4.00	2.00	1.00	1.00	2.00	4.00	4.00
5	3.00	3.00	3.00	3.00	2.00	4.00	3.00	3.00	2.00	3.00	3.00	3.00
6	3.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	4.00	3.00
7	3.00	3.00	3.00	3.00	1.00	3.00	3.00	4.00	2.00	3.00	4.00	2.00
8	3.00	2.00	3.00	2.00	2.00	2.00	2.00	3.00	2.00	2.00	3.00	2.00
9	4.00	3.00	2.00	2.00	2.00	3.00	3.00	2.00	2.00	2.00	2.00	4.00
10	3.00	3.00	3.00	3.00	1.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00
11	3.00	4.00	3.00	4.00	2.00	4.00	3.00	4.00	.	.	.	.
12	3.00	2.00	3.00	3.00	3.00	3.00	2.00	2.00	4.00	1.00	1.00	1.00
13	3.00	3.00	2.00	3.00	2.00	3.00	3.00	2.00	1.00	4.00	4.00	4.00
14	4.00	3.00	3.00	4.00	1.00	3.00	4.00	4.00	1.00	3.00	2.00	2.00
15	4.00	2.00	3.00	2.00	3.00	4.00	3.00	2.00	1.00	3.00	3.00	3.00
16	2.00	3.00	2.00	2.00	3.00	1.00	4.00	3.00	2.00	2.00	1.00	4.00
17	4.00	2.00	3.00	2.00	3.00	4.00	3.00	1.00	1.00	2.00	3.00	4.00
18	4.00	2.00	4.00	2.00	4.00	3.00	3.00	2.00	2.00	1.00	3.00	2.00
19	2.00	4.00	3.00	4.00	1.00	3.00	2.00	3.00	2.00	2.00	4.00	4.00
20	4.00	3.00	3.00	4.00	2.00	2.00	3.00	3.00	1.00	2.00	2.00	4.00
21	4.00	3.00	3.00	4.00	2.00	3.00	4.00	3.00	1.00	4.00	3.00	3.00
22	4.00	3.00	3.00	3.00	1.00	3.00	3.00	3.00	2.00	3.00	2.00	2.00

c:\psppcom.sav

	ps21	sc22	pc22	ab22	st22	ps22	sc23	pc23	ab23	st23	ps23	sc24
1	4.00	1.00	4.00	2.00	4.00	1.00	1.00	3.00	3.00	4.00	4.00	3.00
2	4.00	1.00	4.00	4.00	3.00	1.00	1.00	4.00	4.00	4.00	4.00	3.00
3	4.00	1.00	4.00	4.00	3.00	1.00	1.00	4.00	4.00	4.00	4.00	3.00
4	4.00	4.00	4.00	1.00	4.00	1.00	2.00	4.00	1.00	2.00	4.00	2.00
5	3.00	2.00	4.00	3.00	3.00	2.00	2.00	3.00	3.00	3.00	3.00	3.00
6	3.00	1.00	3.00	4.00	3.00	1.00	2.00	3.00	4.00	3.00	3.00	3.00
7	3.00	2.00	3.00	3.00	4.00	2.00	3.00	4.00	4.00	4.00	4.00	4.00
8	2.00	2.00	4.00	3.00	2.00	2.00	1.00	2.00	4.00	3.00	3.00	3.00
9	3.00	4.00	4.00	4.00	3.00	3.00	2.00	3.00	3.00	2.00	2.00	2.00
10	3.00	2.00	4.00	3.00	3.00	2.00	2.00	3.00	3.00	3.00	3.00	3.00
11	.	.	.	.	.	.	.	.	.	.	.	.
12	1.00	4.00	1.00	1.00	1.00	4.00	4.00	3.00	2.00	1.00	1.00	2.00
13	4.00	1.00	4.00	4.00	4.00	1.00	4.00	4.00	4.00	4.00	4.00	4.00
14	4.00	1.00	4.00	4.00	3.00	1.00	2.00	4.00	4.00	3.00	4.00	4.00
15	2.00	2.00	2.00	2.00	3.00	2.00	4.00	3.00	3.00	2.00	3.00	2.00
16	3.00	2.00	1.00	4.00	3.00	2.00	4.00	4.00	2.00	3.00	4.00	2.00
17	3.00	4.00	4.00	1.00	3.00	1.00	2.00	4.00	2.00	1.00	1.00	1.00
18	4.00	2.00	2.00	1.00	4.00	2.00	4.00	2.00	2.00	3.00	2.00	4.00
19	4.00	1.00	2.00	4.00	3.00	1.00	4.00	2.00	2.00	2.00	2.00	3.00
20	4.00	1.00	4.00	4.00	3.00	1.00	2.00	4.00	2.00	3.00	4.00	3.00
21	3.00	4.00	4.00	4.00	3.00	3.00	1.00	.	3.00	4.00	3.00	3 00
22	2.00	3.00	2.00	1.00	4.00	2.00	1.00	4.00	4.00	4 00	1.00	2.00

	pc24	ab24	st24	ps24	sc25	pc25	ab25	st25	ps25	sc26	pc26	ab26
1	3.00	3.00	4.00	4.00	4.00	4.00	3.00	4.00	4.00	1.00	4.00	3.00
2	4.00	3.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	1.00	4.00	4.00
3	4.00	24.00	4.00	4.00	4.00	3.00	3.00	4.00	1.00	3.00	4.00	4.00
4	2.00	3.00	4.00	2.00	4.00	4.00	2.00	4.00	2.00	2.00	4.00	2.00
5	3.00	3.00	3.00	3.00	4.00	3.00	3.00	2.00	2.00	3.00	3.00	2.00
6	3.00	3.00	3.00	3.00	4.00	3.00	3.00	3.00	2.00	2.00	2.00	3.00
7	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	3.00	2.00	3.00	4.00
8	4.00	1.00	2.00	3.00	4.00	3.00	3.00	3.00	2.00	1.00	2.00	2.00
9	3.00	3.00	3.00	3.00	2.00	3.00	3.00	2.00	2.00	2.00	3.00	3.00
10	3.00	3.00	3.00	3.00	4.00	3.00	3.00	3.00	3.00	2.00	3.00	3.00
11	.	.	.	.	.	.	.	.	.	.	.	.
12	2.00	1.00	1.00	1.00	4.00	2.00	1.00	1.00	1.00	4.00	1.00	1.00
13	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	1.00	1.00	1.00
14	4.00	4.00	4.00	3.00	4.00	3.00	3.00	4.00	4.00	1.00	4.00	4.00
15	3.00	3.00	2.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00
16	4.00	1.00	3.00	2.00	2.00	2.00	3.00	2.00	2.00	3.00	1.00	4.00
17	4.00	1.00	4.00	4.00	1.00	3.00	2.00	3.00	4.00	3.00	4.00	3.00
18	2.00	1.00	1.00	2.00	4.00	4.00	2.00	4.00	2.00	4.00	3.00	3.00
19	1.00	1.00	2.00	4.00	1.00	2.00	4.00	3.00	4.00	1.00	3.00	2.00
20	4.00	2.00	4.00	4.00	4.00	4.00	3.00	3.00	4.00	2.00	3.00	3.00
21	4.00	3.00	3.00	4.00	4.00	4.00	3.00	3.00	2.00	1.00	4.00	2.00
22	2.00	2.00	2.00	1.00	4.00	4.00	2.00	2.00	2.00	4.00	4.00	4.00

	st26	ps26	str1	gender	physcon1	attbod1	scomp1	str2	physcon2	attbod2	scomp2	psw1
1	4.00	4.00	2.83	1	1.83	3.50	2.00	4.00	3.50	2.75	1.67	4.00
2	4.00	4.00	3.50	1	2.00	4.00	2.33	3.83	4.00	3.75	1.67	3.67
3	4.00	4.00	3.50	1	1.83	3.75	2.00	3.67	3.83	9.00	1.67	3.50
4	1.00	3.00	2.17	1	2.50	3.00	2.00	3.17	3.33	2.50	1.67	3.17
5	2.00	3.00	2.67	1	2.83	3.50	2.33	2.67	3.17	2.75	2.33	3.17
6	3.00	3.00	3.50	1	2.33	2.75	1.67	3.00	2.83	3.50	2.33	3.00
7	4.00	4.00	3.00	1	2.33	3.75	1.67	3.67	3.50	3.75	3.00	3.00
8	3.00	3.00	2.50	1	2.33	3.00	2.00	2.50	2.83	2.25	2.00	2.83
9	3.00	2.00	2.83	1	2.00	3.00	2.00	2.83	3.00	3.00	2.00	2.00
10	3.00	3.00	3.17	1	2.50	3.25	2.00	3.00	3.00	3.00	2.33	3.33
11	.	.	3.50	1	2.33	3.75	2.00	.	.	.	.	3.17
12	1.00	1.00	2.17	1	2.33	3.00	2.00	1.00	1.67	1.00	3.33	2.33
13	4.00	4.00	3.00	1	2.33	3.25	1.67	4.00	3.50	3.25	3.00	2.17
14	2.00	4.00	3.33	1	2.17	3.50	2.00	3.00	3.67	3.50	2.33	3.50
15	3.00	3.00	2.83	1	2.00	2.50	2.33	2.67	2.67	2.50	2.33	2.17
16	3.00	2.00	2.50	1	2.50	2.00	2.33	3.00	2.33	2.50	2.67	3.00
17	4.00	1.00	2.50	1	2.17	2.50	1.67	3.17	3.50	2.00	1.33	2.50
18	2.00	1.00	2.00	1	3.33	2.00	1.67	2.67	2.33	2.00	3.33	2.67
19	3.00	1.00	2.83	1	2.00	2.00	1.33	2.83	2.00	2.75	3.00	2.83
20	3.00	4.00	2.67	1	2.17	3.00	2.00	3.33	3.50	2.75	2.00	3 33
21	4.00	2.00	3.17	1	2.83	3.75	2.00	3.33	4.00	3.00	1.67	3.33
22	1.00	4.00	2.50	1	2.17	2.50	1.67	2.50	3.17	2.25	1.67	3.33

	psw2	piosc	scimp11	pcimp11	abimp11	stimp1	scimp12	pcimp12	abimp12	var00001	scimp21	pcimp21
1	3.50	4.00	1.00	4.00	4.00	4.00	4.00	4.00	4.00	.	.	.
2	3.50	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	.	4.00	4.00
3	3.00	4.00	3.00	3.00	3.00	4.00	4.00	4.00	3.00	.	4.00	3.00
4	2.67	4.00	2.00	4.00	4.00	3.00	2.00	1.00	4.00	.	4.00	2.00
5	2.67	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	.	4.00	3.00
6	2.50	3.00	3.00	3.00	2.00	2.00	3.00	3.00	3.00	.	3.00	3.00
7	3.33	4.00	3.00	3.00	2.00	4.00	3.00	3.00	3.00	.	4.00	4.00
8	2.50	2.00	3.00	3.00	2.00	2.00	2.00	2.00	2.00	.	1.00	1.00
9	2.50	2.00	2.00	2.00	2.00	2.00	3.00	2.00	2.00	.	3.00	3.00
10	2.83	4.00	4.00	4.00	3.00	3.00	4.00	4.00	3.00	.	4.00	4.00
11	.	3.00	3.00	3.00	3.00	4.00	4.00	3.00	3.00	.	3.00	3.00
12	1.50	2.00	4.00	2.00	2.00	2.00	2.00	3.00	4.00	.	4.00	4.00
13	3.50	2.00	2.00	2.00	1.00	2.00	2.00	2.00	2.00	.	4.00	2.00
14	3.33	4.00	4.00	4.00	4.00	4.00	3.00	4.00	3.00	.	4.00	4.00
15	2.67	2.00	1.00	2.00	4.00	3.00	2.00	2.00	1.00	.	2.00	1.00
16	2.50	4.00	2.00	4.00	2.00	1.00	2.00	1.00	3.00	.	.	.
17	2.33	3.00	2.00	4.00	2.00	2.00	4.00	2.00	4.00	.	1.00	2.00
18	2.17	4.00	2.00	1.00	2.00	1.00	1.00	3.00	2.00	.	3.00	2.00
19	2.67	4.00	2.00	4.00	4.00	4.00	1.00	4.00	4.00	.	4.00	2.00
20	3.50	3.00	1.00	2.00	3.00	4.00	2.00	2.00	2.00	.	3.00	1.00
21	2.83	3.00	3.00	3.00	3.00	4.00	4.00	3.00	3.00	.	4.00	4.00
22	2.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	.	4.00	4.00

c:\psppcom.sav

	abimp21	stimp21	scimp22	pcimp22	abimp22	stimp22	scimp1	scimp2	pcimp1	pcimp2	abimp1	abimp2
1	.	.	.	.	.	.	1.00	.	4.00	.	4.00	.
2	4.00	3.00	4.00	4.00	4.00	3.00	4.00	4.00	4.00	4.00	4.00	4.00
3	3.00	3.00	4.00	4.00	4.00	3.00	3.50	4.00	3.00	3.50	3.00	3.50
4	4.00	4.00	3.00	2.00	1.00	4.00	3.00	3.50	3.00	2.00	4.00	2.50
5	3.00	3.00	3.00	3.00	4.00	3.00	4.00	3.50	3.50	3.00	4.00	3.50
6	3.00	2.00	2.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	2.50	3.00
7	3.00	3.00	3.00	3.00	4.00	3.00	3.50	3.50	3.50	3.50	2.50	3.50
8	1.00	1.00	1.00	2.00	1.00	1.00	2.00	1.00	2.00	1.50	2.00	1.00
9	2.00	2.00	2.00	2.00	2.00	3.00	2.50	2.50	2.50	2.50	2.00	2.00
10	3.00	3.00	3.00	3.00	3.00	3.00	4.00	3.50	4.00	3.50	3.00	3.00
11	3.00	3.00	4.00	4.00	3.00	3.00	3.00	3.50	3.00	3.50	3.00	3.00
12	3.00	3.00	4.00	3.00	3.00	3.00	4.00	4.00	3.00	3.50	3.00	3.00
13	4.00	1.00	4.00	4.00	3.00	1.00	3.00	4.00	2.00	3.00	1.50	3.50
14	4.00	4.00	4.00	3.00	4.00	3.00	4.00	4.00	4.00	3.50	3.50	4.00
15	2.00	4.00	3.00	2.00	2.00	1.00	1.50	2.50	1.50	1.50	2.50	2.00
16	.	.	.	.	.	.	2.00	.	4.00	.	2.50	.
17	3.00	4.00	1.00	3.00	4.00	3.00	1.50	1.00	3.00	2.50	3.00	3.50
18	3.00	3.00	3.00	3.00	3.00	3.00	2.50	3.00	1.50	2.50	2.00	3.00
19	4.00	4.00	4.00	1.00	4.00	4.00	3.00	4.00	3.00	1.50	4.00	4.00
20	2.00	3.00	4.00	2.00	2.00	2.00	2.00	3.50	1.50	1.50	2.50	2.00
21	4.00	1.00	4.00	4.00	4.00	4.00	3.50	4.00	3.50	4.00	3.00	4.00
22	4.00	4.00	4.00	4.00	4.00	4.00	3.50	4.00	3.50	4.00	3.00	4.00

	stimp2
1	.
2	3.00
3	3.00
4	4.00
5	3.00
6	2.50
7	3.00
8	1.00
9	2.50
10	3.00
11	3.00
12	3.00
13	1.00
14	3.50
15	2.50
16	.
17	3.50
18	3.00
19	4.00
20	2.50
21	2.50
22	4.00

	id	age1	sc1	pc1	ab1	st1	ps1	sc2	pc2	ab2	st2	ps2
23	23.00	11.00	1.00	2.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00
24	24.00	11.00	1.00	2.00	3.00	3.00	3.00	4.00	1.00	4.00	4.00	3.00
25	25.00	11.00	1.00	3.00	3.00	2.00	3.00	2.00	3.00	3.00	2.00	3.00
26	26.00	11.00	1.00	2.00	3.00	3.00	3.00	3.00	3.00	4.00	3.00	3.00
27	27.00	10.00	1.00	1.00	4.00	4.00	4.00	4.00	1.00	4.00	4.00	4.00
28	28.00	11.00	1.00	1.00	4.00	3.00	3.00	3.00	2.00	4.00	2.00	2.00
29	29.00	11.00	1.00	1.00	2.00	2.00	2.00	2.00	4.00	3.00	1.00	2.00
30	30.00	11.00	2.00	2.00	3.00	2.00	2.00	3.00	3.00	3.00	3.00	3.00
31	31.00	9.00	2.00	2.00	3.00	3.00	3.00	4.00	3.00	3.00	4.00	3.00
32	32.00	9.00	2.00	2.00	3.00	4.00	3.00	3.00	2.00	3.00	3.00	3.00
33	33.00	10.00	2.00	1.00	2.00	2.00	2.00	3.00	3.00	1.00	2.00	3.00
34	34 00	9.00	2.00	4.00	1.00	3.00	3.00	4.00	1.00	3.00	2.00	3.00
35	35.00	9.00	2.00	1.00	1.00	4.00	3.00	4.00	4.00	4.00	2.00	3.00
36	36.00	9.00	2.00	3.00	4.00	2.00	3.00	2.00	3.00	4.00	1.00	1.00
37	37.00	9.00	2.00	1.00	2.00	2.00	4.00	2.00	1.00	4.00	2.00	3.00
38	38.00	9.00	2.00	1.00	4.00	4.00	4.00	4.00	1.00	4.00	4.00	4.00
39	267.00	12.00	1.00	1.00	4.00	3.00	4.00	4.00	1.00	4.00	4.00	4.00
40	268.00	12.00	1.00	2.00	3.00	3.00	1.00	3.00	2.00	2.00	3.00	3.00
41	39.00	10.00	2.00	1.00	2.00	2.00	4.00	3.00	4.00	4.00	3.00	2.00
42	40.00	9.00	2.00	1.00	2.00	3.00	3.00	3.00	3.00	2.00	2.00	3.00
43	41.00	10.00	2.00	2.00	2.00	2.00	3.00	3.00	3.00	4.00	2.00	3.00
44	42.00	9.00	2.00	1.00	4.00	1.00	1.00	3.00	3.00	2 00	2.00	3 00

	sc3	pc3	ab3	st3	ps3	sc4	pc4	ab4	st4	ps4	sc5	pc5
23	1.00	2.00	3.00	3.00	4.00	3.00	3.00	4.00	2.00	3.00	3.00	4.00
24	1.00	1.00	4.00	4.00	4.00	4.00	4.00	4.00	2.00	3.00	4.00	4.00
25	3.00	3.00	3.00	3.00	3.00	3.00	2.00	3.00	2.00	3.00	3.00	3.00
26	1.00	2.00	4.00	4.00	4.00	4.00	3.00	4.00	2.00	4.00	4.00	4.00
27	1.00	1.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
28	2.00	1.00	3.00	3.00	2.00	4.00	4.00	4.00	2.00	2.00	4.00	4.00
29	3.00	3.00	2.00	2.00	3.00	2.00	2.00	2.00	1.00	3.00	2.00	4.00
30	2.00	3.00	3.00	4.00	3.00	2.00	2.00	3.00	3.00	2.00	2.00	3.00
31	2.00	2.00	3.00	4.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
32	2.00	2.00	4.00	3.00	3.00	3.00	3.00	4.00	3.00	3.00	3.00	4.00
33	2.00	1.00	2.00	2.00	3.00	2.00	3.00	1.00	3.00	2.00	3.00	2.00
34	1.00	2.00	4.00	3.00	1.00	4.00	3.00	2.00	2.00	2.00	2.00	4.00
35	1.00	2.00	1.00	2.00	3.00	1.00	3.00	1.00	3.00	2.00	4.00	1.00
36	1.00	4.00	3.00	4.00	1.00	4.00	2.00	4.00	2.00	3.00	2.00	4.00
37	2.00	2.00	2.00	2.00	3.00	2.00	3.00	2.00	2.00	3.00	3.00	4.00
38	1.00	1.00	4.00	4.00	4.00	1.00	4.00	4.00	4.00	4.00	4.00	4.00
39	1.00	1.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
40	1.00	2.00	1.00	1.00	3.00	1.00	2.00	1.00	3.00	3.00	3.00	1.00
41	1.00	3.00	4.00	2.00	2.00	2.00	4.00	3.00	2.00	4.00	3.00	2.00
42	2.00	1.00	2.00	2.00	3.00	2.00	3.00	2.00	3.00	2.00	3.00	2.00
43	3.00	3.00	2.00	3.00	4.00	2.00	2.00	3.00	2.00	4.00	2.00	2.00
44	2.00	3.00	1.00	3.00	4.00	1.00	2.00	3.00	2.00	2.00	3.00	4.00

	ab5	st5	ps5	sc6	pc6	ab6	st6	ps6	sc21	pc21	ab21	st21
23	4.00	3.00	3.00	3.00	2.00	3.00	2.00	3.00	2.00	3.00	2.00	3.00
24	4.00	4.00	3.00	4.00	1.00	3.00	3.00	3.00	2.00	3.00	3.00	3.00
25	2.00	3.00	3.00	3.00	3.00	2.00	3.00	3.00	3.00	3.00	2.00	3.00
26	4.00	3.00	3.00	3.00	1.00	3.00	4.00	4.00	2.00	2.00	3.00	3.00
27	4.00	4.00	4.00	4.00	1.00	4.00	4.00	4.00	2.00	4.00	4.00	4.00
28	4.00	3.00	2.00	3.00	2.00	3.00	2.00	4.00	2.00	3.00	3.00	2.00
29	2.00	2.00	2.00	2.00	3.00	2.00	1.00	2.00	1.00	2.00	2.00	2.00
30	3.00	2.00	2.00	2.00	3.00	2.00	3.00	2.00	2.00	3.00	2.00	2.00
31	3.00	3.00	3.00	3.00	1.00	3.00	4.00	3.00	3.00	3.00	3.00	3.00
32	4.00	3.00	3.00	3.00	2.00	3.00	3.00	3.00	2.00	3.00	4.00	3.00
33	4.00	2.00	3.00	1.00	3.00	3.00	2.00	3.00	.	.	.	.
34	3.00	3.00	2.00	4.00	1.00	4.00	2.00	4.00	4.00	1.00	3.00	3.00
35	4.00	1.00	3.00	2.00	3.00	4.00	1.00	2.00	2.00	1.00	4.00	4.00
36	4.00	3.00	3.00	2.00	3.00	3.00	3.00	2.00	3.00	3.00	3.00	3.00
37	3.00	2.00	3.00	2.00	2.00	3.00	2.00	3.00	2.00	3.00	3.00	3.00
38	4.00	4.00	4.00	4.00	1.00	4.00	4.00	4.00	1.00	4.00	4.00	4.00
39	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	2.00	2.00	2.00	3.00
40	3.00	1.00	1.00	1.00	1.00	2.00	3.00	1.00	2.00	3.00	2.00	3.00
41	4.00	3.00	3.00	1.00	1.00	2.00	1.00	2.00	1.00	3.00	3.00	3.00
42	4.00	2.00	3.00	2.00	4.00	3.00	4.00	2.00	1.00	2.00	3.00	3.00
43	2.00	2.00	3.00	2.00	2.00	2.00	1.00	3.00	2.00	2.00	2.00	3.00
44	3.00	2.00	4.00	1.00	4.00	4.00	3.00	2.00	1.00	4.00	1.00	1.00

12

	ps21	sc22	pc22	ab22	st22	ps22	sc23	pc23	ab23	st23	ps23	sc24
23	3.00	3.00	3.00	3.00	3.00	1.00	2.00	3.00	3.00	4.00	3.00	3.00
24	3.00	2.00	4.00	4.00	2.00	2.00	2.00	4.00	4.00	3.00	4.00	3.00
25	2.00	3.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00
26	3.00	3.00	3.00	3.00	3.00	2.00	4.00	4.00	4.00	4.00	4.00	3.00
27	4.00	4.00	4.00	4.00	4.00	4.00	2.00	4.00	4.00	4.00	4.00	4.00
28	3.00	2.00	3.00	3.00	2.00	2.00	2.00	3.00	3.00	2.00	2.00	2.00
29	2.00	4.00	3.00	1.00	2.00	3.00	3.00	2.00	2.00	3.00	2.00	2.00
30	3.00	3.00	3.00	3.00	3.00	2.00	3.00	3.00	4.00	3.00	2.00	2.00
31	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	3.00	3.00	3.00
32	3.00	2.00	3.00	3.00	3.00	2.00	2.00	4.00	3.00	3.00	3.00	3.00
33	.	.	.	.	.	.	.	.	.	.	.	.
34	4.00	1.00	3.00	2.00	3.00	1.00	2.00	4.00	3.00	1.00	4.00	3.00
35	4.00	4.00	4.00	4.00	3.00	3.00	2.00	2.00	2.00	2.00	3.00	2.00
36	3.00	4.00	4.00	2.00	2.00	1.00	4.00	4.00	4.00	4.00	4.00	2.00
37	3.00	1.00	4.00	3.00	3.00	1.00	2.00	3.00	3.00	3.00	3.00	3.00
38	4.00	1.00	4.00	4.00	4.00	1.00	1.00	4.00	4.00	4.00	1.00	4.00
39	3.00	2.00	3.00	2.00	3.00	2.00	2.00	2.00	3.00	2.00	2.00	3.00
40	3.00	1.00	4.00	2.00	3.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00
41	3.00	4.00	3.00	3.00	3.00	2.00	3.00	4.00	2.00	2.00	3.00	3.00
42	3.00	3.00	2.00	2.00	3.00	2.00	1.00	2.00	2.00	3 00	2.00	3.00
43	3.00	3.00	4.00	2.00	3.00	3.00	3.00	2.00	3.00	4.00	2.00	2.00
44	3.00	3.00	2.00	3.00	2.00	2.00	3.00	1.00	3.00	4 00	1.00	2.00

	pc24	ab24	st24	ps24	sc25	pc25	ab25	st25	ps25	sc26	pc26	ab26
23	4.00	2.00	3.00	3.00	4.00	4.00	3.00	3.00	3.00	2.00	3.00	2.00
24	3.00	2.00	3.00	4.00	4.00	4.00	3.00	3.00	3.00	2.00	4.00	3.00
25	3.00	2.00	3.00	3.00	3.00	2.00	3.00	3.00	3.00	3.00	2.00	3.00
26	2.00	2.00	3.00	2.00	4.00	1.00	4.00	1.00	4.00	2.00	2.00	3.00
27	3.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	2.00	2.00	2.00
28	3.00	2.00	2.00	2.00	2.00	2.00	3.00	2.00	3.00	3.00	3.00	2.00
29	2.00	1.00	3.00	2.00	4.00	2.00	2.00	2.00	2.00	3.00	2.00	1.00
30	3.00	3.00	2.00	2.00	3.00	3.00	2.00	2.00	2.00	3.00	2.00	3.00
31	2.00	2.00	3.00	2.00	2.00	2.00	4.00	3.00	2.00	2.00	2.00	3.00
32	4.00	3.00	3.00	3.00	4.00	4.00	3.00	3.00	3.00	2.00	3.00	3.00
33												
34	2.00	2.00	2.00	2.00	4.00	3.00	3.00	2.00	4.00	1.00	4.00	2.00
35	3.00	3.00	3.00	1.00	2.00	4.00	4.00	4.00	2.00	4.00	4.00	1.00
36	2.00	2.00	4.00	4.00	4.00	4.00	4.00	4.00	2.00	3.00	3.00	3.00
37	4.00	3.00	3.00	3.00	4.00	3.00	2.00	3.00	3.00	2.00	3.00	3.00
38	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	1.00	4.00	4.00
39	2.00	2.00	3.00	3.00	2.00	3.00	2.00	3.00	2.00	2.00	3.00	2.00
40	3.00	2.00	3.00	3.00	4.00	3.00	2.00	3.00	3.00	2.00	3.00	2.00
41	3.00	3.00	4.00	3.00	4.00	4.00	2.00	3.00	2.00	3.00	3.00	2.00
42	2.00	3.00	2.00	3.00	2.00	4.00	2.00	3.00	2.00	4.00	3.00	4.00
43	3.00	2.00	4.00	2.00	2.00	2.00	2.00	3.00	2.00	2.00	2.00	1.00
44	3.00	2.00	3.00	4.00	3.00	2.00	4 00	1.00	4.00	4.00	3.00	2.00

	st26	ps26	str1	gender	physcon1	attbod1	scomp1	str2	physcon2	attbod2	scomp2	psw1
23	3.00	4.00	2.50	1	2.67	3.25	1.67	3.17	3.33	2.25	2.33	3.17
24	3.00	4.00	3.33	1	2.17	3.50	2.00	2.83	3.67	3.00	2.33	3.17
25	3.00	3.00	2.50	1	2.83	2.75	2.33	3.00	2.67	2.25	2.67	3.00
26	3.00	2.00	3.17	1	2.50	3.50	2.00	2.83	2.33	2.75	3.00	3.50
27	3.00	4.00	4.00	1	2.00	4.00	2.00	3.83	3.50	3.50	2.67	4.00
28	2.00	3.00	2.50	1	2.33	3.75	2.33	2.00	2.83	2.50	2.00	2.50
29	2.00	2.00	1.50	1	2.83	2.25	2.00	2.33	2.17	1.25	2.00	2.33
30	2.00	2.00	2.83	1	2.67	2.75	2.00	2.33	2.83	2.75	2.33	2.33
31	4.00	3.00	3.50	1	2.33	3.00	2.33	3.17	2.33	2.75	2.67	3.00
32	3.00	4.00	3.17	1	2.50	3.25	2.33	3.00	3.50	3.25	2.33	3.00
33	.	.	2.17	1	2.17	1.75	2.00	.	.	.	.	2.67
34	4.00	3.00	2.50	1	2.50	2.50	2.33	2.50	2.83	2.25	3.00	2.50
35	1.00	1.00	2.17	1	2.33	2.50	1.33	2.83	3.00	3.00	2.00	2.67
36	3.00	3.00	2.50	1	3.17	3.75	2.33	3.33	3.33	2.50	3.00	2.17
37	3.00	3.00	2.00	1	2.17	2.75	2.00	3.00	3.33	3.00	2.33	3.17
38	4.00	1.00	4.00	1	2.00	4.00	1.33	4.00	4.00	4.00	2.00	4.00
39	2.00	3.00	2.99	1	2.50	4.00	2.00	2.67	2.50	2.00	2.33	4.00
40	3.00	4.00	3.14	1	1.67	2.00	1.00	3.00	3.17	2.00	2.33	2.00
41	3.00	2.00	2.17	2	3.00	3.17	1.75	3.00	3.00	2.50	2.75	2.83
42	2.00	3.00	2.67	2	2.33	2.50	2.25	2.67	2.00	2.67	2.25	2.67
43	3.00	2.00	2.00	2	2.33	2.50	2.50	3.33	3.00	2.00	2.50	3.33
44	4.00	4.00	2.17	2	2.00	2.83	2.00	2.50	3.00	2.50	2.75	2.67

	psw2	piosc	scimp11	pcimp11	abimp11	stimp1	scimp12	pcimp12	abimp12	var00001	scimp21	pcimp21
23	2.83	3.00	4.00	2.00	4.00	3.00	1.00	4.00	4.00	.	3.00	4.00
24	3.33	3.00	3.00	3.00	3.00	3.00	2.00	3.00	3.00	.	3.00	3.00
25	2.83	2.00	3.00	2.00	2.00	3.00	3.00	3.00	3.00	.	2.00	3.00
26	2.83	3.00	3.00	2.00	2.00	4.00	3.00	2.00	3.00	.	3.00	3.00
27	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	.	4.00	4.00
28	2.50	3.00	3.00	2.00	3.00	2.00	4.00	3.00	1.00	.	2.00	3.00
29	2.17	3.00	3.00	2.00	2.00	2.00	2.00	3.00	2.00	.	3.00	3.00
30	2.17	3.00	2.00	2.00	4.00	4.00	3.00	3.00	3.00	.	3.00	2.00
31	2.67	3.00	4.00	4.00	3.00	3.00	3.00	3.00	3.00	.	3.00	3.00
32	3.00	4.00	4.00	2.00	2.00	3.00	3.00	2.00	3.00	.	4.00	4.00
33	.	3.00	2.00	3.00	2.00	1.00	3.00	1.00	3.00	.	3.00	2.00
34	3.00	4.00	4.00	4.00	2.00	4.00	3.00	3.00	3.00	.	4.00	4.00
35	2.33	4.00	1.00	4.00	1.00	2.00	4.00	2.00	3.00	.	4.00	3.00
36	2.83	4.00	2.00	3.00	3.00	4.00	3.00	4.00	2.00	.	4.00	4.00
37	2.67	4.00	2.00	1.00	3.00	4.00	4.00	4.00	3.00	.	4.00	4.00
38	2.50	4.00	4.00	4.00	1.00	4.00	4.00	1.00	4.00	.	.	.
39	2.50	4.00	4.00	3.00	4.00	3.00	3.00	4.00	4.00	.	4.00	4.00
40	3.17	3.00	2.00	3.00	2.00	1.00	3.00	2.00	3.00	.	.	.
41	2.50	4.00	4.00	3.00	4.00	4.00	4.00	4.00	4.00	.	4.00	4.00
42	2.50	4.00	1.00	4.00	1.00	2.00	1.00	4.00	1.00	.	4.00	1.00
43	2.33	3.00	2.00	3.00	2.00	1.00	3.00	2.00	3.00	.	3.00	2.00
44	3.00	4.00	3.00	1.00	4.00	4.00	4.00	1.00	4.00	.	4.00	3.00

	abimp21	stimp21	scimp22	pcimp22	abimp22	stimp22	scimp1	scimp2	pcimp1	pcimp2	abimp1	abimp2
23	2.00	4.00	3.00	1.00	4.00	4.00	3.50	3.00	3.00	2.50	4.00	3.00
24	2.00	2.00	2.00	3.00	3.00	3.00	3.00	2.50	3.00	3.00	3.00	2.50
25	2.00	2.00	3.00	3.00	3.00	3.00	2.50	2.50	2.50	3.00	2.50	2.50
26	2.00	2.00	4.00	3.00	2.00	3.00	3.00	3.50	2.50	3.00	2.50	2.00
27	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
28	2.00	2.00	2.00	3.00	2.00	2.00	2.50	2.00	2.50	3.00	2.00	2.00
29	2.00	2.00	2.00	2.00	3.00	2.00	3.00	2.50	2.50	2.50	2.00	2.50
30	2.00	4.00	4.00	3.00	3.00	3.00	2.50	3.50	2.00	2.50	3.50	2.50
31	2.00	3.00	3.00	3.00	4.00	2.00	3.50	3.00	3.50	3.00	3.00	3.00
32	2.00	2.00	3.00	3.00	2.00	3.00	4.00	3.50	3.00	3.50	2.50	2.00
33	3.00	2.00	1.00	3.00	1.00	3.00	2.50	2.00	2.50	2.50	2.50	2.00
34	4.00	2.00	4.00	3.00	3.00	3.00	4.00	4.00	4.00	3.50	2.50	3.50
35	3.00	3.00	2.00	4.00	4.00	3.00	2.50	3.00	3.50	3.50	2.00	3.50
36	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.50	3.50	3.50	2.50	3.00
37	3.00	4.00	4.00	3.00	1.00	3.00	3.00	4.00	2.50	3.50	3.00	2.00
38	.	.	.	.	.	.	4.00	.	4.00	.	2.50	.
39	4.00	4.00	4.00	2.00	3.00	2 00	4.00	4.00	3.50	3.00	4.00	3.50
40	.	.	.	.	.	.	2.00	.	3.00	.	2.50	.
41	3.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	3.50	4.00	4.00	3.50
42	4.00	1.00	2.00	1.00	4.00	1.00	2.50	3.00	2.50	1.00	1.00	4.00
43	3.00	2.00	1.00	3.00	2.00	3.00	2.50	2.00	2.50	2.50	2.50	2.50
44	1.00	4.00	4.00	4.00	1.00	4.00	3.50	4.00	2.00	3.50	4.00	1.00

	stimp2
23	4.00
24	2.50
25	2.50
26	2.50
27	4.00
28	2.00
29	2.00
30	3.50
31	2.50
32	2.50
33	2.50
34	2.50
35	3.00
36	3.00
37	3.50
38	.
39	3.00
40	.
41	4.00
42	1.00
43	2.50
44	4.00

	id	age1	sc1	pc1	ab1	st1	ps1	sc2	pc2	ab2	st2	ps2
45	43.00	10.00	2.00	1.00	4.00	3.00	2.00	3.00	3.00	1.00	2.00	3.00
46	44.00	11.00	2.00	1.00	3.00	1.00	4.00	2.00	1.00	4.00	1.00	4.00
47	45.00	10.00	2.00	2.00	3.00	3.00	4.00	3.00	1.00	4.00	2.00	3.00
48	46.00	11.00	2.00	1.00	3.00	2.00	3.00	4.00	2.00	4.00	3.00	3.00
49	47.00	11.00	2.00	1.00	4.00	4.00	3.00	4.00	1.00	4.00	4.00	3.00
50	48.00	11.00	2.00	1.00	3.00	3.00	4.00	4.00	1.00	4.00	4.00	3.00
51	49.00	10.00	2.00	1.00	4.00	3.00	3.00	4.00	4.00	4.00	4.00	3.00
52	50.00	11.00	2.00	2.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00
53	51.00	11.00	1.00	3.00	4.00	3.00	3.00	1.00	4.00	4.00	3.00	1.00
54	52.00	11.00	2.00	2.00	3.00	2.00	3.00	3.00	3.00	4.00	4.00	2.00
55	53.00	11.00	2.00	3.00	2.00	2.00	1.00	2.00	4.00	4.00	2.00	2.00
56	54.00	11.00	2.00	2.00	2.00	3.00	3.00	3.00	2.00	3.00	4.00	3.00
57	55.00	11.00	2.00	4.00	1.00	1.00	1.00	1.00	4.00	1.00	1.00	1.00
58	56.00	11.00	2.00	4.00	2.00	2.00	2.00	2.00	4.00	1.00	2.00	1.00
59	57.00	9.00	2.00	2.00	3.00	3.00	3.00	3.00	2.00	4.00	2.00	3.00
60	58.00	9.00	2.00	2.00	2.00	2.00	2.00	2.00	4.00	4.00	1.00	2.00
61	59.00	9.00	2.00	2.00	2.00	4.00	2.00	3.00	4.00	2.00	4.00	3.00
62	60.00	11.00	2.00	1.00	3.00	3.00	3.00	3.00	2.00	4.00	2.00	3.00
63	61.00	10.00	2.00	1.00	4.00	4.00	3.00	4.00	4.00	4.00	4.00	2.00
64	62.00	10.00	2.00	1.00	1.00	4.00	4.00	4.00	4.00	4.00	1.00	4.00
65	63.00	10.00	2.00	1.00	1.00	3.00	4.00	4.00	3.00	4.00	1.00	1.00
66	64.00	11.00	2.00	3.00	2.00	2.00	2.00	2.00	4.00	2.00	2.00	3.00

	sc3	pc3	ab3	st3	ps3	sc4	pc4	ab4	st4	ps4	sc5	pc5
45	2.00	1.00	2.00	2.00	3.00	2.00	3.00	2.00	2.00	2.00	3.00	2.00
46	1.00	1.00	3.00	4.00	1.00	4.00	2.00	4.00	4.00	1.00	4.00	2.00
47	1.00	3.00	3.00	4.00	3.00	4.00	3.00	4.00	2.00	4.00	3.00	4.00
48	1.00	2.00	4.00	2.00	4.00	3.00	3.00	4.00	2.00	4.00	3.00	4.00
49	1.00	2.00	4.00	4.00	4.00	4.00	3.00	1.00	3.00	4.00	4.00	4.00
50	1.00	2.00	4.00	4.00	4.00	4.00	3.00	4.00	2.00	4.00	4.00	4.00
51	1.00	1.00	4.00	3.00	4.00	4.00	4.00	4.00	2.00	4.00	4.00	4.00
52	2.00	3.00	2.00	2.00	2.00	2.00	3.00	2.00	2.00	2.00	3.00	3.00
53	2.00	4.00	2.00	4.00	3.00	4.00	4.00	3.00	4.00	3.00	4.00	3.00
54	2.00	2.00	4.00	4.00	3.00	3.00	3.00	4.00	3.00	2.00	3.00	4.00
55	3.00	2.00	2.00	2.00	2.00	2.00	2.00	3.00	1.00	2.00	2.00	4.00
56	1.00	2.00	3.00	4.00	3.00	1.00	3.00	3.00	3.00	3.00	3.00	3.00
57	4.00	4.00	3.00	2.00	1.00	1.00	2.00	2.00	1.00	1.00	1.00	4.00
58	4.00	3.00	1.00	2.00	2.00	1.00	2.00	2.00	2.00	1.00	2.00	2.00
59	1.00	2.00	3.00	3.00	3.00	2.00	3.00	3.00	2.00	3.00	3.00	4.00
60	2.00	3.00	2.00	2.00	1.00	2.00	2.00	2.00	3.00	2.00	2.00	3.00
61	2.00	2.00	2.00	4.00	2.00	4.00	2.00	3.00	4.00	4.00	1.00	1.00
62	2.00	3.00	2.00	3.00	3.00	3.00	3.00	3.00	2.00	3.00	3.00	4.00
63	1.00	3.00	4.00	4.00	2.00	2.00	2.00	4.00	1.00	2.00	3.00	2.00
64	1.00	1.00	1.00	1.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
65	4.00	4.00	2.00	4.00	2.00	1.00	1.00	1 00	2.00	1 00	4.00	1.00
66	2.00	3.00	3.00	3.00	1.00	2.00	2.00	2.00	3.00	2.00	2.00	2.00

	ab5	st5	ps5	sc6	pc6	ab6	st6	ps6	sc21	pc21	ab21	st21
45	4.00	2.00	3.00	2.00	3.00	3.00	4.00	2.00	1.00	4.00	3.00	2.00
46	4.00	4.00	1.00	4.00	1.00	1.00	4.00	1.00	2.00	3.00	2.00	4.00
47	3.00	3.00	3.00	3.00	2.00	3.00	3.00	3.00	2.00	3.00	3.00	4.00
48	3.00	3.00	3.00	2.00	2.00	3.00	3.00	3.00	1.00	3.00	2.00	3.00
49	4.00	4.00	4.00	3.00	2.00	3.00	4.00	4.00	1.00	4.00	4.00	3.00
50	4.00	3.00	4.00	1.00	1.00	4.00	3.00	3.00	1.00	4.00	2.00	4.00
51	4.00	3.00	4.00	4.00	4.00	3.00	3.00	4.00	2.00	3.00	2.00	3.00
52	3.00	2.00	2.00	3.00	2.00	3.00	2.00	2.00	2.00	3.00	3.00	3.00
53	3.00	4.00	3.00	1.00	4.00	3.00	4.00	4.00	1.00	3.00	3.00	3.00
54	4.00	3.00	2.00	3.00	1.00	4.00	2.00	2.00	2.00	3.00	3.00	3.00
55	3.00	2.00	2.00	1.00	2.00	3.00	2.00	2.00	2.00	2.00	3.00	1.00
56	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00
57	2.00	1.00	1.00	1.00	4.00	1.00	1.00	1.00	.	.	.	.
58	2.00	1.00	2.00	1.00	3.00	1.00	1.00	3.00	4.00	2.00	2.00	2.00
59	3.00	3.00	3.00	2.00	2.00	2.00	3.00	2.00	.	.	.	.
60	4.00	1.00	3.00	2.00	2.00	1.00	3.00	3.00	1.00	3.00	2.00	2.00
61	2.00	4.00	3.00	2.00	2.00	4.00	2.00	1.00	.	.	.	.
62	4.00	2.00	3.00	2.00	3.00	3.00	2.00	3.00	2.00	3.00	3.00	3.00
63	1.00	3.00	4.00	3.00	2.00	3.00	2.00	3.00	2.00	3.00	1.00	3.00
64	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	3.00	2.00	3.00	2.00
65	4.00	2.00	1.00	3.00	1.00	4.00	2.00	1.00	2.00	3.00	2.00	3.00
66	3.00	2.00	2.00	3.00	3.00	2.00	3.00	2.00	2.00	1.00	1.00	3.00

	ps21	sc22	pc22	ab22	st22	ps22	sc23	pc23	ab23	st23	ps23	sc24
45	3.00	3.00	1.00	2.00	3.00	2.00	1.00	2.00	2.00	3.00	2.00	3.00
46	3.00	1.00	4.00	2.00	4.00	2.00	1.00	4.00	2.00	4.00	3.00	3.00
47	3.00	1.00	4.00	2.00	3.00	1.00	3.00	3.00	4.00	3.00	4.00	3.00
48	4.00	2.00	4.00	3.00	3.00	1.00	2.00	4.00	2.00	4.00	3.00	3.00
49	4.00	1.00	4.00	4.00	3.00	1.00	2.00	4.00	4.00	4.00	4.00	3.00
50	4.00	1.00	4.00	4.00	3.00	1.00	1.00	4.00	4.00	3.00	4.00	4.00
51	3.00	3.00	4.00	2.00	3.00	2.00	2.00	2.00	3.00	2.00	2.00	1.00
52	3.00	3.00	3.00	3.00	2.00	2.00	3.00	2.00	2.00	2.00	2.00	3.00
53	3.00	2.00	3.00	3.00	3.00	1.00	2.00	3.00	2.00	3.00	3.00	3.00
54	3.00	2.00	3.00	2.00	3.00	2.00	2.00	3.00	3.00	2.00	3.00	3.00
55	3.00	2.00	3.00	3.00	2.00	2.00	2.00	3.00	4.00	1.00	3.00	3.00
56	3.00	2.00	3.00	4.00	3.00	1.00	2.00	3.00	4.00	3.00	1.00	3.00
57	.	.	.	.	.	.	.	.	.	.	.	.
58	2.00	4.00	1.00	2.00	1.00	4.00	3.00	1.00	2.00	2.00	1.00	2.00
59	.	.	.	.	.	.	.	.	.	.	.	.
60	2.00	3.00	4.00	3.00	2.00	2.00	3.00	3.00	2.00	2.00	2.00	2.00
61	.	.	.	.	.	.	.	.	.	.	.	.
62	3.00	2.00	3.00	2.00	3.00	2.00	2.00	3.00	3.00	3.00	2.00	2.00
63	3.00	2.00	4.00	1.00	3.00	3.00	2.00	3.00	2.00	3.00	2.00	3.00
64	2.00	3.00	3.00	2.00	2.00	2.00	3.00	2.00	2.00	2.00	2.00	2.00
65	3.00	2.00	4.00	2.00	3.00	2.00	2 00	2.00	2.00	3.00	3.00	3.00
66	3.00	2.00	4.00	1.00	3.00	3.00	2.00	3.00	3.00	3.00	2.00	4.00

	pc24	ab24	st24	ps24	sc25	pc25	ab25	st25	ps25	sc26	pc26	ab26
45	2.00	2.00	2.00	3.00	2.00	4.00	2.00	3.00	2.00	3.00	3.00	4.00
46	4.00	1.00	4.00	3.00	4.00	3.00	2.00	4.00	2.00	1.00	3.00	2.00
47	4.00	2.00	4.00	3.00	4.00	3.00	3.00	3.00	3.00	2.00	3.00	3.00
48	4.00	2.00	4.00	3.00	4.00	3.00	3.00	3.00	3.00	2.00	3.00	3.00
49	1.00	3.00	4.00	4.00	4.00	4.00	4.00	4.00	3.00	2.00	3.00	4.00
50	4.00	3.00	4.00	4.00	4.00	4.00	3.00	4.00	4.00	1.00	4.00	4.00
51	2.00	1.00	3.00	2.00	2.00	1.00	3.00	2.00	2.00	1.00	2.00	2.00
52	2.00	2.00	2.00	3.00	3.00	3.00	2.00	2.00	3.00	2.00	3.00	2.00
53	3.00	2.00	3.00	3.00	4.00	3.00	3.00	3.00	3.00	2.00	3.00	3.00
54	3.00	2.00	2.00	4.00	3.00	2.00	2.00	3.00	2.00	3.00	2.00	3.00
55	3.00	1.00	2.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	2.00	2.00
56	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.00	3.00	3.00
57	.	.	.	.	.	.	.	.	.	.	.	.
58	2.00	2.00	1.00	2.00	2.00	2.00	1.00	2.00	1.00	3.00	1.00	1.00
59	.	.	.	.	.	.	.	.	.	.	.	.
60	3.00	2.00	2.00	3.00	4.00	3.00	2.00	2.00	2.00	2.00	2.00	2.00
61	.	.	.	.	.	.	.	.	.	.	.	.
62	3.00	2.00	2.00	4.00	2.00	3.00	2.00	3.00	3.00	3.00	2.00	2.00
63	3.00	1.00	2.00	3.00	4.00	3.00	1.00	2.00	2.00	2.00	2.00	1.00
64	2.00	2.00	3.00	3.00	3.00	3.00	3.00	2.00	2.00	3.00	2.00	2.00
65	4.00	1.00	4.00	4.00	3.00	3.00	3.00	3.00	2.00	2.00	3.00	2.00
66	2.00	1.00	3.00	2.00	4.00	2.00	1.00	3.00	1.00	2.00	2.00	1.00

	st26	ps26	str1	gender	physcon1	attbod1	scomp1	str2	physcon2	attbod2	scomp2	psw1
45	2.00	3.00	2.50	2	2.33	2.67	2.25	2.50	2.33	2.50	2.00	2.50
46	3.00	2.00	3.00	2	1.33	3.17	2.25	3.83	3.67	1.83	1.25	2.00
47	3.00	3.00	2.83	2	2.00	3.33	2.25	3.33	3.67	2.83	2.00	3.33
48	3.00	3.00	2.50	2	2.00	3.50	2.25	3.33	3.67	2.50	1.75	3.33
49	4.00	4.00	3.83	2	1.67	3.33	2.50	3.67	3.00	3.83	1.50	3.67
50	3.00	4.00	3.17	2	1.67	3.83	2.00	3.50	4.00	3.33	1.00	3.67
51	3.00	3.00	3.00	2	3.00	3.83	2.75	2.67	3.00	2.17	2.00	3.67
52	2.00	3.00	2.33	2	2.67	2.67	2.50	2.17	2.67	2.33	2.50	2.17
53	3.00	3.00	3.67	2	3.67	3.17	1.25	3.00	3.00	2.67	1.75	2.83
54	3.00	3.00	3.00	2	2.67	3.83	2.50	2.67	3.00	2.50	2.25	2.33
55	3.00	3.00	1.83	2	3.00	2.83	2.00	1.83	2.67	2.67	2.00	1.83
56	3.00	3.00	3.33	2	2.33	2.83	2.25	3.00	2.67	3.33	2.00	3.00
57	.	.	1.17	2	3.33	1.67	2.00	.	.	.	.	1.00
58	3.00	2.00	1.67	2	3.33	1.50	2.25	1.83	1.67	1.67	3.50	1.83
59	.	.	2.67	2	2.33	3.00	2.00	.	.	.	.	2.83
60	2.00	2.00	2.00	2	2.67	2.50	2.00	2.00	3.33	2.17	2.25	2.17
61	.	.	3.67	2	2.67	2.50	2.25	.	.	.	.	2.50
62	3.00	3.00	2.33	2	2.00	3.17	2.25	2.83	3.00	2.33	2.25	3.00
63	2.00	2.00	3.00	2	2.33	3.33	2.50	2.50	3.33	1.17	2.00	2.67
64	2.00	2.00	3.00	2	3.00	3.00	2.75	2.17	2.33	2.33	3.00	4.00
65	3.00	3.00	2.33	2	1.67	2.67	3.25	3.17	3.67	2.00	2.00	1.67
66	3.00	2.00	2.50	2	3.00	2.33	2.25	3.00	2.33	1 33	2.00	2.00

	psw2	piosc	scimp11	pcimp11	abimp11	stimp1	scimp12	pcimp12	abimp12	var00001	scimp21	pcimp21
45	2.50	3.00	3.00	2.00	2.00	2.00	2.00	2.00	2.00	.	3.00	3.00
46	2.50	3.00	4.00	1.00	2.00	4.00	3.00	3.00	2.00	.	4.00	3.00
47	2.83	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	.	4.00	4.00
48	2.83	2.00	4.00	4.00	4.00	1.00	2.00	4.00	3.00	.	4.00	4.00
49	3.33	4.00	4.00	4.00	4.00	4.00	4.00	1.00	3.00	.	2.00	3.00
50	3.50	3.00	2.00	3.00	3.00	3.00	3.00	2.00	3.00	.	3.00	1.00
51	2.33	3.00	3.00	4.00	4.00	3.00	3.00	4.00	4.00	.	4.00	4.00
52	2.67	3.00	1.00	3.00	2.00	3.00	2.00	3.00	4.00	.	3.00	3.00
53	2.67	3.00	4.00	4.00	4.00	3.00	3.00	4.00	3.00	.	4.00	3.00
54	2.83	3.00	3.00	3.00	2.00	2.00	2.00	2.00	2.00	.	3.00	3.00
55	2.67	4.00	1.00	4.00	2.00	2.00	3.00	4.00	4.00	.	.	.
56	2.33	2.00	2.00	1.00	2.00	1.00	1.00	1.00	3.00	.	2.00	2.00
57	.	3.00	3.00	2.00	3.00	3.00	3.00	3.00	2.00	.	3.00	3.00
58	2.00	2.00	4.00	1.00	2.00	3.00	3.00	1.00	1.00	.	3.00	3.00
59	.	2.00	2.00	2.00	1.00	4.00	4.00	3.00	1.00	.	2.00	2.00
60	2.17	2.00	4.00	3.00	4.00	3.00	3.00	3.00	3.00	.	3.00	2.00
61	.	4.00	4.00	4.00	2.00	4.00	4.00	4.00	3.00	.	3.00	3.00
62	2.83	3.00	3.00	3.00	3.00	3.00	3.00	4.00	3.00	.	4.00	4.00
63	2.50	2.00	2.00	1.00	2.00	1.00	1.00	1.00	3.00	.	2.00	2.00
64	2.17	3.00	3.00	2.00	3.00	4.00	3.00	3.00	3.00	.	3.00	3.00
65	2.83	2.00	2.00	3.00	3.00	3.00	2.00	2.00	2.00	.	.	.
66	2.17	4.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	.	.	.

	abimp21	stimp21	scimp22	pcimp22	abimp22	stimp22	scimp1	scimp2	pcimp1	pcimp2	abimp1	abimp2
45	2.00	2.00	2.00	2.00	2.00	2.00	3.00	2.50	2.50	2.50	2.00	2.00
46	4.00	4.00	4.00	3.00	4.00	4.00	4.00	4.00	2.00	3.00	2.00	4.00
47	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
48	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	3.50	4.00
49	1.00	3.00	3.00	3.00	2.00	3.00	3.00	2.50	3.50	3.00	3.50	1.50
50	3.00	2.00	3.00	2.00	3.00	4.00	2.50	3.00	2.00	1.50	3.00	3.00
51	4.00	4.00	4.00	4.00	4.00	3.00	3.50	4.00	4.00	4.00	4.00	4.00
52	3.00	2.00	3.00	3.00	3.00	2.00	2.00	3.00	3.00	3.00	3.00	3.00
53	3.00	4.00	4.00	3.00	3.00	4.00	4.00	4.00	3.50	3.00	3.50	3.00
54	3.00	2.00	2.00	2.00	2.00	2.00	3.00	2.50	3.00	2.50	2.00	2.50
55	.	.	.	.	.	.	1.00	.	4.00	.	3.00	.
56	1.00	2.00	1.00	1.00	1.00	3.00	2.00	1.50	1.50	1.50	2.50	1.00
57	2.00	3.00	3.00	3.00	3.00	2.00	3.00	3.00	2.50	3.00	2.50	2.50
58	3.00	2.00	2.00	3.00	3.00	3.00	3.50	2.50	2.00	3.00	1.50	3.00
59	2.00	1.00	4.00	4.00	3.00	1.00	2.00	3.00	2.00	3.00	1.00	2.50
60	1.00	4.00	3.00	3.00	3.00	3.00	3.50	3.00	2.50	2.50	3.50	2.00
61	3.00	2.00	3.00	3.00	1.00	3.00	3.50	3.00	3.50	3.00	2.50	2.00
62	3.00	4.00	2.00	4.00	3.00	3.00	3.50	3.00	3.50	4.00	3.00	3.00
63	3.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.50	2.00	2.50	2.50
64	4.00	1.00	2.00	3.00	4.00	1.00	3.00	2.50	2.50	3.00	3.00	4.00
65	.	.	.	.	.	.	2.00	.	3.00	.	2.50	.
66	.	.	.	.	.	.	3.00	.	3.00	.	3.00	.

	stimp2
45	2.00
46	4.00
47	4.00
48	4.00
49	3.00
50	3.00
51	3.50
52	2.00
53	4.00
54	2.00
55	.
56	2.50
57	2.50
58	2.50
59	1.00
60	3.50
61	2.50
62	3.50
63	2.00
64	1.00
65	.
66	.

c:\psppcom.sav

	id	age1	sc1	pc1	ab1	st1	ps1	sc2	pc2	ab2	st2	ps2
67	65.00	12.00	1.00	1.00	4.00	3.00	4.00	4.00	1.00	4.00	4.00	4.00
68	66.00	12.00	1.00	2.00	3.00	3.00	1.00	3.00	2.00	2.00	3.00	3.00

	sc3	pc3	ab3	st3	ps3	sc4	pc4	ab4	st4	ps4	sc5	pc5
67	1.00	1.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
68	1.00	2.00	1.00	1.00	3.00	1.00	2.00	1.00	3.00	3.00	3.00	1.00

29

	ab5	st5	ps5	sc6	pc6	ab6	st6	ps6	sc21	pc21	ab21	st21
67	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	2.00	2.00	2.00	3.00
68	3.00	1.00	1.00	1.00	1.00	2.00	3.00	1.00	2.00	3.00	2.00	3.00

c:\psppcom.sav

	ps21	sc22	pc22	ab22	st22	ps22	sc23	pc23	ab23	st23	ps23	sc24
67	3.00	2.00	3.00	2.00	3.00	2 00	2.00	2.00	3.00	2.00	2.00	3.00
68	3.00	1.00	4.00	2.00	3.00	3 00	2.00	3.00	3.00	3.00	3.00	3.00

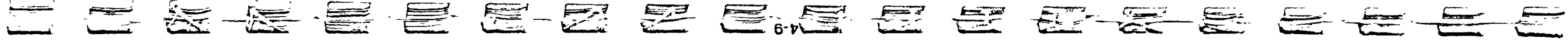
	pc24	ab24	st24	ps24	sc25	pc25	ab25	st25	ps25	sc26	pc26	ab26
67	2.00	2.00	3.00	3.00	2.00	3 00	2.00	3.00	2.00	2.00	3.00	2.00
68	3.00	2.00	3.00	3.00	4.00	3 00	2.00	3.00	3.00	2.00	3.00	2.00

	st26	ps26	str1	gender	physcon1	attbod1	scomp1	str2	physcon2	attbod2	scomp2	psw1
67	2.00	3.00	3.83	2	2.00	4.00	2.50	2.67	2.33	2.17	2.00	4.00
68	3.00	4.00	2.33	2	2.00	2.00	1.50	3.00	3.33	2.17	1.75	2.00

	psw2	piosc	scimp11	pcimp11	abimp11	stimp1	scimp12	pcimp12	abimp12	var00001	scimp21	pcimp21
67	2.50	2.00	2.00	2 00	3.00	2.00	2.00	3.00	2.00	.	3.00	3.00
68	3.17	2.00	2.00	2 00	1.00	4.00	4.00	4.00	4.00	.	4.00	2.00

34

	abimp21	stimp21	scimp22	pcimp22	abimp22	stimp22	scimp1	scimp2	pcimp1	pcimp2	abimp1	abimp2
67	3.00	3.00	3.00	3.00	3.00	2.00	2.50	3.00	2.50	3.00	2.50	3.00
68	3.00	1.00	2.00	3.00	4.00	2.00	3.00	3.00	2.00	2.50	2.50	3.50



	stimp2
67	2.50
68	1.50

c:\psppcom.sav

Appendix 10

Glossary of Terms

Glossary of Terms

- Adolescence – the period where body systems become more adult both structurally and functionally.

- Allometry – statistical techniques used to partition out differences in body size, and used clarify structure/function relationships.

- Behavioural Development – the development of a variety of domains relating to the competence in several domains as the child adjusts to his or her cultural milieu.

- Biological Development – the differentiation of cells along specialised lines of function.

- Blood Lipids – blood-borne fats such as triglyceride or cholesterol.

- Body Size – a person's height and weight.

- Canalisation – maintenance of a variable between adjacent percentile lines on a growth chart.

- Cardiorespiratory Fitness – a measure of the capacity and power of the cardiorespiratory systems.

- Childhood – the end of infancy to the start of adolescence.

- Chronological Age – a measurement made over time.

- Circum-puberty – the period when a child is entering the most rapid phase of development.

- Diastolic Blood Pressure – the lowest arterial pressure resulting from ventricular diastole.

- Fat-Free Mass – the mass of the body that is not fat.

- Fat mass – the absolute amount of body fat.

- Fatigue – an inability to continue work.

- Fatty Streaks – early lipid deposits within blood vessels.

- Gender Differences – any difference between males and females.

- Genotype – the genetic make-up of an individual.

- Growth – an increase in the size of the part or whole body.

- Haemoglobin – the iron-containing pigment in red blood cells that binds oxygen.

- Heart Rate Reserve – the difference between maximal and resting heart rates.

- High-Density Lipoprotein Cholesterol – a cholesterol carrier regarded as a scavenger that removes cholesterol from the arterial wall and transports it to the liver to be metabolised.

- Hyperlipidaemia – elevated levels of blood lipids.

- Hyperkinaesia – high levels of physical activity.

- Hypertension – abnormally elevated levels of blood pressure.

- Hypokinaesia – low levels of physical activity.

- Indirect Calorimetry – a method of estimating energy expenditure by measuring respiratory gases.

- Longevity – the length of the lifespan.

- Longitudinal Study – a study performed over time using the same cohort.

- Maturation – the tempo and timing of progress towards the mature biological state.

- Maximal Aerobic Power – the highest oxygen uptake sustained during testing to exhaustion.

- Maximum Heart rate – the highest heart rate recorded during a maximum effort.

- Mode – the type of exercise.

- Morphological Age – the age of the body according to form and structure.

- Obesity – an excessive amount of body fat.

- Osteoporosis – decreased bone mineral content.

- Overweight – body weight exceeds normal or standard value for a particular individual based on height, sex and age.

- Peak Aerobic Power – the highest recorded oxygen uptake measured, without showing a plateau, during exhaustive testing.

- Phenotype – the child's physical or physiological characteristics.

- Physical Activity – an elevation in body metabolism above the resting state.

- Physical Self-Perceptions – the ability of the individual to differentiate perceptions of the self from within the physical domain.

- Post-puberty – the period following the most rapid phase of development.

- Pre-puberty – the period before a child enters the most rapid phase of development.

- Primary Risk Factors – risk factors that are shown to be implicated in the aetiology of certain diseases.

- Puberty – the point at which a person becomes physiologically capable of reproduction.

- Resting Heart Rate – the heart rate at rest, normally during the sleeping period.

- Skinfold Fat Thickness – the measurement of subcutaneous adiposity using callipers.

- Systolic Blood Pressure – the greatest arterial blood pressure resulting from systole.

- TC:HDL-C Ratio – the ratio between total cholesterol and high-density lipoprotein cholesterol measurements.

- Tracking – the stability in a variable between test visits.