

**Optimising exercise and physical activity support
for young people living with obesity in NHS
Complications from Excess Weight Services-
MOTIVATE-CEW2**

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Abstract

The prevalence of obesity among children and young people in the UK is increasing and is associated with significant physiological and psychosocial complications across the life course (Schwimmer, Burwinkle and Varni, 2003; Reilly and Kelly, 2011; Di Cesare *et al.*, 2019). In response, NHS England has established specialist paediatric Complications from Excess Weight (CEW) services that deliver multidisciplinary care for obesity-related comorbidities. Lifestyle treatment, including exercise and physical activity (PA), is recommended as first-line therapy (Al-Khudairy *et al.*, 2017); however, the optimal approach to delivering these components within CEW services remains unclear (Apperley *et al.*, 2022). To address this, we developed and evaluated the MOTIVATE-CEW exercise and PA intervention in a preliminary feasibility randomised controlled trial within the Alder Hey Children's Hospital CEW service (Davies *et al.*, 2026). The intervention and trial procedures were feasible and showed promising improvements in exercise behaviour, although maintenance of exercise was limited. Therefore, this thesis aimed to refine the MOTIVATE-CEW intervention and its trial methodology and to conduct a second feasibility randomised controlled trial to evaluate the optimised programme.

Study one used a qualitative survey with intervention participants as well as focus groups and semi-structured interviews with both intervention participants and their caregivers to evaluate the acceptability of MOTIVATE-CEW. The study was designed to identify barriers, facilitators and targets for refinement within the original intervention before future refinement could commence. Ten of the twelve intervention participants completed the survey: three participated in a focus group and one in an individual interview. In addition, three caregivers attended a focus group, and one completed an interview. Key facilitators of engagement included personalised, graded action plans and feedback from the exercise physiologist, while the most frequently suggested improvement was a longer intervention duration. This study reported qualitative findings of the mixed method evaluation of the original MOTIVATE-CEW intervention. These findings, along with those of the MOTIVATE-CEW feasibility randomised control trial, informed the subsequent optimisation of the intervention and study methodology in Study two.

Study two used an Intervention Mapping framework alongside a co-development process to refine the MOTIVATE-CEW intervention and develop MOTIVATE-CEW2. This systematic process resulted in a comprehensive, evidence-informed, theory-driven exercise and physical activity (PA) intervention for CEW services that was grounded in the needs of patients, their families and CEW staff. The intervention design comprised five interrelated components: education, person centred counselling, mobile health technologies and self-monitoring, regular remote feedback and support, and ongoing motivation and encouragement strategies. Together, these components were intended to support the maintenance of exercise and PA by improving the quality of motivation, reducing barriers to accessing support and encouraging autonomy in exercise and PA behaviours. The co-development process was also used to refine the study design for the MOTIVATE-CEW2 feasibility randomised control trial. This work informs the feasibility randomised control trial undertaken in study three.

Study three consisted of a single centre, parallel group feasibility randomised controlled trial of the MOTIVATE-CEW2 intervention and study design. 22 CEW service patients were recruited and randomised to receive the MOTIVATE-CEW2 intervention for 6 months alongside usual care or to continue with usual care alone. The intervention showed a promising effect on exercise behaviour. 82% initiated purposeful exercise and 64% remained engaged at 6 months showing good maintenance throughout the intervention period. Participants completed 1.2 ± 1.7 sessions/week and 51 ± 69 minutes/week of exercise. The study had strong recruitment (33% of eligible patients) and good reach with participant characteristics broadly representative of the wider Alder Hey Children's Hospital CEW service population for age, sex, indices of multiple deprivation quintile and ethnicity. However, further optimisation may be required to improve completeness of the proposed primary outcome (77% completion of PedsQL 4.0 data at 6 months) and to consider the generalisability of both the study procedures and the intervention across CEW services in the UK. Overall, the findings support progression to a fully powered, multi-site effectiveness trial.

The iterative process across these three sequential studies enabled the development and feasibility evaluation of a comprehensive, evidence informed exercise and PA

intervention designed specifically for CEW services in the UK. Future research should determine the extent of further refinement required to strengthen the scalability, external validity and implementation readiness of MOTIVATE-CEW2 before progression to a multi-site effectiveness trial.

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Declaration

I declare that the work presented in this thesis was conducted in accordance with the regulations of Liverpool John Moores University. I declare that all work presented in this thesis is my own and no portion of the work has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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Abbreviations

ADHD- attention deficit hyperactivity disorder

ALT- Alanine Transaminase

ASD- autism spectrum disorder

AST- Aspartate Aminotransferase

BCT- Behaviour Change Technique

BMI- Body Mass Index

BP- Blood Pressure

CEW- Complications from Excess Weight

CI- Confidence Interval

CPET- Cardiopulmonary Exercise Testing

CRF- Cardiorespiratory Fitness

CYP- Children and Young People

EQ-5D-Y-5L- EuroQol-5 Dimensions- Youth-5 Levels

HbA1C- Glycated Haemoglobin

HCP- Healthcare Professional

HDL- High Density Lipoprotein Cholesterol

HIIT- High Intensity Interval Training

HOMA-IR- Homeostatic Model Assessment of Insulin Resistance

HRQoL- Health Related Quality of Life

IMD- Index of Multiple Deprivation

IWQOL-Lite- Impact of Weight on Quality of Life-Lite

LD- Learning Difficulties

LDL- Low Density Lipoprotein Cholesterol

MAP- Mean Arterial Blood Pressure

MASLD- Metabolic Dysfunction-Associated Steatotic Liver Disease

MCID- Minimal Clinically Important Difference

MDT- Multidisciplinary Team

METs- Metabolic Equivalent of Task

mHealth- Mobile Health

MRC- Medical Research Council
MVE- Moderate-to-vigorous intensity exercise
MVPA- Moderate-to-Vigorous Physical Activity
NAFLD- Non-alcoholic fatty liver disease
NCMP- National Child Measurement Programme
NHS- National Health Service
NICE- National Institute for Health and Care Excellence
PA- Physical Activity
PedsQL 4.0- Pediatric Quality of Life Inventory 4.0
RCADS- Revised Child Anxiety and Depression Scale
RCT- Randomised Control Trial
RSE- Rosenberg Self Esteem Scale
SD- Standard Deviation
SDS BMI- Body Mass Index Standard Deviation Score
SWAT- Study Within a Trial
TIDieR- Template for Intervention Development and Replication
WHO- World Health Organisation
6MWT- Six-minute Walk Test

1. Literature Review

1.1. Trends in children and young people living with obesity

1.1.1. Definitions and classification

Obesity is a global public health crisis with more than 1 billion people living with obesity worldwide (NCD Risk Factor Collaboration, 2024). Defined by the World Health Organization (WHO) as abnormal or excessive fat accumulation that presents a risk to health (WHO, 2025a), obesity is commonly quantified as having a body mass index (BMI) greater than or equal to 30 in adults. In children and adolescents aged 5 to 19 years old, age must be considered when quantifying obesity, therefore a BMI standard deviation score (SDS BMI) greater than 2 standard deviations is used to classify obesity (WHO, 2025b). Due to rising prevalence and an increased severity of health risk factors, an additional subset of obesity is required to define those living with severe obesity. Worldwide the classification of severe obesity in children and young people is not consistent (Valerio *et al.*, 2024), however, in England the definition of severe obesity is a BMI centile greater than or equal to 99.6, which equates to an SDS BMI score greater than or equal to 2.68 (NICE, 2025). Figure 1.1 summarises the use of SDS BMI to categorise obesity and severe obesity in children and adolescents in England. To ensure clarity and consistency throughout this thesis, the term children and young people (CYP) will be used when referring to individuals aged 0–18 years. Where greater specificity is required, those aged 11–18 years will be described as young people, and those under 11 years as children.

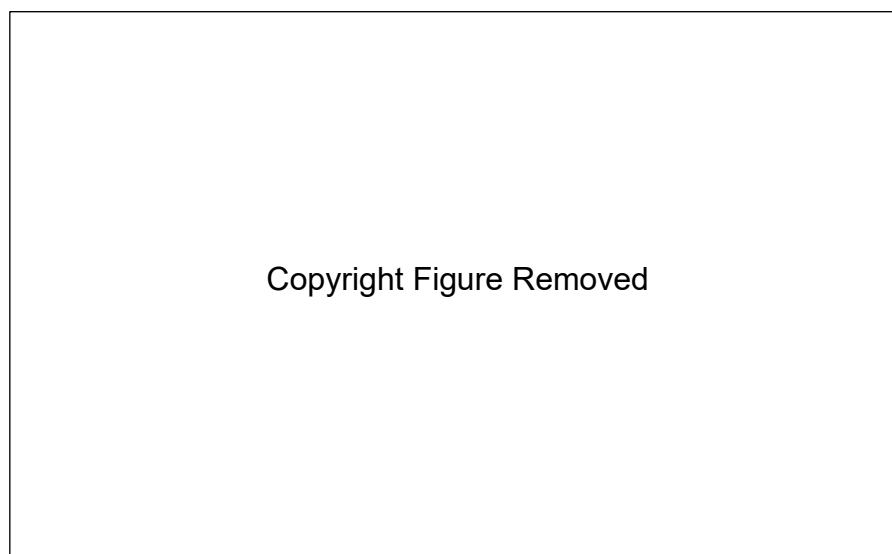


Figure 1.1. Body mass index chart 2-20 years. (RCPCH, 2013)

Source: Adapted from Royal College of Paediatrics and Child Health.
BMI, body mass index; *SD*, standard deviation.

1.1.2. Prevalence of children and young people living with obesity

The prevalence of CYP living with obesity has increased worldwide over the past 36 years. In 1990, only 2% of 5-19-year-olds were living with obesity globally, however, obesity rates in this age group have since tripled, with 8% of 5-19-year-olds living with obesity worldwide in 2022 (WHO, 2025b). In England, the prevalence of CYP living with obesity exceeds global levels, with 15% of CYP aged 2-15 year living with obesity according to the Health Survey for England (NHS-Digital, 2026). Young people aged 11-15 years account for a disproportionately large share of the CYP living with obesity, with 19% affected, compared to 13% in children aged 2-10. The prevalence of obesity in 11-15-year-olds in England mirrors global trends, having increased by 4% since 1995 (NHS-Digital, 2026).

Of particular concern in England is the proportion of CYP living with severe obesity, which has also increased in recent years. While data on severe obesity prevalence isn't available for adolescents aged 11-15 years at a national level, the National Child Measurement Programme provides data for children aged 10-11 years. Within this age group, the prevalence of severe obesity has increased from 3.2% in 2006/07 to 5.5% in 2023/24 (NHS-Digital, 2024b).

1.1.2.1 Socioeconomic disparities in obesity prevalence

Evidence suggests that these increases are not evenly distributed across the population, with notable socioeconomic disparities in obesity prevalence among CYP in England. Area-level deprivation is commonly measured using the English Index of Multiple Deprivation (IMD) which incorporates 7 domains (Income, Employment, Education, Health, Crime, Barriers to Housing & Services and Living Environment) within its methodological framework to rank 33,755 small areas within England from most deprived to least deprived. When this ranking is grouped into quintiles, 21% of children aged 2-15 years old living in the most deprived areas are affected by obesity, compared with just 9% in the least deprived areas (NHS-Digital, 2026). Data from the National Child Measurement Programme for the 2023/24 school year demonstrates a comparable pattern, with a higher prevalence of severe obesity among children aged 10-11 years living in the most deprived areas than among those in the least deprived areas (NHS-Digital, 2024b). When IMD is grouped into deciles, a graded increase in

severe obesity prevalence is observed across increasing levels of deprivation, with 9.0% of children in the most deprived decile living with severe obesity, compared with 2.2% in the least deprived decile (Figure 1.2). Although the Health Survey for England (2022) and the National Child Measurement Programme (2023/24) cover different age groups, both datasets demonstrate consistent patterns.



Figure 1.2. Severe obesity prevalence in 10-11-year-olds by IMD decile (based on postcode of the child), 2023/24. (NHS-Digital, 2024b)

Source: National Child Measurement Programme, England 2023-24, NHS England.

1.1.2.2. Obesity prevalence in children from minoritised ethnic backgrounds

Additional inequalities in the prevalence of CYP living with obesity have also been observed in people from different ethnic groups. Data from the National Child Measurement Programme reported that the proportion of 10-11 year-olds living with obesity was highest in Black children (30.4%) (NHS-Digital, 2024b). Children from Asian, Mixed and Other ethnic groups also had a proportion greater than White children, suggesting that obesity is overrepresented in children from minoritised ethnic backgrounds. The BMI thresholds for obesity used within the National Child Measurement Programme are the same for all young people and are based on a white population reference. Therefore, these thresholds do not consider ethnicity, despite evidence suggesting that BMI overestimates body fat in children from Black ethnic groups and underestimates body fat in children from South Asian ethnic groups (Firman *et al.*, 2020). Data suggests 19.7% more children from South Asian backgrounds would have been placed in a heavier weight category while 19.1% of

children from Black backgrounds would have been categorised in a lighter weight bracket. Given the data that shows CYP from Asian backgrounds have increased metabolic risk at current BMI thresholds (Hong, Zhang and Hartmann, 2026), and the evidence in adult populations that cardiometabolic risk occurs at a lower BMI in people with a South Asian, Chinese, other Asian, Middle Eastern, Black African or African–Caribbean background (NICE, 2025), consideration should be given as to who is most at risk from the increased prevalence of CYP living with obesity.

1.1.2.3. Obesity prevalence in children with neurodevelopmental conditions

Obesity is also overrepresented in, CYP with neurodevelopmental conditions such as autism spectrum disorder (ASD), attention deficit hyperactivity disorder (ADHD), and learning difficulties (Emerson *et al.*, 2016; Maiano *et al.*, 2016; Kahathuduwa *et al.*, 2019). A systematic review and meta-analysis by Maiano *et al.* (2016) reported that adolescents with intellectual disabilities are 1.8 times more likely to be living with obesity than adolescents without neurodevelopmental conditions.

The over representation of obesity in CYP from more deprived backgrounds, minoritised ethnic groups and in CYP with neurodevelopmental conditions highlights the need for prevention and treatment strategies to consider CYP backgrounds and additional needs in their design and implementation.

1.1.3. Drivers of children and young people living with obesity and socioeconomic inequalities

The increased prevalence of CYP living with obesity and severe obesity in England reflects the influence of numerous socioecological, environmental, and genetic influences (Hampl *et al.*, 2023). At its core, obesity is a result of a sustained imbalance between energy intake and energy expenditure (Ahmed and Mohammed, 2025) with lifestyle and environmental factors shaping behaviours that contribute to increased energy intake and reduced energy expenditure. Dietary patterns in England have changed over time, with the diets of CYP now characterised by higher intakes of sugar, fat, and salt, alongside low consumption of fruit and vegetables, as evidenced by the National Diet and Nutrition Survey (GOV.UK, 2024). This pattern, coupled with increased consumption of sugar-sweetened drinks (Abbasalizad Farhangi *et al.*, 2022)

contributes towards excessive energy intake in CYP. In-parallel, reductions in physical activity (PA) and increases in sedentary behaviour among CYP have been observed over time (Brodersen *et al.*, 2007) with evidence suggesting that PA decreases and sedentary time increases as children progress into adolescence (Jago *et al.*, 2020).

Socioeconomic inequalities in childhood obesity prevalence are partly driven by unequal exposure to these behavioural and environmental risk factors. Children living in more deprived areas often experience reduced access to affordable, healthy food and increased availability of unhealthy food options (Cetateanu and Jones, 2014; Williamson *et al.*, 2017; Desbouys *et al.*, 2020). Lower levels of physical activity in these populations may be further influenced by poorer access to recreational facilities and safe environments for activity (Eyre *et al.*, 2014), financial constraints associated with engaging in organised PA (Somerset and Hoare, 2018) and higher levels of screen time and sedentary behaviour within more deprived households (Libuy, Bann and Fitzsimons, 2021).

The differences in childhood obesity prevalence observed in minoritised ethnic groups are likely to reflect a complex interplay of socioeconomic, environmental and cultural influences (El-Sayed, Scarborough and Galea, 2012; Min *et al.*, 2021). One important mechanism is the unequal distribution of deprivation across minoritised ethnic groups in England, with children from several minority ethnic groups more likely to live in the most deprived neighbourhoods (ONS, 2020). Consequently, the behavioural and environmental risk factors associated with deprivation are disproportionately experienced by these groups. Together, these structural inequalities are likely to contribute to the widening socioeconomic and ethnic disparities in obesity and severe obesity prevalence among CYP in England.

1.2. Consequences of living with obesity for children and young people

1.2.1. Cardiometabolic consequences

Living with obesity during childhood and adolescence is associated with numerous cardiometabolic risk factors (Reilly *et al.*, 2003; Skinner *et al.*, 2015) as well as the development of multiple comorbidities both during childhood and in the future during

adulthood (Reilly and Kelly, 2011; Kumar and Kelly, 2017). Obesity in childhood and adolescence also increases the risk of premature mortality (Reilly and Kelly, 2011; Lindberg *et al.*, 2020).

Dyslipidaemia is one of the cardiometabolic risk factors associated with obesity. Increases in triglycerides and low density lipoprotein cholesterol (LDL), paired with decreases in high density lipoprotein cholesterol (HDL), are known blood lipid profile changes experienced by CYP living with obesity (Kwiterovich Jr, 2008; Skinner *et al.*, 2015; Kavey, 2023). CYP living with severe obesity are also at greater risk of developing dyslipidaemia than those with obesity (Bendor *et al.*, 2020). The long-term result of dyslipidaemia is an increased risk of atherosclerosis which can lead to many serious cardiovascular events including coronary artery disease, stroke and angina (Kopin and Lowenstein, 2017). Although clinically diagnosed atherosclerosis is uncommon in childhood and often remains asymptomatic until adulthood, childhood obesity and dyslipidaemia are associated with vascular changes that are considered part of the early atherogenic process. (Berenson, 2009; Chung, Krenek and Magge, 2023). Consistent with this, studies have reported impaired endothelial function and other markers of subclinical vascular change in CYP living with obesity compared with healthy-weight peers, suggesting early vascular dysfunction that may contribute to the later development and progression of atherosclerosis (Järvisalo *et al.*, 2002; Pena *et al.*, 2006; Skilton and Celermajor, 2006). Figure 1.3 illustrates the progression of atherosclerosis and summarises the key mechanisms through which this process occurs.

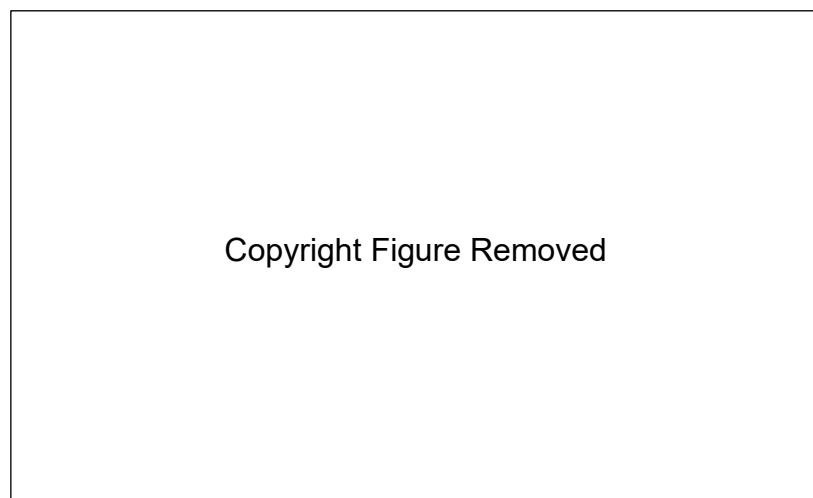


Figure 1.3. Atherosclerosis progression

This figure illustrates the gradual progression of atherosclerosis from a healthy artery to a complicated lesion. It shows how early intimal thickening and lipid accumulation can develop into atherosclerotic plaque, which may become vulnerable, rupture, and lead to blood clot formation. This process can narrow or obstruct arteries and contribute to cardiovascular events.

Source: ID 408643193 @ Andreus Dreamstime.com

Hypertension is another known cardiometabolic risk factor with increased prevalence in CYP living with obesity (Wühl, 2019). The mechanisms that cause hypertension in CYP living with obesity are complex and are still being investigated, however, two known causes are hyperinsulinemia stimulating the sympathetic nervous system and activation of the renin–angiotensin system resulting in vasoconstriction and the retention of sodium and fluid (Kotsis *et al.*, 2010; Becton, Shatat and Flynn, 2012; Landsberg *et al.*, 2013). High blood pressure is also known to cause endothelial dysfunction in blood vessels which once again can result in the thickening of artery walls and the development of atherosclerotic plaques (Figure 1.3)(Gonzalez-Guerra *et al.*, 2021; Poznyak *et al.*, 2022). CYP living with severe obesity are at greater risk of developing hypertension (Bass and Eneli, 2015) which underlines the concern around the rising prevalence of severe obesity in this population.

Obesity is also associated with insulin resistance which is another well-known cardiometabolic risk factor (Hannon, Rao and Arslanian, 2005; Barazzoni *et al.*, 2018). The accumulation of excess body fat associated with obesity results in excess free fatty acids circulating in the blood which impacts insulin signalling across multiple sites in the body (Hannon, Rao and Arslanian, 2005; Kahn, Hull and Utzschneider, 2006). Excess fat also triggers the release of inflammatory cytokines that block insulin signalling pathways and visceral fat deposits around the liver and pancreas also directly impairs function and insulin sensitivity of these organs (Hannon, Rao and Arslanian, 2005; Kahn, Hull and Utzschneider, 2006). Insulin resistance disrupts the body's ability to lower blood glucose which in turn forces beta-cells in the pancreas to produce more insulin (Kahn, Hull and Utzschneider, 2006). Over time beta-cells become overworked and can fail resulting in hyperglycaemia and the onset of type 2 diabetes (Kahn, Hull and Utzschneider, 2006; Wysham and Shubrook, 2020). A review by Cioana *et al.* (2022) combined data from 8942 participants across 53 studies and

found that found that 75.27% of CYP with type 2 diabetes were living with obesity. This data highlights the dangers of insulin resistance and shows that CYP living with obesity not only risk developing type 2 diabetes as adults (Biro and Wien, 2010), but also risk early onset of type 2 diabetes which is associated with an increased risk of health complications in later life. These include, but are not limited to, visual impairment, kidney failure (Pavkov *et al.*, 2006) and limb amputations (Dean and Sellers, 2007). Furthermore, living with severe obesity places CYP under greater threat of developing type 2 diabetes, once again highlighting the dangers of increased obesity severity (Bendor *et al.*, 2020).

Obesity, dyslipidaemia, and insulin resistance are all strongly associated with metabolic dysfunction-associated steatotic liver disease (MASLD) (Temple *et al.*, 2016) which can result in liver failure, cardiovascular disease and a variety of other cardiometabolic issues (Mantovani *et al.*, 2020). MASLD has recently replaced non-alcoholic fatty liver disease (NAFLD) as the preferred terminology for steatotic liver disease occurring in the presence of cardiometabolic risk factors. In CYP, MASLD may be diagnosed where there is evidence of hepatic steatosis alongside at least one cardiometabolic criterion, although paediatric-specific thresholds remain incompletely standardised, particularly in younger children; therefore, earlier studies using NAFLD terminology may not align fully with updated MASLD diagnostic criteria (European Society for Pediatric Gastroenterology *et al.*, 2024). There is an increased prevalence of MASLD in CYP living with obesity compared to the general population (Anderson *et al.*, 2015), once again putting CYP living with obesity at greater risk of early onset morbidity and mortality. Preliminary data from the ENHANCE study support these earlier findings, with MASLD diagnosed in 30% of sampled patients attending CEW services (Matu *et al.*, 2025). Further, to the cardiometabolic risk factors and comorbidities discussed above, CYP living with obesity are at greater risk of sleep apnoea (affecting up to 60% of obese children) (Narang and Mathew, 2012), early onset puberty (Ahmed, Ong and Dunger, 2009) and most alarmingly, multiple forms of cancer (Lauby-Secretan *et al.*, 2016; Weihrauch-Blüher, Schwarz and Klusmann, 2019).

In addition to the multiple health complications, CYP living with obesity were found to be approximately five times more likely to live with obesity in adulthood than those

who were not obese (Simmonds *et al.*, 2016). Age and obesity severity also impacts the likelihood of obesity tracking into adulthood with older age and greater severity increasing the probability (Simmonds *et al.*, 2016). Cardiovascular disease risk in adulthood is also increased as a result of living with obesity during childhood and adolescence (Baker, Olsen and Sørensen, 2007; Faienza *et al.*, 2020), with one study suggesting the presence of multiple cardiovascular disease risk factors during adolescence resulted in an almost 15-fold increase in the risk of developing cardiovascular disease before the age of 50 (Morrison, Friedman and Gray-McGuire, 2007). The extensive list of cardiovascular risk factors and comorbidities that result from CYP living with obesity, both in the short and long term, emphasises the importance of developing treatment strategies for affected populations, particularly for those living with severe obesity, for whom the consequences are often more serious and occur earlier in life.

1.2.2. Psychosocial consequences

In addition to the numerous physiological consequences that result from living with obesity, CYP are also more likely to suffer from a range of psychosocial difficulties. Health related quality of life (HRQoL) is an important outcome measure, as it captures overall well-being rather than focusing solely on clinical risk factors or disease outcomes (Freire and Ferreira, 2018). Compared with their healthy-weight peers, CYP living with obesity consistently report significantly poorer HRQoL, based on both self-reported and parent-proxy assessments (Tsiros *et al.*, 2009; van der Heijden *et al.*, 2021). Alarming, CYP with severe obesity are reported to have a quality of life similar to that of CYP diagnosed with cancer (Schwimmer, Burwinkle and Varni, 2003).

Beyond the reductions in quality of life that are experienced by many CYP living with obesity, living with obesity is associated with increased prevalence of mental health problems, particularly anxiety and depression (Kokka, Mourikis and Bacopoulou, 2023; Öz and Kivrak, 2023; Chen *et al.*, 2024). The study by Öz and Kivrak (2023) also highlighted that CYP living with obesity have lower self-esteem, and had more difficulties in emotion regulation than healthy weight control participants.

Furthermore, CYP living with obesity are more likely to experience social exclusion and negative body image (Zeller, Reiter-Purtill and Ramey, 2008; Moradi *et al.*, 2021).

These psychosocial outcomes are thought to be driven, at least in part, by increased exposure to weight-based stigma, bullying, and social exclusion, particularly within school settings, which disproportionately affect CYP living with obesity (Van Geel, Vedder and Tanilon, 2014; Moradi *et al.*, 2021). Emerging evidence further suggests that these consequences may persist into adulthood, highlighting the long-term implications of childhood obesity on psychosocial outcomes (Gallagher *et al.*, 2023).

Finally, living with obesity during childhood and adolescence may also impact educational outcomes. A systematic review of longitudinal evidence suggests that CYP living with obesity may be at increased risk of poorer academic achievement, with this relationship potentially mediated by psychosocial factors such as weight-related bullying, school distress, and reduced engagement in physical education (Martin *et al.*, 2017). Therefore, the psychosocial consequences of obesity may extend beyond emotional well-being and social functioning, with potential implications for school experience and educational attainment.

1.2.3. Economic and health service burden

Due to the rising prevalence and increased severity of CYP living with obesity in England, additional financial strain is placed on the National Health Service (NHS) as it aims to treat the myriad of health consequences that can present in CYP living with obesity. A recent study estimated the total annual costs attributable to childhood excess weight in England was £273 million (Onyimadu *et al.*, 2025) with another study reporting that a surge in overweight and obesity prevalence in 10-11 year olds during the COVID-19 pandemic could cost the NHS an additional £800 million in lifelong healthcare costs within this cohort (Ochoa-Moreno *et al.*, 2024). In part, this is a result of rising hospital admissions related to CYP living with obesity in the immediate future (Jones Nielsen *et al.*, 2013), and additional hospitalisations in the future due to obesity and its associated health risks tracking into adulthood (Baker, Olsen and Sørensen, 2007; Simmonds *et al.*, 2016; Faienza *et al.*, 2020). The increased economic burden of CYP living with obesity is also evident worldwide with a studies from Germany (Sonntag *et al.*, 2015) and the United States (Levitt, Jackson and Morrow, 2016) reporting notable added lifetime medical costs. To counteract the significant health consequences that come with living with obesity during childhood and adolescence,

and to reduce the burden that sustained obesity into adulthood places on health services, early intervention is required (Gortmaker *et al.*, 2015; Okunogbe *et al.*, 2021).

1.3. Exercise and physical activity in children and young people living with obesity

1.3.1. Definitions and guidelines

In light of the rising prevalence of CYP living with obesity and the substantial health and psychosocial consequences associated with this, there is a growing interest in modifiable lifestyle behaviours that may mitigate risk factors associated with obesity. Exercise and PA are key targets, given their potential to improve health outcomes and quality of life in CYP living with obesity.

PA has long been defined as “any bodily movement produced by the skeletal muscles that result in energy expenditure” (Caspersen, Powell and Christenson, 1985). This definition includes daily activities, active transport, play and exercise. Exercise is therefore a subset of PA and defined as planned, structured and repetitive with the intention to improve or maintain physical fitness (Caspersen, Powell and Christenson, 1985). Another important and relevant term to define when considering activity in CYP living with obesity is sedentary behaviour, which can be defined as “any waking behaviour characterized by an energy expenditure ≤ 1.5 metabolic equivalent of task (METs) while in a sitting or reclining posture” (Barnes *et al.*, 2012; Reilly *et al.*, 2015). The UK government PA and sedentary behaviour guidelines for 5-18 year olds recommends at least 60 minutes of moderate-to-vigorous PA per day, incorporating a variety of activity types (GOV.UK, 2019). Guidelines also encourage CYP to minimise prolonged sedentary behaviour. While the guidelines recognise PA as an important factor for overall health and preventing obesity, they do not provide additional levels of detail to guide CYP living with obesity and fail to provide direction on how recommendations should be interpreted or applied for those living with obesity and severe obesity.

1.3.2. Benefits of physical activity in children and young people living with obesity

Research into the physiological and psychosocial effects of PA in CYP living with obesity is limited, but the research that exists offers insights into the benefits of habitual PA in this population. The systematic review of prospective epidemiological studies and randomised control trials by Georgoulis *et al.* (2026) reported the positive effect of higher PA levels on obesity related health outcomes in CYP living with obesity. This review also highlighted the importance of PA intensity to improve obesity related outcomes. Data from isothermal substitution studies showed changes from lower intensity to higher intensity PA resulted in a beneficial effect on obesity related outcomes. This was particularly evident when substituting sedentary time with PA of any intensity and when completing more vigorous PA than lower intensity PA. This study also conducted a meta-analysis of 16 randomised control trials assessing PA interventions. Results showed that increased PA was associated with significant reductions in BMI and SDS BMI in PA interventions lasting greater than a year. Collectively this study not only highlights the impact of PA on obesity related health outcomes for CYP living with obesity but also evidences the value of exercise within this population, particularly at a moderate-to-vigorous and vigorous intensity.

While the evidence base in CYP living with obesity is sparse, the body of evidence for the impact of PA in general paediatric population is extensive (Wilhite *et al.*, 2023). Janssen and LeBlanc (2010) conducted a review of 11,088 studies examining the relationship between PA, cardiorespiratory or musculoskeletal fitness and health in school-aged CYP. Studies within the review adopted multiple different PA measurement techniques including questionnaires, activity diary, pedometers and accelerometers. PA was associated with reductions in cardiometabolic risk, blood pressure, metabolic syndrome risk and depression symptoms as well as improvements in lipid profile and bone density. A dose-response relationship was also reported with more PA being associated with greater health benefits. As discussed in the review by Georgoulis *et al.* (2026) this review also reported that higher intensity activities are associated with greater health benefits, further supporting the role of exercise to improve health-related outcomes. A systematic review of objectively measured PA and health benefits in CYP further supports the findings from Janssen

and LeBlanc, and once again reports a dose-response relationship between PA and health benefits (Poitras *et al.*, 2016). Studies have also reported a positive effect of PA on HRQoL in healthy weight (Zhang, Lu and Wu, 2020; Bermejo-Cantarero *et al.*, 2024) and overweight CYP (Shoup *et al.*, 2008) which is of particular importance in due to the poor HRQoL reported in CYP living with obesity (Schwimmer, Burwinkle and Varni, 2003). Taken together the findings of these studies conclusively describes the benefit of increased habitual PA in CYP. Furthermore, reviews from both CYP in the general population and those living with obesity suggest that PA at higher intensities resulted in greater benefits on health and obesity related outcomes. This suggests exercise should also be reviewed and encouraged in CYP living with obesity.

1.3.3. Current physical activity levels in children and young people living with obesity

Although PA in CYP living with obesity is associated with positive health outcomes, the current levels of participation within this cohort is low compared to their healthy weight peers (Elmesmari *et al.*, 2018). A systematic review by Elmesmari *et al.* (2018) reported findings from 26 studies that obtained accelerometer measured levels of PA and sedentary time in CYP with obesity, with 22 of these studies providing comparisons to healthy weight peers. CYP living with obesity spent significantly less time completing moderate-to-vigorous PA (MVPA) than the control groups. Sedentary time was also higher in CYP living with obesity than in the non-obese groups. This trend is also observed in CYP living with severe obesity where reduced physical levels have once again been reported in comparison to normal weight peers (Danielsen *et al.*, 2022).

In addition to having lower levels of activity than their healthy weight peers, CYP living with obesity commonly reduce MVPA and increase sedentary time as they age. A study conducted in Southwest England reported that children living with obesity at aged 6 reduced MVPA and increased sedentary time by age 11 (Jago *et al.*, 2020). Overweight and healthy weight peers also reported reductions in PA and increases in sedentary time between the ages of 6 and 11 years, however, the reduction in PA was significantly greater in children living with obesity. Li *et al.* (2020) examined the longitudinal influence of overweight and obesity on PA levels among young people

aged 10-17 years. Consistent with patterns observed in children, PA levels among young people living with overweight were strongly and inversely associated with age. In contrast, those living with obesity demonstrated very low levels of PA at age 10, and these levels remained persistently low through to age 17, with little evidence of change over time. Considering these trends in activity and with the understanding of the numerous and significant health benefits associated with exercise and PA for CYP living with obesity, it is clear that interventions are required to promote engagement in exercise and PA.

The consistently lower PA levels in CYP living with obesity are driven by a complex interaction of individual, interpersonal and environmental barriers (Chen, Bai and Ni, 2024). The systematic review of qualitative studies by Stankov, Olds and Cargo (2012) identified that weight-related stigma, low self-efficacy, lack of inclusive environments, social judgement and parental logistical barriers all reduce willingness to participate in activity in this population. Although many of these barriers are also experienced by healthy weight peers they are amplified in the presence of obesity, which partly explains the lower PA levels observed. In addition, physical discomfort and reduced fitness increase the perceived difficulty of movement and diminish enjoyment of activity, providing a further explanation for disengagement from PA (Riddiford-Harland, Steele and Baur, 2006).

1.3.4. Benefits of exercise interventions for children and young people living with obesity

In contrast to PA, there is a substantial evidence base for the benefits associated with increased exercise in CYP living with obesity. Studies evaluating these exercise interventions typically involve the completion of purposeful bouts of planned exercise, under supervised conditions.

1.3.4.1. Benefits to anthropometric outcomes

Exercise interventions have consistently been associated with positive influence on body composition in CYP living with obesity. A systematic review of meta-analyses by García-Hermoso, Ramírez-Vélez and Saavedra (2019) reported moderate improvements in BMI and small improvements in body mass, central obesity and fat

mass when combining reviews that included aerobic, resistance or combined aerobic and resistance exercise modalities. When further considering the effect of individual exercise modalities on body composition outcomes, evidence suggests that all exercise types are associated with favourable changes in CYP living with obesity. A recent meta-analysis of the effects of aerobic exercise on body composition in CYP living with overweight and obesity reported significant reductions in BMI, body mass, waist circumference, fat mass, body fat percentage and visceral adipose tissue (Yan *et al.*, 2025). The exercise programmes completed in the review by Yan *et al.* (2025) were all completed at moderate intensity with interventions lasting between 4 and 22 weeks. Significant decreases in body weight, BMI and fat mass were also observed in the meta-analysis by Garcia-Hermoso, Sanchez-Lopez and Martinez-Vizcaino (2015) that reviewed combined aerobic and resistance exercise interventions (8–24 weeks duration) for CYP living with obesity. Resistance training interventions alone have also produced improvements in body composition with a meta-analysis showing significant reductions in body fat percentage and significant increases in fat-free mass (Huang *et al.*, 2023). In contrast, BMI did not significantly change as a result of resistance training alone, a finding supported by another meta-analysis of exercise interventions in which CYP living with obesity completed exercise on average 3 times per week for 50 minutes per session over a 12-week period (Kelley, Kelley and Pate, 2017). A lack of change in BMI despite engagement in resistance training may be a result of concurrent increases in lean mass (Van Der Heijden *et al.*, 2010).

1.3.4.2. Benefits to cardiovascular disease risk

Exercise and physical activity have been associated with improvements in multiple cardiovascular disease risk factors, including dyslipidaemia, hypertension, and insulin resistance (Chen *et al.*, 2021; Garcia-Hermoso *et al.*, 2023; Zhou *et al.*, 2025). A systematic review of moderate intensity aerobic and resistance exercise interventions in CYP living with overweight and obesity reported reductions in triglycerides, total cholesterol, and LDL, although no consistent improvements in HDL were observed across studies (Chen *et al.*, 2021). Findings from individual trials suggest that intervention duration may influence lipid responses. Monteiro *et al.* (2015) reported significant reductions in triglycerides and very-low-density lipoprotein following both moderate-to-vigorous intensity aerobic and combined aerobic–resistance exercise, alongside significant increases in HDL after a 20-week intervention. In contrast, many

of the trials included in the review by Chen *et al.* (2021) were of shorter duration (6–16 weeks, mean = 12 weeks) which may partly explain the absence of consistent HDL improvements. Supporting this interpretation, a review by Li and Chen (2021) suggests that interventions lasting longer than 12-weeks may be more effective in improving lipid profiles among adolescents living with obesity than shorter interventions.

Hypertension is another cardiovascular risk factor that can positively respond to exercise and PA in CYP living with obesity. A meta-analysis of randomised controlled trials reported significant reductions in both systolic and diastolic blood pressure following exercise interventions in CYP living with obesity (Zhou *et al.*, 2025). A 3-month randomised control trial examining combined aerobic and resistance training reported significant reductions in systolic and diastolic blood pressure, as well as lower rates of hypertension in the intervention group post-intervention (Farpour-Lambert *et al.*, 2009). Notably, participants completing the combined aerobic and resistance training also reported significant improvements in arterial stiffness and arterial intima-media thickness at 6-month follow up. These findings suggest that regular exercise and physical activity may contribute not only to short-term blood pressure reductions but also to favourable changes in early markers of vascular health and atherosclerosis progression.

1.3.4.3. Benefits to glucose regulation

Alongside the broader impact on cardiometabolic health, exercise and physical activity are key determinants of glucose regulation and insulin sensitivity in CYP living with obesity, outcomes that are closely linked to future risk of type 2 diabetes. The systematic review of meta-analyses by García-Hermoso, Ramírez-Vélez and Saavedra (2019) reported that exercise was associated with a medium reduction in fasting glucose and a small reduction in fasting insulin across the four meta-analyses that reported glucose and insulin outcomes. These findings are supported by the meta-analysis by Li and Chen (2021) which demonstrated a significant improvement in homeostatic model assessment of insulin resistance (HOMA-IR) among CYP living with obesity participating in aerobic exercise, combined aerobic and resistance exercise or high intensity interval training (HIIT) interventions. Resistance exercise has also demonstrated improved insulin sensitivity and reductions in glucose production rate for adolescents living with obesity following a 12-week intervention (Van Der Heijden *et al.*, 2010). Improvements in insulin resistance, alongside favourable

changes in lipid metabolism, are important factors in reducing the risk of MASLD. Consistent with this, a systematic review and meta-analysis reported reductions in visceral adiposity and the liver enzyme gamma-glutamyl transferase following exercise interventions in CYP, although no significant changes were observed in other liver enzymes (Gonzalez-Ruiz *et al.*, 2017). Taken together, these findings provide supportive evidence that exercise and physical activity may contribute to reduced MASLD risk in CYP living with obesity through improvements in insulin sensitivity, lipid metabolism, and visceral fat accumulation.

1.3.4.4. Benefits to cardiorespiratory fitness

Beyond these metabolic and vascular benefits, exercise and physical activity also confer important functional and psychosocial benefits for CYP living with obesity. Cardiorespiratory fitness is associated with reduced metabolic risk factors (Ruiz *et al.*, 2006) and low levels of cardiorespiratory fitness are associated with insulin resistance, dyslipidaemia, and metabolic syndrome in CYP, highlighting the value of improvements in CRF (Katzmarzyk, Malina and Bouchard, 1999; Carnethon, Gulati and Greenland, 2005; Imperatore *et al.*, 2006). Research commonly shows improvements in cardiorespiratory fitness following an exercise intervention in CYP living with obesity (García-Hermoso, Ramírez-Vélez and Saavedra, 2019). Li *et al.* (2021) showed significant improvement in cardiorespiratory fitness across the 12 studies in their meta-analysis designed to understand the physiological effects of different exercise modalities in adolescents with obesity. Aerobic exercise, combined aerobic and resistance exercise and HIIT training all significantly improved peak oxygen uptake, however, resistance training had no effect on cardiorespiratory fitness (Li and Chen, 2021)..

1.3.4.5. Benefits to health-related quality of life

Measures of HRQoL are one of the most effective ways to gain insights into the psychosocial status of CYP living with obesity. A systematic review and meta-analysis by Henderson *et al.* (2025) reported a small effect on HRQoL from 23 randomised control trials investigating the effect of exercise interventions in CYP living with obesity. Exercise modality varied across studies with aerobic, resistance and combined aerobic and resistance interventions all included in the analysis. The randomised control trial by Lopera *et al.* (2016) reported significant improvements in HRQoL

measured through the Pediatric Quality of Life Inventory 4.0 (PedsQL 4.0) following a 16-week multidisciplinary obesity treatment program that included three 60-minute exercise sessions a week of either land or water-based exercise. These findings are supported by Goldfield *et al.* (2017) who reported that following a 22-week intervention that consisted of either aerobic exercise, resistance exercise or combined aerobic and resistance exercise, all exercise groups showed significant improvements in overall HRQOL, physical functioning, psychosocial HRQOL, and emotional functioning. There were also no significant between-group differences for any improvements in HRQoL. Together, these studies suggested exercise of any modality can improve HRQoL in CYP living with obesity. As well as the broader benefits on HRQoL, exercise and PA are associated with additional benefits to psychosocial health in CYP living with obesity. A systematic review and meta-analysis reported findings from 29 studies that included a supervised PA program of at least moderate intensity and interventions that ranged from 8 weeks to 6 months (King *et al.*, 2020). PA interventions were associated with significantly reduced depression, increased self-esteem and improved body image in CYP living with obesity. Collectively, these studies evidence the positive impact exercise can have on HRQoL, psychosocial health, and overall well-being in CYP living with obesity.

1.4. Multidisciplinary interventions for children and young people living with obesity

1.4.1. Previous multidisciplinary interventions utilising exercise and physical activity

To support health improvements in CYP living with obesity, studies have investigated the use of multidisciplinary interventions. These interventions have used a range of approaches, including dietary education and restriction, psychological support, behavioural education, and exercise education and delivery. Due to their multicomponent nature, it is not possible to isolate the effects of exercise and PA from the other elements, however, the overall intervention effects can be evaluated. The Cochrane review by Al-Khudairy *et al.* (2017) examined the effects of lifestyle interventions in adolescents aged 12–17 years living with overweight or obesity. Across 44 randomised controlled trials, lifestyle interventions resulted in reductions in

BMI, SDS BMI, and body weight, supporting the value of multidisciplinary approaches for this population. Lifestyle interventions also resulted in moderate improvements in HRQoL; however, self-esteem was not changed. The review and meta-analysis by Henderson *et al.* (2025) also evaluated the effect of multicomponent lifestyle interventions on health outcomes, but took an additional step and isolated the effect of different intervention types. Multicomponent interventions improved cardiometabolic, anthropometric, and patient-reported outcomes in CYP living with obesity. Notably, this review reported that PA interventions improved HRQoL, blood pressure, lipid profile, BMI SDS, and insulin resistance. Meanwhile, nutrition interventions improved the same physiological outcomes but had no effect on HRQoL. As such, exercise and PA can be considered necessary components of multicomponent interventions and should be included in the care of CYP living with obesity.

Although these systematic reviews provide valuable insight into the overall potential of PA and multidisciplinary interventions, the interventions themselves are complex and vary considerably between studies. The following section therefore examines these interventions in greater detail, with particular emphasis on how their exercise and PA components have been developed and delivered. The multicomponent interventions that currently exist within this area typically fit into one of three categories: In-patient and residential interventions, outpatient and clinic-based interventions, and home-based and digital interventions. While the value of multidisciplinary approaches that incorporate exercise and PA is well established, the optimal method of implementation remains unclear. It is therefore important to critically review the delivery within these different intervention models. A summary of the literature relating to multidisciplinary interventions for CYP living with obesity is presented in Table 1.1 at the end of Section 1.4.1.3.

1.4.1.1. In-patient multidisciplinary interventions

In-patient and residential interventions typically require CYP living with obesity to be admitted to hospitals and treatment centres for durations ranging from approximately 5 to 12 months. The study by Braet *et al.* (2003) is the earliest example of an inpatient obesity intervention in CYP. Participants completed a 10-month inpatient multicomponent intervention in the Netherlands that included dietary restriction,

regular PA, and a 12-week cognitive-behavioural treatment programme. The intervention also included parental education to support healthy lifestyle changes following discharge. PA consisted of individualised training programmes delivered for 4 hours a week and participants were encouraged to exercise during leisure time before and after school. Details of the type of exercise completed were not provided. Participants in the intervention group significantly reduced BMI at 5- and 10-month time points and had significant improvements in their perception of their physical appearance, social competence and athletic competence. Cardiorespiratory fitness and habitual PA were not reported, however, data from the Dutch version of the Self-Perception Profile for Children reported significant improvements in self-perception of physical appearance, athletic competence and social competence. At 6- and 14-month follow-ups, participants' BMI increased with 66% of participants regaining weight. Improvements in body composition following an inpatient intervention were also reported by Aguer *et al.* (2010) who evaluated the effect of a shorter 5-month multidisciplinary programme in 23 females (14-18 years) living with obesity in France. The inpatient intervention included nutritional education, dietary restriction, PA, and consultations with a psychologist. The PA elements consisted of four exercise sessions a week: two 30-minute running sessions, one 60-minute swimming session, and one 60-minute resistance session. Significant reductions were observed in body weight, BMI, fat mass and fat free mass post-intervention while significant increases in MVPA and aerobic fitness were reported. The study did not include a follow-up to determine if changes were maintained. A similar multidisciplinary inpatient intervention was conducted by do Prado *et al.* (2009) with participants once again participating in dietary education and reduction, exercise and psychotherapy at the Rehabilitation Centre Insula in Germany. The study included 728 adolescents living with severe obesity who participated in a multidisciplinary inpatient obesity treatment programme lasting between 3 and 9 months (mean = 5.88 months). Participants exercised four times a week with each session lasting at least 90 minutes. The exercise modality was varied between participants, but aerobic and resistance modalities were most commonly utilised. All body composition outcomes (body weight, BMI, fat mass, and fat free mass) were significantly improved following the inpatient intervention, and mirror the findings of the study by Aguer *et al.* (2010). Collectively, these studies suggest that long-term (5–12 months), multicomponent inpatient interventions that include an exercise and physical activity component can produce short-term

improvements in body composition and selected psychosocial outcomes in CYP living with obesity.

Alongside longer-term residential programmes, shorter-duration inpatient interventions have also been evaluated in CYP living with obesity. The study by Knöpfli *et al.* (2008) assessed the effects of an 8-week multicomponent, inpatient intervention, delivered at the Alpine Children's Hospital in Davos, Switzerland. The programme comprised dietary education and restriction, PA, and psychological behaviour modification in the form of consultations and workshops in 130 CYP living with severe obesity. Participants completed an individually adapted exercise and PA programme consisting of two 60-to-90-minute exercise sessions per day focussed on aerobic endurance. The intervention resulted in significant reductions in body weight, BMI, fat mass and fat free mass alongside significant improvements in aerobic fitness and HRQoL. Similar findings were reported by Karner-Rezek *et al.* (2013) who evaluated the same 8-week intervention in 28 CYP living with overweight or obesity and observed significant reductions in body weight, BMI, and fat mass. These findings suggest that short-term (8-week) multicomponent inpatient interventions incorporating structured exercise and physical activity can produce meaningful improvements in body composition, cardiorespiratory fitness, and HRQoL in CYP living with obesity. Importantly, all these in-patient studies primarily use supervised structured exercise programmes to target PA.

Several studies have directly compared the effectiveness of longer-term inpatient interventions with shorter inpatient approaches and outpatient interventions. Makkes *et al.* (2016) reported the effects of the HELIOS study which includes a six-month inpatient treatment program in the Netherlands and compared this to a two-month inpatient period followed by four months of biweekly two-day return visits. Both interventions adopted a multicomponent lifestyle approach targeting nutrition, physical activity, and behavioural change in CYP and their parents. Although the physical activity component was not described in detail, participants in the six-month inpatient group completed four group exercise sessions per week, while those in the shorter inpatient group completed three sessions per week during admission and two sessions per week during return visits (Makkes *et al.*, 2011). PA outside of hospital visits is not reported within the study. After six months both intervention groups significantly

reduced SDS BMI from baseline, with a significant between group difference in favour of the six-month inpatient group at this timepoint. Significant reductions in SDS BMI were maintained at follow-up (12 months), however, there were no significant between-group differences at this time point. Both treatment groups also reported significant improvements in waist circumference, diastolic blood pressure and HDL at 12-month follow-up. These findings suggest that inpatient treatment may be more effective during the intervention period but differences between these interventions are not sustained at long term follow up, with similar effects for key outcomes for both groups at 12-month follow-up. A complementary analysis of the HELIOS study combined data from the two intervention arms and demonstrated significant improvements in both generic and weight-related HRQoL at 12 and 24 months (Hoedjes *et al.*, 2018). Although the independent effect of intervention duration cannot be determined from these findings, the results support the positive impact of inpatient and combined inpatient and outpatient multicomponent interventions on HRQoL.

Further comparison with outpatient care was provided by van der Baan-Slootweg *et al.* (2014) who compared the HELIOS 6-month inpatient intervention in the Netherlands to an outpatient intervention involving 12 hospital visits over a 6-month period for CYP living with obesity. The inpatient group completed supervised exercise sessions four times per week (30–60 minutes per session), while the outpatient group completed one hour of supervised exercise per visit and were encouraged to exercise independently three additional times per week. As exercise adherence and habitual physical activity were not reported, direct comparison of exercise adherence between groups was not possible. At 6 months both groups reported statistically significant reductions in SDS BMI with a greater proportion of clinically meaningful reductions observed in the inpatient group (54%) compared with the outpatient group (23%). However, these between-group differences were not sustained at post intervention follow-ups (3, 6, 12, or 24 months after the intervention end). Despite greater short-term effectiveness, the lack of sustained benefit suggests that outpatient interventions that utilise supervised exercise may represent a viable alternative to inpatient care. While inpatient interventions clearly demonstrate clinical utility, their intensity, resource demands, and delivery requirements raise important challenges regarding their practicality and scalability within NHS services, particularly given the high and growing prevalence of childhood obesity in England.

1.4.1.2. Out-patient multidisciplinary interventions

Given the resource intensity and scalability challenges associated with inpatient interventions, multicomponent outpatient interventions for CYP living with obesity have been evaluated within the literature. The studies evaluating outpatient interventions typically compare supervised exercise to educational interventions only. Cadenas-Sanchez *et al.* (2022) assessed the effect of adding supervised exercise training to a pre-existing family-based lifestyle program for CYP living with overweight or obesity in Spain. All participants received their regular lifestyle programme which consisted of two 45-minute psychoeducation sessions per month over 22 weeks, promoting healthy dietary habits, PA, and good sleep behaviour. Participants in the exercise programme group additionally completed 90 minutes of combined aerobic and resistance exercise, three times a week, supervised by an exercise physiologist. Both groups demonstrated reductions in visceral, subcutaneous and intermuscular adipose tissue following the intervention, however a significant between-group difference was observed in favour of the exercise group. The exercise group also included a significantly greater proportion of participants achieving clinically meaningful reductions in visceral and subcutaneous adipose tissue.

Another example of a supervised outpatient multicomponent intervention was conducted by Carnier *et al.* (2013). A sample of CYP living with obesity in Brazil participated in a 12-month multicomponent intervention that compared the effect of aerobic training to combined aerobic and resistance training in 26 adolescents living with obesity. Participants received clinical support, dietary education, weekly psychological group sessions and physical exercise. Both groups completed 60 minutes of supervised exercise 3 times a week for one year, with the combined aerobic and resistance training group spending 30 minutes completing each exercise modality. While data at 6 months suggested only the combined aerobic and resistance training group improved BMI and body weight, at 12-months both interventions significantly reduced body weight, BMI, and body fat.

Eliakim *et al.* (2002) also evaluated the effects of a multicomponent outpatient intervention across 3 and 6 months. Participants all received a 3-month intervention and upon completion all participants were offered the choice to extend the intervention

to 6 months. A total of 177 CYP living with obesity completed the 3-month intervention with 65 participants opting to continue completing the intervention to 6 months. Participants completed monthly dietetics meetings, twice weekly supervised exercise, and a series of four evening lectures delivered to parents and participants. The exercise sessions each lasted 1 hour and consisted of endurance activities with participants encouraged to complete PA at least once a week outside of these sessions. At 6 months both groups reported significant reductions in BMI from baseline, however, there was a significant between-group difference at this timepoint in favour of the 6-month group. Improvements in endurance time were also shown in both groups at 6 months. These findings further support the use of supervised outpatient exercise to improve body composition in CYP living with obesity and suggest a longer intervention duration can lead to more favourable improvements. The results from this study should be interpreted with caution as participants opted into a longer intervention duration and therefore a greater proportion of participants who are motivated to adhere to the intervention were present in the 6-month group and this factor could explain the between group differences.

Similarly, Videira-Silva *et al.* (2021) evaluated the addition of supervised exercise to usual multidisciplinary treatment for CYP living with obesity in Portugal. Unlike the other inpatient interventions above, this study also evaluated the use of consultation-based approaches to support exercise and PA. Participants either received usual care or usual care alongside one of the two additional PA interventions. Usual care consisted of baseline screening with a paediatrician followed by a nutrition consultation. Participants in this group also received a PA brochure. Participants in the two additional intervention groups received either regular physical activity consultations, or physical activity consultations alongside two supervised 60-minute exercise sessions per week for the six-month intervention period. Exercise sessions consisted of combined aerobic and resistance exercise and were supervised by an exercise physiologist. At 6 months both intervention groups demonstrated significant improvements in SDS BMI, fat mass, waist-to-height ratio, and MVPA compared with usual care. Although the supervised exercise group accumulated significantly more MVPA, the consultation-only group demonstrated greater improvements in waist-to-height ratio. At 12-month follow-up both intervention groups maintained significant improvements in SDS BMI compared with usual care, with the supervised exercise

group also demonstrating greater improvements in waist-to-height ratio. Collectively, these findings support evidence from Cadenas-Sanchez *et al.* (2022) that the addition of exercise to outpatient lifestyle interventions can enhance outcomes beyond usual multidisciplinary care. However, findings suggest that consultation-based approaches designed to support independent PA may achieve comparable improvements in body composition to supervised outpatient exercise.

While evidence suggests outpatient interventions positively impact health outcomes for CYP living with obesity, identifying approaches that are both effective and cost-efficient remains a priority for health services. In this context, Hintze *et al.* (2021) compared an intensive interdisciplinary outpatient intervention with a semi-intensive, predominantly home-based interdisciplinary programme in Brazil. The study recruited 166 young people aged 14-19 years living with obesity, who were allocated via convenience sampling to one of the two intervention groups over a 22-week period. Participants in the intensive intervention received weekly in-person nutritional and psychological support meetings, and three supervised exercise sessions each week. Exercise sessions included aerobic and resistance exercise and lasted 60 minutes each. In contrast, participants in the semi-intensive intervention had access to weekly recorded lessons based on healthy eating behaviours and attended six in-person group meetings for psychological support and six in-person exercise orientation sessions across the 22-week intervention. The content of the exercise orientation sessions was not presented in the study. The semi-intensive group were then encouraged to independently exercise for 60 minutes three times a week. Following the intervention both groups reported significant reductions in body weight, BMI and fat mass, however, there were significant between-group differences in favour of the intensive group for all these outcomes. Waist circumference, glucose, and triglycerides also decreased significantly in both groups, but significant reductions in systolic and diastolic blood pressure were only present in the intensive group. Metabolic syndrome prevalence also decreased in both groups. Collectively, these findings suggest that while intensive outpatient interventions may elicit greater improvements in outcomes, semi-intensive interventions incorporating a substantial home-based component can still produce significant improvements in clinical outcomes and may offer a more scalable alternative that has reduced burden for participants and HCPs. However, most of these studies still had a considerable amount of PA delivered as supervised

exercise sessions. As such, these findings provide a clear rationale for further examination of home-based lifestyle interventions for CYP living with obesity.

1.4.1.3. Home-based multidisciplinary interventions

Home-based lifestyle interventions offer a more flexible alternative to inpatient and outpatient studies, however, the evidence base in this area remains limited, with comparatively few studies evaluating their effectiveness. Lisón *et al.* (2012) compared two lifestyle interventions for CYP living with obesity in Spain to a sex and age matched control group (n=24). One group completed a home-based diet and exercise intervention (n=41), while the other completed a hospital-based programme (n=45). Both intervention groups attended two 1-hour educational sessions covering nutrition and exercise. The hospital-based group were provided with 5 supervised exercise sessions per week for 6 months, and patients were required to attend a minimum of three of these sessions per week. Session lasted 60 minutes each supervised by a physical education instructor with a combination of aerobic and resistance exercise conducted in each session. Participants in the home-based group were similarly instructed to complete 5 exercise sessions a week (minimum 3) of aerobic and resistance exercise lasting approximately 60 minutes; however, this was to be completed at home unsupervised. A demonstration of how to perform the exercises was provided and written instructions with images were distributed to participants to support their exercise. A self-report logbook was also required to be maintained for the 6-month intervention period. At 6 months participants in both intervention groups reported significant reductions in SDS BMI and body fat, while the control group reported no difference in these outcomes. The home-based group also reported significant reductions in waist circumference while the hospital-based group showed non-significant reductions, suggesting that a 6-month home-based lifestyle intervention incorporating exercise and PA may be effective for CYP living with obesity.

Ahmadi *et al.* (2020) also evaluated the effects of home-based exercise as part of a lifestyle intervention for CYP living with obesity in Iran. This study compared three exercise modalities with a non-exercising control group. All participants in an exercising intervention group received three 60-minute educational sessions based on healthy nutrition and exercise. The three exercise modalities included HIIT, resistance training, and a combination of HIIT and resistance training. Each intervention group

completed 30-minutes of their assigned exercise 3 times a week for 8 weeks. Following the 8-week intervention period the combined HIIT and resistance training group significantly reduced BMI. No other significant changes in body composition were reported for any other group except a significant increase in waist circumference in the resistance training group and a significant reduction in hip circumference in the HIIT group. While this study identified some meaningful changes in outcomes following home-based exercise, the overall findings provide less consistent support for the effectiveness of short-term home-based interventions. One possible explanation is intervention duration, as participants engaged in the programme for only eight weeks compared with the 6-month intervention evaluated by Lisón *et al.* (2012) which demonstrated clearer improvements in body composition. Intervention duration may therefore be a key factor influencing the effectiveness of home-based lifestyle interventions.

Giovanelli *et al.* (2025) recently evaluated the effects of a 12-week remotely supervised, online exercise intervention in CYP living with obesity in Italy. The study included 35 participants aged 8–13 years, who were required to complete three 60-minute exercise sessions per week. Exercise sessions were supervised in real time by two exercise specialists via video calls. Participants received an individualised exercise prescription specifying exercise type, intensity, duration, frequency, and progression, with sessions primarily focused on aerobic and strength-based activities. The intervention resulted in significant improvements in SDS BMI and six-minute walk test performance, an indicator of cardiorespiratory fitness. Improvements in six-minute walk test were also correlated with improved insulin levels, HOMA-IR, cholesterol and health perception. These findings suggest that relatively short-term home-based interventions may produce improvements in multiple health outcomes in CYP living with obesity. However, these results should be interpreted with caution, as the remotely supervised nature of the intervention may have been central to achieving adequate exercise adherence, a feature not consistently present in other home-based intervention studies. Despite these limitations, this study contributes to the emerging evidence base indicating that home-based and remotely delivered exercise interventions can improve health outcomes in CYP living with obesity.

Based on the studies cited above, multidisciplinary interventions appear to be effective for CYP living with obesity attending weight management services. Studies have primarily used supervised exercise within these interventions but have shown that exercise and PA form important parts of successful interventions. Research to incorporate exercise and PA into less intense interventions including those that adopt a home-based element is limited, but the studies that exist in this area also suggest exercise can be effectively incorporated. Further research is therefore required in home-based interventions, particularly with respect to intervention duration and the optimal methods for assessing exercise adherence and dose in remote settings.

Table 1.1. Multidisciplinary interventions utilising exercise and physical activity in children and young people with obesity.

Reference	Duration(s)	Multidisciplinary Component(s)	Exercise Component(s)	Impact on Outcomes at post-intervention
<i>In-patient multidisciplinary interventions</i>				
Aguer et al. (2010)	5 months	- Nutritional education - Dietary restriction - Psychologist consultations	4 exercise sessions a week: 2x 30-minutes running. 1x 60 minutes swimming. 1x 60 minutes resistance training.	↓ BMI * ↓ Fat mass * ↓ Fat free mass * ↑ MVPA * ↑ Aerobic fitness *
Braet et al. (2003)	10 months	- Dietary restriction 12-week cognitive-behavioural treatment programme - Parental education	4 hours a week of an individualised training programme.	↓ BMI * ↑ Self-report physical appearance * ↑ Self-report athletic competence * ↑ Self-report social competence *
do Prado et al. (2009)	3 to 9 months (mean = 5.88 months)	- Dietary education - Dietary reduction - Psychotherapy	4x 90 minutes exercise sessions a week. Aerobic and resistance most common modalities.	↓ Weight * ↓ BMI * ↓ Fat mass * ↓ Fat free mass *
Karner-Rezek et al. (2013) ^a	8 weeks	- Dietary education - Dietary reduction - Psychological behaviour modification consultations and workshops	2x 60-to-90-minute exercise sessions a day focussed on aerobic endurance.	↓ Weight * ↓ BMI * ↓ Fat mass *
Knöpfli et al. (2008) ^a	8 weeks	- Dietary education - Dietary reduction - Psychological behaviour modification consultations and workshops	2x 60-to-90-minute exercise sessions a day focussed on aerobic endurance.	↓ Weight * ↓ BMI * ↓ Fat mass * ↓ Fat free mass * ↑ Aerobic fitness * ↑ HRQoL *
Makkes et al. (2016)	6 months inpatient OR 2 months inpatient then 4 months biweekly two-day return visits	- Nutrition - Behavioural change	6-month inpatient group: 4x group exercise sessions a week. 2-month inpatient group: 3x a week during admission and 2x a week during return visits.	Both groups reported: ↓ SDS BMI * Greater reduction in the 6-month group.

van der Baan-Slootweg et al. (2014)	6 months in-patient OR 6 months out-patient	• Nutrition • Behavioural change	Inpatient: 4x 30–60 minutes supervised exercise a week. Outpatient: 1-hour supervised exercise per visit (12 visits in 6 months).	Both groups reported: ↓ SDS BMI * In-patient = greater proportion of clinically meaningful SDS BMI reductions (54% in-patient, 23% out-patient).
<i>Out-patient multidisciplinary interventions</i>				
Cadenas-Sanchez et al. (2022)	22 weeks	• Psychoeducation sessions • Healthy dietary habits promotion • Good Sleep behaviour promotion	3x 90 minutes supervised combined aerobic and resistance exercise a week.	↓ Visceral adipose tissue ↓ Subcutaneous adipose tissue ↓ Intermuscular adipose tissue
Carnier et al. (2013)	12 months	• Clinical support • Dietary education • Psychological group sessions	3x 60 minutes supervised exercise a week (aerobic training or combined aerobic and resistance training).	Both modalities reported: ↓ Weight * ↓ BMI * ↓ Fat mass *
Eliakim et al. (2002)	3 months OR 6 months	• Dietetics meetings • Evening lectures	2x 60 minutes supervised endurance exercise a week	Both groups reported: ↓ BMI * ↑ Endurance time *
Hintze et al. (2021)	22 weeks intensive intervention OR 22 weeks semi-intensive intervention	• Psychological support meetings • Nutritional support meetings or pre-recorded healthy eating lessons	Intensive: 3x 60 minutes supervised aerobic and resistance training a week. Semi-intensive: 6x in-person exercise orientation sessions, the content of which was not presented in the study.	Both groups reported: ↓ Weight * ↓ BMI * ↓ Fat mass * ↓ Waist circumference * ↓ Glucose * ↓ Triglycerides * ↓ Metabolic syndrome prevalence * Intensive group reported: ↓ Systolic and diastolic blood pressure *
Videira-Silva et al. (2021)	6 months	• Clinical screening with a paediatrician • Nutrition consultation	2x 60 minutes supervised, combined aerobic and resistance exercise a week. OR Regular physical activity consultations.	Both groups reported: ↓ SDS BMI * ↓ Fat mass * ↓ waist-to-height ratio * ↑ MVPA *
<i>Home-based multidisciplinary interventions</i>				

Ahmadi et al. (2020)	8 weeks	Health eating education sessions	3x 30-minutes of HIIT, resistance or HIIT and resistance training, a week, unsupervised at home.	Combined HIIT and resistance training group reported: ↓ BMI * Resistance training group reported: ↑ Waist circumference * HIIT group reported: ↓ Hip circumference *
Giovanelli et al. (2025)	12 weeks	Exercise only	3x 60 minutes remotely supervised, personalised exercise a week (focused on aerobic and strength-based activities)	↓ SDS BMI * ↑ six-minute walk test performance * Improvements in six-minute walk test were also correlated with: ↑ insulin levels, ↑ HOMA-IR ↑ Cholesterol ↑ Health perception
Lisón et al. (2012)	6 months out-patient OR 6 months home-based	Nutrition education sessions	Out-Patient: 5x 60 minutes supervised, combined aerobic and resistance training a week. Home-based: Instructed to complete 5x 60 minutes unsupervised aerobic and resistance exercise a week	Both groups reported: ↓ SDS BMI * ↓ Fat mass * Home-based group reported: ↓ Waist circumference *

* Indicates significance, ^a Knöpfli et al. (2008) and Karner-Rezek et al. (2013) evaluated the same intervention in different individuals. *BMI*, body mass index; *MVPA*, moderate-to-vigorous physical activity; *HRQoL*, health-related quality of life; *SDS BMI*, standard deviation score body mass index; *HIIT*, high intensity interval training.

1.5. NHS England's approach to treatment and management of the complications from excess weight in children and young people

1.5.1. Creation of Complications from Excess Weight services

While policy and research commonly focus on the prevention of obesity the rising prevalence of CYP living with severe obesity, and its associated complications, have dictated that approaches for treating severe obesity are also required. In response to this, and as a result of the large body of evidence that supports the use of multidisciplinary intervention approaches in CYP living with obesity, NHS England have developed paediatric Complications from Excess Weight (CEW) services. These services specialise in the treatment of severe obesity and the health complications associated with severe obesity. The development of these pilot services delivers on the NHS Long Term Plan which aimed to treat up to a further 1,000 children a year for severe complications related to their obesity (NHS-England, 2019). CEW services adopt a holistic approach to treating the health complications related to CYP living with severe obesity and employ a multidisciplinary team to deliver care. Each CEW service is responsible for the employment of its own multidisciplinary team and service leaders at individual sites have discretion over the distribution of funds to employ team members with differing specialities. This allows services freedom to employ healthcare professionals (HCPs) across a breadth of specialities to appropriately treat the numerous and varied complications associated with severe obesity. As such, the make-up of the multidisciplinary teams is dependent on the centre, but often consist of physicians, dieticians, psychologists, physiotherapists, social workers and nurse specialists. A blended approach to care is adopted within CEW services and patients receive a mixture of remote telehealth appointments and traditional in-person clinic appointments, with some patients also receiving home and school visits. Within each CEW service patients will receive varying levels of input from different HCPs according to their individual clinical needs and the expertise within the MDT.

1.5.2. Exercise and physical activity within CEW services

CEW services report to NHS England and the care each service provides is evaluated using the national core outcome set developed for clinical paediatric obesity services (Stilwell *et al.*, 2023). As such the outcomes developed during the Delphi process

highlight the eight physical health, five mental health and three self-management outcomes CEW services should be aiming to impact. Two of the self-management outcomes are exercise habits and physical activity habits. In addition to the core outcome set, National Institute for Health and Care Excellence (NICE) guidelines recommend lifestyle intervention, including increasing PA, as the primary treatment for CYP living with obesity (NICE, 2025). Together, these reports highlight the essential need for CEW services to support patients to participate in regular exercise and become more habitually active. While exercise and PA are regarded as essential components in the treatment of CYP living with obesity, CEW services are still in their infancy and the best approach to supporting exercise and PA is still unknown (Roberts *et al.*, 2021a; Apperley *et al.*, 2022). The complexity of severe obesity is reflected in the patient profile within CEW services, where there is a marked overrepresentation of young people from deprived areas, minoritised ethnic groups, and those with neurodevelopmental conditions including ASD, ADHD, and learning difficulties (Hawton *et al.*, 2025; Matu *et al.*, 2025). These characteristics reinforce the need for exercise and physical activity provision that is adapted to the varied and intersecting needs of this population. Consideration should therefore be given to the best approach to engage CEW service patients in exercise and PA.

1.5.3. Requirements of an exercise and physical activity intervention for CEW service patients

The scoping review by Roberts *et al.* (2021a) provides detailed insight into patient and family needs within clinic-based obesity treatment. Families reported a need for specific exercise recommendations tailored to their unique family structures, schedules, and available resources. In contrast, general exercise advice, while providing content, was perceived as insufficient and potentially overwhelming. Accordingly, the review recommended that interventions be individualised to the child and family context, with providers considering financial resources, parental and child time constraints, and developmental stage. Assessing family preferences to develop personalised plans, including detailed day-to-day exercise guidance, was considered particularly important, as this provided clear, actionable steps and better supported sustainable lifestyle change.

The use of technology to enhance ongoing support was also identified as a potentially important facilitator of intervention success (Roberts *et al.*, 2021a). However, the use of technology-supported interventions also requires consideration of digital inclusion. While smartphone and internet access are now widespread among adolescents, with Ofcom reporting that almost all UK children aged 3–17 years went online in 2023 and that mobile phone ownership is almost universal by age 11, access alone does not ensure equitable engagement (Ofcom, 2024). Families from underserved communities may still experience barriers related to device sharing, data costs, digital literacy and confidence using health technologies, which has been demonstrated in paediatric type 1 diabetes, where access to and use of diabetes technologies remain socially patterned by deprivation and ethnicity despite their clinical benefit (Tonga *et al.*, 2026). These concerns are also relevant to adolescent obesity interventions, with a recent systematic review highlighting the need for digital health interventions to better consider equity, access and the wider digital determinants of health (Partridge *et al.*, 2024). These considerations may be particularly relevant in CEW services, where young people from more deprived areas, minoritised ethnic backgrounds and those with neurodevelopmental conditions are overrepresented (Matu *et al.*, 2025). Therefore, technology-supported exercise and PA interventions should not assume universal digital readiness, but should assess access, provide devices or data support where needed, offer clear onboarding, and retain flexible non-digital routes for families who require them. These requirements should therefore be central to any exercise and PA intervention delivered within a CEW service cohort. However, the heterogeneity of CEW service patients compared to the wider population of CYP living with obesity indicates that context-specific approaches are required for this setting.

Consequently, an exercise and PA intervention for CEW service patients should build upon the findings of Roberts *et al.* (2021a) and the existing evidence base for multicomponent interventions in CYP living with obesity, while also accounting for additional factors that may influence participation that are unique to CEW services and their patients. Furthermore, structural and operational constraints within CEW services need to be considered. Inpatient interventions are therefore not appropriate due to the substantial financial costs associated with prolonged inpatient stays (Dreyer *et al.*, 2019). Home-based interventions with remote support should therefore be explored for this service context.

Data from Hawton *et al.* (2025) indicate that 41.4% of patients attending the Bristol and Liverpool CEW services live in the most deprived postcodes (IMD decile 1), compared with only 4.4% living in the least deprived postcodes (IMD decile 10). This aligns with national data demonstrating a strong association between childhood obesity prevalence and socioeconomic deprivation (NHS-Digital, 2024b; 2026). Preliminary data from the NIHR-funded ENHANCE project further highlights this disparity, with children from the most deprived IMD deciles (1–3) being significantly over-represented among the 4,784 CEW service patients included in the study (Matu *et al.*, 2025). For families living in more deprived areas, the financial burden associated with repeated travel to hospital-based appointments may represent a substantial barrier to engagement. A study conducted in adults attending clinical appointments at a London NHS trust previously identified that patients from socioeconomically deprived backgrounds report greater logistical barriers to attending in-person outpatient care, including transport costs, journey complexity and competing work or caring demands (Sung *et al.*, 2024). The reliance on frequent in-person exercise sessions, which is a core component of many outpatient interventions described in the literature, may therefore exacerbate existing health inequalities within CEW service populations. Furthermore, as illustrated by Figure 1.4, only 37 CEW services exist in England, meaning the catchment area for many services is large, requiring families to travel considerable distances to attend CEW service appointments. This logistical challenge provides further justification for an intervention approach that does not require regular in-person attendance. In this context, home-based and remotely delivered exercise and physical activity interventions may offer a more suitable and equitable alternative.

In addition to socioeconomic challenges, neurodevelopmental conditions are highly prevalent within CEW services. Data from Hawton *et al.* (2025) report that 27.0%, 10.3%, and 14.1% of patients attending the Liverpool and Bristol services have diagnosed ASD, ADHD, and learning difficulties, respectively. These findings are once again supported by preliminary data from the ENHANCE study which reported that 24.0% and 23.1% of patients had diagnoses of ASD and learning difficulties, respectively (Matu *et al.*, 2025). In contrast, government statistics suggest that approximately one in seven young people in the general population have a diagnosed

neurodevelopmental condition (GOV.UK, 2025), indicating a disproportionately high prevalence within CEW service populations. Exercise and PA interventions delivered within CEW services must therefore account for a wide range of neurodevelopmental needs, and standardised approaches may be inappropriate for many CYP living with severe obesity.

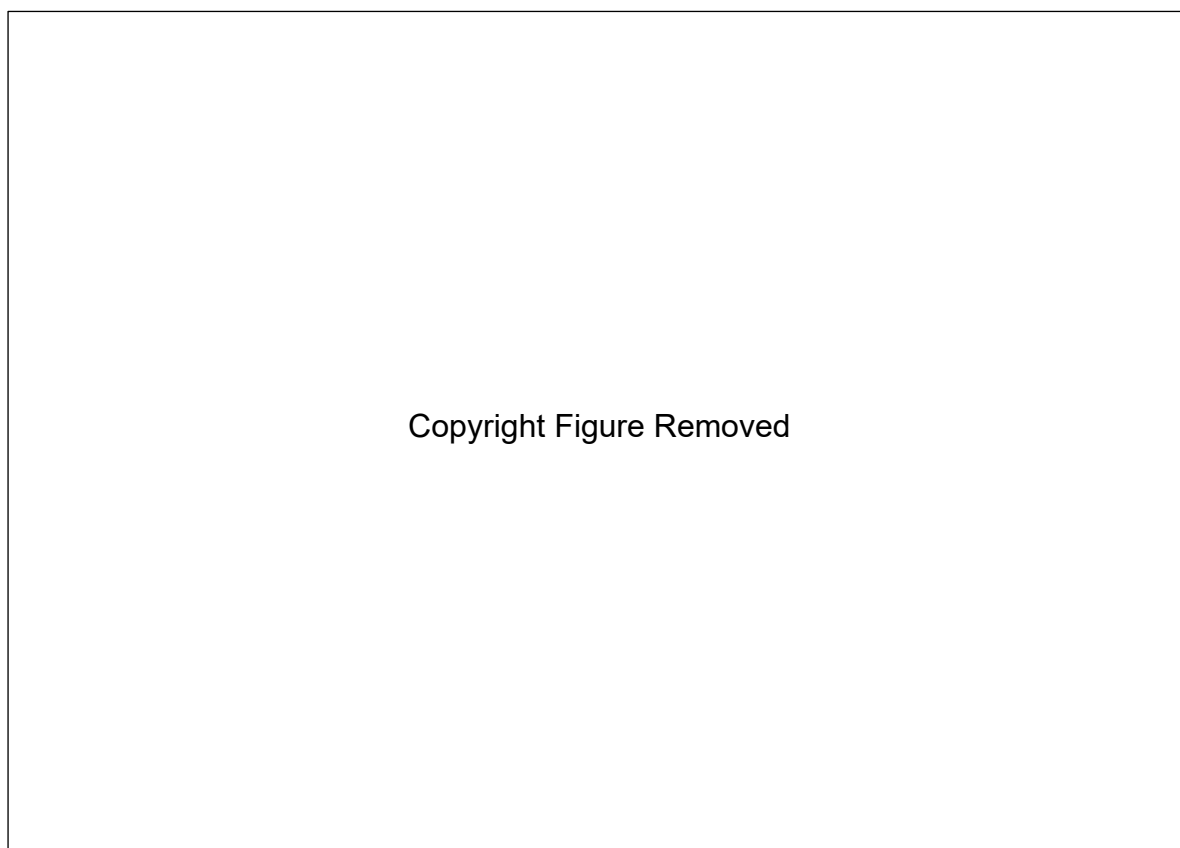


Figure 1.4. Complications from Excess Weight (CEW) clinic locations. (NHS England)

Source: NHS England

CEW Services are arranged in a Hub and Scope model. Hub clinics are the primary CEW services within an area, while spoke clinics represent associated local sites that extend access to specialist CEW care within the same service network.

Data from Hawton *et al.* (2025) and the ENHANCE study also report that people from minoritised ethnic backgrounds are overrepresented within CEW services (Matu *et al.*, 2025). This data is also supported by the National Child Measurement programme showing the prevalence of obesity is higher within underserved ethnicities (NHS-Digital, 2024b). In the general population, 74.4% of individuals identify as White British (ONS, 2022) while the ENHANCE study cohorts reported 59.9% of CEW patients were

White British. This data further demonstrates the disproportionate representation of people from minoritised ethnic groups within these services and highlights the necessity for exercise and PA interventions to consider this within their design.

However, socioeconomic deprivation and ethnicity should not be interpreted as entirely independent characteristics within CEW service populations, as minoritised ethnic groups are disproportionately represented in more deprived areas in England (GOV.UK, 2020). Although preliminary ENHANCE data demonstrate that both children living in the most deprived IMD deciles and children from Black and minority ethnic groups are overrepresented within CEW services, publicly available data do not yet appear to report whether ethnic differences persist after accounting for deprivation, or whether deprivation differs across ethnic groups within the CEW cohort (Matu *et al.*, 2025). Therefore, while these data highlight important inequalities in CEW service attendance and patient complexity, caution is required when interpreting the representativeness of single-site cohorts, including the cohort described later in this thesis.

Taken together, the socioeconomic, demographic, geographic, and neurodevelopmental complexities faced by families accessing CEW services highlight the need for intervention approaches that are flexible, personalised, and sensitive to the realities of patients' everyday lives. The systematic review by Stankov, Olds and Cargo (2012) identified weight-related stigma, low self-efficacy, a lack of inclusive environments, social judgement, and parental logistical constraints as key barriers to participation in physical activity among CYP living with obesity. Given the additional complexities experienced by families attending CEW services, these barriers are likely to be further intensified, reinforcing the importance of patient-centred, personalised models of care. Home-based and remotely supported exercise and PA interventions offer a promising framework through which such tailored support may be delivered within CEW services. However, despite their potential suitability, there remains a limited evidence base evaluating personalised home-based and remotely delivered exercise and PA interventions specifically designed for use within CEW services, highlighting the need for further research to develop and evaluate interventions of this nature.

1.6. The MOTIVATE-CEW Study

1.6.1. Design of the MOTIVATE-CEW Intervention and feasibility study

In response to the limited research into personalised, home-based and remotely delivered exercise and PA interventions for CYP living with obesity, the CEW service at Alder Hey Children's Hospital approached our research group at Liverpool John Moores University to develop an intervention for their service. The project was called Integrating an Exercise Specialist Supported by mHealth technology to increase exercise and physical activity adherence in a paediatric Complications from Excess Weight Service - MOTIVATE-CEW (Davies *et al.*, 2026). The programme was adapted from an intervention previously developed for adults living with or at elevated risk of developing long term conditions (Hesketh *et al.*, 2021; Bannell *et al.*, 2023; Hesketh *et al.*, 2025). Refinements were informed by existing evidence on barriers and facilitators to physical activity among CYP attending weight management services (Roberts *et al.*, 2021a), alongside insights from healthcare professionals within the Alder Hey Children's Hospital CEW service. These were further underpinned by established behaviour change theory (Michie *et al.*, 2013; Michie *et al.*, 2015). The resulting intervention was a 3-month, home-based virtual counselling intervention delivered by an exercise specialist, incorporating mobile health technology and biofeedback to support engagement in exercise and PA. The 3-month intervention duration was selected to align with the typical length of many UK exercise referral schemes (Rowley *et al.*, 2018). The research team and lead consultant at Alder Hey Children's Hospital also considered this timeframe to be more feasible for implementation within the service. The intervention was designed to complement, rather than replace, existing CEW service usual care by providing structured exercise and PA support alongside ongoing multidisciplinary clinical management. Participants co-created personalised and progressive action plans with their exercise specialist, with the aim of increasing both purposeful exercise and habitual PA. Core intervention components included regular behavioural counselling sessions, integrated biofeedback via a fitness watch, and regular remote feedback delivered through personalised messages.

To evaluate the acceptability of the intervention and the feasibility of conducting a future definitive randomised controlled trial to assess its effectiveness across CEW

services nationally, we undertook a feasibility randomised controlled trial within the Alder Hey Children's Hospital CEW service (n=25, MOTIVATE-CEW n=12; usual care n=13). This study formed the basis of my MPhil, and the resulting manuscript has been published in Archives of Disease in Childhood (Davies *et al.*, 2026)(see Appendix 7). As this work underpins the subsequent programme of research presented in this thesis, the following section provides a brief overview of the trial and summarises the key learning that has informed the development of this programme of work.

The feasibility study aimed to assess intervention acceptability through a process evaluation based on MRC guidelines for the evaluation of complex interventions (Skivington *et al.*, 2024). In line with this guidance acceptability was explored by assessing intervention reach, dose and fidelity and using qualitative methods to explore barriers and facilitators to the intervention within its context. The study also assessed the feasibility of the trial methodology by assessing participant recruitment, retention and collection of outcome measures.

Reach was examined by observing the demographics of the participants recruited to the study and comparing these characteristics to those of the CEW service as a whole. Dose was assessed using wearable devices (fitness watch, blinded heart rate monitor) alongside self-report questionnaires, capturing exercise frequency, duration, and intensity across the 3-month intervention period. Fidelity was assessed via consultation attendance and response rates to feedback messages.

Recruitment and retention rates were recorded to inform the feasibility of a future trial. Finally, outcome measures intended for a future definitive trial were piloted at baseline and three months, including assessments of body composition, cardiovascular disease risk, metabolic health, habitual PA and HRQoL. Data completeness for each of these outcomes was reported to assess the methodology and provide reference values for a CEW service cohort.

The qualitative exploration of intervention acceptability and trial methodology was not included in the published manuscript or earlier MPhil thesis, as it was beyond the scope of a single paper and would not have allowed sufficient depth of analysis. Accordingly, a comprehensive qualitative evaluation of the intervention, drawing on

surveys, interviews, and focus groups, will be undertaken in Study 1 of this PhD. This will provide a broader, more in-depth, understanding of the acceptability of the intervention and the trial processes from the perspectives of participants and their caregivers.

1.6.2. Findings from the original MOTIVATE-CEW feasibility study

The MOTIVATE-CEW feasibility study was the first trial within a CEW service to assess the feasibility of an exercise specialist led, mobile health technology supported exercise and physical activity intervention for CYP living with obesity.

Participant recruitment and retention was considered feasible with 27% of the CEW service cohort aged over 12 years recruited and a retention rate of 88%. The intervention demonstrated good reach, with participant characteristics broadly representative of the wider CEW service population for age, sex and proportion of participants from the most deprived IMD quintile. However, participants from minoritised ethnic backgrounds were under-represented (4% in MOTIVATE-CEW compared with 12% across the CEW service) suggesting methods of recruiting these participants require further consideration. The under-representation of participants from minoritised ethnic backgrounds limits the generalisability of the study and indicates a need for improved recruitment strategies in future CEW-based studies.

While the inclusion criteria were considered appropriate for a first attempt at developing a PA intervention for CEW services when developing the study, reflections following its completion suggest that this could be improved. Specifically, the study excluded patients with severe neurodevelopmental conditions, however as discussed, research completed since the conclusion of the MOTIVATE-CEW feasibility study indicates that these groups represent a substantial proportion of CEW service populations (Hawton *et al.*, 2025; Matu *et al.*, 2025). Future interventions should therefore be designed to support the inclusion of participants with neurodevelopmental conditions.

Participants receiving incretin therapies were also excluded due to their inconsistent use at the time of the original study design. The increasing use of incretin therapies in

paediatric obesity management (Locatelli *et al.*, 2024) highlights the need for exercise and PA interventions that complement pharmacological treatment. Accordingly, future intervention should also include participants receiving incretin therapies and stratify randomisation based on their use.

Attendance at MOTIVATE-CEW consultations (70%) was comparable to that of CEW service appointments (66%) and dietetics meetings (68%). The participant response rate to feedback messages was 72%. Collectively, these findings suggest that intervention fidelity was good and that the programme was delivered largely as intended.

Adherence data used to assess intervention dose indicated promising engagement with the MOTIVATE-CEW intervention. Compared with usual care, participants in the MOTIVATE-CEW group completed a greater number of exercise sessions per week, spent more time exercising, and accumulated more MVPA. Uptake of exercise was also substantially higher in the MOTIVATE-CEW group with 83% of participants completing at least 1 purposeful exercise session during the intervention period compared to only 15% in usual care. However, despite good uptake, maintenance of purposeful exercise across the intervention was poor, with only 33% of MOTIVATE-CEW participants still exercising at 3 months. Although a greater proportion of participants in the MOTIVATE-CEW group continued to exercise during the final week of the intervention compared with usual care (33% vs 8%), overall adherence declined substantially over time, highlighting the need for further development of the intervention to better support sustained engagement in exercise and PA.

The methodology for collecting in-clinic health outcomes was robust with good data completeness for all outcomes. In contrast, data completeness for free-living glycaemia was poor. Similarly, habitual physical activity data availability was poor with 46% of data available for the wrist worn accelerometer and 40% available for the thigh worn accelerometer. In contrast to this data, previous studies in young people with obesity have reported good data completeness for PA monitoring using research-grade accelerometers in CYP living with obesity (Aguer *et al.*, 2010). The poor data availability for PA and free living glycemia, both collected through wearable devices,

suggests that future studies should consider the reason for this and seek to implement alternative approaches for obtaining habitual PA data and free-living glycaemia.

Collectively, the findings from the MOTIVATE-CEW study suggests that the intervention and study design is feasible and acceptable but future refinement is needed to better maintain exercise, reach a wider demographic of CEW patients, and obtain outcome measures through wearables. Methods to further evaluate and develop the MOTIVATE-CEW study should be considered and implemented before moving to a future randomised control trial to assess intervention effectiveness. This development process underpins the remainder of this thesis. Before outlining the formal aims and objectives, it is important to consider the methodological literature on the development and evaluation of complex interventions such as the one proposed. This provides the foundation for, and justification of, the decisions made regarding the subsequent development and evaluation process.

1.7. Evaluating and developing a complex intervention for a CEW service

1.7.1. Rationale for a mixed-method evaluation of complex interventions

The MOTIVATE-CEW intervention can be classified as a complex intervention due to the integration of multiple interacting components and behavioural processes within its design. Contemporary guidance emphasises that the development and evaluation of complex interventions should be viewed as an iterative process, in which evidence generated at each stage informs subsequent refinement and implementation (Skivington *et al.*, 2024). The effectiveness of complex interventions can be influenced by the context in which they are employed and the way in which they are implemented and therefore the evaluation process cannot rely on quantitative data alone. Medical Research Council (MRC) guidance emphasises the value of qualitative and mixed-method evaluations in producing context-sensitive evidence that can inform the refinement and real-world implementation of complex interventions (Skivington *et al.*, 2024). This is particularly relevant within CEW services, where patient populations are heterogeneous and face diverse social, developmental, and contextual barriers to behaviour change. Incorporating qualitative evaluation alongside quantitative

feasibility data enables a more comprehensive understanding of how and why interventions are engaged with, and for whom they are most effective.

A qualitative evaluation of the MOTIVATE-CEW intervention provides an opportunity to contextualise findings from the feasibility study by exploring service user and caregiver perspectives. In particular, qualitative feedback can offer insight into factors influencing engagement with exercise and physical activity, reasons for non-engagement or attrition, and perceptions of intervention acceptability. Furthermore, any suggested refinements to the intervention could be obtained, providing a focus for intervention elements that need to be further developed. Semi-structured interviews and focus groups are commonly regarded as appropriate methods for obtaining qualitative feedback from CYP in health research, as they allow for flexible exploration of experiences and perspectives while being sensitive to developmental needs (Adler, Salanterä and Zumstein-Shaha, 2019; DeJonckheere and Vaughn, 2019). Combining semi-structured interviews with focus groups is advantageous, as interviews facilitate participation from individuals less comfortable in group settings, while focus groups yield more contextually rich, interactive data. Supporting this approach, a systematic review by Jones *et al.* (2019) demonstrated that qualitative studies of adolescents living with obesity provide valuable insight into intervention design and delivery, reinforcing the importance of qualitative methods in this field.

1.7.2. Development of a complex intervention for a CEW service

MRC guidance recommends that complex interventions developed for healthcare settings should be informed by both theory and empirical evidence (O'Cathain *et al.*, 2019). While this guidance outlines key principles for intervention development, it offers limited practical direction regarding how theory and evidence should be translated into intervention components. Therefore, intervention development frameworks are commonly used. Multiple intervention development frameworks exist with some offering more prescriptive guidance than others. Intervention Mapping is a commonly used framework that offers detailed actionable steps for designing the intervention, and integrates both theoretical and practical aspects of behaviour change (Eldredge *et al.*, 2016). The six-step process is a rigorous and detailed approach to developing an intervention, and it has previously been shown to be effective within a

healthcare context (Hurley *et al.*, 2015; Greaves *et al.*, 2016; Fernandez *et al.*, 2019). The use of such a framework may be particularly advantageous in CEW services, where interventions must be adaptable to complex clinical pathways and diverse patient needs.

Partnership with key informants during the development of the intervention is also highlighted within the MRC guidance as an approach that can enhance acceptability and feasibility of an intervention (O'Cathain *et al.*, 2019). Adopting an intervention development framework and combining this with a partnership approach could ensure an intervention is appropriately designed for the population it is targeted to support and suitable for the specific healthcare setting it is embedded within. Within CEW services, the perspectives of healthcare professionals, patients, and caregivers are all likely to be critical in shaping intervention content and delivery. Patients can provide insight into intervention features that support motivation and engagement, while caregivers and healthcare professionals can offer practical perspectives on implementation within service constraints. The inclusion of multiple stakeholder perspectives in intervention development is increasingly recognised as good practice in complex healthcare research (Griffiths *et al.*, 2015; Buckley *et al.*, 2018; Livanou *et al.*, 2024). Although co-development approaches remain under-represented in interventions targeting children and young people living with obesity, similar partnership models have been successfully applied in the development of mobile health interventions for CYP, supporting their relevance for CEW service populations (Martin *et al.*, 2020; Creaser *et al.*, 2023).

1.7.3. Evaluating the feasibility of complex intervention

Prior to conducting a definite randomised control trial to assess intervention effectiveness, MRC guidance recommends the use of feasibility studies to evaluate the practicality of both the intervention and the proposed study design (Skivington *et al.*, 2024). Feasibility randomised controlled trials provide an opportunity to assess key uncertainties, including recruitment, retention, adherence, acceptability, and data collection procedures, and to refine interventions accordingly (O'Cathain *et al.*, 2019). In this way, feasibility studies play a critical role in supporting evidence-informed decision-making about progression to larger-scale evaluation.

Some intervention development frameworks, including Intervention Mapping, explicitly incorporate feasibility testing within the development process. Specifically, the fifth step of the Intervention Mapping framework focuses on adoption and implementation considerations, which can be addressed through feasibility evaluation. Feasibility studies should be reported in accordance with the CONSORT 2010 extension for pilot and feasibility trials (Eldridge *et al.*, 2016), ensuring transparent reporting of methodological and intervention-related outcomes. The MOTIVATE-CEW feasibility study adhered to these reporting standards and illustrates the value of feasibility testing within the development of complex interventions (Davies *et al.*, 2026). Through this process, important limitations relating to intervention design and study procedures were identified, providing clear direction for intervention refinement and informing future research aimed at optimising exercise and physical activity interventions for children and young people living with obesity.

1.8. Thesis Rationale, Aims and Objectives

1.8.1. Thesis Rationale

This literature review clearly highlights the potential benefits that exercise and PA can have on CYP living with obesity who receive care from CEW services. The review also demonstrates that existing intervention approaches to promote exercise and PA in CYP living with obesity may not be practical for CEW service patients with many interventions being too resource intensive and poorly scalable. While homebased and remote interventions may offer a solution to these problems, there is limited research on their effectiveness within CYP living with obesity. Furthermore, preliminary data suggests that the CYP supported by CEW services are heterogeneous and multiple under-served groups are overrepresented including young people with neurodivergent diagnoses and those living in the most deprived areas (Hawton *et al.*, 2025; Matu *et al.*, 2025). Considering these factors, alongside the MRC and NICE guidance for obesity management and complex intervention development (Skivington *et al.*, 2024; NICE, 2025) and the existing literature on the intervention needs of CYP living with obesity (Al-Khudairy *et al.*, 2017; Roberts *et al.*, 2021a) there is a clear rationale for a CEW service-specific exercise and PA intervention.

The original MOTIVATE-CEW intervention aimed to fulfil this gap and provide a home-based virtual counselling intervention delivered by an exercise specialist, incorporating mobile health technology and biofeedback to promote exercise and PA (Davies *et al.*, 2026). Despite showing promising effects on exercise behaviour and reporting that the study design could be feasible within future trials, poor maintenance of exercise suggested that further work to refine the intervention was required.

Therefore, the **overall aim** of this thesis was to refine the MOTIVATE-CEW intervention and its trial methodology before conducting a second feasibility RCT to evaluate the potential of the optimised intervention; this aim was addressed through an interlinked programme of research.

1.8.2. Study specific Aims and Objectives

Study 1

Aim- Explore the perspectives of CEW service patients and their caregivers on the original MOTIVATE-CEW intervention to inform its optimisation.

Objectives:

1. Explore the acceptability of the original MOTIVATE-CEW intervention and study methodology, including barriers and facilitators to engagement, through qualitative surveys, semi-structured interviews and focus groups.
2. Develop recommendations for refining the MOTIVATE-CEW intervention and informing the methodology of a future trial.

Study 2

Aim- Develop a refined version of the MOTIVATE-CEW intervention using a combined intervention mapping and partnership approach.

Objectives:

1. Identify the problem, target for change, and relevant determinants of change through a needs assessment.
2. Develop change objectives and map determinants of change to appropriate behaviour change techniques and theories.
3. Develop the programme elements for a refined intervention.

Study 3

Aim- Assess the feasibility and acceptability of the MOTIVATE-CEW2 intervention, and trial methodology, in order to inform the design of a definitive RCT evaluating clinical effectiveness in young people receiving care from CEW services.

Objectives:

1. Determine the number of eligible patients, the proportion willing to participate, the proportion retained at 6 months, and examine their characteristics.
2. Assess the feasibility and acceptability of data collection tools and procedures.
3. Generate data to inform the sample size for a definitive trial.
4. Evaluate the feasibility and acceptability of the intervention and determine adherence rates during the intervention period.

The 3 studies within this thesis and the original MOTIVATE-CEW feasibility study (Davies *et al.*, 2026) that was reported as part of my MPhil programme of study form a continuous, iterative, intervention development and evaluation process as shown in the timeline depicted in Figure 1.5.

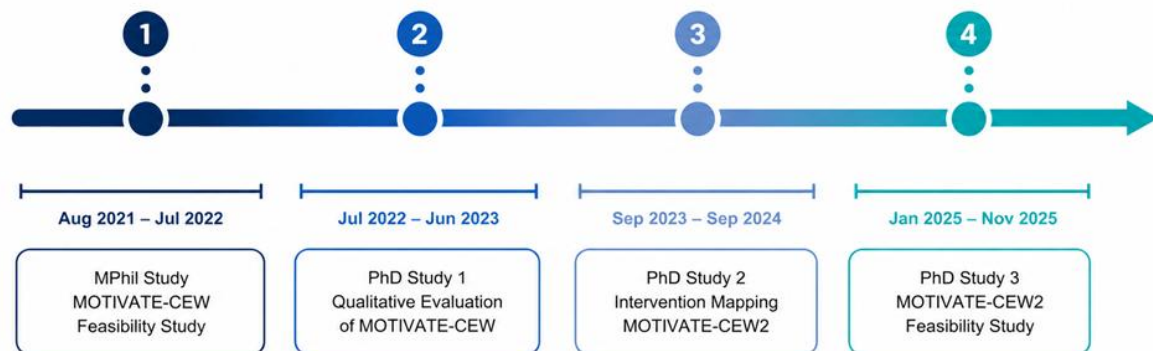


Figure 1.5. Timeline of the MOTIVATE-CEW2 development and evaluation process.

2. Study 1- Qualitative perceptions of a randomised control trial investigating the feasibility of integrating an exercise physiologist supported by mHealth technology to a Complications from Excess Weight Service in the UK: MOTIVATE-CEW

2.1. Introduction

The rising prevalence of young people living with severe obesity is a major public health concern (WHO, 2025b). In England, the National Child Measurement Programme (NCMP) for 2023/24 revealed that 22% of 10- to 11-year-olds are living with obesity, placing them at increased risk of conditions such as asthma and type 2 diabetes mellitus (Gungor *et al.*, 2005). Obesity in childhood also tracks into adulthood, where it is associated with higher risks of cardiovascular disease (Li *et al.*, 2004), type 2 diabetes mellitus (Franks *et al.*, 2010), liver disease (Bass and Eneli, 2015) and 16 different cancers (Lauby-Secretan *et al.*, 2016). In response, NHS England have established 37 Complications from Excess Weight (CEW) services, which employ a multidisciplinary team to treat obesity related conditions.

The National Institute for Health and Care Excellence (NICE) guidelines recommend lifestyle-based interventions, including increasing physical activity (PA) as a key component of treatment for young people living with obesity (NICE, 2025). A Cochrane Review further supports the effectiveness of PA interventions (Al-Khudairy *et al.*, 2017), however, CEW services are still in their infancy, therefore the optimal approach to implementing exercise and PA interventions for patients within their care is not yet understood (Roberts *et al.*, 2021a). Severe obesity is also a complex condition and young people often face unique barriers to PA such as stigma (Rees *et al.*, 2014; Roberts *et al.*, 2021b; Hamer *et al.*, 2023) and additional comorbidities (Gungor *et al.*, 2005). These challenges further justify the need for individualised approaches, rather than relying on interventions developed for young people who are overweight (Kelly *et al.*, 2013).

Therefore, our team developed the MOTIVATE-CEW intervention, an exercise physiologist-led, mHealth supported, PA and exercise programme for CEW services. The design of the MOTIVATE-CEW intervention was guided by a logic model incorporating five priority behaviour change techniques (BCT) intended to underpin its delivery (Michie *et al.*, 2013; Michie *et al.*, 2015). A feasibility randomised control trial was conducted to evaluate the intervention, with quantitative findings indicating promising effects on exercise behaviour (Davies *et al.*, 2026). However, despite good initial uptake, exercise maintenance at the end of the 3-month intervention period was

low, suggesting further refinement of the MOTIVATE-CEW intervention is required. Exploring the perspectives of participants and their caregivers using qualitative methods offers valuable insight into the barriers and facilitators of sustained engagement with the intervention.

Medical Research Council (MRC) guidance for the evaluation of complex interventions (Skivington *et al.*, 2024) highlights that quantitative outcomes alone are insufficient to fully understand how and why interventions work and recommends the use of qualitative or mixed-methods approaches to generate contextually rich evidence to inform intervention optimisation and implementation. Consistent with this guidance, utilising qualitative techniques may provide important insight into how BCTs (Michie *et al.*, 2013; Michie *et al.*, 2015) embedded within the MOTIVATE-CEW intervention were experienced and perceived by patients and caregivers. Accordingly, this study aimed to use qualitative methods to explore the perspectives of CEW service patients and their caregivers to inform the optimisation of the MOTIVATE-CEW intervention. The specific objectives were to explore the acceptability of the original MOTIVATE-CEW intervention and study methodology, including barriers and facilitators to engagement, and to generate recommendations for refinement of the intervention components.

2.2. Methods

2.2.1. Study Design

Three qualitative methods were employed to evaluate the MOTIVATE-CEW intervention: focus groups, semi-structured interviews and a qualitative survey. All participants randomised to the intervention arm of the previously reported randomised controlled feasibility study (Davies *et al.*, 2026) were invited to complete the qualitative survey and to participate in either a focus group or interview (n=12), following completion of the intervention. To maximise participation and accommodate participant preference, patients and caregivers were offered a choice between a focus group and an interview. Separate focus groups were held for patients and caregivers to support open discussion. Full details of the MOTIVATE-CEW feasibility trial have been published elsewhere (Davies *et al.*, 2026), including inclusion criteria. In brief, all

participants were aged 12-18 years, had a BMI >30, and were recruited from the CEW service at Alder Hey Children's Hospital.

2.2.2. MOTIVATE-CEW Intervention

The MOTIVATE-CEW intervention was an exercise physiologist facilitated, self-care support service, which used biometrics from wearable technologies to support a home-delivered, personalised PA and exercise programme for patients within the Alder Hey Children's Hospital CEW service. Participants co-designed a 3-month individualised PA and exercise programme with the aim of gradually increasing purposeful exercise of moderate-to-vigorous intensities and increasing lifestyle PA of any intensity. Exercise was individualised by allowing participants to choose the mode, type, initial duration, and intensity of sessions, as well as the rate of progression. Lifestyle PA was encouraged through targets and tips within their routine.

To support the development and delivery of the PA and exercise programmes, the MOTIVATE-CEW service utilised three integrated core components: (1) regular virtual (Microsoft Teams) behavioural exercise counselling sessions for patients and their caregivers; (2) an mHealth package, including a wrist worn fitness watch, synced to an online coaching platform and a smartphone App for participants; and (3) a mechanism for providing regular remote feedback on data captured by the wearable technologies through the Microsoft Teams App. Together, these components were designed to target five priority BCTs (Michie *et al.*, 2013; Michie *et al.*, 2015) (Table 2.1). These BCTs sought to enhance competence to engage in purposeful exercise and lifestyle PA, support autonomous motivation for exercise and PA and foster relatedness with healthcare professionals, with the aim of improving uptake and maintenance of exercise and PA. The key components and five priority behaviour change techniques were mapped within a logic model (Figure 2.1).

Table 2.1. Priority Behaviour Change Technique categories embedded within the intervention and the activities employed to achieve this.

Priority BCT category	Activities	Target basic psychological need
Information about health consequences	Initial counselling sessions aimed to help participants understand the value and benefits of lifestyle PA and purposeful exercise	Autonomy
Creation of graded action plan with specific behavioural goal	- Participants, their caregivers and exercise physiologists co-designed individualised graded action plans with specific behavioural goals - Action plans were built by exercise physiologists within the coaching platform, using the participants co-developed programme to specify what type and mode of purposeful exercise was to be completed when	Competence
Instructions on how to perform behaviour and biofeedback to assist this	- Instructions on how to perform purposeful exercise sessions were provided by the fitness watch with pre-set sessions prescribing the duration of phases within each session (i.e., warm up, workout and cool-down) - Biofeedback (heart rate) provided guidance to participants on the appropriate intensity for each phase - Videos were available to participants on the trial website with pre-set sessions on the watch matched the videos format - Participants could view biofeedback from the fitness watches accelerometer, providing information on progress towards a daily lifestyle PA goal	Competence
Self-monitoring of behaviour and review of behavioural goals	- Participants could modify their programme to fit with their lifestyle and self-monitor progress towards their behavioural goals in the participant App - Participants could also provide comments on purposeful exercise sessions within the app, informing the exercise physiologist about the appropriateness of the session's duration and intensity, as well as their enjoyment of the session and PA type	Autonomy
Regular feedback on behaviour	- The exercise physiologist used the biofeedback captured by the fitness watch (heart rate during purposeful exercise and progress towards the lifestyle PA target) and participant comments to develop personalised feedback for participants - Feedback was delivered to participants and their caregivers through messages within the Microsoft Teams App, initially after each purposeful exercise session (0-1month), then weekly (2-3 months) - Participants could respond to this feedback and together reassess goals and adapt future schedules where necessary - Biofeedback was also used to create a dialogue between the participant, their caregivers and exercise physiologist in later counselling meetings.	Relatedness

PA, Physical Activity

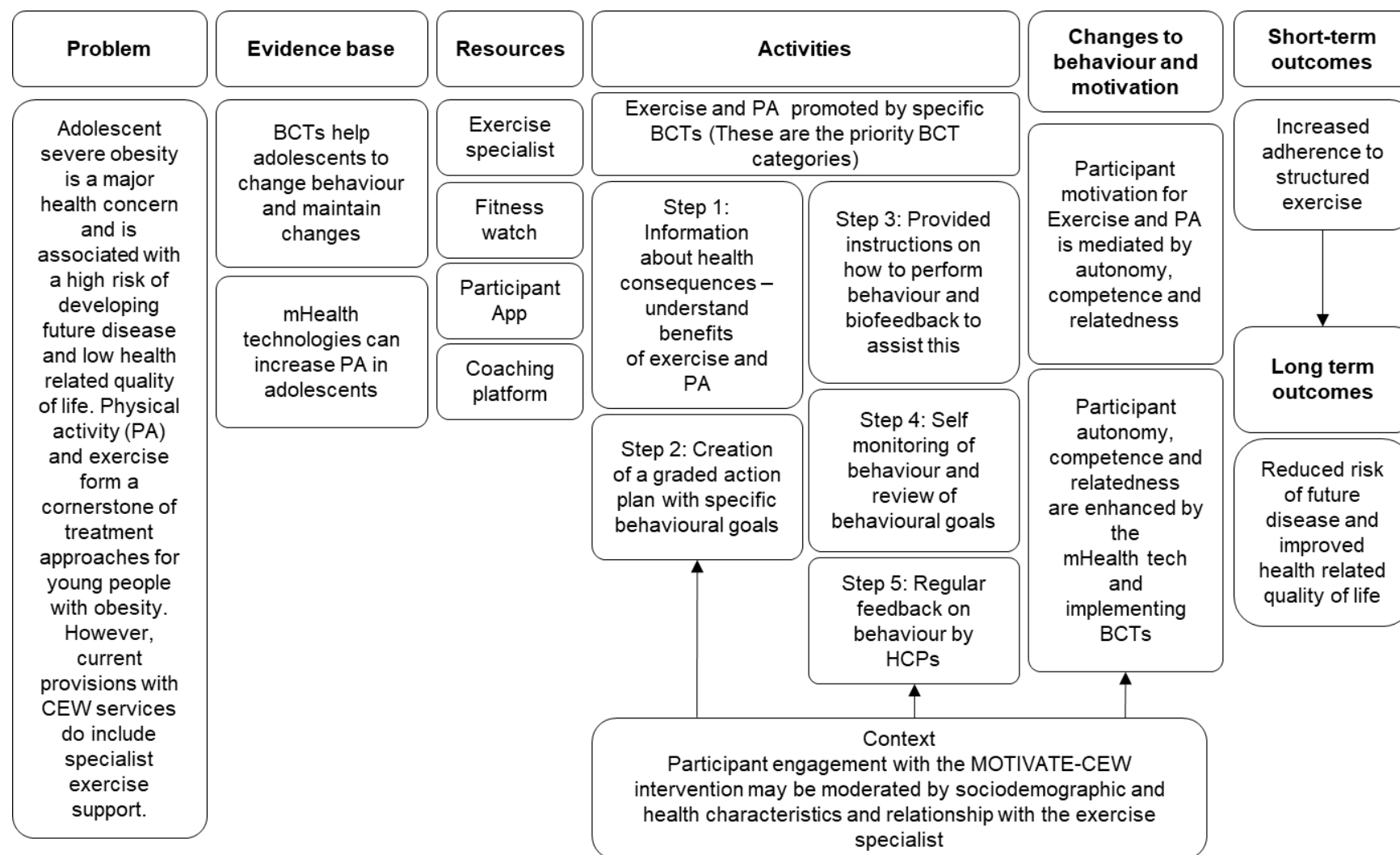


Figure 2.1. MOTIVATE-CEW Logic Model

PA, Physical Activity; CEW, Complications from excessive weight; BCTs, Behaviour Change Techniques; mHealth, Mobile Health; HCPs, Healthcare Professionals

2.2.3. Data Collection

Focus Groups and Interviews

All intervention arm participants (n=12) and their caregivers (n=12) were invited to attend a virtual focus group or semi-structured interview (Teams, Microsoft Corporation). Control participants were not invited to focus groups/interviews, as the aim was to critique and refine the intervention, which they had not received. A pre-defined topic guide was developed (Appendix 1 & 2) and although AD completed all other research-based activities, focus groups/interviews were led by a member of the research team (AC) who did not interact with participants during other trial components. AD was the exercise specialist delivering the MOTIVATE-CEW intervention therefore this approach was adopted to allow for open and honest critique. AC's role within the study was limited to facilitating the focus group/interview discussions only, with all other research activities undertaken by AD. The focus group/interview discussed: (1) experiences of exercise; (2) experience of the exercise counselling; (3) experience of mHealth technology (fitness watch and app); and (4) experiences of feedback (text messages and exercise counselling). Participants were encouraged to openly express their views and probed further to facilitate deeper understanding throughout the focus groups and interviews.

Qualitative Survey

Post-intervention all intervention arm participants (n=12) were invited to complete an anonymous online survey exploring barriers and facilitators to purposeful exercise and lifestyle PA (Appendix 3). Questions were developed, piloted within, and revised by the research team using appropriate literature (Scott *et al.*, 2019).

2.2.4. Data Analysis

Focus groups and interviews were recorded and transcribed verbatim, and qualitative survey responses were collated. Thematic analysis (Terry *et al.*, 2017) was used to deductively analyse transcripts and survey responses based on the five-priority BCT categories outlined in the logic model (Figure 2.1). Primary analysis was conducted by AD with frequent debriefing sessions with the research team (MC, KH & FK) who acted as "critical friends" during the analytical process (Smith and McGannon, 2018).

The analysis consisted of coding survey responses and statements from the focus groups and interviews according to the logic model priority BCT categories. Each of the codes was critically discussed, refined, and challenged before being grouped into the relevant themes that present the existing barriers/facilitators and areas for improvement within MOTIVATE-CEW. This information was used to reach a consensus on the relevance of each priority BCT category to adherence behaviour for participants. A priority group was agreed to be 'relevant' if it was coded more than once and the content linked directly to the behaviour of interest. The researcher also conducted disconfirming analysis where focus group and interview discussions and survey responses were reviewed to specifically look for cases that did not fit within the BCT categories. This entire analytical process resulted in 5 themes being developed as well as comments on future directions for the intervention, barriers to exercise and methods of overcoming these barriers. The themes are illustrated using participant quotes.

2.3. Results and Discussion

2.3.1. Study participants

The flow of participants through the MOTIVATE-CEW study and subsequent qualitative analysis is shown in Figure 2.2. Between July 2022 and June 2023, 12 participants were randomised to the intervention arm. Qualitative data were collected from the intervention group only. Two focus groups were conducted, one with patients and one with caregivers (n=3 patients and n=3 caregivers), alongside two individual interviews (n=1 patient and n=1 caregiver). Qualitative survey responses were obtained from 10 of the 12 intervention group participants (Appendix 3). Participant characteristics are summarised in Table 2.2.

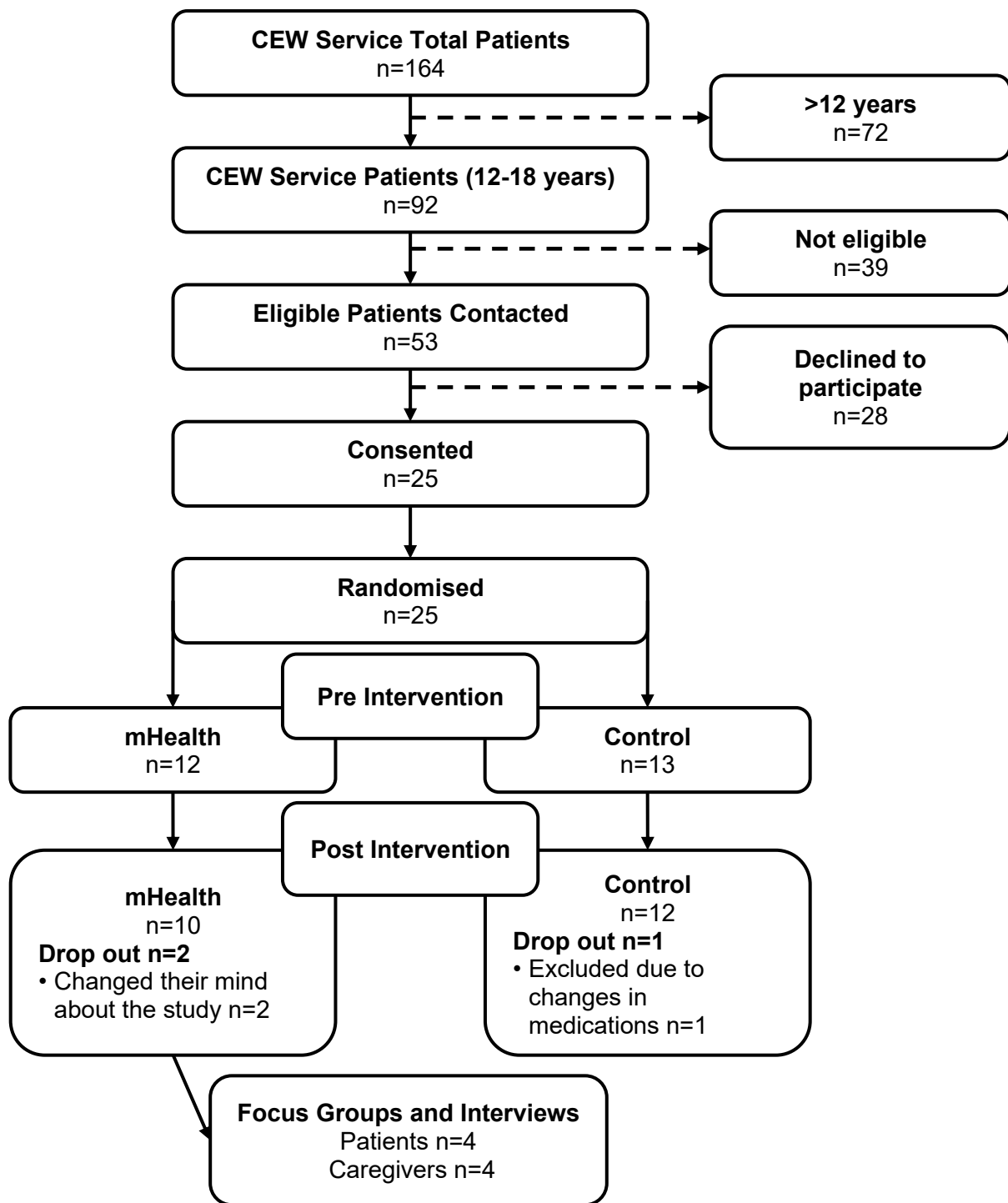


Figure 2.2. Participant consort diagram

CEW, Complications from excessive weight; mHealth, Mobile Health

Table 2.2. Participant Characteristics

	MOTIVATE-CEW Study (n = 25) n (%)	Intervention Participants (n=12) n (%)	Focus Group & Interview Participants (n = 4) n (%)	Qualitative Survey Respondents (n= 10) n (%)
Age <i>mean ±SD</i>	15±1	15±1	16±1	15±1
12-15	16 (64)	7 (58)	1 (25)	5 (50)
16-18	9 (36)	5 (42)	3 (75)	5 (50)
Sex				
Male	12 (48)	4 (33)	0 (0)	3 (30)
Female	13 (52)	8 (67)	4 (100)	7 (70)
Ethnicity				
White	21 (84)	11 (92)	4 (100)	9 (90)
Other	1 (4)	0 (0)	0 (0)	0 (0)
Not Stated	3 (12)	1 (8)	0 (0)	1 (10)
IMD Quintile				
1	18 (75)	11 (92)	3 (75)	9 (90)
2	1 (4)	0 (0)	0 (0)	0 (0)
3	2 (8)	0 (0)	0 (0)	0 (0)
4	2 (8)	0 (0)	0 (0)	0 (0)
5	1 (4)	1 (8)	1 (25)	1 (10)

SD, Standard Deviation; IMD, Index of Multiple Deprivation

2.3.2. BCT 1: Information about health consequences.

Changes in perceptions of the impact of activity on health and wellbeing

Focus group and interview discussions highlighted changes in how participants perceived the benefits of a physically active lifestyle. At the start of the programme many families were focussed on weight loss alone, but discussions revealed that after the intervention participants possessed a wider understanding of the benefits of PA including improved confidence and better mental health. Person-centred counselling sessions, in which the exercise physiologist emphasised the role of purposeful exercise and lifestyle PA in supporting overall health, appeared to motivate participants to engage in exercise and PA.

“[The exercise physiologist] spoke all about wellbeing and it was about your health and [the exercise physiologist] didn't focus on weight... it's also engaged [the participant] more because it was the first time that someone had suggested

something, and it wasn't revolving around [the participant's] weight so [the participant] wanted to give it a go.” (Caregiver 1)

Providing participants with a focus beyond weight loss alone appeared to be beneficial. Both participant and caregiver highlighted the positive impact of purposeful exercise and lifestyle PA on participants mental health, with several participants reporting that they had previously been unaware of these benefits. Some participants also reported improvements in fitness and glucose control.

“It's helped me continue [exercising] even now and put me in a better lifestyle and better attitude towards exercise and better mental health” (Participant 1)

This shift in how the benefits of PA were perceived is supported by existing research in young people with obesity, where a wider understanding of the health benefits of PA has previously been shown to enhance motivation for engagement in exercise and PA (Vasconcellos *et al.*, 2014; Zhang *et al.*, 2024). Moving away from an exclusive focus on weight-related outcomes, particularly when wider health benefits valued by participants are emphasised, may promote autonomy and support sustained behaviour change. However, evidence suggests that information provision alone may be insufficient to alter exercise and PA behaviours. A systematic review of digital interventions for improving diet and PA in young people found that although most interventions included educational components (Rose *et al.*, 2017), less than half resulted in significant improvements in behaviours. This suggests that while information about health consequences is unlikely to be enough in isolation, it remains an important component of a complex intervention.

Perception of no benefit from activity

Despite a greater understanding of the health benefits associated with purposeful exercise and lifestyle PA, some parents reported that the absence of weight loss led them to perceive the intervention as having little or no benefit.

“It didn't have an impact on her weight at the end of the programme, but again, maybe that's where it falls down.” (Parent/ Guardian 2)

This perception was only expressed in the caregivers focus group and was not shared by all. Some caregivers believed the programme had achieved the desired effect by improving wellbeing, and in one instance, the intervention had contributed to a reduction in weight.

“[The participant] did get all the tests at the beginning and then at the end, we didn't really know any different and then [the participant] happened to have an appointment with the Doctor and they confirmed that [the participant] had actually had the benefit of losing weight.” (Caregiver 1)

Previous literature has shown that young people participating in lifestyle interventions for obesity often view weight loss as the primary outcome of interest (Jones *et al.*, 2019). Consequently, a lack of visible weight change may contribute to participants dropping off from exercise routines. Incorporating education on the wider benefits of exercise and PA, could counteract this and encourage long-term engagement in activity.

There was limited participant response from the qualitative questionnaire that could be related to information about health consequences.

2.3.3. BCT 2: Graded action plans with specific behavioural goals.

Structured, pre-programmed exercise to inspire accountability

The development of structured action plans within the intervention was identified as a facilitator for purposeful exercise.

“It gave me the motivation to be able to actually get out and do it and get on the app and be like, ok, well now I'm going to do this at this time and actually do it... I had the motivation to be like, no, you're doing it today, you're doing it at this time and that's it.” (Patient 3)

Participants discussed the benefits of following a clear plan that had been collaboratively developed with them. The inclusion of structured, achievable goals, within the programme provided a sense of accountability and motivated engagement in the sessions. These findings are consistent with previous literature, including a scoping review of stakeholder perspectives on clinic-based obesity services, which identified personalised action plans as a facilitator of increased exercise and PA adherence (Roberts *et al.*, 2021a). Goal setting has also been shown to promote health behaviour change in people with obesity when combined with other intervention components (Pearson, 2012), highlighting the value of action plans based off structured, achievable goals. This effect may reflect the role of action plans in creating implementation intentions to achieve the goals established with the exercise

physiologist. In a population of inactive adults with obesity, implementation intentions were shown to support engagement in PA (Bélanger-Gravel *et al.*, 2013; Kompf, 2020).

Personalised, progressive programme to encourage participant enjoyment, reduce barriers and promote uptake of exercise

The ability to personalise the programme to individual preferences was identified as a key factor promoting engagement. During discussions with the exercise physiologist, participants were able to select exercise types they found enjoyable, which were incorporated into their action plan.

“It’s made me see what I prefer...it was good, so it made me learn that not all exercise is awful, you know you can enjoy it.” (Patient 2)

Caregivers also valued this flexibility.

“I liked the variety [the exercise physiologist] offered in the way [the exercise physiologist] honed in on [the participants] likes and dislikes so [the exercise physiologist] wasn’t like you’ve got to go for a run, because [the participant] hated running, there was lots of different options for them to choose from” (Parent/Guardian 2)

Personalisation also helped participants overcome barriers to exercise. Most barriers reported related to external factors such as limited time, weather, illness and access to facilities, rather than the intervention itself. Despite these challenges, participants described how the flexibility of their action plans, combined with support from the exercise physiologist to adapt their programme, enabled them to maintain engagement.

“I really struggled with the certain amount of length it would be and the amount of cool down I’d have so then when I mentioned it to [the exercise physiologist] during those meetings, I mentioned how I was having a problem with this. Then we changed it to fast walking instead of the running and it definitely opened my eyes that I can still do it in a different way that makes me happy and [the exercise physiologist] definitely listened and changed and amended it and I think it was very good rather than just sticking with the same, you could change it up.” (Patient 1)

These findings are consistent with previous reviews by Roberts *et al.* (2021a) and Jones *et al.* (2019) which highlight the importance of designing personalised action plans that consider barriers such as financial constraints and limited family time. By allowing participants to choose exercises they enjoy, personalisation may also support

autonomy, a key mechanism identified in Self-Determination Theory as facilitating sustained engagement in behaviour change. A feasibility study of a mobile app adopting a personalised approach found that increased personalisation strengthened user autonomy, further reinforcing this theoretical perspective (Tong *et al.*, 2022).

Participants also identified the progressive nature of the action plan as a key benefit of the intervention. They valued being able to start at a level that matched their current ability and increase the intensity and duration as their fitness improved.

“The thing for me is how it progressed so you started with not doing as much and then you'd build up that fitness and then you're able to do more and more and I think that made it a lot easier for me.” (Patient 2)

Progressive, or graded, action plans have previously been shown to enhance self-efficacy and competence in young people with obesity (Suksong, Maphong and Sriramatr, 2024) and have also been shown to improve adherence to PA guidelines in other clinical populations (Kinnear *et al.*, 2020).

2.3.4. BCT 3: Instruction on how to perform behaviours.

Following Resources to replicate behaviours

Participants were given an exercise instruction booklet and access to online videos that demonstrated how to complete exercises. A few participants cited the booklet as a useful tool for ensuring correct technique, while others highlighted the videos as valuable in supporting them to complete their personalised exercise plans.

“[The exercise physiologist] showed me some of the videos and how to get on them and, a few booklets and it was just great really... I liked the videos, I felt that they were useful for when you couldn't go to the gym and you could do them in your own home, you didn't need a lot of space, you didn't need a lot of equipment” (Patient 4)

The videos also supported flexibility, enabling participants to engage in exercise at home and adapt their routines as needed, complementing the personalised action plans discussed earlier. While previous literature has shown the success of utilising videos to guide behaviours in adults with excess weight (Shishira *et al.*, 2025), there is limited evidence in young people with obesity. Findings from the present study suggest such resources may represent a valuable component of future interventions targeting this population.

Participants also valued the exercise videos because *“it was almost as if, I’m not the only one doing it, so if I’m watching it, at least there’s more people doing it”* (Participant 2). This suggests that this instructional platform fostered a sense of social support, which provided an additional motivation to take up exercise.

Use of biofeedback to instruct behaviours and instil confidence

Instructions from the exercise physiologist were complemented by biofeedback from the fitness watch, received both during and upon completion of each exercise sessions. The real-time heart rate guidance enabled participants to personalise exercise intensity, allowing them to engage at a level they felt confident they could sustain.

“I don’t push myself to the limit where I don’t want to do it anymore. I’m just in the right limit and I feel better in myself and physically.” (Patient 1)

Providing participants with the tools to guide their exercise intensity resulted in improved attitudes towards exercise and an increased sense of competence to complete their exercise. Although research in this area among young people with obesity is limited, previous work from our group assessing the feasibility of an mHealth intervention to increase exercise and physical activity in sedentary adults highlighted participants positive experiences of incorporating live heart rate feedback to guide exercise sessions (Bannell *et al.*, 2023).

2.3.5. BCT 4: Self-Monitoring of behaviours

Self-Monitoring behaviours via the App to promote autonomy in exercise behaviours

The ability to self-monitor behaviour and assess progress towards behavioural goals was perceived as a benefit by all participants. In addition to real-time feedback, participants were able to review previously completed exercise sessions using the participant app. Caregivers commented that the use of technology felt appropriate and engaging for the adolescent population, a view echoed by participants, who valued the ability to review past sessions and preview upcoming pre-planned exercise sessions. Overall, the use of this technology appeared to support a sense of autonomy in participants’ exercise and activity behaviours.

“I think it was good for me to see because I actually realised how many classes I actually went to a week and then it was, I just felt quite proud that I’d stuck to that as

well... it was nice that you could sync it up and I could see exactly how my heart rate zones were the whole way through my exercise. And [the exercise physiologist] planned the sessions in so that I knew I had something to complete, so it was nice to see that.” (Patient 4)

Self-monitoring progress towards PA goals using mobile apps has been consistently supported by young people with obesity (Toscos *et al.*, 2008; Appel *et al.*, 2014; Rivera *et al.*, 2018). In addition, previous literature has highlighted young people’s acceptance of technology within broader lifestyle obesity treatment interventions, suggesting that young people with obesity are able to engage with and use mHealth technologies with ease (Jones *et al.*, 2019).

2.3.6. BCT 5: Regular feedback on behaviour by HCP’s

Feedback from a credible source to encourage purposeful exercise and PA

The exercise physiologist conducted monthly exercise consultations with participants and sent regular, personalised messages to provide participants with feedback on their exercise and PA. Feedback from HCP’s was viewed as the most popular element of the intervention from the qualitative survey and discussions from the focus groups and interviews also revealed that the exercise consultations were viewed as a beneficial pathway to receive feedback. Having an exercise physiologist that cared about their activity and was able to discuss this was highlighted as a facilitator within exercise consultations.

“I think for me it was the fact that there was somebody on the other end of the line wanting me to do this.” (Patient 2)

All parents described the exercise physiologist as a friendly and approachable figure whose role in the programme meant their guidance was valued by participants. This facilitated strong rapport without participants feeling judged. As a result, there appeared to be less resistance to engaging in purposeful exercise when support was provided by the exercise physiologist rather than by caregivers.

“I felt [the participant] listened more to [the exercise physiologist] and I don’t think it was done in like a controlled way, it was just the way they seemed to be able to read [the participant] and what their needs were and spoke to [the participant] at the level they required and that encouraged [the participant] to want to it. I ask her to exercise

all the time and it's like "yeah, ok, whatever." But [the participant] was actually the one to say, "come on, let's get out."" (Caregiver 1)

Reports that participants listened to the exercise physiologist suggest that the credibility of the individual providing feedback and support is important, and that motivation may be influenced by the delivery agent. This aligns with evidence from adult exercise referral schemes, where the provider of support has been shown to affect participant motivation (Rouse *et al.*, 2011), and with a qualitative systematic review indicating that professional support is perceived as more valuable than peer or family support when attempting to lose weight (Jones *et al.*, 2019). Consistent with this, participants and caregivers perceived a HCP with specialist expertise in exercise as the most appropriate person to support engagement and deliver feedback.

"I had a physio at one point, and I wouldn't say the advice I got was as useful as the advice I got from [the exercise physiologist] ... I think [the exercise physiologist's] knowledge helped a lot in that way and helped me continue [exercising]." (Patient 1)

Feedback on behaviours via Messages to reinforce positive habits and support participants

The personalised feedback messages were sent to participants via the Microsoft Teams app after each exercise session during the first month of the intervention, and weekly during months two and three. Feedback was tailored using biofeedback recorded by the fitness watch, with heart rate data informing exercise intensity during purposeful sessions and accelerometry data tracking progress towards daily physical activity targets. All participants and caregivers spoke positively about the feedback messages, noting that they provided additional motivation to continue engaging with the programmed exercise sessions.

"I thought it was really positive. [The messages] were one of the most motivating things. Even if I'd felt like I'd not done as good this week, [the exercise physiologist] always made me feel better for what I'd done. I just thought [the exercise physiologist] was really nice, that's what you want." (Patient 2)

Participants were able to respond to messages or contact the exercise physiologist with questions at any time via the Microsoft Teams App, which was also seen as a facilitator of engagement. Many participants and caregivers noted that responses were timely and appropriate, helping to build trust while clearly explaining expectations and exercise requirements in an accessible and understandable manner.

“If there was something that [the participant] wanted to ask there was the freedom to get in touch with [the exercise physiologist]. [The participant] felt confident enough that they could message [the exercise physiologist] and [the participant] was understanding what [the exercise physiologist] was saying back to [the participant].”

(Caregiver 3)

Focus group and interview data suggest that the personalised, data-driven feedback messages effectively embedded practical support within the intervention. This finding is consistent with previous research demonstrating the value of feedback messages in providing practical support for young people with obesity (Sharifi *et al.*, 2013), however, the tone, content and timing of such messages are critical to ensure they are positively received by (Smith *et al.*, 2014). Notably, participants appeared to perceive the messages as a form of emotional social support, despite this component not being designed to deliver this BCT. This suggests that the supportive nature of the messages was as important as the informational feedback they contained and that they supported the basic psychological need for relatedness (Ryan and Deci, 2000). To the authors knowledge, this is the first study to show that messages sent by a healthcare professional can be perceived as social support by young people with obesity and, in turn, enhance motivation to engage in exercise. Evidence from studies in overweight and sedentary adults further supports this interpretation showing that social support from healthcare professionals can aid motivation for PA (Fukuoka *et al.*, 2011)

Link with the wider multi-disciplinary team to provide wider knowledge on behaviours

The link to other HCPs within the Alder Hey CEW multidisciplinary team was deemed to be a beneficial aspect of the intervention. Previously patients had been referred to external partners offering exercise and PA support. It was mentioned that these services do not have the same ability to provide feedback to the multidisciplinary team and therefore inform participants care plan. Integrating an exercise physiologist into the CEW multidisciplinary team enabled timely communication with other team members about participants' engagement in purposeful exercise and lifestyle PA. This was seen as a positive by both participants and caregivers with both focus groups and interviews, praising the idea that all members of the CEW service were accurately informed on activity levels of the participant.

“That's one of the things I did like about the trial that [the exercise physiologist] did have communication with Alder Hey and the team because they got to understand

what I do because [the exercise physiologist's] seen it and because [the exercise physiologist's] got all the stuff recorded. But I think it was good that Alder Hey got to see that too, because it proves that I am really active, and I don't just like sit about and do-nothing kind of thing." (Patient 4)

"[The participant] could actually prove that I am active and yet I'm still big."
(Caregiver 3)

2.3.7. Future Directions

In addition to reviewing the current MOTIVATE-CEW intervention, focus group and interview participants were encouraged to provide feedback on areas that could be developed within the intervention.

The most suggested improvement was extending the duration of the intervention. Both patients and caregivers felt that a longer intervention could help establish routines and increase the likelihood of sustained exercise post-intervention.

"I'd make it longer though, so we had more time to be able to get into the routine and then when it stopped to be able to finish and keep going with that routine" (Patient 3)

Although participants perceived that a longer intervention may support habit formation and post-intervention maintenance, extending intervention duration does not necessarily improve adherence in isolation. Evidence from behavioural trials targeting childhood obesity suggests that greater intervention dose or contact time is generally associated with stronger effects on outcomes, but this must be balanced against the practical demands placed on families and services (Heerman *et al.*, 2017). These issues are particularly relevant in CEW services, where families may already experience substantial social, health and logistical complexity. Extending MOTIVATE-CEW may therefore provide a longer period of support for behaviour change but would also increase the burden on health services due to increase in exercise physiologist time and monitoring requirements. Previous work has also shown that family-based child weight-management interventions can impose time and monetary costs on families, which may be under-recognised when considering intervention feasibility (Arai *et al.*, 2015). Therefore, future refinement should examine whether the potential benefits of a longer intervention justify the additional participant burden and service-level resource requirements.

It was suggested by some that having more face-to-face contact for exercise consultations, or purposeful exercise sessions, may have further enhanced their experience. However, some felt that the virtual approach made the intervention more accessible due to reductions in cost for transport, and the ability to schedule consultations at times that were convenient around caregivers work obligations and participants education.

“I think the fact that you're not hospital based as well, we have to go through the tunnel to go to the hospital. We live on the Wirral and it's at Alder Hey, so then you have to pay for parking, so really, before you've even got there, it's cost you £10 before your petrol” (Caregiver 2)

The time and monetary costs associated with participation in family-based child weight-management interventions are also relevant when interpreting this recommendation. Although additional in-person contact may be beneficial for some families, this should be balanced against participant burden and the service-level resources required to deliver further face-to-face support (Arai *et al.*, 2015).

Caregivers discussed the potential value of a community group to facilitate shared experiences and mutual encouragement. However, this was not raised by participants themselves.

“I don't know whether she would have done, but whether it would have been nice to have contact with other young people who are in the same position” (Caregiver 4)

The presence of a community group within the intervention would add further social support in addition to the support provided by the HCP (Section BCT 5). Prior research has shown that young people with obesity value peer networks in lifestyle interventions, as they provide a sense of belonging and shared understanding (Jones *et al.*, 2019). Given the overrepresentation of neurodevelopmental conditions among CYP receiving care from CEW services, the feasibility and acceptability of peer support groups should be considered carefully. Although peer support may provide social connection and shared understanding for some patients, group-based approaches may not be suitable or desirable for all CYP. Further patient and caregiver consultation is therefore required to determine whether peer support should be included in future iterations of the intervention and how it could be delivered in a flexible and inclusive way.

Finally, caregivers suggested that the ability to complete the intervention with the use of other fitness watches may have been beneficial. Many patients already owned devices capable of tracking exercise and heart rate, and integration could improve feasibility while reducing the burden of wearing multiple devices.

To support interpretation of the qualitative findings, Table 2.3 summarises how each intervention component was perceived by participants and caregivers, alongside implications for refinement and future evaluation of the MOTIVATE-CEW intervention.

2.3.8. Clinical Implications

The qualitative findings from this study suggest that the BCTs embedded within the intervention were indeed perceived as facilitators of engagement in exercise and PA by patients and their caregivers. Given the complex, multicomponent nature of the intervention, it is not possible to isolate the individual effects of each BCT. However, previous research in young people with obesity has shown that incorporating goal-setting, self-monitoring and text message support, within an mHealth based PA intervention, can significantly increase daily active minutes and daily steps (Cummings *et al.*, 2022). The successful implementation and positive reception of these techniques within the MOTIVATE-CEW intervention therefore adds weight to their clinical relevance, supporting their potential to enhance engagement in exercise and PA in this population.

Table 2.3. Summary of qualitative findings and implications for future refinement of the MOTIVATE-CEW intervention

Intervention component / BCT	Summary of participant and caregiver perceptions	Implications for future intervention refinement
BCT 1: Information about health consequences.	• Broader health and wellbeing benefits were valued. • Moving beyond weight loss appeared motivating. • Some caregivers still perceived limited benefit without weight loss.	• Retain education on wider benefits of exercise and PA. • Manage expectations around weight change.
BCT 2: Graded action plans with specific behavioural goals.	• Personalised plans were viewed positively. • Achievable, progressive goals supported engagement. • Flexibility helped overcome barriers and maintain enjoyment.	• Retain personalised and graded action plans. • Adapt plans around preferences, barriers, confidence and fitness.
BCT 3: Instruction on how to perform behaviours.	• Booklets and videos supported exercise completion. • Home-based resources increased flexibility. • Heart rate feedback helped guide intensity and confidence.	• Retain accessible exercise instructions and video resources. • Use simple biofeedback to guide safe exercise intensity.
BCT 4: Self-Monitoring of behaviours	• App-based progress tracking was motivating. • Participants valued reviewing completed and upcoming sessions. • Technology was viewed as appropriate for adolescents.	• Retain mHealth-supported self-monitoring. • Ensure participants can track progress and upcoming goals.
BCT 5: Regular feedback on behaviour by HCP's	• Personalised feedback was highly valued. • Regular contact provided motivation and accountability. • Support from an exercise specialist was perceived as credible and non-judgemental.	• Retain regular personalised feedback. • Feedback should be delivered by a credible HCP with exercise expertise.
Future directions	• Longer intervention duration was suggested. • Some face-to-face contact may be beneficial. • Peer/community support and wearable compatibility were suggested by caregivers.	• Consider a longer intervention period. • Explore flexible hybrid delivery. • Consider optional peer support and compatibility with existing watches.

BCT, Behaviour Change Technique; PA, Physical Activity; mHealth, Mobile-Health; HCP, Health Care Professional

2.3.9. Strengths and Limitations

The study included several strengths. This is the first study to obtain the qualitative perspectives of patients and caregivers on the design and delivery of an exercise

intervention delivered within a CEW service. The use of two qualitative research methods generated contextually rich data, providing deeper insight into participants' views of the intervention. In addition, the focus groups and interviews were conducted by a researcher independent of the intervention development and delivery, reducing the risk of leading responses.

Despite a good response rate for the qualitative survey (83%), the focus groups and interviews included only four patients that participated in the intervention and four caregivers. Although this sample size is comparable to that of other qualitative studies in young people with excess weight (Hester, McKenna and Gately, 2010; Hemetek *et al.*, 2014), the small sample size made it difficult to obtain a representative sample of intervention participants (Table 2.2). All participants were female, had engaged with the intervention, and consented to take part in additional qualitative analysis. As a result, the focus groups and interviews did not capture the perspectives of male patients or those who disengaged from, or dropped out of, the intervention. Consequently, data saturation across all areas of enquiry was unlikely to have been achieved, and additional interviews may have identified further barriers, facilitators, or alternative perspectives regarding intervention acceptability. Nevertheless, the qualitative evaluation provided valuable insights from patients and caregivers who had direct experience of the intervention, and these findings were used to inform recommendations for future refinement.

2.4. Conclusion

This study utilised the perspectives of CEW service patients and their caregivers to evaluate the MOTIVATE-CEW intervention. Participants valued the inclusion of personalised, graded action plans based on exercise and PA goals. Clear instructions on how to carry out these behaviours, opportunities for self-monitoring, and regular feedback from an exercise physiologist were all perceived as facilitators of engagement. Participants also recognised the value of increasing understanding of the health consequences of exercise and PA, though this component could be strengthened in future iterations. While refinements to specific intervention elements should be considered in order to further optimise their delivery, participants also generated specific suggestions for improvement including extending the duration of

the intervention and enhancing opportunities for social support to encourage higher levels of activity. Future research should look to further utilise service user and stakeholder perspectives to refine the MOTIVATE-CEW intervention and promote sustained engagement in structured exercise and daily PA among patients receiving treatment from CEW services.

3. Study 2- Using intervention mapping to develop an exercise physiologist led, mHealth facilitated, physical activity intervention for use in a paediatric Complications from Excess Weight Service: Creating MOTIVATE-CEW2

3.1. Introduction

The rising prevalence of obesity among young people is a major public health concern. Since 1990, the global number of young people living with obesity has quadrupled (WHO, 2025b), and in England, 15% of those aged 2–15 meet criteria for obesity (NHS-Digital, 2024a). The prevalence of severe obesity is also increasing (NHS-Digital, 2024b), heightening the risk of both immediate and long-term health consequences (Bass and Eneli, 2015). Alarming, the health-related quality of life (HRQoL) of young people with severe obesity has been reported to be comparable to that of young people living with cancer (Schwimmer, Burwinkle and Varni, 2003). In response to this growing obesity crisis, NHS England established CEW services in 2021, and 37 services are now operating nationwide. These services provide multidisciplinary, holistic care for young people with obesity-related conditions.

The National Institute for Health and Care Excellence (NICE) (NICE, 2025) recommends that lifestyle interventions, including support to increase daily physical activity (PA) and engage in structured, purposeful exercise, should form the first-line treatment within CEW services. To facilitate engagement with PA and exercise, we developed MOTIVATE-CEW, an exercise physiologist-led, mobile health (mHealth) supported intervention embedded within a UK CEW service. Qualitative findings from a single-site feasibility randomised controlled trial indicated that many components of the intervention were acceptable to participants (Study 1), and early data suggested good uptake of purposeful exercise (Davies *et al.*, 2026). However, adherence declined substantially over time, with only 33% of participants remaining active at post-intervention (3 months). These findings suggest that while the intervention concept is promising, further refinement is needed to support sustained engagement in purposeful exercise and daily PA.

The Medical Research Council (MRC) guidance for developing complex interventions emphasises the use of established, theory-informed frameworks, such as Intervention Mapping, to ensure that intervention components are developed systematically and are clearly linked to their intended mechanisms of action (O'Cathain *et al.*, 2019). The guidance also highlights the importance of co-development and partnership-based approaches, recognising that meaningful involvement of patients, caregivers,

practitioners, and other key informants, enhances acceptability, feasibility, and real-world relevance. A combined approach may be especially important in CEW services, where young people often face multiple, interrelated challenges and have complex needs. For example, unpublished data from the Alder Hey Children's Hospital CEW service (2025), supported by Hawton *et al.* (2025), indicate that 61% of patients have neurodevelopmental conditions (autism spectrum disorder, attention deficit hyperactivity disorder, or learning difficulties), compared with approximately one in seven young people in the general population (GOV.UK, 2025). Severe obesity is also disproportionately concentrated in areas of socioeconomic deprivation; CEW service data show that 41% of patients live in the most deprived areas (IMD decile 1), compared with only 4% in the least deprived (IMD decile 10), a distribution significantly different from that expected (Hawton *et al.*, 2025).

This study describes the development and theoretical foundations of a refined version of the MOTIVATE-CEW intervention, designed to support improved uptake and sustained maintenance of exercise and PA among young people with obesity attending CEW services. The development process combined the systematic, theory-driven structure of Intervention Mapping with a partnership-based co-development approach involving key informants.

3.2. Methods

3.2.1. Intervention Development Model

In line with MRC guidance (O'Cathain *et al.*, 2019) we refined the MOTIVATE-CEW intervention through a six-step intervention mapping framework (Eldredge *et al.*, 2016), that integrated a co-development process in all relevant steps.

Step 1- Identifying the problem and target for change through a needs assessment

Step 2- Developing change objectives and identifying the determinants of change

Step 3- Mapping determinants of change to behaviour change techniques and theories

Step 4- Developing the programme and creating resources

Step 5- Understanding adoption and implementation issues

Step 6- Creating an evaluation plan to assess the processes and effectiveness

Intervention mapping is a widely used framework for developing complex clinical interventions (Greaves *et al.*, 2016). By first identifying the target issue through an evaluation of the existing evidence base, developers can ensure that the intervention is appropriate for the intended population and feasible within the context in which it will be implemented. Working backwards from the programme objectives and identifying the barriers and facilitators to achieving these objectives allows intervention strategies to be designed with explicit consideration of the determinants of change. Incorporating a partnership-based approach alongside evidence and theory further strengthens the development process and can ultimately lead to improved outcomes and clearer performance objectives (Kwah *et al.*, 2024).

An outline of the intervention development process is presented in Figure 3.1. The subsequent sections summarise the initial five steps of the intervention mapping approach as implemented in the creation of the MOTIVATE-CEW2 intervention.

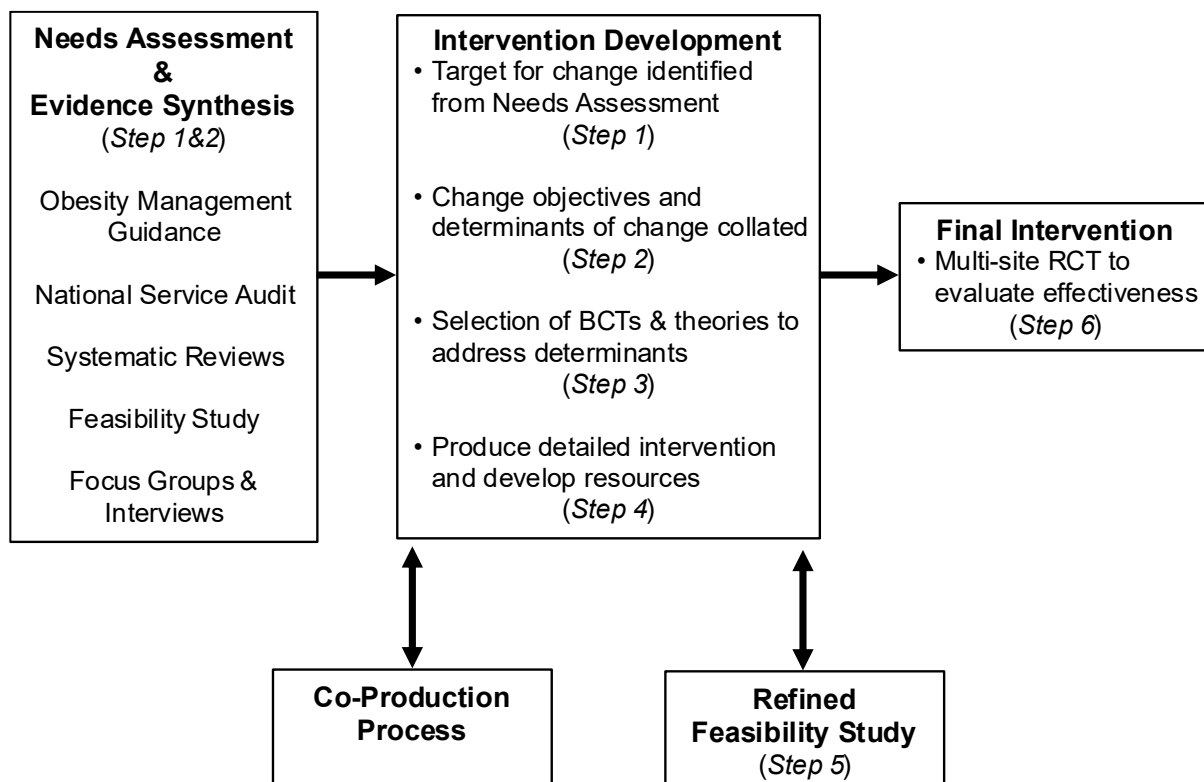


Figure 3.1. The intervention development process

3.3. Step 1- Needs assessment to identify the problem and target for change

The intervention mapping process began with an assessment of the exercise and PA needs of young people receiving care from CEW services, and their caregivers. The aim of this step was to synthesise information on what is needed for this cohort and what is currently being delivered.

The first source of evidence was the NICE guidelines for obesity management (NICE, 2025), which emphasises that exercise and PA should be core components of obesity management interventions. Within these guidelines two elements stand out as vital components of a potential exercise and PA intervention.

- 1) Young people should be encouraged to increase their levels of PA, regardless of any changes in weight, due to the other health benefits associated with PA.
- 2) Any obesity management interventions must ensure the inclusion of maintenance advice and techniques.

These guidelines therefore identify both PA uptake and ongoing maintenance as essential components of effective intervention design.

The Cochrane Review by Al-Khudairy *et al.* (2017) demonstrated that lifestyle interventions for young people with overweight or obesity can lead to maintained weight loss and moderate improvements in health-related quality of life, findings that are consistent with those reported in a systematic review of exercise and PA interventions (Ruotsalainen *et al.*, 2015). Despite positive outcomes from lifestyle interventions, the studies that measured PA behaviour in the Cochrane Review reported limited PA maintenance. Of the twelve studies collecting data on PA behaviour only two showed significant improvements in self-report PA at the end of the intervention when compared to a control group (Gourlan, Sarrazin and Trouilloud, 2013; Pakpour *et al.*, 2015). These findings suggest that, although lifestyle interventions can be beneficial, existing approaches have limited impact on sustained PA behaviour, indicating a need for interventions with a stronger focus on supporting exercise and PA maintenance.

Understanding the current exercise and PA provisions for patients within CEW services was also essential for identifying gaps that an exercise and PA intervention

should address. To inform this our research group conducted a service audit using a survey (Appendix 4) developed from the scoping review by Roberts *et al.* (2021a), with input from the Alder Hey Children's Hospital CEW service multidisciplinary team and insights from focus groups and interviews with CEW service patients and families, described below. This questionnaire was distributed between August 2023 and June 2024 to all 21 CEW services setup at this time (37 now exist). Fifteen services responded (71% response rate), providing sufficient rigour and meeting the minimum response rate recommended for Delphi-style processes (Hasson, Keeney and McKenna, 2000).

Survey findings indicated that current CEW provisions may be insufficient to effectively encourage exercise and PA uptake. Most services currently provide generic PA advice, typically based on government guidelines delivered during routine clinic appointments. Some services also offer group-based exercise sessions, behavioural counselling sessions and referrals to external services, often delivered by non-specialist staff. While these approaches can support increases in exercise and PA, NICE guidelines (NICE, 2025) emphasise the importance of individually tailored interventions, and yet the current approaches do not align with this recommendation. The review by Roberts *et al.* (2021a) also supports the suggestion that general PA recommendations are insufficient to encourage long term adherence to increased PA with many viewing them to be overwhelming. The survey also revealed that only half of the services provide patients with an exercise and PA action plan, in line with the NICE guidelines (NICE, 2025), and just three services review these plans as frequently as intended. This suggests that current approaches may not provide sufficient support to promote sustained PA engagement, highlighting the need for enhanced, tailored intervention strategies.

To support PA provision in CEW services, our research team developed and evaluated the MOTIVATE-CEW intervention through a single-site feasibility RCT (Davies *et al.*, 2026). The intervention aimed to increase lifestyle PA and purposeful exercise using virtual counselling sessions, goal setting, action planning, and real-time biofeedback to support self-monitoring and personalised feedback. Despite good initial uptake of purposeful exercise in the intervention group (83%) only 33% of participants were still

exercising by week 12. This mirrors the wider evidence discussed above that current approaches struggle to support PA maintenance over time.

Qualitative analysis, conducted through online interviews and focus groups with participants (n=4) and their families (n=4), offered further insights into the strengths and limitations of the original intervention (Study 1). Participants valued personalised, graded action plans, clear exercise instructions, opportunities for self-monitoring, and regular feedback from an exercise physiologist, all of which facilitated early engagement. However, they also identified areas requiring improvement, including extending the intervention duration and increasing opportunities for social support to help sustain PA behaviour. These findings suggest that although the intervention concept is acceptable and feasible, refinement is needed to enhance long-term engagement in both purposeful exercise and daily PA.

Collectively, the findings from this needs analysis indicate that young people receiving care from CEW services require more personalised, sustained support to maintain exercise and PA behaviour over time. Although PA is prioritised within national guidelines and valued within CEW services, current approaches lack the individual tailoring, and consistent follow-up needed to achieve long-term behaviour change. As such, a key unmet need is an intervention that provides ongoing, tailored support specifically targeting exercise and PA maintenance in young people attending CEW services.

3.4. Co-Development

To support the identification and understanding of the performance objectives and determinants of change in Step 2, and to inform the refinement of the intervention in Steps 3 and 4, we conducted a co-development process in partnership with CEW service patients, caregivers, and healthcare professionals (HCPs).

3.4.1. Co-Development Design and Setting

23 key informants participated in the co-development process, from July 2024 to September 2024. These informants formed two groups, 1) a young person group of patients (n=7), 2) an adult group of caregivers of these patients (n=5), and HCPs linked with the Alder Hey Children's Hospital CEW service (n=11). CEW service patients and

caregivers were identified during routine clinic appointments and approached by a member of the Alder Hey Children's Hospital CEW service multidisciplinary team. A member of the research team then provided participants with information sheets and obtained informed consent. Professionals with involvement in the Alder Hey Children's Hospital CEW service were approached by the research team using preexisting professional contacts with the service. Participants aged 16-18 provided written informed consent, while participants aged 11-15 provided written assent with their caregiver providing consent. Caregivers of CEW service patients, and HCPs, provided their own written informed consent for participation.

The study was approved by the North-West NHS Research Ethics Committee (24/NW/0133) and conformed to the Declaration of Helsinki.

3.4.2. Co-Development Workshops

Workshops were conducted with the young person group first so information from those sessions could inform the adult group. The baseline demographics of the young people contributing to the co-development, alongside the demographics of the Alder Hey Children's Hospital CEW service as a whole are presented in Table 3.1. Attendance at each workshop can be found in Table 3.2. Both groups attended 4 workshops, three in-person (delivered at Liverpool John Moores University) and one online (Zoom), with learnings from each workshop informing the content of the next to lead to the iterative development of the intervention. Workshops were designed to be interactive and incorporate small-group activities as well as whole group discussions to ensure all informants were given a voice. Multiple qualitative methods were used to document the intervention development process and capture data relevant to the research objectives. Members of the research team collected data via observation, reflective notes and photographs of white board and flip chart content. All workshop discussions were observed by at least two members of the research team to ensure that they could act as critical friends during any interpretation of the data.

Table 3.1. Baseline demographics of co-development participants from the AHCH CEW cohort and the AHCH CEW cohort.

		Co-Development Participants (n=7) n (%)	CEW Service (n = 264) n (%)
Age	<i>mean ±SD</i>	15 ±1	13 ±4
	<11	0 (0)	74 (28)
	11-15	5 (71)	124 (47)
	16-18	2 (29)	64 (24)
	>18	0 (0)	2 (1)
Sex	<i>Male</i>	4 (57)	136 (52)
	<i>Female</i>	3 (43)	128 (48)
Ethnicity	<i>White British</i>	6 (86)	200 (76)
	<i>Any Other Ethnic Group</i>	0 (0)	14 (5)
	<i>Any other White Background</i>	0 (0)	6 (2)
	<i>White and Black African</i>	0 (0)	3 (1)
	<i>Any other Black Background</i>	0 (0)	3 (1)
	<i>White and Black Caribbean</i>	0 (0)	2 (1)
	<i>Any other Asian Background</i>	0 (0)	1 (0)
	<i>Black African</i>	0 (0)	1 (0)
	<i>Not Stated</i>	1 (14)	34 (13)
IMD Quintile*	1	5 (71)	166 (63)
	2	0 (0)	33 (13)
	3	1 (14)	25 (9)
	4	1 (14)	25 (9)
	5	0 (0)	14 (5)
Neurodevelopmental Condition**		5 (71)	89 (39)
	ASD	5 (71)	72 (32)
	ADHD	1 (14)	30 (13)
	LD	1 (14)	28 (12)

AHCH, Alder Hey Children's Hospital; CEW, complications of excess weight; IMD, indices of multiple deprivation; ASD, autism spectrum disorder; ADHD, attention deficit hyperactivity disorder; LD, learning difficulties.

*CEW Service n=263 (1 Patient Located in the Isle of Man and does not have an IMD Quintile). **CEW Service n=228 (Data was only available for a sample of patients)

Table 3.2. Co-Development Workshop Attendance

Workshop	1	2	3	4
Young Person Group (n)	6	4	5	3
Adult Group (n) (Caregivers/HCPs)	4 (3/1)	6 (5/1)	5 (3/2)	14 (3/11)

HCPs, Health Care Professionals

During the first three workshops' participants collaborated with the research team on four co-development activities:

1. Exploring the factors that may influence engagement in increased exercise and PA.
2. Reviewing the behaviour change techniques (BCTs) used in the initial intervention, alongside additional BCTs identified in the literature as effective for increasing PA among young people (Part of Step 2).
3. Iteratively refining the design and delivery of the intervention components that together form the updated MOTIVATE-CEW2 intervention.
4. Identifying outcomes that are most important to participants and determining the most acceptable methods for collecting these outcomes to support data availability.

The fourth workshop involved presenting the co-developed intervention back to participants. During this session, the intervention was collaboratively reviewed and refined, with participants providing detailed feedback on each component to ensure it was ready for feasibility testing (Step 5).

3.4.3. Co-Development Analysis

Observations, reflective notes, surveys and visual data (i.e. diagrams, flow charts etc.) were combined to extrapolate key themes that represent the progress of the iterative development. Primary analysis was conducted by AD, with frequent debriefing sessions with research team members (BB, KH, GM, MC) to discuss and debate

emerging data and inform the development of subsequent participatory meetings. As details of intervention components emerged, they were iteratively mapped to the Template for Intervention Development and Replication (TIDieR) checklist (Hoffmann *et al.*, 2014).

3.5. Step 2- Program outcomes and objectives designed to elicit change

After identifying exercise and PA maintenance as the target for change, the next step focused on specifying who and what needed to change to achieve this outcome (Eldredge *et al.*, 2016). To do this, specific performance objectives were developed that influence exercise and PA maintenance in young people with obesity. Four methods were employed to obtain these performance objectives:

1. Evidence identified during the needs assessment stage (NICE guidance (NICE, 2025), Cochrane Review (Al-Khudairy *et al.*, 2017), service audit, MOTIVATE-CEW feasibility study).
2. Evidence from the Qualitative analysis of the original MOTIVATE-CEW intervention.
3. Systematic Reviews of non-school-based lifestyle interventions for young people (Brown *et al.*, 2016; Klos *et al.*, 2020; Goodyear *et al.*, 2023; Sivaramakrishnan *et al.*, 2024).
4. Evidence from the Co-Development process with CEW service patients, their caregivers and HCPs (methods described above).

The performance objectives identified during this step are presented in Table 3.3. Insights from the co-development process, alongside evidence from the existing literature were central to shaping the interventions performance objectives: 1) Patients and their caregivers highlighted the importance of designing an intervention that supports the development of autonomy in their exercise and PA behaviours, 2) Patients emphasised that sustained motivation is essential for engagement, noting that without it they would be unlikely to maintain exercise or PA, and 3) Caregivers and HCPs identified the need for ongoing support to help families overcome barriers that limit patient's participation in exercise and PA. For each performance objective, modifiable determinants of change were then identified (Table 3.3). These determinants of change describe the perspectives of the key informants and informs the third stage of the intervention mapping process.

Table 3.3. Intervention mapping matrix

Performance Objectives (Step 2)	Determinants of Change (Step 2)	Behaviour Change Techniques (Step 3)	Intervention Elements (Step 4)
Encourage autonomy in exercise and PA behaviours for young people with obesity to facilitate long term adherence	Having the flexibility and control to change their exercise and PA	Action Planning (1.4)	Action Planning (A,B,C)
	Being able to review and track their own exercise	Self-monitoring of Behaviour (2.3) Biofeedback (2.6)	Self-Monitoring behaviours (C)
	Feeling confident that the exercise is being executed correctly	Instructions on how to perform the behavior (4.1) Feedback on behaviour (2.2) Biofeedback (2.6)	Instructions on how to exercise (A,B,C,D) Feedback from HCP's (D)
	Being reminded to exercise from a source of their choice	Prompt/Cues (7.1)	Co-developed automated prompts (E)
Improve quality of motivation to take up and maintain exercise and PA	Knowing more about the importance of PA for health	Information about health consequences (5.2)	Education Session (A)
	Making exercise and PA a priority		
	Feeling supported by HCPs	Social support (emotional) (3.3)	Feedback from HCP's (D)
	Feeling confident in their ability to exercise	Instructions on how to perform the behavior (4.1)	Instructions on how to exercise (A,B,C,D)
	Completing exercise that helps achieve their goals	Goal Setting (outcome) (1.3)	Goal Setting (A,B,C)
	Engaging in exercise that they enjoy	Action Planning (1.4)	Action Planning (A,B,C)
	Feeling connected to other young people	Social Comparison (6.2)	Leaderboards (E)
	Seeing progress	Self-monitoring of outcome(s) of behaviour (2.4) Biofeedback (2.6)	Self-Monitoring progress (C)
	Being rewarded for achieving goals	Material incentive (behaviour) (10.1) Incentive (outcome) (10.8) Reward (outcome) (10.10)	Incentives (E)
Reduce the barriers to accessing support for families to up-take and maintain exercise/PA	Being offered support to access the preferred exercise and PA	Restructuring the physical Environment (12.1) Restructuring the social Environment (12.2)	Finding and financing activities (B)
	Being supported to personalise exercise and PA while considering family constraints	Action Planning (1.4)	Action Planning (A,B,C)

Numbers in brackets [e.g. (5.2)] refers to the Behaviour Change Technique taxonym number

Letters in brackets [e.g. (A)] refers to the intervention component: A- Education, B- Person Centred Counselling, C- mHealth Technologies and Self-Monitoring, D- Regular Remote Feedback, E- Ongoing Motivation and Engagement Strategies
PA, Physical Activity; HCPs, Health Care Professionals

3.6. Step 3- Mapping determinants of change to behaviour change techniques and theories

In Step 3, the behavioural theories and behaviour change techniques that could act on the identified determinants of change were selected. Embedding established behavioural theories at this stage ensured that the intervention components developed in Step 4 were evidence-based and followed a theoretically grounded pathway to change. The selection of theories and behaviour change techniques was informed by the research team, the co-development process, the Behaviour Change Technique Taxonomy (Michie *et al.*, 2013), and the existing systematic reviews of non-school-based lifestyle interventions for young people (Brown *et al.*, 2016; Klos *et al.*, 2020; Goodyear *et al.*, 2023; Sivaramakrishnan *et al.*, 2024).

Two key theories were chosen to underpin the intervention, Social Cognitive Theory (Bandura, 1986), and Self-Determination Theory (Ryan and Deci, 2000). Social Cognitive Theory was selected as its emphasis on self-efficacy and patient-centred support aligns closely with the key determinants identified (e.g. feeling confident in their ability to exercise). In addition, several other identified determinants align with Social Cognitive Theory constructs, including outcome expectations, social support, self-regulation, observational learning, and environmental facilitation. Additionally, the three basic psychological needs defined in Self-Determination Theory (autonomy, competence, and relatedness) were frequently reflected in participants' priorities. Therefore, developing intervention components that align with Self-Determination Theory will help foster autonomous motivation for exercise and PA, increasing the likelihood of maintenance.

The behaviour change techniques included within the intervention are presented in Table 3.3. This intervention mapping matrix illustrates how each performance objective is associated with relevant determinants of change, and how each of these determinants have been mapped to behaviour change techniques selected to address them. Several behaviour change techniques were retained or refined from the original MOTIVATE-CEW intervention, while additional techniques were incorporated based on evidence from the literature and insights generated during the co-development

process (Mendonça *et al.*, 2014; Barte and Wendel-Vos, 2017; Brigden *et al.*, 2020; Lawler, Heary and Nixon, 2020; Rhodes *et al.*, 2020; Goodyear *et al.*, 2023).

3.7. Step 4- Developing the programme and creating resources

Drawing on the determinants, theoretical mapping, and co-development process, Step 4 focused on translating these findings into intervention components and supporting materials. This process resulted in a comprehensive, evidence-informed, theory-driven exercise and PA intervention for CEW services, grounded in the needs of patients, their families, and CEW staff. The intervention was then further refined during the final co-development workshop where participants reviewed all elements of the intervention. The outcome of the intervention mapping process from Step 1 to 4 is summarised in the intervention logic model (Figure 3.2). The final MOTIVATE-CEW2 intervention is comprised of the following interrelated core components:

3.7.1. Education

At the start of the intervention, participants will attend an education session designed to introduce the components and establish the principles of effective action planning. The session will cover the benefits of PA and the health consequences of inactivity, followed by an introduction to the FITT (Frequency, Intensity, Time, and Type) principle and approaches to progressing activity levels. This information will provide participants with basic knowledge needed to begin shaping their own action plan. They will then be supported to reflect on their activity preferences and articulate their motivations for becoming more active, initiating the development of a personalised plan. The education session will be delivered as an in-person group session, with a one-to-one online alternative available for those unable to attend in person due to logistical or social constraints.

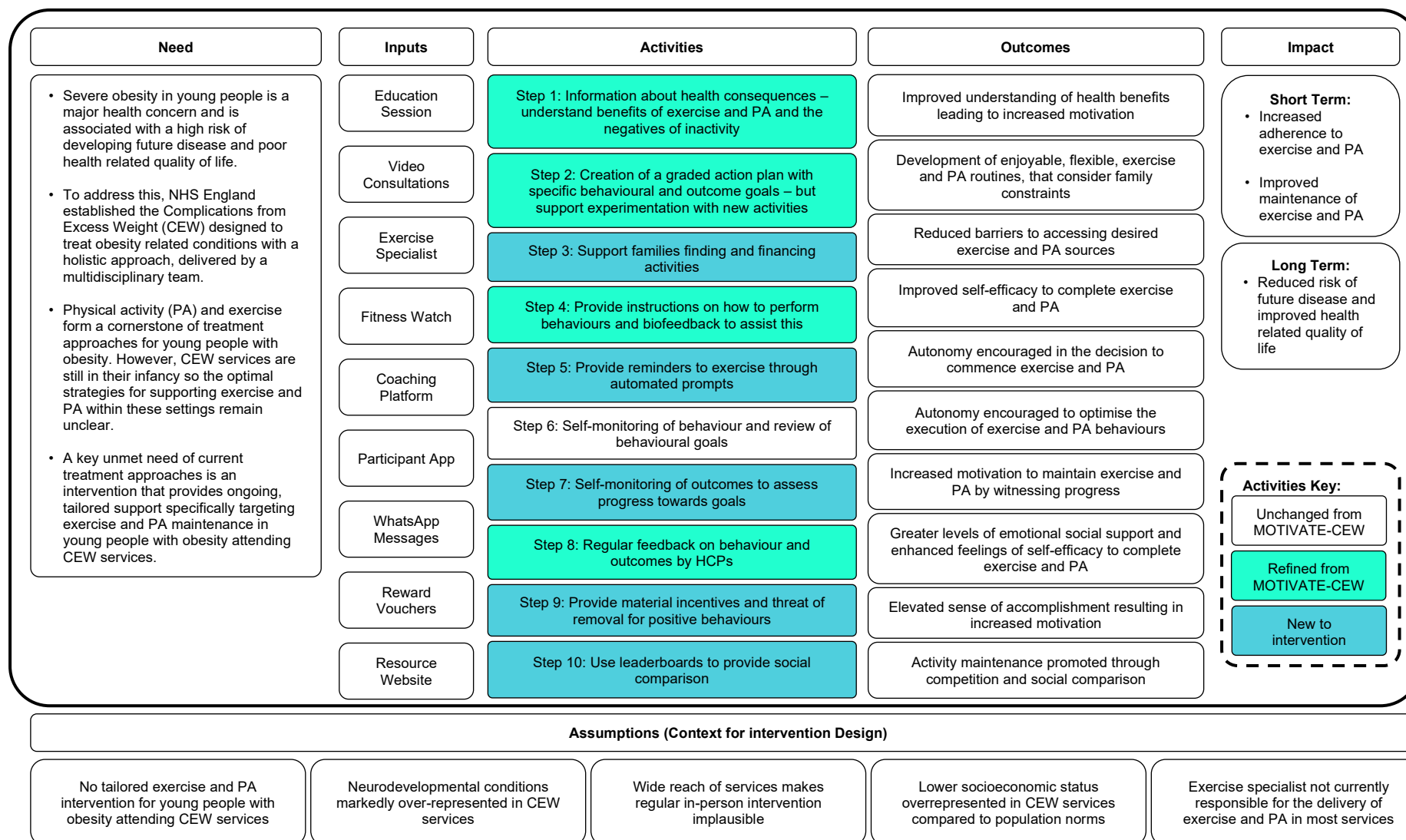


Figure 3.2. Refined MOTIVATE-CEW2 Logic Model
CEW, Complications from excessive weight

3.7.2. *Person Centred Counselling*

Throughout the 6-month intervention, participants and their parents/guardians will take part in regular virtual exercise consultations (via Microsoft Teams) with an exercise physiologist. Building on the foundations established during the initial education session, these consultations will focus on co-developing and refining individualised, graded action plans using person-centred counselling techniques (Miller and Rollnick, 2012). Each plan will include specific goals for both purposeful exercise and lifestyle PA, with participants encouraged to explore a range of activity options that match their abilities and preferences. Where appropriate, the exercise physiologist will also connect families with local services and facilitate access, including covering costs for paid activities during the intervention period. Action plans will be designed with family circumstances in mind, and caregivers will be contacted privately outside the consultations to ensure that the proposed plans are feasible and can be supported by the family.

3.7.3. *mHealth Technologies and Self-Monitoring*

To enhance the implementation of action plans, enable regular action-informed remote feedback and support ongoing self-monitoring, the intervention will incorporate mHealth technologies. A digital coaching platform will be used to generate personalised activity plans that outline both purposeful exercise sessions and daily lifestyle PA targets, including prescribed duration and intensity of exercise sessions based on individualised heart-rate zones. These plans will synchronise with a fitness watch (Polar Pacer, Polar Electro) and its companion smartphone application (Polar Flow – Sync & Analyze), enabling participants to access their plans and track their progress in real time. Biofeedback collected by the smartwatch will display progress toward daily lifestyle PA goals, and during purposeful exercise participants will be able to compare their current heart rate with their target zone. For participants completing resistance-based activities, instructional demonstration videos will be available through the QuickCoach application.

3.7.4. Regular Remote Feedback and Support

Biofeedback captured by the smartwatch will be available to the exercise physiologist via the coaching platform. This information will be used to generate personalised messages, delivered regularly via WhatsApp (Meta Platforms Inc.), to encourage continued engagement with the programme, provide guidance on completing exercise sessions safely and effectively, and offer emotional and social support from a credible source. The biofeedback will also inform discussions during virtual counselling sessions, enabling the exercise physiologist to review progress, address challenges, and adapt action plans as needed. Together, these ongoing interactions will support the continuous refinement of participants' action plans and help maintain progress toward their exercise and PA goals.

3.7.5. Ongoing Motivation and Engagement Strategies

Finally, the intervention will incorporate gamification, rewards, and prompts to further enhance motivation and support ongoing engagement. Anonymous weekly leaderboards, generated from participants' biofeedback data, will be shared to provide opportunities for positive social comparison and to foster a sense of collective progress. Participants will also receive financial incentives (£5 per week) for each week in which they complete at least one recorded purposeful exercise session. In addition, co-developed, automated prompts, in the form of calendar reminders, will be uploaded to participants' phones for those who wish to receive them. These features are intended to reinforce behaviour change through social comparison and positive reinforcement, while also promoting autonomy by ensuring that participation remains the young person's choice.

3.7.6. Intervention delivery

The research team agreed that the intervention should be considered for patients of secondary school age (11-18 years) to ensure they have suitable competency to operate the mHealth technology and literacy to engage in exercise consultations with the exercise physiologist. The exercise physiologist will be appropriately trained to deliver personalised and prescribed exercise to young people with severe obesity and

will be experienced in motivational interviewing to support the person-centred counselling techniques adopted in exercise consultations.

3.8. Step 5- Understanding adoption and implementation issues

3.8.1. Considerations for Future Intervention Evaluation

Feedback from patients, families and service staff was used to refine procedures and inform the design of a future randomised controlled trial. These discussions, together with interviews and focus groups from the original feasibility study and reflections from the research team, further refined the study design and provided insight into poor adherence to wearable devices observed in the first MOTIVATE-CEW feasibility study. Participants highlighted discomfort and unattractive design of research-grade accelerometers as key reasons for non-adherence. As a result, using the intervention smartwatch to capture PA data, rather than a separate research-grade device, alongside compensation in the form of shopping vouchers, was viewed as a positive strategy to improve uptake.

In-clinic outcome measures were considered appropriate and required no substantial changes, although participants suggested that data collection should align with routine clinical appointments wherever possible to reduce family burden. Finally, the proposed HRQoL questionnaires were reviewed and endorsed, with a recommendation to offer both paper and online formats to accommodate different completion preferences.

3.8.2. Feasibility Randomised Control Trial

Following ethical approval, a feasibility randomised control trial (NCT04854915) was conducted to assess the feasibility and acceptability of the intervention and critique its delivery. Participants were recruited from all stages of care within the Alder Hey Children's Hospital CEW service with 22 participants randomised to receive usual care alone (n=11) or the refined MOTIVATE-CEW2 intervention (n=11). Participants aged 16-18 provided written informed consent, while participants aged 11-15 provided written assent with their parent/guardian providing consent. Data to assess feasibility, acceptability and quality of intervention delivery (intervention fidelity) was collected from multiple sources including exercise consultation recordings, fidelity checklists, a

qualitative survey, and interviews with participants and their parents/guardians. Findings from the feasibility trial will be reported in full in the future.

3.9. Discussion

This study describes the development and refinement of the MOTIVATE-CEW2 intervention through an intervention mapping approach. The study combined intervention mapping with insights from key informants to guide the design and refinement of the intervention, with the overriding aim of supporting exercise and PA maintenance in young people receiving care from CEW services. The refined MOTIVATE-CEW2 intervention is an exercise physiologist led, evidence-based, theory-driven exercise and PA intervention, grounded in the needs of patients, their families, and CEW staff. This complex intervention was formed as a result of the first four steps of the intervention mapping process which involved identifying the intervention need, developing change objectives and determinants of change, mapping these change objectives to theory and behaviour change techniques (Michie *et al.*, 2013; Michie *et al.*, 2015) before ultimately developing the detailed intervention (Eldredge *et al.*, 2016). The intervention utilises a variety of interlinking support techniques that are summarised into five core components: 1) education, 2) person-centred counselling, 3) mHealth technologies and self-monitoring, 4) regular remote feedback and support, 5) ongoing motivation and engagement strategies. While these components accurately summarise the different elements that are present within the intervention, their delivery is far more integrated, with each component sharing the use of mHealth technologies and seeking to impact all the performance objectives outlined in Step 2. The intervention mapping process described in this paper aligns with the MRC guidance for developing complex interventions (Skivington *et al.*, 2024) and considers the needs and preferences of a range of CEW service key informants, namely patients, parents/guardians and HCPs.

This is the first study to use an intervention mapping process to develop an exercise and PA intervention for a CEW service, and to the authors' knowledge, it is also the first to utilise co-development in any aspect of CEW service care. The inclusion of a breadth of key informant perspectives in the development and refinement of complex healthcare interventions is becoming increasingly common (Griffiths *et al.*, 2015;

Buckley *et al.*, 2018; Livanou *et al.*, 2024), and the findings from the present study provide further support for the value of this approach. The integration of multiple workshops within the design of the co-development process and the inclusion of both in-person and online workshops likely contributed to the success of the study. The opportunity to build relationships and trust with participants through multiple sessions facilitated the collaborative process and the hybrid approach to conducting the workshops allowed us to be inclusive and capture a wider range of participant perspectives.

3.9.1. Limitations

A limitation of the intervention mapping process was that it was solely developed within the Alder Hey Children's Hospital CEW service, and so the intervention generalisability is unknown. Alder Hey Children's Hospital is located in Liverpool in the North-West of England, an area with high levels of deprivation. The suitability of the intervention for other CEW services with different demographics is therefore unknown. Although the co-development participants shared similar demographics with the wider Alder Hey Children's Hospital CEW service and had good representation of young people from deprived areas and those with neurodevelopmental conditions, children from minoritised ethnic backgrounds were not represented within the co-development group. Preliminary data from the ENHANCE study indicates that young people from minoritised ethnic backgrounds are overrepresented within CEW services nationally (Matu *et al.*, 2025), therefore, future intervention refinement should seek to capture the views of young people and families from minoritised ethnic backgrounds to ensure that the intervention is acceptable and appropriate for the wider CEW service population. Another limitation of the process was inconsistent attendance at co-development workshops, meaning not all key informants contributed to every meeting. Workshops for the patients were scheduled during school holidays and those for the caregivers and HCPs after standard working hours, yet attendance still varied. The final workshop, in which participants reviewed the proposed intervention, was attended by the majority of the Alder Hey Children's Hospital CEW service multidisciplinary team, allowing in-depth consideration of how best to implement the refined intervention within the service.

3.10. Conclusion

By combining an intervention mapping process with a partnership-based co-development approach involving key informants, we have refined MOTIVATE-CEW into a comprehensive, evidence-informed, theory-driven exercise and PA intervention designed to meet the specific needs of patients and caregivers attending CEW services. Integrating the perspectives of patients, caregivers, and HCPs during the development process may enhance PA maintenance and support the practical integration of the intervention into routine care. Future research will evaluate the feasibility of the revised intervention within the Alder Hey Children's Hospital CEW service before progressing to a full-scale, multi-site randomised control trial.

4. Study 3- A randomised controlled feasibility trial of a refined mobile health-supported, exercise physiologist-led home-based physical activity intervention within a paediatric Complications from Excess Weight service: MOTIVATE-CEW2

4.1. Introduction

The rising prevalence of obesity in young people is a major public health concern both in the UK and globally (NHS-Digital, 2024a; WHO, 2025b). Childhood obesity frequently tracks into adulthood (Singh *et al.*, 2008), with a meta-analysis indicating that 80% of 12-to-18 year olds living with obesity continue to experience obesity in adult life (Simmonds *et al.*, 2016). A substantial body of evidence demonstrates that young people living with obesity are at increased risk of premature mortality and physical morbidity in adulthood (Reilly and Kelly, 2011). In parallel, the prevalence of severe obesity in young people is rising (NHS-Digital, 2024b), heightening the risk of both immediate and long-term health consequences (Bass and Eneli, 2015). The impact of severe obesity on health-related quality of life (HRQoL) is particularly concerning, with evidence suggesting that young people living with severe obesity report levels comparable to those of young people living with cancer (Schwimmer, Burwinkle and Varni, 2003). In response, NHS England established Complications from Excess Weight (CEW) services in 2021, which employ a multidisciplinary team (MDT) to deliver holistic care for young people with obesity-related conditions.

Current National Institute for Health and Care Excellence (NICE) guidelines recommend that lifestyle interventions incorporating purposeful exercise and daily physical activity (PA) should form a central component of obesity treatment for young people within CEW services (NICE, 2025). This guidance is supported by a Cochrane review, which provides evidence that lifestyle interventions, including PA, can promote weight loss and improve HRQoL in young people living with overweight and obesity (Al-Khudairy *et al.*, 2017). Further evidence from a recent meta-analysis indicates that PA-based interventions are associated with improvements in HRQoL in young people living with obesity, with limited evidence supporting dietary interventions alone for improving HRQoL in this population (Henderson *et al.*, 2025). Despite this evidence base, CEW services remain in the early stages of development, and optimal intervention strategies for supporting exercise and PA are yet to be established (Roberts *et al.*, 2021a; Apperley *et al.*, 2022). Severe obesity is a complex condition, and emerging evidence from CEW services suggests that young people from the most deprived areas, minoritised ethnic backgrounds and those with neurodevelopmental diagnoses (autism spectrum disorder, attention deficit hyperactivity disorder, or

learning difficulties) are significantly overrepresented in CEW services (Hawton *et al.*, 2025). These population characteristics highlight the need for tailored exercise and PA interventions that are responsive to the diverse and complex needs of CEW services and their patients.

To support the integration of exercise and PA within CEW services, we developed MOTIVATE-CEW (Davies *et al.*, 2026), an exercise physiologist-led, mobile health (mHealth) supported intervention. A preliminary feasibility randomised controlled trial (RCT) was conducted within the Alder Hey Children Hospital CEW service. Findings indicated that the overall intervention concept was acceptable to participants and their caregivers, however, long-term maintenance of exercise and PA was poor, highlighting the need for refinement to better support sustained engagement. Building on findings from the initial feasibility trial, the MOTIVATE-CEW2 intervention was refined and developed in accordance with Medical Research Council (MRC) guidance for complex interventions (O'Cathain *et al.*, 2019). This process adopted an intervention mapping approach and was informed by co-development with key informants. The resulting MOTIVATE-CEW2 intervention was a comprehensive, evidence-informed, theory-driven exercise and PA programme for CEW services, grounded in the needs of patients, their caregivers, and CEW staff.

The overarching aim of this study was to assess the feasibility and acceptability of the MOTIVATE-CEW2 intervention and trial methodology, in order to inform the design of a definitive RCT evaluating clinical effectiveness in young people receiving care from CEW services. The specific objectives were to:

1. Determine the number of eligible patients, the proportion willing to participate, the proportion retained at 6 months, and examine their characteristics.
2. Assess the feasibility and acceptability of data collection tools and procedures.
3. Generate data to inform the sample size for a definitive trial.
4. Evaluate the feasibility and acceptability of the intervention and determine adherence rates during the intervention period.

4.2. Methods

This study adheres to the CONSORT 2010 guidelines for pilot and feasibility trials (Eldridge *et al.*, 2016)(Appendix 5).

4.2.1. Design

The MOTIVATE-CEW2 trial was a single-centre, parallel-group, feasibility RCT, with mixed method process evaluation. Participants were randomised 1:1 to usual care alone (control) or MOTIVATE-CEW2 plus usual care (intervention). Randomisation was stratified by age (11-15 years or 16-18 years) and GLP-1 agonist prescription (prescribed or not) and administered using a computer-generated random allocation sequence, created and administered by an independent researcher. Blinding of the participants or researchers was not possible. The study was approved by the East Midlands-Derby NHS Research Ethics Committee (21/EM/0030) and conformed to the Declaration of Helsinki. Participants aged 16-18 provided written informed consent, while participants aged 11-15 provided written assent with their caregivers providing consent. The protocol was prospectively registered on clinicaltrials.gov (identifier: NCT04854915).

4.2.2. Study Population and Setting

Participants were young people aged 11–18 years receiving care from the CEW service at Alder Hey Children’s Hospital and their caregivers. Young people were excluded if they were non-verbal and lacked Gillick competence to provide consent, or they were deemed unsuitable for participation by the CEW service MDT. Young people were deemed unsuitable if they were unable to complete unsupervised exercise, had ongoing family safeguarding concerns, or were scheduled for imminent discharge. Participants were recruited from all stages of care by a member of the MDT.

4.2.3. Interventions

Usual Care

All participants continued to receive usual care from the Alder Hey Children’s Hospital CEW service MDT (Davies *et al.*, 2026). The MDT assessed initial needs with the

patient and their caregiver, then developed an individual care plan, with follow-up appointments approximately every four weeks.

Intervention: MOTIVATE-CEW2

The MOTIVATE-CEW2 intervention and its development, using a combined Intervention Mapping and partnership-based co-development approach, have been described in detail elsewhere (Study 2). In summary, MOTIVATE-CEW2 is a comprehensive, evidence-informed, theory-driven exercise and PA intervention for CEW services, designed to address the needs of patients, their caregivers, and CEW staff. The intervention supports CEW service patients and their caregivers to co-develop personalised action plans that encourage both purposeful exercise and daily lifestyle PA. The 6-month, exercise physiologist led intervention, includes five core components each targeting key behaviour change processes.

1. Education: Participants attended an in-person group session (with 1:1 online alternative if required) introducing the benefits of PA, consequences of inactivity, and key principles for action planning, including the FITT (frequency, intensity, time, type) principle. Participants were also supported in the exploration of activity preferences and motivations to inform personalised plans.
2. Person Centred Counselling: throughout the intervention, participants and their caregivers attended monthly virtual counselling sessions with an exercise physiologist. Using a person-centred approach, specialists co-developed graded action plans to support purposeful exercise and lifestyle physical activity, promoted engagement in activities aligned with individual needs and preferences, and facilitated access to local services, including funding paid services during the intervention. Participants were also able to personalise the frequency of meetings to align with their preferences.
3. mHealth Technologies and Self-Monitoring: Action plans were delivered via a digital coaching platform synchronised to a smartwatch (Polar Pacer, Polar Electro) and mobile application (Polar Flow – Sync & Analyze). This was used to deliver detailed instructions for purposeful exercise sessions and a personalised daily lifestyle PA target. Exercise instructions provided specific guidance on the duration and target intensity based on personalised heart rate zones. Participants undertaking resistance training accessed demonstration videos via the

QuickCoach application. Participants used the system to track progress and provide ongoing feedback to their exercise physiologist.

4. Regular Remote Feedback and Support: Exercise physiologists reviewed biofeedback and participant feedback to inform ongoing counselling sessions and provide regular personalised WhatsApp messages. This supported ongoing dialogue, goal review, plan adaptation, and emotional support from a credible source. Messages were sent after each exercise session for the first month and reduced to weekly after this.
5. Ongoing Motivation and Engagement Strategies: Motivation was enhanced by embedding gamification strategies (weekly leaderboards) and financial incentives for achievement of weekly goals (£5/week), reinforcing behaviour change through social comparison and positive reinforcement. Optional automated reminders were also available to encourage engagement.

4.2.4. Outcomes

Primary Feasibility Outcomes

Primary feasibility outcomes included:

- Eligibility: percentage of CEW patients aged 11-to-18 years eligible for the study
- Recruitment rate: percentage of eligible patients approached who consented
- Reach: the age, sex, ethnicity, Index of Multiple Deprivation (IMD) and proportion of young people living with a neurodivergent diagnosis among consented participants and those who declined participation were compared to the overall Alder Hey Children's Hospital CEW service population. At the time of thesis submission, neurodivergent diagnosis data was only available for a sample (n=228) of the CEW service population, obtained prior to study recruitment.
- Retention: percentage of randomised participants with complete Pediatric Quality of Life Inventory (PedsQL 4.0) data at 6 months.
- Intervention adherence: data collected by the intervention smartwatch over the 6-month period was used to assess the proportion of participants who remained engaged in purposeful exercise during the final 2 weeks. The smartwatches optical heart rate monitor was also used to capture exercise frequency (number of sessions), duration, and time spent in moderate-to-vigorous intensity exercise (MVE), calculated by summing time in moderate (50–70% heart rate max) and

vigorous ($\geq 70\%$ heart rate max $\times 2$) intensity zones. Attendance at counselling sessions was recorded and compared with attendance at routine Alder Hey Children's Hospital CEW service appointments during the same period to provide a contextual comparison.

Secondary Outcomes

Secondary outcomes were based on the core outcome set developed for CEW services (Stilwell *et al.*, 2023). Outcomes were collected at baseline (pre-randomisation) and 6-months post-randomisation. Patient- and proxy-reported outcomes were collected using paper or online formats, depending on participant preference. A 7-day comparative assessment of purposeful exercise and PA was conducted using the intervention smartwatch (Polar Pacer) in both groups. Exercise capacity was assessed using an unsupervised outdoor 6-minute walk test, conducted using the smartwatch. Clinical outcomes were collected during routine clinical visits. The measures taken are outlined in Table 4.1, with detailed descriptions provided in Appendix 6.

Process Evaluation

A process evaluation was conducted in accordance with Medical Research Council guidelines for evaluation of complex interventions (Skivington *et al.*, 2024), to explore the feasibility and acceptability of both the intervention and study design, as well as intervention fidelity and the barriers and facilitators to exercise and PA. Findings from semi-structured interviews with participants and caregivers, together with the fidelity assessment, will be reported in full in a future complimentary manuscript.

Table 4.1. Measures conducted at baseline (pre-randomisation) and follow-up (6-months)

Measured	Measurement strategy	Outcome
<i>Patient- and proxy-reported outcomes</i>		
HRQoL	Questionnaires (Paper or Online)	1. PedsQL 4.0, 2. EQ-5D-Y-5L, 3. PedsQL 4.0 (Proxy), 4. EQ-5D-Y-5L (Proxy)
Weight-Related HRQoL		1. IWQOL-Lite, 2. IWQOL-Lite (Proxy)
Anxiety and Depression		1. RCADS, 2. RCADS (Proxy)
Self-Esteem		1. RSE
<i>Comparative assessment of purposeful exercise and physical activity</i>		
Purposeful Exercise	7-day device derived assessment (Polar Pacer smartwatch)	1. Frequency (number of sessions), 2. Duration (min), 3. Time spent in MVE (min)
Physical Activity		1. Active Time (min), 2. Standing Time (min), 3. Sedentary Time (min), 4. Steps, 5. Calories (kcal)
Exercise Capacity	Unsupervised, outdoor, 6-minute walk test, conducted using the Polar Pacer smartwatch	Distance (m)
Clinical Outcomes	Collected during routine clinical visits	1. Height, 2. Weight, 3. BMI, 4. Body fat %, 5 Fat mass, 6. Fat free mass, 7 Systolic BP, 8. Diastolic BP, 9. MAP, 10. HbA1c, 11. Total cholesterol, 12. HDL, 13. LDL, 14. Triglycerides, 15. AST, 16. ALT, 17. Albumin

HRQoL, Health-related quality of life; PedsQL 4.0, Pediatric Quality of Life Inventory; EQ-5D-Y-5L, EuroQol-5 Dimensions- Youth-5 Levels; IWQOL-Lite, Impact of Weight on Quality of Life-Lite; RCADS, Revised Child Anxiety and Depression Scale; RSE, Rosenberg Self Esteem Scale; MVE, Moderate-to-vigorous intensity exercise; BMI, Body Mass Index; BP, blood pressure; MAP, mean arterial blood pressure; HbA1C, Glycated Haemoglobin; HDL, high density lipoprotein cholesterol; LDL, low density lipoprotein cholesterol; AST, aspartate aminotransferase; ALT, alanine transaminase

Quantitative assessment of intervention acceptability

At 6-months, all young people in the MOTIVATE-CEW2 group completed a survey designed to identify the intervention components they perceived as most beneficial. Responses to each item were scored on a numerical scale from 0 to 5, with higher scores indicating more positive perceptions of the component. Acceptability of each component was considered adequate if the mean score was ≥ 3 . This approach was adapted from the fidelity scoring system used in similar intervention studies (Frost *et al.*, 2019; Purcell *et al.*, 2020).

Economic Assessment

The average cost per-participant of the MOTIVATE-CEW2 intervention was estimated by collating delivery costs related to intervention resources and exercise physiologist time per participant.

4.2.5. Statistical Analysis

Planned recruitment target of 22 young people was based on published recommendations for pilot and feasibility studies (Kieser and Wassmer, 1996). Feasibility outcomes of trial eligibility, recruitment and retention are reported as percentages with 90% confidence intervals (CIs). Participant characteristics, as well as those of young people who declined participation and of the Alder Hey CEW service population, are summarised using numbers and percentages. Intervention adherence is reported as the proportion of participants who remained engaged in purposeful exercise. The proportion of participants with complete secondary outcome data at 6 months is reported overall and by study group for each proposed outcome. Mean and SD values for secondary outcomes at baseline are presented by group, together with mean changes and corresponding 90% CIs for within- and between-group comparisons. Consistent with guidance for exploratory studies, formal hypothesis testing was not undertaken and p-values are not reported (Lancaster, Dodd and Williamson, 2004; Eldridge *et al.*, 2016). CIs and minimal clinically important differences (MCIDs) are presented to suggest plausible evidence of effect for respective study arms (Lee *et al.*, 2014; Bell, Whitehead and Julious, 2018).

4.3. Results

4.3.1. Primary Feasibility Outcomes

A CONSORT diagram detailing participant flow through the study is presented in Figure 4.1. Recruitment occurred between January and March 2025 with final follow-up assessments completed in November 2025. Of the 264 patients within the Alder Hey Children's Hospital CEW service, 107 were screened for eligibility, including 22 aged under 11 years. Of the remaining 85 patients, 66 were eligible (78% CI 69% to 84%). 44 declined to participate, resulting in 22 participants randomised (MOTIVATE-CEW2 n=11, Usual Care n=11), representing a recruitment rate of 33% (CI 25% to 43%) of eligible patients.

Baseline demographics of study participants are presented by group and overall, in Table 4.2. Summary data from the Alder Hey Children's Hospital CEW service and the young people who declined participation are included for comparison. Participant demographics were similar to those of young people who declined participation and the CEW service as a whole for sex, ethnicity, neurodevelopmental diagnoses and deprivation, measured via IMD. However, young people who declined participation tended to be younger. Within the study, the two groups were comparable with respect to age, sex and GLP-1 use, however, the usual care group demonstrated greater ethnic diversity and a higher proportion of participants from the most deprived areas and with a neurodevelopmental diagnosis.

17 participants completed follow-up assessments and provided complete PedsQL 4.0 questionnaire data, giving a retention rate of 77% (CI 60% to 88%). Among participants who provided data at the 6-month follow-up, completion rates for patient-reported outcomes and comparative assessment of purposeful exercise and PA exceeded 80% across all measures. In contrast, data completeness for clinical outcomes was more variable, with complete datasets available in more than 80% of participants for 4 out of 18 measures and in less than 50% of participants for 6 of out 18 measures (Table 4.3). Adherence to MOTIVATE-CEW2 was 64%, with 7 of the 11 participants remaining engaged in purposeful exercise during the final 2 weeks of the intervention. Overall, 82% of MOTIVATE-CEW2 participants initiated exercise (completed ≥ 1 purposeful exercise session).

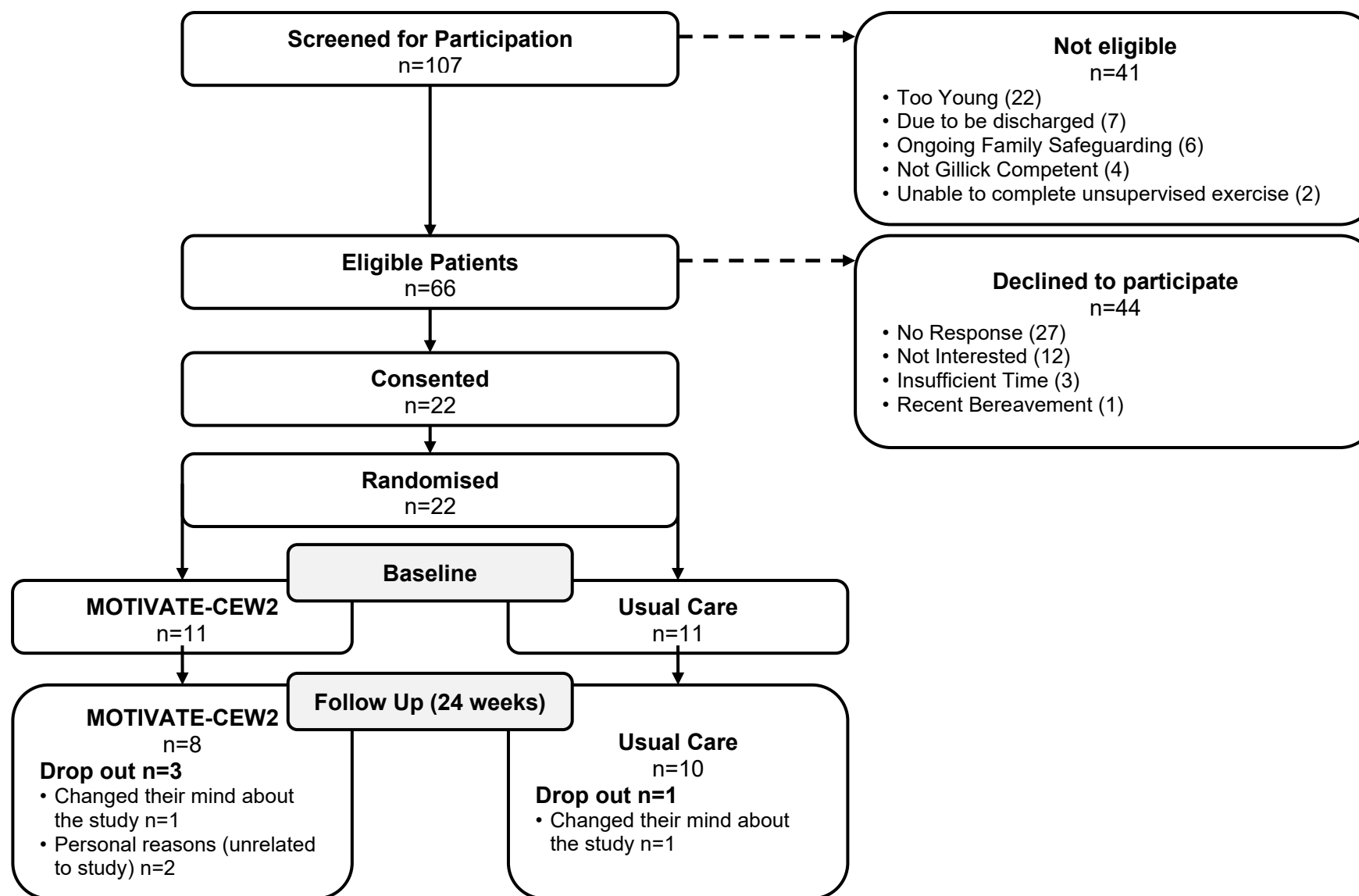


Figure 4.1. Participant consort diagram.

Table 4.2. Baseline demographics of study participants and the AHCH CEW cohort.

		Study Participants (n=22) n (%)	Usual Care (n=11) n (%)	MOTIVATE-CEW2 (n=11) n (%)	Declined Participation (n=44) n (%)	CEW Service (n = 264) n (%)
Age	<i>mean ±SD</i>	15 ±2	15 ±1	15 ±2	14 ±2	13 ±4
	<11	0 (0)	0 (0)	0 (0)	0 (0)	74 (28)
	11-15	14 (64)	7 (64)	7 (64)	35 (81)	124 (47)
	16-18	8 (36)	4 (36)	4 (36)	9 (20)	64 (24)
	>18	0 (0)	0 (0)	0 (0)	0 (0)	2 (1)
Sex	<i>Male</i>	12 (55)	6 (55)	6 (55)	22 (50)	136 (52)
	<i>Female</i>	10 (45)	5 (45)	5 (45)	22 (50)	128 (48)
Ethnicity	<i>White British</i>	16 (73)	7 (64)	9 (82)	29 (66)	200 (76)
	<i>Any Other Ethnic Group</i>	3 (14)	1 (9)	2 (18)	4 (9)	14 (5)
	<i>Any other White Background</i>	1 (5)	1 (9)	0 (0)	2 (5)	6 (2)
	<i>White and Black African</i>	1 (5)	1 (9)	0 (0)	0 (0)	3 (1)
	<i>Any other Black Background</i>	0 (0)	0 (0)	0 (0)	0 (0)	3 (1)
	<i>White and Black Caribbean</i>	0 (0)	0 (0)	0 (0)	1 (2)	2 (1)
	<i>Any other Asian Background</i>	0 (0)	0 (0)	0 (0)	0 (0)	1 (0)
	<i>Black African</i>	0 (0)	0 (0)	0 (0)	1 (2)	1 (0)
	<i>Not Stated</i>	1 (5)	1 (9)	0 (0)	7 (16)	34 (13)
IMD Quintile*	<i>1</i>	12 (55)	7 (64)	5 (45)	26 (59)	166 (63)
	<i>2</i>	3 (14)	1 (9)	2 (18)	6 (14)	33 (13)
	<i>3</i>	3 (14)	0 (0)	3 (27)	5 (11)	25 (9)
	<i>4</i>	4 (18)	3 (27)	1 (9)	3 (7)	25 (9)
	<i>5</i>	0 (0)	0 (0)	0 (0)	4 (9)	14 (5)
Neurodevelopmental Condition**		11 (50)	7 (64)	4 (36)	18 (41)	89 (39)
	<i>ASD</i>	9 (41)	5 (45)	3 (27)	14 (32)	72 (32)
	<i>ADHD</i>	5 (23)	3 (27)	0 (0)	7 (16)	30 (13)
	<i>LD</i>	4 (18)	1 (9)	2 (18)	3 (7)	28 (12)
Receiving GLP-1		6 (27)	3 (27)	3 (27)	15 (34)	46 (17)

AHCH, Alder Hey Children's Hospital; CEW, complications of excess weight; IMD, indices of multiple deprivation; GLP-1, Glucagon-like peptide-1; ASD, autism spectrum disorder; ADHD, attention deficit hyperactivity disorder; LD, learning difficulties. *CEW Service n=263 (1 Patient Located in the Isle of Man and does not have an IMD Quintile). **CEW Service n=228 (Data was only available for a sample of patients)

Table 4.3. Data collection completeness of individuals that attended 6-month follow-up for secondary outcome measures

	Overall (n=18) (%)	Usual Care (n=10) (%)	MOTIVATE- CEW2 (n=8) (%)
PedsQL 4.0	94	90	100
PedsQL 4.0 (Proxy)	94	90	100
RCADS	94	90	100
RCADS (Proxy)	94	90	100
IWQOL-Lite	94	90	100
IWQOL-Lite (Proxy)	94	90	100
EQ-5D-Y-5L	94	90	100
EQ-5D-Y-5L (Proxy)	94	90	100
RSE	94	90	100
Purposeful Exercise	100	100	100
Physical Activity	89	100	75
Exercise Capacity	61	60	63
Height	83	70	100
Weight	83	70	100
BMI	83	70	100
Body Fat	28	30	25
Blood Pressure	17	10	25
HbA1c	56	60	50
Blood Lipids	56	60	50
Liver Enzymes	72	80	63

PedsQL 4.0, Pediatric Quality of Life Inventory; RCADS, Revised Child Anxiety and Depression Scale; IWQOL-Lite, Impact of Weight on Quality of Life-Lite; EQ-5D-Y-5L, EuroQol-5 Dimensions- Youth-5 Levels; RSE, Rosenberg Self Esteem Scale; BMI, Body Mass Index; HbA1C, Glycated Haemoglobin.

*Body Composition includes aspartate body fat %, fat mass and fat free mass
Blood Lipids includes total cholesterol, high-density lipoprotein, low-density lipoprotein, and triglycerides*

Liver Enzymes includes aspartate aminotransferase (AST), alanine aminotransferase (ALT), and Albumin

Figure 4.2 illustrates the decline in training engagement over the 24-week intervention period. Across the 6-month intervention period, participants completed 1.2 ± 1.7 exercise sessions per week, and a mean of 51 ± 69 minutes of exercise per week, including 54 ± 61 minutes of moderate-to-vigorous intensity exercise. MOTIVATE-CEW2 consultations had a 78% attendance with 14% of meetings needing to be rearranged. During the same period, 64% of Alder Hey Children's Hospital CEW Service clinical appointments (endocrinologist and nurse specialists) and 64% of lifestyle appointments (dietician, physiotherapist, psychologist) were attended.

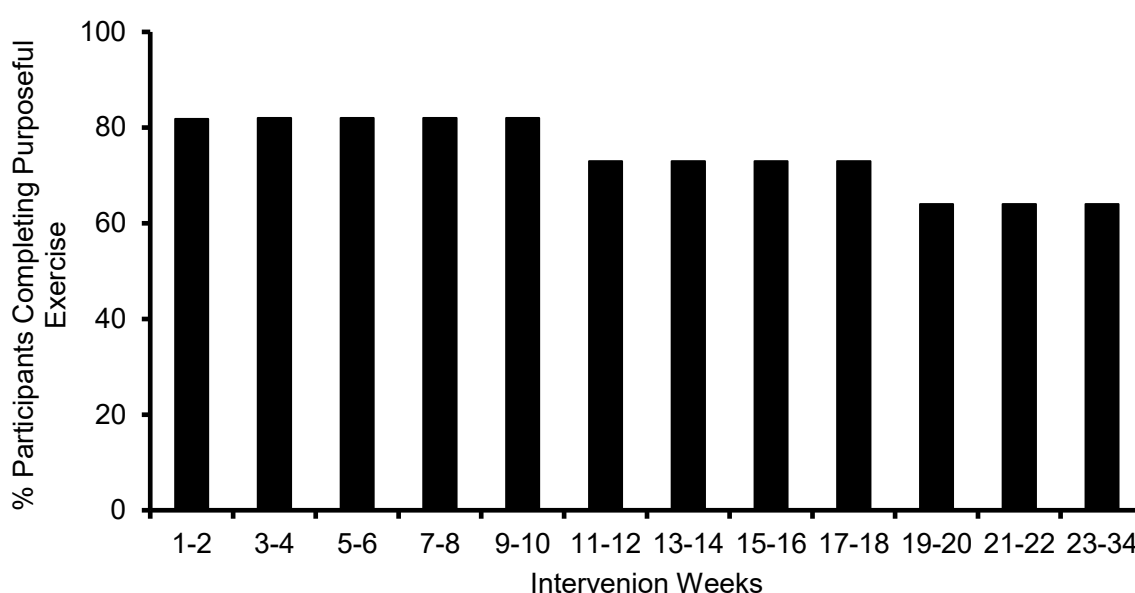


Figure 4.2. Decline in purposeful exercise engagement over the 24-week intervention period

4.3.2. Secondary Outcomes

Results of patient- and proxy-reported outcomes, comparative assessment of exercise and PA, exercise capacity and clinical measures are presented in Tables 4.4 and 4.5. Outcomes with less than 50% of data completeness, including data from participants lost to follow-up, are not reported. Only summary scores have been presented for self- and proxy-reported outcomes, additional dimensions/domains are reported in Tables 4.6 and 4.7. Data availability for alternative PA wear-times are reported in Table 4.8. CIs and MCIDs, displayed in Table 4.4, suggest plausible evidence of effect in favour of MOTIVATE-CEW2 for our likely full RCT primary outcome PedsQL4.0.

Table 4.4. Baseline, Within- and Between-Group Differences at 6-month follow-up; patient- and proxy-report outcomes, comparative assessment of purposeful exercise and physical activity and exercise capacity

Outcome (MCID)	Baseline Mean $\pm$ SD		Within Group Mean Difference (90% CI)		Between Group Mean Difference (90% CI)
	Usual Care	MOTIVATE-CEW2	Usual Care	MOTIVATE-CEW2	
PedsQL 4.0					
Total Score (4.4-5.4)	50 $\pm$ 20	56 $\pm$ 14	4 (-5 to 14)	11 (7 to 15)	7 (-3 to 17)
Proxy Total Score (4.50-5.16)	42 $\pm$ 18	51 $\pm$ 19	10 (5 to 16)	5 (-19 to 9)	-5 (-14 to 3)
RCADS					
Total Anxiety	40 $\pm$ 17	32 $\pm$ 18	-3 (-14 to 8)	-5 (-10 to 0)	-2 (-14 to 10)
Total Internalizing	51 $\pm$ 22	43 $\pm$ 23	-4 (-19 to 11)	-6 (-11 to -1)	-2 (-17 to 13)
Proxy Total Anxiety	47 $\pm$ 20	37 $\pm$ 20	-9 (-22 to 3)	-3 (-14 to 7)	6 (-9 to 21)
Proxy Total Internalizing	58 $\pm$ 25	46 $\pm$ 25	-11 (-27 to 5)	-5 (-19 to 9)	6 (-14 to 26)
IWQOL-Lite					
Total (4.8)	57 $\pm$ 22	70 $\pm$ 19	4 (-5 to 14)	3 (0 to 6)	-1 (-11 to 9)
Proxy Total	55 $\pm$ 24	61 $\pm$ 18	5 (0 to 10)	4 (-5 to 13)	-1 (-11 to 9)
EQ-5D-Y-5L					
VAS	51 $\pm$ 22	55 $\pm$ 16	11 (-11 to 33)	10 (-3 to 24)	-1 (-25 to 24)
Proxy VAS	57 $\pm$ 15	49 $\pm$ 21	11 (5 to 17)	6 (-14 to 26)	-5 (-26 to 15)
RSE	14 $\pm$ 2	15 $\pm$ 2	1 (0 to 2)	0 (-2 to 2)	-1 (-3 to 1)
Purposeful Exercise					
Number of sessions per week	1 $\pm$ 2	0 $\pm$ 0	-1 (-2 to 0)	2 (0 to 3)	3 (1 to 4)
Weekly Exercise Duration (min)	57 $\pm$ 95	1 $\pm$ 3	-40 (-73 to -8)	76 (-6 to 159)	117 (30 to 203)
Weekly MVE (min)	70 $\pm$ 135	1 $\pm$ 4	-50 (-99 to 0)	77 (7 to 147)	127 (44 to 209)
Physical Activity					
Weekly Active Time (min)	96 $\pm$ 91	80 $\pm$ 99	-15 (-60 to 31)	42 (-9 to 93)	57 (-6 to 120)
Weekly Standing Time (min)	322 $\pm$ 117	283 $\pm$ 97	5 (-36 to 46)	29 (-14 to 72)	24 (-31 to 78)
Weekly Sedentary Time (min)	765 $\pm$ 233	678 $\pm$ 157	71 (-103 to 245)	5 (-122 to 133)	-66 (-267 to 135)
Weekly Steps	11392 $\pm$ 6092	8326 $\pm$ 4218	720 (-4456 to 5895)	3292 (1052 to 5532)	2572 (-2855 to 8000)
Weekly Calories (kcal)	3312 $\pm$ 691	3325 $\pm$ 1206	-12 (-232 to 209)	108 (-106 to 321)	119 (-164 to 402)
Exercise Capacity (m)	550 $\pm$ 67	494 $\pm$ 108	-102 (-205 to 2)	-1 (-34 to 32)	100 (-4 to 205)

MCID, Minimal clinically important difference; SD, Standard Deviation; CI, Confidence Interval; PedsQL 4.0, Pediatric Quality of Life Inventory; RCADS, Revised Child Anxiety and Depression Scale; IWQOL-Lite, Impact of Weight on Quality of Life-Lite; EQ-5D-Y-5L, EuroQol-5 Dimensions- Youth-5 Levels; VAS, visual analogue scale; RSE, Rosenberg Self Esteem Scale; MVE, Moderate-to-vigorous intensity exercise. Physical Activity wear time was ≥ 10 hours for at least 1 day. Where possible, minimal clinically important differences have been included; PedsQL 4.0 4.4-5.4 (USPSTF, 2024; Henderson et al., 2025), Proxy PedsQL 4.0 4.50-5.16 (Hilliard et al., 2013; Henderson et al., 2025), IWQOL-Lite 4.8 (Modi and Zeller, 2011; Henderson et al., 2025)

Table 4.5. Baseline and Within- and Between-group Differences at 6-month follow-up; clinical measures

Outcome (MCID)	Baseline Mean ± SD		Within-Group Difference (90% CI)		Between-group difference (90% CI)	
	Usual Care	MOTIVATE-CEW2	Usual Care	MOTIVATE-CEW2		
Body composition						
Height (cm)	169.2 ±9.1	166.4 ±19.7	2.5 (1.1 to 3.9)	7.0 (-6.3 to 20.3)	4.5 (-8.8 to 17.8)	
Weight (kg)	113.08 ±23.28	117.31 ±24.42	3.60 (-3.02 to 10.21)	4.44 (0.43 to 8.44)	0.84 (-6.41 to 8.09)	
BMI (kg/m ²) (1.08 kg/m ²)	39.33 ±6.39	39.46 ±7.19	0.37 (-2.07 to 2.81)	1.42 (-0.17 to 3.01)	1.05 (-1.67 to 3.77)	
SDS BMI (0.25 to 0.5)	3.55 ±0.45	3.49 ±0.64	0.01 (-0.15 to 0.18)	0.06 (-0.06 to 0.19)	0.05 (-0.14 to 0.24)	
Liver Enzymes						
AST (U/L)	25 ±10	20 ±6	-2 (-7 to 3)	1 (-4 to 7)	3 (-3 to 10)	
ALT (U/L)	27 ±15	21 ±12	0 (-7 to 7)	3 (-9 to 15)	3 (-9 to 16)	
Albumin (g/L)	89 ±136	46 ±3	-53 (-155 to 49)	1 (-1 to 3)	54 (-48 to 156)	

MCID, Minimal clinically important difference; SD, Standard Deviation; CI, Confidence Interval; BMI, Body Mass Index; SDS BMI, standard deviation score body mass index; AST, aspartate aminotransferase; ALT, alanine transaminase
Where possible, minimal clinically important differences have been included; BMI 1.08 kg/m² (Huang et al., 2025), SDS BMI 0.25 to 0.5 (Henderson et al., 2025)

Table 4.6. Health related quality of life questionnaires- Questionnaire Domains (Self-Report): changes from baseline mean and SD, within group mean difference and CI, and between group mean difference and CI.

Outcome	Baseline Mean ±SD		Within Group Mean Difference (CI)		Between Group Mean Difference (CI)
	MOTIVATE-CEW2	Usual Care	MOTIVATE-CEW2	Usual Care	
PedsQL 4.0					
Psychosocial Health Summary	53 ±15	51 ±17	15 (11 to 19)	3 (-7 to 14)	12 (1 to 22)
Physical Health Functioning	61 ±15	48 ±27	4 (-1 to 10)	6 (-5 to 18)	-2 (-14 to 10)
Emotional Functioning	53 ±16	47 ±20	19 (10 to 27)	8 (-9 to 25)	11 (-7 to 29)
Social Functioning	59 ±15	60 ±27	16 (8 to 24)	7 (-2 to 16)	9 (-2 to 21)
School Functioning	48 ±26	46 ±16	9 (1 to 18)	-6 (-15 to 4)	15 (3 to 27)
RCADS					
Separation Anxiety Disorder	5 ±3	7 ±4	0 (-2 to 1)	-1 (-3 to 2)	0 (-2 to 3)
Social Phobia	8 ±4	9 ±4	-2 (-3 to 0)	0 (-2 to 2)	-1 (-4 to 1)
Generalized Anxiety Disorder (GAD)	6 ±3	7 ±3	-1 (-2 to 0)	0 (-2 to 2)	-1 (-3 to 2)
Panic Disorder	8 ±5	11 ±6	0 (-2 to 1)	-1 (-5 to 3)	1 (-3 to 5)
Obsessive-Compulsive Disorder (OCD)	5 ±4	7 ±3	-2 (-3 to 0)	-1 (-2 to 1)	-1 (-3 to 1)
Major Depressive Disorder (MDD)	8 ±4	7 ±5	-2 (-3 to 0)	-1 (-4 to 2)	-1 (-4 to 2)
IWQOL-Lite					
Physical Comfort	74 ±17	58 ±36	1 (-9 to 11)	8 (-11 to 26)	-7 (-27 to 13)
Body Esteem	49 ±33	26 ±30	-1 (-9 to 7)	6 (-5 to 18)	-8 (-21 to 6)
Social Life	76 ±20	68 ±30	7 (-4 to 19)	4 (-6 to 14)	3 (-11 to 17)
Family Relations	93 ±12	97 ±4	3 (-2 to 8)	-7 (-15 to 2)	9 (0 to 19)
EQ-5D-Y-5L					
Mobility	2.00 ±0.89	2.30 ±1.16	0.12 (-0.3 to 0.55)	0.11 (-0.26 to 0.48)	0.01 (-0.52 to 0.55)
Looking after myself	1.27 ±0.65	1.60 ±1.07	0.00 (-0.31 to 0.31)	-0.38 (-0.87 to 0.12)	0.38 (-0.18 to 0.93)
Doing usual activities	1.64 ±1.03	2.40 ±1.17	0 (-0.8 to 0.8)	-0.38 (-1.17 to 0.42)	0.38 (-0.67 to 1.42)
Having pain or discomfort	2.00 ±0.63	3.00 ±0.94	-0.25 (-0.72 to 0.22)	0.00 (-0.31 to 0.31)	-0.25 (-0.78 to 0.28)
Feeling worried, sad or unhappy	2.09 ±1.14	3.00 ±1.49	0.00 (-1.19 to 1.19)	-0.11 (-0.9 to 0.68)	0.11 (-1.23 to 1.45)

SD, Standard Deviation; CI, Confidence Interval; PedsQL 4.0, Pediatric Quality of Life Inventory; RCADS, Revised Child Anxiety and Depression Scale; IWQOL-Lite, Impact of Weight on Quality of Life-Lite; EQ-5D-Y-5L, EuroQol-5 Dimensions- Youth-5 Levels

Table 4.7. Health related quality of life questionnaires- Questionnaire Domains (Proxy-Report): changes from baseline mean and SD, within group mean difference and CI, and between group mean difference and CI.

Outcome	Baseline Mean $\pm$ SD		Within Group Mean Difference (CI)		Between Group Mean Difference (CI)
	MOTIVATE-CEW2	Usual Care	MOTIVATE-CEW2	Usual Care	
PedsQL 4.0 (Proxy)					
Psychosocial Health Summary	50.19 $\pm$ 20	44.42 $\pm$ 16	4 (-4 to 12)	8 (3 to 13)	-4 (-13 to 5)
Physical Health Functioning	51.14 $\pm$ 20	37.19 $\pm$ 26	7 (-2 to 15)	14 (5 to 24)	-8 (-20 to 5)
Emotional Functioning	50.45 $\pm$ 19	37.00 $\pm$ 15	-1 (-12 to 11)	15 (7 to 23)	-16 (-29 to -2)
Social Functioning	53.07 $\pm$ 23	51.67 $\pm$ 27	5 (-5 to 15)	5 (-7 to 17)	0 (-14 to 14)
School Functioning	48.17 $\pm$ 27	43.50 $\pm$ 23	9 (0 to 18)	4 (-4 to 13)	5 (-7 to 16)
RCADS (Proxy)					
Separation Anxiety Disorder	6 $\pm$ 4	9 $\pm$ 3	0 (-2 to 2)	-2 (-4 to 1)	2 (-2 to 5)
Social Phobia	9 $\pm$ 5	13 $\pm$ 5	-1 (-4 to 2)	-2 (-5 to 1)	1 (-3 to 6)
Generalized Anxiety Disorder (GAD)	6 $\pm$ 3	9 $\pm$ 4	0 (-2 to 2)	-2 (-4 to 0)	2 (-1 to 5)
Panic Disorder	10 $\pm$ 6	12 $\pm$ 6	-1 (-4 to 1)	-1 (-4 to 2)	0 (-4 to 4)
Obsessive-Compulsive Disorder (OCD)	6 $\pm$ 4	7 $\pm$ 3	-1 (-4 to 1)	-2 (-4 to 0)	1 (-2 to 3)
Major Depressive Disorder (MDD)	7 $\pm$ 5	7 $\pm$ 6	-1 (-4 to 2)	-1 (-5 to 3)	0 (-5 to 4)
IWQOL-Lite (Proxy)					
Physical Comfort	63 $\pm$ 19	54 $\pm$ 37	-8 (-23 to 8)	0 (-14 to 13)	-8 (-27 to 12)
Body Esteem	37 $\pm$ 26	28 $\pm$ 31	16 (3 to 29)	9 (-9 to 26)	7 (-14 to 27)
Social Life	72 $\pm$ 17	56 $\pm$ 35	4 (-8 to 15)	9 (-6 to 25)	-6 (-24 to 12)
Family Relations	84 $\pm$ 30	98 $\pm$ 6	-1 (-4 to 1)	0 (-3 to 4)	-2 (-5 to 2)
EQ-5D-Y-5L (Proxy)					
Mobility	2.36 $\pm$ 1.21	2.40 $\pm$ 1.26	-0.25 (-0.84 to 0.34)	0 (-0.54 to 0.54)	-0.25 (-1.00 to 0.50)
Looking after myself	1.55 $\pm$ 1.04	2.10 $\pm$ 1.20	0.12 (-0.71 to 0.96)	-0.56 (-1.18 to 0.07)	0.68 (-0.30 to 1.66)
Doing usual activities	2.27 $\pm$ 1.10	3.00 $\pm$ 1.56	0 (-0.62 to 0.62)	-0.44 (-1.07 to 0.18)	0.44 (-0.38 to 1.27)
Having pain or discomfort	2.55 $\pm$ 0.93	3.20 $\pm$ 1.48	0 (-0.8 to 0.8)	-0.44 (-1.21 to 0.32)	0.44 (-0.59 to 1.48)
Feeling worried, sad or unhappy	2.36 $\pm$ 1.12	3.10 $\pm$ 1.20	0 (-0.72 to 0.72)	-0.22 (-0.97 to 0.52)	0.22 (-0.74 to 1.19)

SD, Standard Deviation; CI, Confidence Interval; PedsQL 4.0, Pediatric Quality of Life Inventory; RCADS, Revised Child Anxiety and Depression Scale; IWQOL-Lite, Impact of Weight on Quality of Life-Lite; EQ-5D-Y-5L, EuroQol-5 Dimensions- Youth-5 Levels

Table 4.8. Influence of wear-time criteria on data availability for device derived physical activity

Measure	Overall (%)	Usual Care	MOTIVATE-CEW2	Reasons for missing data (n)
---------	-------------	------------	---------------	------------------------------

			Baseline (%)	Post (%)	Baseline (%)	Post (%)	
Physical Activity							
Returned	89	100	91	100	64	Drop Out (4), Participant refused (2)	
4 Days (3WD,1WE)	73	82	91	82	36	Insufficient Wear Time (6)	
4 Days	80	91	91	91	45	Insufficient Wear Time (3)	
1 Day	84	100	91	91	55	Insufficient Wear Time (1)	

4 Days (3WD,1WE), 4 days including at least 1 weekend day; Physical Activity required 10 hours wear time for a valid day.

4.3.3. Process Evaluation

Intervention acceptability

The quantitative survey indicated high levels of satisfaction with the MOTIVATE-CEW2 intervention. 11 of the 13 intervention components received scores of ≥ 3 , indicating adequate acceptability. Reminders and progress monitoring tests being the only components below this threshold (2.4 ± 2.1 and 2.3 ± 2.3 respectively) (Table 4.9).

Economic Assessment

The average cost of the intervention per participant was estimated to be £612.90 (Table 4.10).

Table 4.9. Quantitative assessment of intervention acceptability.

Intervention Element	Mean Score $\pm$ SD
The intervention was Flexible	4.5 $\pm$ 0.8
The intervention was Personalised	4.8 $\pm$ 0.5
Participant felt in control of their own intervention	4.8 $\pm$ 0.5
Education Session helped them understand the health implication of activity	4.6 $\pm$ 0.5
Action Plan helped them take up exercise	4.3 $\pm$ 0.7
Action Plan helped them maintain exercise	4.3 $\pm$ 1
Polar Flow App motivated them	3.4 $\pm$ 1.3
Instructions on how to perform their exercise sufficiently supported them	4.1 $\pm$ 1.4
Rewards helped them take up exercise	4.4 $\pm$ 1.1
Rewards helped them maintain exercise	4.4 $\pm$ 1.1
Leaderboards encouraged them to exercise more	3.5 $\pm$ 1.5
Used Reminders to help them exercise more	2.4 $\pm$ 2.1
Completed progress monitoring exercise test	2.3 $\pm$ 2.3

SD, Standard Deviation

Table 4.10. Estimated Delivery Cost of the MOTIVATE-CEW2 Intervention per participant

Intervention Element	Time ^a
Education Session	35*
Exercise Consultation 1	25
Exercise Consultation 2	35
Exercise Consultation 3	20
Exercise Consultation 4	20
Exercise Consultation 5	20
Exercise Consultation 6	25
Exercise Consultation 7	20
Total Consultation Time	200
Watch set up and Package creation	25
Sending messages	265
Exercise programming	80
Leaderboard Update	5
Total Intervention Time	575
Estimate Total Exercise Specialist Cost per participant ^b	£412.09
Additional Resource Costs	
Watch ^c	£111.60
Mean Rewards Cost ^d	£77
Postage ^e	£4.45
Exercise Specialist Sim Card	£5.46
Printing Costs ^f	£0.74
Envelopes ^f	£1.56
Estimated delivery cost of the MOTIVATE-CEW2 intervention per participant	£612.90

*a. Mean delivery time has been rounded up to nearest 5 minutes. b. Staff grade equivalent to NHS Agenda for Change band 5 (staff salary at £30,142 per annum), from Unit Costs of Health and Social Care 2024 – version 2, p96. Estimated cost per hour = £43 (Jones et al., 2025); Includes salary, salary on costs, overheads (management costs and non-staff costs (including travel/transport)), capital overheads, and excludes costs for qualifications. c. Based on using a Polar Pacer, with NHS trade discount (prices relevant for 2025). d. Mean total of vouchers paid to participants as part of intervention reward scheme for completed exercise. Participants were paid £5 per week in Love2Shop vouchers for each week that they completed a structured exercise session. e. UK - Royal Mail - postage averages (prices relevant to 2025). f. Price is quoted per item when 100 items are ordered. *Average time per participant (7 Participants across 2 Education Sessions)*

4.4. Discussion

This study reports the feasibility of a comprehensive, evidence informed exercise and PA intervention designed for UK CEW services. The findings indicate that the intervention was acceptable to participants, with good maintenance of purposeful exercise throughout the intervention period. Study findings also suggest that it is feasible to recruit CEW service patients with characteristics representative of the wider CEW population. However, the retention rate, suggests that improvements in primary outcome data collection may be required for a future definitive RCT. In addition, data completeness indicated that using routine clinic appointments is unlikely to be a feasible approach for collecting clinical outcome measures.

A key learning from the original MOTIVATE-CEW trial was the need to broaden the inclusion criteria to ensure that participants were representative of the wider CEW service population and that the intervention should therefore address the needs of as many CEW service users as possible. This was particularly important in relation to neurodivergence, as young people with a neurodivergent diagnosis are over-represented among CEW service patients (Hawton *et al.*, 2025). Accordingly, eligibility criteria were made less restrictive, and the co-development process prioritised accessibility in both study design and intervention delivery. As a result, 78% of young people aged 11 years or over were eligible to participate, compared with 58% in the original study, with exclusion limited primarily to those who were not Gillick competent or had an ongoing safeguarding concern. When those excluded due to imminent discharge from the service were removed, 85% of CEW service patients screened were eligible for the trial.

Efforts to maximise inclusion are also reflected in the participant characteristics, which were broadly representative of the CEW service as a whole and of those who declined participation in terms of ethnicity, socio-economic status (IMD quintile) and neurodevelopment diagnoses. The only difference was age, with older patients slightly overrepresented among MOTIVATE study participants. At the time of thesis submission, we were able to compare the characteristics of participants with those who declined participation with respect to neurodevelopmental diagnoses. However, we were unable to determine the overall proportion of patients with a

neurodevelopmental condition or learning difficulty across the entire Alder Hey Children's Hospital CEW service cohort. Nevertheless, comparison of the study sample with data reported by Hawton *et al.* (2025) alongside a smaller sample of patients from the Alder Hey Children's Hospital CEW service, suggests that we were able to recruit a representative group of patients with living with a neurodevelopmental conditions. This is particularly important for a future definitive trial, as young people from minoritised ethnic backgrounds, those living in the most deprived areas, and those with neurodivergent diagnoses are overrepresented in CEW services (Hawton *et al.*, 2025) and are typically under-recruited in research (Buscemi *et al.*, 2015; NIHR, 2020). These findings highlight the importance of embedding equity, diversity, and inclusion principles in intervention and trial design, and demonstrate the value of partnership-based, co-developed approaches that incorporate service users and key informant perspectives (Study 2).

While the two study groups were largely comparable, differences in ethnicity, deprivation and neurodevelopmental diagnoses require consideration. These imbalances likely reflect the small sample size and the absence of stratification based upon additional participant characteristics. As these factors may influence intervention engagement and outcome completion, future trials should consider whether stratified randomisation by selected participant characteristics is required.

The trial achieved its planned recruitment target of 22 young people within 3 months, corresponding to a recruitment rate of 33% of eligible patients. Although this rate was lower than the original MOTIVATE-CEW study (47% of eligible patients), this likely reflects the substantially shorter recruitment period of 3 months compared to 11 months in the original study. The recruitment rate is also consistent with other trials targeting PA in young people with obesity, where rates of 20–40% are commonly considered indicative of feasibility (Ennis *et al.*, 2017; Cummings *et al.*, 2022). As the primary reason for non-participation among eligible patients was the inability of the study team to contact caregivers, recruitment in a future definitive trial could potentially be improved through more structured recruitment processes. One approach could be to utilise the wider CEW multidisciplinary team to promote recruitment, rather than relying solely on an exercise physiologist. The provision of dedicated funding to

support recruitment within CEW services, which was not available in the present study, is another possible solution.

The retention rate of 77%, based on completion of PedsQL 4.0 data at 6 months follow-up is promising but suggests that improvements may be required to support the success of a future definitive trial. Other feasibility trials have commonly used an 80% retention rate as a benchmark of feasibility (Ennis *et al.*, 2017), however, retention of young people from minority ethnic groups, those living in the most deprived areas, and those with neurodivergent diagnosis is known to be challenging (Buscemi *et al.*, 2015; LeCroy *et al.*, 2023). As such, a lower retention target of approximately 75% may be more realistic for a future definitive trial. However, in the original MOTIVATE-CEW trial, complete PedsQL 4.0 data was available in 84% of participants, suggesting scope for improvement. The lower retention observed in the present study may reflect its longer duration, as a previous review has shown that retention rates in paediatric obesity prevention and treatment trials tend to decline with increasing intervention length (Cui *et al.*, 2015). Missing PedsQL 4.0 data resulted from a combination of loss to follow-up (18%) and participant refusal (5%), with two participants withdrawing for study-related reasons. Telephone-based data collection may improve questionnaire response rates, however, an evidence-informed approach to reducing loss to follow-up may be required. This may include drawing on evidence from the wider paediatric literature and further co-development work, given the limited research specific to CEW service populations. Such strategies could be evaluated within a methodological sub-study embedded in a future definitive trial.

Data completeness for clinical measures was also variable, with fewer than 50% of participants providing complete data for half of the measures. This was likely due to the use of routine clinic appointments for data collection, rather than study-specific visits, as implemented in the original MOTIVATE-CEW study, which achieved high completeness of clinical measures (82%). This approach was informed by feedback from the co-development process, which indicated that both clinical staff and caregivers preferred clinical assessments to be integrated into routine care to minimise participant burden. Consequently, a future definitive trial should carefully consider optimal strategies for collecting clinical outcome data. This may include reintroducing

study-specific appointments; however, such an approach must be balanced against the risk of increasing burden and potentially excluding harder-to-reach groups.

To our knowledge MOTIVATE-CEW and MOTIVATE-CEW2 are the first comprehensive exercise and PA interventions for patients and caregivers attending CEW services. The MOTIVATE-CEW2 intervention was created through an iterative design process that refined the original programme based on participant feedback and combined this with an evidence-informed, theory-driven approach involving key informants throughout development. This ensured that the intervention addressed the specific needs of patients and caregivers, with a primary focus on maximising long-term maintenance of exercise and PA. High levels of uptake and adherence to purposeful exercise throughout the intervention period suggest that MOTIVATE-CEW2 is a promising approach for promoting sustained PA within CEW services. The ongoing, tailored support provided by the intervention was associated with 82% of participants initiating exercise and 64% remaining engaged in purposeful exercise at the end of the intervention. This represents a substantial improvement compared with the first iteration, MOTIVATE-CEW (Davies *et al.*, 2026), in which only 33% of participants were exercising after 12 weeks and therefore supports the feasibility of the intervention. Comparisons with previous trials are challenging, as to the authors knowledge no other studies have reported exercise adherence among young people living with obesity receiving care from specialist weight management services. Furthermore, within multicomponent lifestyle interventions for paediatric obesity, exercise adherence is rarely reported across the intervention period (Browne *et al.*, 2020; Schneiders *et al.*, 2021). Although this feasibility study was not powered to demonstrate statistical superiority in secondary outcomes, comparative assessments of exercise and PA consistently favoured MOTIVATE-CEW2, supporting the observed adherence findings.

Recent data from young people attending CEW services suggest that HRQoL, as measured through the PedsQL 4.0, is substantially lower than that of healthy peers and is also lower than levels reported across a range of chronic childhood conditions (Hawton *et al.*, 2025). Accordingly, HRQoL is likely to be the primary outcome in a future definitive RCT. Methodological guidance recommends using CIs and MCIDs to interpret findings from feasibility studies (Lee *et al.*, 2014; Bell, Whitehead and Julious,

2018). Applying this approach, our results suggest that a clinically meaningful difference in PedsQL 4.0 total mean score between the MOTIVATE-CEW2 and usual care groups is plausible. This favourable direction of change is supported by a Cochrane review of behavioural interventions for overweight and obese young people, which reported moderate improvements in HRQoL following interventions that included PA (Al-Khudairy *et al.*, 2017). A recent meta-analysis from Henderson *et al.* (2025) also reported that PA-based interventions are associated with improvements in HRQoL in young people living with obesity, further supporting the plausibility of our findings.

Based on the PedsQL 4.0 questionnaire total score as the primary outcome, a full trial comparing the MOTIVATE-CEW2 plus usual care versus usual care alone would require recruitment of 101 CEW service patients per group. This estimate is based on detecting a minimum clinically important difference on the PedsQL 4.0 of 5.4 points (USPSTF, 2024; Henderson *et al.*, 2025) a SD of 17 points (as seen in this feasibility study), a within-patient correlation of 0.8 (between baseline and the 6-month follow-up calculated from data from this study) and an assumed attrition rate of 25% (as seen in this feasibility study), at 90% power and 5% α level.

This study has several limitations. As a feasibility study, it was not designed or powered to definitively evaluate the effectiveness of the MOTIVATE-CEW2 intervention. In addition, the study was conducted at a single site, which may limit the generalisability of the findings to CEW services across England. Consequently, the study should be considered preliminary, and despite encouraging trends, an adequately powered, multi-site, RCT is required to confirm these findings.

4.5. Conclusion

In summary, this feasibility trial indicates that the MOTIVATE-CEW2 exercise and PA intervention for young people receiving care from CEW services has feasible trial processes. Furthermore, the intervention was acceptable to participants, and suggests promising effects on the uptake and maintenance of PA. However, refinements to retention strategies and clinical outcome data collection should be explored before progression to a definitive trial. Findings from this feasibility study will inform a funding

application for a fully powered, multi-site randomised controlled trial to evaluate the effectiveness of the MOTIVATE-CEW2 intervention in young people receiving care from CEW services.

5. General Discussion

5.1. Aims and Objectives

The aim of this thesis was to refine the MOTIVATE-CEW intervention and its trial methodology, before conducting a second feasibility randomised control trial to evaluate the potential of the new MOTIVATE-CEW2 intervention. The overarching hypothesis was that, by following Medical Research Council (MRC) guidance for the development and evaluation of complex interventions and by adopting a recognised framework alongside a partnership-based approach, the feasibility and acceptability of the MOTIVATE-CEW2 intervention would be enhanced. This discussion first briefly summarises the findings of the three research studies, presented across Chapters 2, 3, and 4, before discussing and interpreting the findings from the three studies. Finally, the chapter considers the limitations and future directions for this programme of research, including further refinements to a) the MOTIVATE-CEW2 intervention to support its ongoing iterative development, and b) the evaluation methodology to support progression to a fully powered, multi-site, randomised control trial to evaluate the effectiveness of the MOTIVATE-CEW2 intervention.

5.2. Summary of Findings

5.2.1. Study 1 Findings

Study 1 aimed to explore the perspectives of Complications from Excess Weight (CEW) service patients and their caregivers on the acceptability and the factors influencing engagement with the original MOTIVATE-CEW intervention to inform its optimisation. A qualitative survey was completed by participants post-intervention, and both patients and caregivers were invited to take part in semi-structured interviews and focus groups. Findings indicated that the provision of personalised exercise and physical activity (PA) action plans supported by an exercise physiologist was valued by both patients and caregivers. Personalised feedback delivered by the exercise physiologist was perceived to provide motivation as well as emotional support. The use of multiple, interacting intervention components appeared to encourage behaviour change, while mobile health (mHealth) technology was cited as a useful tool to support intervention delivery. Extending the duration of the intervention and incorporating additional peer support elements were suggested as potential refinements to MOTIVATE-CEW. Overall, the findings suggest that the MOTIVATE-CEW intervention

concept was an acceptable approach for promoting exercise and physical activity in children and young people receiving care from CEW services; however, future research should continue to incorporate service user and key informant perspectives to support ongoing intervention refinement.

5.2.2. Study 2 Findings

The aim of Study 2 was to develop a refined version of the MOTIVATE-CEW intervention using a recognised theoretical framework. This study combined the systematic, theory-driven structure of Intervention Mapping with a partnership-based co-development approach involving key informants. This process resulted in an exercise physiologist-led, theory-driven, evidence-informed, co-developed complex intervention tailored to the needs of CEW service patients, their caregivers and the services delivering this care. The development framework ensured each of the five core intervention components were designed to target the determinants of change and were underpinned by clear theoretical foundations. Integrating the perspectives of patients, caregivers, and health care professionals (HCPs) during the development process ensured the intervention was aligned with the realities of service delivery. This alignment had the potential to improve the feasibility and acceptability of both the intervention and the study methodology and may have supported maintenance of physical activity behaviours. The next step required after this process was a feasibility randomised controlled trial of the intervention conducted within the Alder Hey Children's Hospital CEW service.

5.2.3. Study 3 Findings

The final study within this thesis aimed to assess the feasibility and acceptability of the MOTIVATE-CEW2 intervention and the associated study methodology developed in Study 2. Study 3 was a single-centre, parallel-group, feasibility randomised controlled trial with a mixed-methods process evaluation, in which participants received either usual care or MOTIVATE-CEW2 in addition to usual care for a period of six months. Findings from this feasibility trial indicated that both the intervention and the overall study design were feasible and acceptable for young people receiving care from CEW services. In particular, the intervention demonstrated promising uptake and

maintenance of purposeful exercise and PA in MOTIVATE-CEW2 participants. However, while delivery and engagement were feasible, opportunities were identified to further optimise participant retention and the completeness of self-reported, and in-clinic outcome measures in future studies. Overall, these findings indicate that MOTIVATE-CEW2 is suitable for progression to a fully powered, multi-site randomised controlled trial to evaluate intervention effectiveness, with only minor methodological refinements required to optimise study procedures.

5.3. General Discussion of Findings

5.3.1. Interpretation of the programme of research

The three studies presented within this thesis represent three sequential phases in the development and evaluation of an exercise and PA intervention for CEW services in England. The original MOTIVATE-CEW intervention (Davies *et al.*, 2026) was adapted from an intervention implemented in adults living with or with elevated risk of developing long term conditions (Hesketh *et al.*, 2021; Bannell *et al.*, 2023; Hesketh *et al.*, 2025). It was subsequently evaluated using a mixed-method feasibility design, consistent with recommendations for the evaluation of complex interventions (Skivington *et al.*, 2024). The feasibility of the intervention, trial design and data collection was reported in previous published work (Davies *et al.*, 2026), and the qualitative evaluation of the intervention was completed as Study 1 in this thesis. Findings from this qualitative evaluation subsequently informed the structured refinement and development of the intervention using an Intervention Mapping framework in Study 2, aligning with guidance advocating theory-driven, transparent approaches to intervention development (Eldredge *et al.*, 2016; Skivington *et al.*, 2024). This development was further strengthened through a partnership-based co-development process involving CEW service patients, caregivers and HCPs. Following this development phase, the feasibility of the refined MOTIVATE-CEW2 intervention was re-evaluated in Study 3. This iterative and sequential process of intervention development, combining mixed-method insights, structured theoretical design, and feasibility testing, reflects best practice in complex intervention research and serves to strengthen the credibility, acceptability, and implementation readiness of the intervention (O'Cathain *et al.*, 2019). As a result of this process, the MOTIVATE-

CEW2 intervention and associated trial procedures appear theoretically sound, acceptable to service users, and feasible to deliver within CEW services, supporting progression to a definitive evaluation.

5.3.2. Qualitative insights into intervention success

The qualitative findings from Study 1 provide critical insight into participants' experiences of the original MOTIVATE-CEW intervention and the mechanisms underpinning engagement, helping to contextualise and explain the feasibility findings reported in the original feasibility randomised controlled trial. During the semi-structured interviews and focus groups both participants and caregivers expressed an interest in outcomes beyond weight reduction alone, with particular emphasis placed on wellbeing and quality of life. This change in focus is particularly important given the known association between severe obesity and poor health-related quality of life (HRQoL) (Schwimmer, Burwinkle and Varni, 2003; Hawton *et al.*, 2025). In line with this, Study 3 identified HRQoL as a likely primary outcome for a future definitive randomised controlled trial, reinforcing the significance of this shift in the perceived value of wellbeing and quality of life.

Participants and caregivers highlighted the importance of having choice within the exercise and physical activity intervention, particularly in enabling them to overcome previously perceived barriers to engagement. Exercise type, duration, intensity, and location were collaboratively agreed between families and the exercise physiologist, supporting autonomy and promoting enjoyment of exercise. The graded nature of action plans was reported to instil feelings of competence in participants, while additional support mechanisms including biofeedback, resource videos and booklets, further supported participant competence by providing clear instructions on how to perform behaviours. The support participants received from the exercise physiologist was viewed as one of the most valuable intervention elements. The delivery of this intervention component through the mHealth technology, personalised messages and person-centred counselling promoted relatedness by providing ongoing encouragement and emotional support. Collectively the multicomponent design of the intervention supported the three core psychological needs proposed by Self-

Determination Theory, autonomy, competence, and relatedness, which are considered central to sustained engagement in health behaviour change (Deci and Ryan, 1985).

The literature review within this thesis identified that previous studies of remote or home-based exercise and PA interventions are limited but the available data suggested that exercise and PA could be effectively incorporated into these settings. The findings from Study 1 demonstrate the suitability of this approach in young people receiving care from CEW services and suggest that the combined approach of support from an exercise physiologist and mHealth technology could be key to providing the level of guidance required by participants in an unsupervised environment. This blended approach may be particularly valuable in providing the level of guidance, reassurance, and motivation required in largely unsupervised settings. Previous literature in children and young people (CYP) living with obesity has demonstrated that both wearable technologies (Chen *et al.*, 2017) and remotely delivered support from exercise professionals (Vandoni *et al.*, 2022) can independently increase physical activity levels. It is therefore unsurprising that the integrated approach adopted within MOTIVATE-CEW was perceived positively by both participants and caregivers as a means of supporting engagement in exercise and PA.

5.3.3. Use of Intervention Mapping and co-development to strengthen intervention design and feasibility

Due to the unique demographics and characteristics of patients attending CEW services (Hawton *et al.*, 2025; Matu *et al.*, 2025) the development of effective exercise and physical activity interventions for this population is inherently complex. Poor reporting and unclear mechanisms in the design of interventions can limit the ability of researchers and practitioners to interpret, replicate, and implement published interventions (Hopewell *et al.*, 2025). The use of recognised frameworks for intervention development can therefore improve the transparency, reproducibility, and methodological rigour of such interventions (Eldredge *et al.*, 2016). Partnership-based approaches also offer a solution, with the suggestion that a co-developed intervention may be better aligned with real-world service contexts and therefore more implementation-ready. In-line with this, Study 2 of the thesis describes the development process of the MOTIVATE-CEW2 intervention which utilises both an

Intervention Mapping framework and co-development with CEW service patients, caregivers and healthcare professionals (Eldredge *et al.*, 2016).

Intervention Mapping ensured that delivery of the individual components of MOTIVATE-CEW2 were grounded in theory, based off determinants of change, linked to behaviour change techniques and based off evidence-informed approaches. The use of co-development also ensured that the study design and intervention were acceptable to young people, their caregivers and the CEW service HCPs. Together, these methods appeared to enhance the feasibility and acceptability of the MOTIVATE-CEW2 intervention in Study 3. In particular, MOTIVATE-CEW2 reported promising effects on exercise uptake and maintenance of exercise and PA compared to usual CEW service care. At the end of the 6-month intervention 64% of participants remained engaged in exercise and PA, which represents a notable increase from the original MOTIVATE-CEW study (Davies *et al.*, 2026). Previous research has emphasised the need for family-centred, theory based approaches to interventions for CYP living with obesity (Skelton *et al.*, 2020) as well as the value of incorporating key informant perspectives during intervention development (Jones *et al.*, 2019). The collective findings of the work across the three studies presented within this thesis support these recommendations and illustrate how structured, theory-driven, and co-developed approaches can enhance intervention acceptability and feasibility within complex healthcare settings.

5.4. Limitations and Future Directions

In this section I will discuss limitations and future directions of this programme of work, with the aim of informing the development of a definitive randomised control trial to evaluate effectiveness of the MOTIVATE-CEW2 intervention. These insights and considerations form another step in the iterative process of developing and evaluating a complex exercise and PA intervention for CYP receiving care from CEW services.

5.4.1. MOTIVATE-CEW 2 study design considerations

5.4.1.1. Improving Intervention Retention

The MOTIVATE-CEW2 study suggested that the methodology was broadly feasible for use within a CEW service, however, there are a number of areas that could be optimised in future research. The retention rate of MOTIVATE-CEW2 was 77% which is slightly below the 80% retention rate benchmark commonly used to define feasibility (Ennis *et al.*, 2017) and lower than the 84% achieved in the original MOTIVATE-CEW study. Participant retention was based on completion of the proposed primary outcome for a future definitive randomised control trial (PedsQL 4.0 questionnaire) at post-intervention (6 months). While 80% is a commonly used benchmark for feasibility, it is conceivable that a 75% retention target is a valid and more appropriate approach within a CEW service cohort. It is also plausible that retention in a large, multi-centre randomised controlled trial would be lower than that observed in the single-site feasibility study presented in this thesis. Accordingly, careful consideration of strategies to optimise participant retention will be essential in the design of a future definitive trial.

In addition to ensuring that findings are robust and generalisable, participant retention is critical to the overall feasibility of recruitment. High levels of attrition and incomplete data necessitate inflation of recruitment targets to maintain adequate statistical power, thereby increasing the resource and logistical demands of the trial. The power calculation conducted in Study 3 indicated that 202 CEW service patients would need to be recruited, based on a projected attrition rate of 25%. In England, 37 CEW services are currently in operation, and data from the ENHANCE trial suggest that each service typically manages approximately 150 patients (Matu *et al.*, 2025). Based on the recruitment rate observed in the MOTIVATE-CEW2 study, it is estimated that screening 1,000 CEW service patients would achieve the required sample size. This equates to the involvement of approximately 7 of the 37 CEW services in a randomised controlled trial to evaluate effectiveness. Although administratively complex, this level of national engagement does not appear unrealistic and supports the viability of a 75% retention target. Furthermore, given the well-documented tendency for research studies to exclude, and experience greater attrition among, young people from minoritised ethnic background, those living in the most deprived areas, and those with neurodivergent diagnosis, a reduced retention threshold may be considered justified (Buscemi *et al.*, 2015; LeCroy *et al.*, 2023).

Despite the possible feasibility of the 77% retention rate achieved in MOTIVATE-CEW2, consideration should be given to methods of improving this. The most common reason for incomplete PedsQL 4.0 data at post-intervention was loss to follow-up (18%), with the remaining missing data a result of participants refusing to complete the questionnaire (5%). In comparison, the original MOTIVATE-CEW study reported 84% of data was available for the PedsQL 4.0 at post-intervention with loss to follow-up once again the primary reason for missing data (12%) and refusal to complete the questionnaire accounting for the remaining proportion (4%) (Davies *et al.*, 2026). Although outcome measures were collected at 3 months in the original study compared with 6 months in MOTIVATE-CEW2, this comparison nonetheless suggests scope for improvement in participant retention. These findings suggest that minimising participant drop-out should be the primary focus of any strategies to improve study retention. A Cochrane review has previously reported strategies to improve retention in randomised trials, however, a number of these techniques have already been employed within the study, including reminders and monetary incentives (Gillies *et al.*, 2021). Evidence on retention strategies for underserved populations of CYP remains limited. However, a decentralised clinical trial in adults implemented innovative, personalised, data-driven retention methods that may offer transferable insights for MOTIVATE-CEW2 (Zwiers *et al.*, 2025). These approaches combined precision retention, where participant interaction with study technology was continuously monitored, with broader engagement techniques. Of these, social media communication and a compliance-based follow-up schedule appear most readily adaptable to a CEW service cohort. The key contribution, however, is the use of real-time data to identify participants at increased risk of drop-out and intervene proactively. Although further work is required to determine the most appropriate response once higher-risk participants are identified, this precision, risk-stratified approach represents a potentially efficient and scalable retention strategy for MOTIVATE-CEW2.

Participant refusal was the other cause of incomplete PedsQL 4.0 questionnaires. In the original MOTIVATE-CEW study, patient-reported outcomes were collected during a study specific post-intervention clinic appointment. However, findings from Study 2 indicated that additional visits increased burden for participants, caregivers, and HCPs. As a result, post-intervention appointments were removed and outcome measures were instead obtained during routine clinical care or remotely, with patient-

reported outcomes completed at home using paper-based or online formats. These approaches were discussed and approved during the Study 2 co-development process. An additional strategy that was not explored during co-development, but which may reduce refusal rates, is telephone-based data collection. A further method to improve data completeness would be to reduce the number of patient- and proxy-reported outcome measures, thereby minimising participant burden while retaining clinically meaningful endpoints. Although concerns about questionnaire volume were raised during co-development, all measures were retained to assess their suitability as potential primary outcomes. With the PedsQL 4.0 now identified as the most likely primary outcome, progression to a definitive randomised controlled trial would allow the number of patient-reported outcome to be reduced.

Further work to develop retention techniques for CEW service patients is still required. Following the development of one or more strategies to retain participants, a study within a trial (SWAT) could be conducted as part of the randomised control trial to assess the effectiveness within MOTIVATE-CEW2. SWATs are considered to be one of the strongest methods for testing the effectiveness of retention strategies and previous research has shown success from this approach when provided with both funding and practical support (Parker *et al.*, 2024). Embedding a SWAT would enable a formal evaluation of retention strategies while also maximising participant retention and improving the completeness of PedsQL 4.0 data.

5.4.1.2. Reconsidering methodology for obtaining in-clinic outcome measurements

One of the strengths of the original MOTIVATE-CEW study was the high level of data completeness for in-clinic outcome measurements with, ≥82% completeness reported across all outcomes (Davies *et al.*, 2026). In that study participants attended study-specific appointments at Alder Hey Children's Hospital during which clinical outcome measures were collected by members of the CEW service multidisciplinary team (MDT). Although this approach was considered both feasible and effective in maximising data completeness, feedback from the co-development process indicated that clinical staff and caregivers preferred clinical assessments to be integrated into routine care in order to minimise participant and service burden. The feedback suggested that additional hospital visits may have acted as a barrier to participation in

the original MOTIVATE-CEW study, with such barriers likely to disproportionately affect underserved populations, including those living in more deprived areas, who represent a substantial proportion of CEW service patients.

As a result, clinical assessments were integrated into routine CEW service appointments in the refined MOTIVATE-CEW2 study. However, the use of routine clinic visits for outcome collection was associated with notably reduced data completeness compared with the original MOTIVATE-CEW study. Missing data were primarily due to non-attendance at clinic appointments and the omission of measures by clinical staff. These findings highlight an important methodological trade-off between maximising data completeness and minimising burden for caregivers and HCPs. Reintroducing study-specific appointments represents one potential strategy to improve outcome completeness; however, this approach may increase burden for families and clinical staff and risk excluding harder-to-reach groups. Greater integration of the MOTIVATE-CEW2 study within CEW service care could improve collaboration between the research team and clinical staff and help ensure that study outcomes are collected when patients attend clinic, although this may further increase HCP workload. Employing a dedicated research nurse to conduct study-specific assessments could mitigate the burden on HCPs but would not address the additional demands placed on caregivers should this require an additional clinical appointment.

A combined approach may therefore be most appropriate. Improved identification of study participants attending, alongside the employment of a research nurse to conduct study-specific assessments within these routine visits, offers a potential solution. For participants without a scheduled appointment, or who fail to attend, a study specific appointment with a research nurse could be arranged, or remote data collection methods could be employed for certain outcomes where this is feasible. Prior to progressing to a definitive effectiveness trial of MOTIVATE-CEW2, this approach should be discussed with CEW service MDTs at the participating sites to ensure that a future trial balances methodological rigour with acceptability and inclusivity while maximising data completeness.

5.4.1.3. Evaluating methods of measuring habitual PA

In the original MOTIVATE-CEW study habitual PA was assessed using traditional methods that included two different accelerometers, a GENEActiv wrist-worn monitor and an ActivPAL thigh-worn monitor. Contrary to findings from other studies in young people living with obesity (Aguer *et al.*, 2010) the use of wearable accelerometers resulted in poor PA data completeness within the CEW service cohort. To address this limitation in the MOTIVATE-CEW2 study, the method of recording habitual PA was co-developed during Study 2 of this thesis. Participants in the co-development process highlighted discomfort and unattractive design of research-grade accelerometers as key reasons for non-adherence in the original study. Consequently, capturing habitual physical activity using the intervention smartwatch, rather than a separate research-grade device, alongside compensation in the form of shopping vouchers, was viewed as a positive strategy to improve uptake in MOTIVATE-CEW2. The use of a Polar Pacer smartwatch substantially improved data completeness, with 84% of participants providing at least one day of valid wear time (≥ 10 hours), consistent with previously applied criteria in this population (Pallan *et al.*, 2018). Furthermore, when only participants who did not withdraw from the study are considered, 94% of data was available across both timepoints. Although consumer wearable devices are not considered gold-standard measures of PA, the validity of Polar's activity tracking technology to estimate PA-related energy expenditure has been examined previously (Polar Research Center, 2021). The Polar Activity Tracking white paper compared metabolic equivalent of task (MET) values derived from indirect calorimetry with those estimated by Polar devices and reported moderate-to-good agreement across a range of activity intensities, with accuracy varying by activity type. The substantial improvement in data completeness combined with evidence supporting reasonable validity, suggests that the use of this approach may be justified in a future randomised controlled trial, particularly when balanced against the poor adherence observed with research-grade accelerometers.

5.4.1.4. Pilot measure of exercise capacity

The Delphi process completed by Stilwell *et al.* (2023) established exercise and activity habits as core outcomes for CEW services to evaluate. Despite this there is no set outcome measure developed to assess this in CEW services. As such, a measure that assess change in a patient's physical condition or aerobic fitness could offer an objective insight into exercise and activity habits. The MOTIVATE-CEW2 trial therefore

sought to incorporate a measure of physical condition. The best measure of physical condition is cardiorespiratory fitness (CRF). Exercise interventions have been shown to improve CRF in young people living with obesity (Li and Chen, 2021), and higher levels of CRF are associated with reduced metabolic risk factors (Ruiz et al., 2006). The gold-standard clinical assessment of CRF is cardiopulmonary exercise testing (CPET), however, this approach is resource-intensive and not feasible within routine CEW service provision, therefore other methods of assessing physical condition were required. Alternative maximal exercise tests, such as treadmill or cycle ergometer protocols, also require specialist equipment and trained personnel. In addition, evidence suggests that young people with obesity may struggle to achieve maximal effort during such tests, indicating that submaximal assessment methods may be more appropriate in this population (Peled *et al.*, 2025). As a result we instead explored methods of introducing a measure of exercise capacity as a practical and clinically acceptable alternative to a measure of CRF (Ross *et al.*, 2016). The six-minute walk test (6MWT) is a commonly used submaximal test in clinical paediatric populations, requiring individuals to walk as far as possible in 6 minutes along a measured runway, typically 30 metres long (Patel *et al.*, 2017; Qu *et al.*, 2022). However, this traditional format was not considered feasible within the Alder Hey Children's Hospital CEW service due to the lack of access to a private runway and concerns that young people may feel uncomfortable completing an exercise test in a public hospital corridor. Several other submaximal assessments of exercise capacity exist, such as the incremental shuttle walk test. However, these approaches are subject to the same constraints as the 6MWT in a CEW service setting. In response to this, an exploratory remote 6MWT was incorporated as an outcome measure within the MOTIVATE-CEW2 study.

Previous research has attempted to explore remote 6MWT protocols in other clinical populations, however, mixed success has resulted in no set protocol being developed to date (Lachant *et al.*, 2022; LaPatra *et al.*, 2022; Wickerson *et al.*, 2024). Remote assessments of exercise capacity have also not been evaluated in young people with obesity receiving care from a multidisciplinary weight management service. Within MOTIVATE-CEW2, data completeness for the remote 6MWT was moderate, with 61% of recordings suitable for analysis. Excluding participants who dropped out 86% of participants attempted to record a 6MWT suggesting the test was acceptable. Notably,

41% of missing data were attributable to recording errors, suggesting that improvements in participant instruction, digital guidance, and protocol standardisation could enhance completeness in future trials. Collectively, these findings indicate that incorporating a remote measure of exercise capacity within a CEW service context has promise but requires further optimisation to ensure reliable implementation. Future research should prioritise refining the protocol, improving data capture procedures, and formally evaluating the validity and reproducibility of the remote 6MWT before its adoption as a definitive outcome measure in a fully powered randomised control trial.

5.4.2. Generalisability of MOTIVATE-CEW2

The feasibility and acceptability of the MOTIVATE-CEW2 intervention and study design were developed and evaluated within a single CEW service at Alder Hey Children's Hospital. Although the findings demonstrated largely positive feasibility and acceptability, evaluation at a single site means it remains unclear if MOTIVATE-CEW is generalisable to other CEW services. However, the ENHANCE study, which reported data from 4,784 patients across 32 CEW clinics in England, provides a useful benchmark for comparing the Alder Hey CEW population and those recruited to CEW services nationally (Matu *et al.*, 2025). MOTIVATE-CEW2 included a similar proportion of young people with neurodevelopmental disorders to those reported in ENHANCE, and both studies indicated that young people from the most deprived postcodes made up the majority of participants. However, MOTIVATE-CEW2 included a lower proportion of participants from minoritised ethnic backgrounds compared to ENHANCE (73% White British in MOTIVATE-CEW2 versus 60% in ENHANCE). This difference likely reflects demographic variation between services rather than an inability to recruit a representative sample, as 76% of patients attending the Alder Hey CEW service are White British, closely aligning with the study sample. As such, before a definitive randomised controlled trial is commenced, further work should be undertaken to discuss the study methodology and intervention design with CEW service patients and caregivers from minoritised ethnic backgrounds. Establishing a patient and public involvement (PPI) group that actively encourages contributions from these populations could provide a platform for these discussions, and previous research supports the use of such groups to enhance the inclusivity, cultural relevance and acceptability of research design (Dudley *et al.*, 2015). Variation in workforce

structure across services may also influence implementation in other settings. Additional consultation with members of the MDTs at the participating sites would provide an opportunity to discuss study procedures and ensure that the MOTIVATE-CEW2 study is feasible across each CEW service. These discussions with key informants would ensure that the intervention is adaptable to varying regional demographics and service configurations.

5.4.3. Further development of the MOTIVATE-CEW2 intervention

Quantitative findings from Study 3 demonstrated that the MOTIVATE-CEW2 intervention was feasible and acceptable within a CEW service setting. Qualitative data have not yet been analysed; therefore, broader determinants of acceptability cannot be explored, and this analysis may identify areas for future refinement.

Although the intervention was successfully delivered, reflections from the research team suggest that aspects of the digital design were shaped by pragmatic decisions made within the constraints of available time, funding, and technological infrastructure. In its current form, MOTIVATE-CEW2 relied on multiple digital platforms to deliver the components. Personalised action plans were accessed through the Polar Flow application linked to the Polar Pacer smartwatch; completed sessions were tracked through the Polar Coach and QuickCoach websites; resistance training prescriptions were provided via the QuickCoach website; feedback messages were delivered through WhatsApp; exercise consultations were conducted using Microsoft Teams; the gamified leaderboard was presented on a dedicated website; and reminders were embedded within participants' personal calendar applications. These methods also required the exercise physiologist to manually input data into the gamified leaderboards as well as calculate and send reward vouchers to participants rather than utilise automated systems for these intervention components. Although each component functioned effectively in isolation, this design required participants to navigate several platforms, potentially increasing cognitive load and reducing efficiency of delivery. Furthermore, the need to use several websites and applications made implementation of the intervention slower and more complex. These factors limit the suitability of the intervention for wider roll-out, by increasing both the complexity of training exercise physiologists require and the burden associated with intervention

delivery. A unified smartphone application integrating these components would represent a logical next step in the evolution of MOTIVATE-CEW2. Consolidating action planning, wearable integration, feedback messaging, consultation scheduling, and gamification within one platform could enhance usability, streamline communication, reduce participant burden, and improve data integration for both participants and clinicians. During the co-development process in Study 2, participants also expressed interest in using their own wearable devices to complete exercise and physical activity prescriptions. Integration of alternative wearable technologies was not feasible within the constraints of the present study. However, the development of a unified platform could enable interoperability across multiple smartwatch providers, increasing accessibility and reducing reliance on study-specific devices, which in turn has the potential to reduce the cost of the intervention. Future research should therefore explore the development of a dedicated MOTIVATE-CEW2 application designed to optimise the intervention's digital architecture. The development of this digital service should adopt a partnership-based approach, with early involvement of CEW service patients, caregivers and HCPs to inform design preferences. These key informants should also be central to subsequent usability testing and refinements. Utilising partnership-based methods would ensure that the platform is optimised for end users. As this would enhance the mode of delivery rather than modify the core intervention components, a further full feasibility study would not be required, and the newly developed application could be evaluated within the definitive randomised control trial.

5.4.4. Summary of recommendations for future studies and funding

The overarching aim of this thesis was to develop an intervention and trial methodology to inform a future definitive evaluation of an exercise and PA intervention within English CEW services. This aim has largely been achieved, with 7 key recommendations resulting from this work:

1. Conduct a focused optimisation phase before a definitive randomised controlled trial, involving CEW service patients, caregivers and MDT members from multiple sites.

2. Prioritise strategies to improve participant retention and PedsQL 4.0 data completeness, including telephone-based follow-up, reduced questionnaire burden and risk-stratified retention approaches.
3. Use a SWAT within the future definitive trial to formally evaluate one or more retention strategies.
4. Consider adopting a hybrid approach to in-clinic outcome measurement, combining routine-care integration with research nurse support and remote collection where appropriate.
5. Further optimise and validate the remote 6MWT protocol before using it as a definitive outcome measure.
6. Explore development of a unified MOTIVATE-CEW2 digital platform to improve scalability, reduce delivery burden and support future implementation.
7. Establish a PPI group that actively includes young people and caregivers from minoritised ethnic backgrounds and underserved communities to strengthen inclusivity and external validity.

In order to action the recommendations outlined above three potential approaches to a future definitive trial are proposed. The first option is to proceed directly to a fully powered, multi-site randomised controlled trial to evaluate the effectiveness of the MOTIVATE-CEW2 intervention. Findings from this programme of work suggest that both the intervention and study procedures are feasible, indicating that this would be the most straightforward, time-efficient, and cheapest progression.

However, such an approach may be premature given the remaining uncertainties regarding the generalisability of findings beyond a single-service context. These uncertainties could influence trial feasibility and, ultimately, the likelihood of success. Furthermore, this strategy would not address outstanding implementation challenges, particularly the absence of a unified intervention platform. While it may be possible to accommodate this within a definitive trial, doing so could complicate subsequent implementation and reduce effectiveness when delivered within routine clinical practice.

The second potential direction is to undertake an additional cycle of partnership-based refinement involving CEW service patients, caregivers, and HCPs, focussing on the

generalisability of the intervention and study procedures, and on strategies to improve participant retention. This process would help ensure that both the intervention and its associated procedures are acceptable across participating services and capable of recruiting a representative CEW population, with particular attention to ethnic diversity. It would also provide an opportunity to identify optimal approaches to maximise retention. Following the development of strategies to improve retention a future multi-site trial could incorporate a SWAT to formally evaluate strategies aimed at improving participant retention. Following this optimisation phase, the intervention could then progress to a multi-site randomised controlled trial to evaluate effectiveness as outlined above. This approach is likely to be the most pragmatic and resource-efficient progression pathway, requiring relatively minimal additional time and funding while maximising the likelihood of success in a future definitive trial; however, it would not address the longer-term implementation challenges associated with the use of multiple digital platforms.

The third approach would be a wider programme of work incorporating the methodological refinements outlined above with the development of a dedicated MOTIVATE-CEW2 digital platform, as outlined in Section 5.4.3. Although the current iteration of MOTIVATE-CEW2 is feasible and acceptable, investment in an integrated digital application presents an opportunity to streamline delivery, enhance scalability, and potentially further improve user experience and engagement. This approach would also maximise the likelihood that effectiveness demonstrated within a clinical trial translates into meaningful real-world clinical benefit during subsequent implementation.

To make the implications of this programme of work explicit, the three pathways for future research are summarised in Table 5.1. The table also provides a summary of the advantages and disadvantages that each approach offers. Collectively, these three pathways represent differing levels of optimisation and investment, ranging from immediate definitive evaluation to a more iterative programme of refinement and digital development. The most appropriate route will depend on available funding mechanisms and strategic priorities; however, each option builds upon the strong theoretical foundation, co-developed design, and demonstrated feasibility established within this thesis. Regardless of the chosen pathway, the next phase of research

should aim to strengthen scalability, external validity, and implementation readiness to support sustainable integration of MOTIVATE-CEW2 within CEW services across England.

Table 5.1. Future directions for the MOTIVATE-CEW2 Intervention

Approach	Advantages	Disadvantages
1. Proceed directly to a fully powered, multi-site RCT	• Fastest approach to an effectiveness evaluation • Builds directly on demonstrated feasibility and acceptability • Lowest-cost option in the short term	• Potentially premature due to single-site feasibility testing • Uncertainty around generalisability to other CEW services • Retention and outcome completeness may be lower in a multi-site trial • May require further refinement before routine implementation, even if effective
2. Focused optimisation phase before a definitive multi-site RCT	• Strengthens trial readiness before major investment • Allows consultation with patients, caregivers and MDTs across sites • Can address retention, inclusivity and data completeness • Supports recruitment of a more representative CEW population • Enables development and testing of retention strategies through a SWAT • Relatively resource-efficient compared with full digital platform development	• Delays progression to effectiveness testing • Requires a small amount of additional funding and coordination • Will not resolve the limitations of using multiple digital platforms
3. Wider programme of refinement, including a dedicated MOTIVATE-CEW2 digital platform	• Addresses the main digital implementation limitation • Could reduce participant and staff burden • Improves scalability and implementation readiness • May improve user experience and engagement • Could allow integration with different wearable devices • Strongest pathway for long-term real-world implementation	• Most expensive and time-consuming option • Requires specialist digital development and maintenance • Delays definitive effectiveness testing • New platform may introduce technical or usability issues • May require further usability or feasibility testing before a definitive RCT

CEW, complications of excess weight; RCT, randomised controlled trial; MDTs, multidisciplinary teams; SWAT, study within a trial.

5.5. Reflections and Summary

This thesis reports the development and feasibility evaluation of a comprehensive, evidence-informed exercise and PA intervention designed specifically for CEW services in England. To my knowledge, the original MOTIVATE-CEW and the refined MOTIVATE-CEW2 represent the first comprehensive exercise and PA interventions developed for patients and caregivers attending CEW services. Collectively, this programme of research establishes a strong theoretical, methodological, and practical foundation for the future integration of MOTIVATE-CEW2 within NHS CEW provision. Furthermore, these studies demonstrate the value of applying Medical Research Council guidance to the development and evaluation of complex healthcare interventions. The importance of partnership-based approaches in shaping MOTIVATE-CEW2 cannot be overstated, and future research within healthcare settings should continue to prioritise meaningful collaboration with service users and clinicians.

On a personal level, I feel privileged to have had the opportunity to conduct research with the potential to directly improve the health and wellbeing of children and young people living with obesity. Looking ahead, I hope that the original MOTIVATE-CEW study and the subsequent studies presented in this thesis will serve as the foundations for an NHS-endorsed exercise and PA intervention delivered within CEW services to support children and young people for years to come.

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7. Appendix

Appendix 1. Focus Group and interview Topic Guide Patients

Post-intervention Focus Group and interview schedule (Patients)

The semi-structured focus groups and interviews will be based on key features of the CEW + mHealth programmes. The main themes are identified below, although specific content and structure will be led by the participant responses. Example probes are provided although will only be used when appropriate. The aim is to gauge participant perceptions of the exercise/ PA components of their programme.

Key questions (-) with probes (o) to be discussed include:

Intervention questions:

- Can you tell me about your experience of the CEW (Complications of Excess Weight service run by Alder Hey Children's Hospital) service over the last 3 months?
 - o What did you like about CEW?
 - o What didn't you like about CEW?
 - o How could we make CEW better?
- How did you find the exercise advice?
 - o Did it help you exercise?
 - o Who helped you exercise?
- What else would have helped you exercise?
- How do you feel about exercising now compared to before you took part in the programme
- What makes it easier for you to exercise?
- What makes it harder or more challenging for you to exercise? Does anything help you get over those challenges
- If this programme was to become a routine part of care, what would you keep the same or change?

mHealth questions:

- How useful were the exercise counselling sessions for supporting you to exercise?
 - o What were the good and bad things about talking to your exercise physiologist?
 - o Would sessions have been better face-to-face?
 - o Session duration
 - o Number/ frequency of sessions
- Who do you think would be the best person to give you advice about exercise? What would their job be?
- To what extent did the text messages from your exercise physiologist encourage you to keep exercising?
 - o How could the language in text have been improved?
 - o Number/ frequency of texts
 - o Did you feel like you could reply to the messages?

- How useful did you find the participant App (Polar Flow) for helping you exercise more?
 - o How often did you use the participant app?
 - o IF USED participant app, what did you use it for?
 - o What features did you like? Any features you disliked?
 - o If you could change the app in any way, what would you change?
 - o Would you recommend it to others? Why or why not
- How useful was the fitness watch (Polar Flow) for helping you to exercise more?
 - o How often did you wear fitness watch?
 - o IF USED, what did you use it for?
 - o What features did you like? Features you disliked.
 - o Would you recommend it to others? Why or why not?
 - o What would you change anything on it if you could?
- Do you think the exercise videos helped you exercise more?
 - o Elements of the videos that worked well
 - o Elements of the videos that could be improved
- Which other parts of the programme (App, texts, watch, videos) did you find most useful for helping you to exercise more?

Research Process questions:

- Why did you want to take part in the programme?
- Was there anything that put you off taking part in the study?
- To what extent was the programme what you thought it was going to be when you read the information sheet and after the initial meeting?
- How did you find communicating with the research team?
- If there was one thing we could do to make the study easier for you to take part in, what would it be?
- We are planning to undertake a larger scale study similar to the one you have taken part in. What sort of things would you change about the study that might make people want to take part in it more?
 - o How could we encourage you to wear the physical activity watch and glucose monitor during pre and post testing.
- Overall, what did you feel was good or bad about taking part in the study?

Appendix 2. Focus Group and interview Topic Guide Caregivers

Post-intervention Focus Group and interview schedule (Caregiver)

The semi-structured interviews will be based on key features of the CEW + mHealth programmes. The main themes are identified below, although specific content and structure will be led by the participant responses. Example probes are provided although will only be used when appropriate. The aim is to gauge participant perceptions of the exercise/ PA components of their programme.

Key questions (-) with probes (o) to be discussed include:

Intervention questions:

- Can you talk me through your experience of the CEW (Complications of Excess Weight service run by Alder Hey Children's Hospital) service over the last 6 months?
 - o What areas of CEW did you and your child like
 - o What areas of CEW didn't you or your childlike / find difficult
 - o Recommendations for improvement
- How well supported did you feel your child was in terms of the exercise advice?
 - o Who supported you and your child?
 - o Do you think this helped your child's exercise behaviour?
- Is there any additional support that could have further encourage your child to exercise?
- How do you and your child feel about taking part in exercise following the programme?
- What parts of the programme particularly helped your child exercise?
- What made it harder for your child to exercise?
 - o To what extent were you able to overcome these challenges?
- If this intervention was to become a routine part of care, what elements would you keep the same or change?

mHealth questions:

- How useful do you feel the exercise counselling sessions were for supporting a change in your child's exercise habits?
 - o What were the pro and cons of talking to the exercise physiologist?
 - o Would sessions have been better face-to-face?
 - o What did the sessions look like? (length/frequency/content)
- If you could choose any profession, who would you most like to receive counselling from?
- To what extent did the text messages from the exercise physiologist encourage your child to keep exercising?
 - o How could the language in text have been improved?
 - o Number/ frequency of texts

- Did you feel able to reply to the messages?
- How useful did you find the participant App (Polar Flow) for supporting a change in your child's exercise habits?
 - How did you engage with the participant app?
 - IF USED participant app, what did you use it for?
 - What features did you like? Any features you disliked?
 - If you could change the app in any way, what would you change?
 - Would you recommend it to others? Why or why not
- How useful did you find the fitness watch (Polar Flow) for supporting a change in your child's exercise habits?
 - To what extent was the watch easy to use. If no, could we ask what you would change?
- Do you think the exercise videos supported a change in your child's exercise habits?
 - Elements of the videos that worked well
 - Elements of the videos that could be improved
- Which additional support elements (App, texts, watch, videos) did you think were most useful for supporting a change in your child's exercise habits?

Research Process questions:

- Why did you want to take part?
- Did you have any concerns prior to the study starting?
- Did the study meet your expectations from the PIS and initial meeting?
- How well was communication with the research team well managed?
- If there was one thing we could do to make the study easier for you to take part in, what would it be?
- We are planning to undertake a larger scale study similar to the one you have taken part in. What sort of things would you change about the study that might make people want to take part in it more?
 - How could we encourage young people to wear the physical activity watch and glucose monitor during pre and post testing.
- Overall, what did you feel was good or bad about taking part in the study?

Appendix 3. Survey questions post-intervention for MOTIVATE-CEW participants.

Questions	
1.	Did you find any factors particularly helpful in increasing your exercise levels?
2.	What barriers did you face to increasing your exercise levels?
3.	What did you like about the extra support (e.g., Polar Flow app, fitness watch, counselling sessions and feedback from researcher and heart rate feedback during exercise)? What could be improved?
4.	What did you like about the counselling sessions? What could be improved?
5.	What did you like about the Teams messages? What could be improved?
6.	Were there any challenges to accessing or using the participant app? How could these challenges be overcome?
7.	Were there any challenges to using the fitness watch? How could these challenges be overcome?
8.	Were there any challenges to using the exercise videos? How could these challenges be overcome?

Appendix 4. Service Audit survey for Complications from Excess Weight service multidisciplinary team members.

CEW Service Exercise Provision Questionnaire

The purpose of this questionnaire is to better understand the provision of exercise within CEW Services across the UK.

This questionnaire should be completed by the person(s) responsible for the provision of exercise and physical activity within your CEW service.

This information will be used to inform the development of a physical activity and exercise programme that will be examined within a CEW service. The evaluation has been developed by researchers at Alder Hey Children Hospital and Liverpool John Moores University.

If you have any questions about this questionnaire or the research being conducted, please contact Andy Davies on A.P.Davies@2023.ljmu.ac.uk

Section 1. Physical Activity Recommendations

a. Does your service provide general Physical Activity (PA) advice to your patients (e.g., Complete 60mins of moderate or vigorous activity per day. Children should engage in a variety of types and intensities of physical activity across the week to develop movement skills, muscular fitness, and bone strength) Link: UK Chief Medical Officers' Physical Activity Guidelines	Tick the correct answer	
YES If YES, please answer all remaining Section 1 Questions		
NO If NO, please move to Section 2		
b. Which members of staff are responsible for the delivery of this exercise and PA advice?	Tick all that apply	Specify where required
Physiotherapist		

Physician Associate		
Exercise Physiologist		
Dietician		
Clinical Fellow		
Consultant		
Nurse Specialist		
Personal Trainer		
Health and Wellbeing Coach		
Youth Worker		
Therapy Assistant		
Other (define)		
c. How often is exercise and PA advice delivered to patients?	Tick all that apply	Specify where required
Twice Weekly		
Weekly		
Bi-Weekly		
Monthly		
Bi-Monthly		
Quarterly		
Annually		
Other (please specify)		
d. Please provide any information on how this is provided	Write response	

Section 2. Exercise and PA behaviour change consultations	
a. Does your service provide behaviour change consultations, specific to exercise and PA, to your patients. These sessions should include planned/explicit behaviour change techniques such as: • Goal setting	Tick the correct answer

• Discussing consequences of health behaviour • Encouraging self-monitoring • Feedback on behaviour These are some examples of behaviour change techniques, but others could be used within the consultations.		
YES		
If YES , please answer all remaining Section 2 Questions		
NO		
If NO , please move to Section 3		
b. Which members of staff are responsible for the delivery of these consultations?	Tick all that apply	Specify where required
Physiotherapist		
Physician Associate		
Exercise Physiologist		
Dietician		
Clinical Fellow		
Consultant		
Nurse Specialist		
Personal Trainer		
Health and Wellbeing Coach		
Youth Worker		
Therapy Assistant		
Other (define)		
c. Are these sessions delivered in a group or on an individual basis?	Tick all that apply	
Group		
Individual		
Both		
d. How often are these sessions delivered?	Tick the correct frequency	Specify where required

Twice Weekly		
Weekly		
Bi-Weekly		
Monthly		
Bi-Monthly		
Quarterly		
Annually		
Other (please specify)		
e. What is the average duration of these sessions?	Tick the correct duration	Specify where required
30 minutes		
1 hour		
2 hours		
Other (please specify)		
f. How long is this support available to the patient for?	Tick the correct duration	Specify where required
1 month		
3 months		
6 months		
1 Year		
Until no longer required		
Other (please specify)		
g. Please provide any information on how this is provided	Write response	

Section 3. Personalised graded physical Activity Action plans	
a. Does your service provide a personalised graded exercise and physical activity action plan. Action plans are specific for each patient, taking into consideration their readiness to begin exercising, baseline fitness, support available at home and	Tick the correct answer

resources available to them. Patients are given a physical copy (online or paper) of their plan with information on the duration intensity and frequency of the exercise or PA. Action plans are progressive, i.e., the duration, frequency or intensity of exercise/PA will increase over time, with instructions on how to do this.		
YES		
If YES , please answer all remaining Section 3 Questions		
NO		
If NO , please move to Section 4		
a. Which members of staff are responsible for the delivery of this exercise provision?	Tick all that apply	Specify where required
Physiotherapist		
Physician Associate		
Exercise Physiologist		
Dietician		
Clinical Fellow		
Consultant		
Nurse Specialist		
Personal Trainer		
Health and Wellbeing Coach		
Youth Worker		
Therapy Assistant		
Other (define)		
b. How often are these action plans reviewed?	Tick the correct frequency	Specify where required
Each Session		
Weekly		
Bi-Weekly		
Monthly		
Bi-Monthly		

Quarterly		
Annually		
Other (please specify)		
c. Is the current frequency, with which action plans are reviewed, sufficient in your opinion?	Yes/No	Specify where required
Yes		
No		
d. How often would you like to be able to review these action plans	Written Response	Specify where required
e. How long is this action plan designed for?	Tick the correct duration	Specify where required
1 month		
3 months		
6 months		
1 Year		
Until no longer required		
Other (please specify)		
f. Please provide any information on how this is provided	Write response	

Section 4. Activity tracking and monitoring	
a. Does your service use technology to support the provision of exercise and physical activity within your service?	Tick the correct answer
YES	
If YES , please answer all remaining Section 4 Questions	
NO	

If NO , please move to Section 4 j		
b. How is the technology provided	Tick all that apply	Specify where required
Provided by CEW Service		
Patients own technology utilised		
Both		
c. What method is used to monitor exercise behaviour?	Tick all that apply	Specify where required
Pedometer		
Accelerometer		
Pedometer		
Accelerometer		
Heart Rate Monitor		
Smart Watch		
Smart phone tracking		
Other		
d. Which members of staff are responsible for the delivery of this tool?	Tick all that apply	Specify where required
Physiotherapist		
Physician Associate		
Exercise Physiologist		
Dietician		
Clinical Fellow		
Consultant		
Nurse Specialist		
Personal Trainer		
Health and Wellbeing Coach		
Youth Worker		
Therapy Assistant		
Other (define)		

e. How long are patients monitored for?	Tick the correct frequency	Specify where required
1 to 6 days (please specify number of days)		
A Week		
Two Weeks		
A Month		
Two Months		
Three Months		
More than 3 months (please specify)		
Other (please specify)		
f. Do patients engage well with this technology?	Free Text	
g. Is feedback provided on the data collected from monitoring?	Tick the correct duration	
Yes (Answer f & g)		
No (Move to next section)		
h. How regularly is feedback provided?	Tick the correct duration	Specify where required
Twice Weekly		
Weekly		
Bi-Weekly		
Monthly		
Bi-Monthly		
Quarterly		
Annually		
Other (please specify)		
i. Please provide any additional information on the delivery of activity monitoring	Write response	
(After this move to section 5)		

j. Do you think having access to technology would help with the delivery of exercise and PA within your service?	Write response	
Answer only if they said no to use of tech		

Section 5. Supervised exercise sessions		
a. Does your service provide supervised exercise sessions for patients (these can be virtual)?	Tick the correct answer	
YES		
If YES , please answer all remaining Section 5 Questions		
NO		
If NO , please move to Section 6		
b. Are the sessions for this type of exercise provision delivered in a group or on an individual basis? Tick all that apply	Tick all that apply	
Group		
Individual		
Virtual (via video call)		
c. Who supervises these sessions?	Tick all that apply	Specify where required
Physiotherapist		
Physician Associate		
Exercise Physiologist		
Dietician		
Clinical Fellow		

Consultant		
Nurse Specialist		
Personal Trainer		
Health and Wellbeing Coach		
Youth Worker		
Therapy Assistant		
Other (define)		
d. How often are these sessions delivered?	Tick the correct frequency	Specify where required
Twice Weekly		
Weekly		
Bi-Weekly		
Monthly		
Bi-Monthly		
Quarterly		
Annually		
Other (please specify)		
e. What is the duration of these sessions?	Tick the correct duration	Specify where required
30 minutes		
45 minutes		
1 hour		
2 hours		
Other (please specify)		
f. How long is this support available to the patient for?	Tick the correct duration	Specify where required
1 month		
3 months		
6 months		
1 Year		
Until no longer required		

Other (please specify)		
g. Please specify the type of exercise completed in these sessions and give any further details about the sessions		
k. If you had the capabilities to, would you want to include Supervised exercise sessions within your service? Please provide as much information on what you'd like to offer in the section below.	Write response	
Answer only if they said no to question A		

Section 6. CEW Service resources to help increase PA		
a. Does your service provide resources that were developed by the service to help increase PA?	Tick the correct answer	
YES		
If YES , please answer all remaining Section 6 Questions		
NO		
If NO , you have answered all questions and completed this questionnaire.		
b. Which members of staff developed these resources?	Tick all that apply	
Physiotherapist		
Physician Associate		
Exercise Physiologist		
Dietician		
Clinical Fellow		
Consultant		
Nurse Specialist		

Personal Trainer		
Health and Wellbeing Coach		
Youth Worker		
Therapy Assistant		
Other (define)		
c. Where are these resources accessed, if possible, could you provide us with a link to access the resources?	Write response	
d. How are these resources delivered?	Tick the correct duration	
Videos		
Websites		
Apps		
Paper Resources		
Other (please specify)		
e. What type of content is covered in these resources?	Write response	
f. If you had the capabilities to, would you want to include specialist CEW developed resources within your service?	Write response	
Answer only if they said no to question A		

Section 7. Signposting to resources to help increase PA

a. Does your service signpost patients to externally developed resources to help increase exercise and PA	Tick the correct answer
---	-------------------------

YES			
If YES , please answer all remaining Section 7 Questions			
NO			
If NO , you have answered all questions and completed this questionnaire.			
b. Where are these resources accessed? (Please provide the URL of these resources where possible)		Write response	
c. How are these resources delivered?		Tick the correct duration	
Videos			
Websites			
Booklets & Leaflets			
Other (please specify)			
d. What type of content is covered in these resources?		Write response	
e. Please provide any information about these online resources		Write response	
f. If you had the capabilities to, would you want to include signposting to resources within your service?		Write response	
Answer only if they said no to question A			

Section 8. App based support		
a. Does your service signpost patients to any apps to help increase PA	Tick the correct answer	
YES		
If YES , please answer all remaining Section 8 Questions		
NO		
If NO , you have answered all questions and completed this questionnaire.		
b. Are you aware of the development of any apps?	Write response	
Answer only if they said no to question A		
c. Please name the apps that patients are encouraged to use?	Write response	
d. What type of content is covered on these apps?	Write response	
e. Please provide any information about these apps	Write response	
f. If you had the capabilities to, would you want to include the use of apps within your service?	Write response	
Answer only if they said no to question A		

Section 9. Signposting to services		
a. Does your service give patients the details of other organisations that will be able to offer them a range of exercise services delivered by non-CEW specialist staff (e.g., exercise classes, sports clubs, support services).	Tick the correct answer	
YES		
If YES , please answer all remaining Section 6 Questions		
NO		
If NO , please move to Section 7		
b. Which members of staff are responsible for the signposting of this exercise provision?	Tick all that apply	Specify where required
Physiotherapist		
Physician Associate		
Exercise Physiologist		
Dietician		
Clinical Fellow		
Consultant		
Nurse Specialist		
Personal Trainer		
Health and Wellbeing Coach		
Youth Worker		
Therapy Assistant		
Other (define)		
c. Where do these activities take place?	Tick all that apply	Specify where required
Clinical setting (e.g., hospital, primary care)		
Online/e-health/m-health		
Home-based		
Sports club/ Leisure centre/ Commercial gym		

Green/outdoor space (define)		
Do not know		
Other (define)		
d. Are the sessions for this type of exercise provision delivered in a group or on an individual basis?	Tick all that apply	
Group		
Individual		
Both		
Do not know		
e. Do patients have to pay for these services or are they provided free of charge?	Tick all that apply	
Free		
Paid		
Both		
f. Do all patients have access to the same services or are services dependent on patients' geographical location?	Tick all that apply	
Same for all		
Area specific		
g. How often are these sessions delivered (if known)?	Tick the correct frequency	Specify where required
Twice Weekly		
Weekly		
Bi-Weekly		
Monthly		
Bi-Monthly		
Quarterly		
Annually		
Do not know		
Other (please specify)		
h. What is the duration of these sessions?	Tick the correct duration	Specify where required
30 minutes		

45 minutes		
1 hour		
2 hours		
Do not know		
Other (please specify)		
i. How long is this support available to the patient for?	Tick the correct duration	Specify where required
1 month		
3 months		
6 months		
1 Year		
Until no longer required		
Other (please specify)		
j. Please specify how you use these services.	Write response	
k. If you had the capabilities to, would you want to include signposting to external services within your service?	Tick all that apply	
Answer only if they said no to question A		
If you have anything you would like to add about the provision of exercise and PA within CEW services, please use the space provided below:		
THANK YOU Thank you for completing this questionnaire. Please press submit to confirm your response. If you have any questions, please email Andy Davies (A.P.Davies@2023.ljmu.ac.uk)		



Appendix 5. CONSORT 2010 checklist of information to include when reporting a pilot or feasibility trial*

Section/Topic	Item No	Checklist item	Reported on page No
Title and abstract			
	1a	Identification as a pilot or feasibility randomised trial in the title	110
	1b	Structured summary of pilot trial design, methods, results, and conclusions (for specific guidance see CONSORT abstract extension for pilot trials)	3
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale for future definitive trial, and reasons for randomised pilot trial	112
	2b	Specific objectives or research questions for pilot trial	112,113
Methods			
Trial design	3a	Description of pilot trial design (such as parallel, factorial) including allocation ratio	113
	3b	Important changes to methods after pilot trial commencement (such as eligibility criteria), with reasons	NA
Participants	4a	Eligibility criteria for participants	113, 114
	4b	Settings and locations where the data were collected	113, 114
	4c	How participants were identified and consented	113, 114
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	114, 115
Outcomes	6a	Completely defined prespecified assessments or measurements to address each pilot trial objective specified in 2b, including how and when they were assessed	115,116
	6b	Any changes to pilot trial assessments or measurements after the pilot trial commenced, with reasons	NA

	6c	If applicable, prespecified criteria used to judge whether, or how, to proceed with future definitive trial	NA
Sample size	7a	Rationale for numbers in the pilot trial	118
	7b	When applicable, explanation of any interim analyses and stopping guidelines	NA
Randomisation:			
Sequence generation	8a	Method used to generate the random allocation sequence	113
	8b	Type of randomisation(s); details of any restriction (such as blocking and block size)	113
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	113
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	113
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those assessing outcomes) and how	113
	11b	If relevant, description of the similarity of interventions	NA
Statistical methods	12	Methods used to address each pilot trial objective whether qualitative or quantitative	118
Results			
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were approached and/or assessed for eligibility, randomly assigned, received intended treatment, and were assessed for each objective	119, 120
	13b	For each group, losses and exclusions after randomisation, together with reasons	119, 120
Recruitment	14a	Dates defining the periods of recruitment and follow-up	119
	14b	Why the pilot trial ended or was stopped	NA
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	121

Numbers analysed	16	For each objective, number of participants (denominator) included in each analysis. If relevant, these numbers should be by randomised group	119, 121, 122
Outcomes and estimation	17	For each objective, results including expressions of uncertainty (such as 95% confidence interval) for any estimates. If relevant, these results should be by randomised group	119, 123
Ancillary analyses	18	Results of any other analyses performed that could be used to inform the future definitive trial	123, 129
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	NA
	19a	If relevant, other important unintended consequences	NA
Discussion			
Limitations	20	Pilot trial limitations, addressing sources of potential bias and remaining uncertainty about feasibility	135
Generalisability	21	Generalisability (applicability) of pilot trial methods and findings to future definitive trial and other studies	131, 132, 133, 134
Interpretation	22	Interpretation consistent with pilot trial objectives and findings, balancing potential benefits and harms, and considering other relevant evidence	131, 132, 133, 134
	22a	Implications for progression from pilot to future definitive trial, including any proposed amendments	132, 133, 134, 135
Other information			
Registration	23	Registration number for pilot trial and name of trial registry	113
Protocol	24	Where the pilot trial protocol can be accessed, if available	NA
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	NA
	26	Ethical approval or approval by research review committee, confirmed with reference number	113

Citation: Eldridge SM, Chan CL, Campbell MJ, Bond CM, Hopewell S, Thabane L, et al. CONSORT 2010 statement: extension to randomised pilot and feasibility trials. BMJ. 2016;355.

*We strongly recommend reading this statement in conjunction with the CONSORT 2010, extension to randomised pilot and feasibility trials, Explanation and Elaboration for important clarifications on all the items. If relevant, we also recommend reading CONSORT extensions for cluster randomised trials, non-inferiority and equivalence trials, non-pharmacological treatments, herbal interventions, and pragmatic trials. Additional extensions are forthcoming: for those and for up to date references relevant to this checklist, see www.consort-statement.org

Appendix 6. Clinical Outcomes Methods for MOTIVATE-CEW2 Study

Patient- and proxy-reported outcomes

Multiple patient- and proxy-reported outcomes were collected from young people and their caregivers. Questionnaires were completed either on paper or online according to participant preference. Paper copies were returned by post, and online questionnaires were administered via Google Forms (Google Forms, Google LLC, Mountain View, CA, USA).

Health related quality of life was assessed using the Pediatric Quality of Life Inventory (PedsQL 4.0) (Varni, Seid and Kurtin, 2001) and the EuroQol-5 Dimensions- Youth-5 Levels (EQ-5D-Y-5L) (Kreimeier *et al.*, 2019).

The PedsQL 4.0 comprises 23 items rated on a 5-point Likert scale from 0 (never a problem) to 4 (almost always a problem), referring to the previous month. Items are reverse-scored and linearly transformed to a 0–100 scale, with higher scores indicating better HRQoL. Scores can be reported as a Total Scale Score or as two summary scores: the Physical Health Summary Score (8 physical functioning items) and the Psychosocial Health Summary Score (15 items covering emotional, social, and school functioning).

The EQ-5D-Y-5L assesses five dimensions: mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. Each dimension has five response levels indicating increasing severity. The instrument also includes a visual analogue scale on which participants rate their overall health from “the best health you can imagine” to “the worst health you can imagine.”

Weight-related HRQoL was assessed using the Impact of Weight on Quality of Life-Lite (IWQOL-lite) (Kolotkin *et al.*, 2017) a 27-item questionnaire assessing four domains: physical comfort, body esteem, social life, and family relations. Items are rated on a 5-point scale and transformed to domain scores ranging from 0 to 100, with higher scores indicating better HRQoL.

Symptoms of anxiety and depression were assessed using the Revised Child Anxiety and Depression Scale (RCADS) (Chorpita *et al.*, 2000). The RCADS contains 47 items rated from 0 to 3 and yields six subscale scores: separation anxiety disorder, generalized anxiety disorder, panic disorder, social anxiety disorder, obsessive–compulsive disorder, and major depressive disorder. Summary scores are calculated for total anxiety (all anxiety subscales) and total internalising symptoms (sum of all domains).

Self-esteem was measured using the Rosenberg Self Esteem Scale (RSE) (Rosenberg, 1965) a 10-item measure scored from 0 to 3 per item, yielding a total score range of 0–30. Higher scores indicate greater self-esteem. Scores of 15–25 are considered within the normal range, while scores below 15 indicate low self-esteem. Proxy versions of the EQ-5D-Y-5L, IWQOL-lite, RCADS and PedsQL 4.0 were administered to caregivers.

Comparative Exercise and Physical Activity

All young people in both usual care and MOTIVATE-CEW2 groups wore a Polar Pacer fitness watch (Polar Electro Oy, Kempele, Finland) for 7 days at baseline and during the final 7 days of the intervention period. At baseline, the watch-face displayed only the time and date. At follow-up, the watch-face in the usual care group continued to display only the time and date, whereas participants in the intervention were provided with watch-faces displaying physical activity (PA) and structured exercise metrics as part of the intervention.

Purposeful exercise sessions were captured through the Polar Pacer's optical heart rate monitor, via photoplethysmography. At baseline and follow-up participants manually started the exercise mode when performing structure purposeful exercise sessions. The watch-face displayed session duration and current heart rate. At baseline neither group had been informed how to use heart rate or personalised heart rate zones to guide exercise. At follow-up MOTIVATE-CEW2 participants were using the information provided by the watch-face to guide exercise as part of the intervention. Purposeful exercise metrics derived from heart rate data included frequency (number of sessions), duration, and time spent in moderate-to-vigorous intensity exercise (MVE), calculated by summing time in moderate (50–70% heart rate max) and vigorous ($\geq 70\%$ heart rate max $\times 2$) intensity zones.

Lifestyle PA metrics were recorded from the Polar Flow for Coach application. The validity of Polar technology to measure energy expenditure, step count and PA under free-living conditions has been examined previously (Polar, 2021). Physical activity is recorded in 30-second epochs and estimated using wrist acceleration and heart rate data combined with participant characteristics to derive energy expenditure, which is converted to METs. This is then classified into 5 activity levels within the Polar platform

(resting, sitting, low, medium, high). Lifestyle PA metrics collected included mean steps per week, mean calories (kcal) expended per week, and the distribution of time across different activity intensities. For analysis, resting and sitting categories were combined as sedentary time, low intensity as standing time, and medium and high intensity as active time. To explore if different ways of processing PA data influenced data availability and outcomes four wear-time criteria were considered, ≥ 16 hours for 4 days including at least 1 weekend day, ≥ 10 hours for 4 days including at least 1 weekend day, ≥ 10 hours over any 4 days, and ≥ 10 hours over 1 day. In line with previous literature in weight management programmes for young people ≥ 10 hours over 1 day was used (Pallan *et al.*, 2018).

Exercise Capacity

Functional exercise capacity was assessed using a remote six-minute walk test (6MWT) in young people. Participants were instructed to wear a Polar Pacer fitness watch (Polar Electro Oy, Kempele, Finland) and initiate a pre-programmed 6MWT session, which displayed a 6-minute countdown and used the integrated GPS system to record distance covered. Tests were conducted outdoors, with participants instructed to walk as far and as fast as possible for six minutes. Participants were permitted to pause to rest if required but were encouraged to resume walking promptly. Standardised instructions were displayed on the watch-face before the test and reinforced verbally by the exercise specialist in a video call. Total distance walked was extracted from the Polar Flow for Coach platform. The remote 6MWT delivered via wearable technology provides a valid and practical measure of exercise capacity under free-living conditions (Jamieson *et al.*, 2024).

Clinical Outcomes

Body composition was assessed using Bio-Impedance Scales (Tanita MC-980MA-N Plus, Tanita Corporation, Tokyo, Japan). The device was used to assess body fat percentage, fat mass and fat free mass. SDS BMI was calculated using clinical access to the growth chart software GrowthXP Endo. Blood pressure was measured using an automated blood pressure monitor (Propaq LT monitor; Welch-Allyn, Beaverton, OR, USA). HbA1c, blood lipids and liver enzymes were assessed from a venous blood sample. Blood samples were analysed by the Alder Hey Children's Hospital clinical chemistry laboratory using two different methods. HbA1c was measured by

immunoassay using a Siemens DCA Vantage analyser while blood lipids and liver enzymes were measured using spectrophotometric assays on an Abbott Alinty ci analyser.