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Relationship Between Individual and Composite FMS™ Scores with the Anthropometric and Physical Characteristics of Elite Touch (Rugby) Players

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Abstract

Purpose To describe and compare the movement patterns, anthropometric and physical characteristics of male and female Touch players; and examine the relationships between Functional Movement Screening (FMS™) scores and the anthropometric and physical characteristics.

Methods This was a cross-sectional study with 35 elite Touch players (18 males, age = 24.7 ± 4.9 years; 17 females, age = 26.7 ± 5.2 years). Anthropometric (stature, body mass) and physical characteristics (sprint times, glycolytic change-of-direction test, and countermovement jump (CMJ) flight time and peak power) were assessed alongside movement patterns using the FMS™ battery. Data were analysed for between-sex differences (independent *t*-test, Mann–Whitney U) and relationships (Spearman's correlation coefficient).

Results Between-sex differences in body mass ($t = 6.082, P < 0.001$), stature ($t = 9.247, P < 0.001$), CMJ flight time ($t = 3.576, P = 0.001$), relative CMJ peak power ($t = 6.578, P < 0.001$), 10 m sprint time ($t = 15.861, P < 0.001$), glycolytic change of direction test time ($t = -11.831, P < 0.001$) and Yo–Yo IR1 ($t = 6.842, P < 0.001$) were observed. There were minimal differences for deep squat ($Z = -1.036, P = 0.443$), in-line lunge ($Z = -1.284, P = 0.303$), shoulder mobility ($Z = -0.173, P = 0.883$), trunk stability push-up ($Z = -0.896, P = 0.483$) and rotary stability ($Z = -1.537, P = 0.273$). The correlation between total and individual FMS™ scores with anthropometric and physical characteristics ranged from trivial-to-moderate ($r = -0.502$ to 0.488).

Conclusion The lack of difference for the FMS™ composite score and small-to-trivial differences in individual scores allows a comparison between mixed populations within Touch. Whilst many of the correlations were trivial-to-small, there were differences between sexes in the associations and evidence that improvements in functional deficiencies could translate into improved physical performance.

Keywords Movement screening · Physical qualities · Fitness · Rugby

Introduction

Touch rugby (Touch) is an amateur sport played at varying standards. International Touch tournaments comprise 40-min matches over successive days, with six fielded players and a further eight 'rolling' substitutes. Touch

match-play elicits high mean heart rates ($\sim 65\% \text{HR}_{\text{max}}$) in response to the high-intensity intermittent movements completed across 6–14 bouts of activity lasting ~ 2 –3 min [5, 18, 37, 55]. The high-intensity nature of Touch, and the requirement to complete up to 11 matches over a 4-day period, requires players to possess well-developed physical characteristics with equally efficient movement patterns. These might help mitigate factors that could contribute to injury risk and decrements in performance [18, 29]. For example, superior sprint performance and intermittent running ability can reduce the odds of an injury through moderating the effects of neuromuscular fatigue [36], which is known to negatively impact running performance [20], muscle imbalance [20] and joint kinematics [12, 54]. In addition, efficient

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movement patterns enable athletes to perform key sporting tasks without compensatory movement [13, 14] or added biomechanical stress [23], thus potentially moderating injury risk.

Identifying the anthropometric and physical characteristics of athletes has important implications for tournament and match performance, establishing normative values, determining effectiveness of training programmes [17, 25] and potentially moderating injury risk [13, 14, 23, 36]. To date, few studies have documented the anthropometric and physical characteristics of Touch players [19, 45, 46], reporting on short (0–10 m) and longer (10–30 m) sprint performance, predicted $\text{VO}_{2\text{max}}$ and anthropometric measures of stature, body mass and skin fold thickness. O'Connor [45] also included a 'glycolytic change of direction test' that required players to complete repeated high intensity efforts comprising linear and lateral running movements. However, two of these studies were over 10 years old, and were limited to the Southern Hemisphere where the game is more established. Studies also failed to include physical characteristics that are known to influence movement and internal responses during Touch matches, such as intermittent running performance and lower body muscle power [19].

Various screening batteries have been developed to standardise movement assessment and support an individual's return to function and required activity. These have minimal technological requirements and subjectively define the components of movement needed [10, 13, 14, 38, 40]. By far the most common is the Functional Movement Screening (FMS™) tool, developed to quantify movement patterns and identify individuals with dysfunctional patterns related to deficits in stability, mobility, or neuromuscular control, that might expose them to a greater risk of injury [13, 14]. The FMS™ consists of seven tests, each rated on a 4-point scale with a total possible score of 21 [13, 14]. Individuals receive a score based on whether they can complete the described movement without compensatory movements or pain [13, 14].

Studies using FMS™ vary in purpose from; establishing normative data [2, 22, 49], examining between-sex differences [1, 3, 7], moderating injury risk [24, 28, 41, 42] and assessing its relationship with physical characteristics [34, 35, 47, 48]. Associations between FMS™ and physical characteristics are contradictory. Parchmann and McBride [48] observed no relationship between the total FMS™ (TFMS™) score and physical characteristics such as, 10-m sprint performance and vertical jump height in collegiate golfers. In contrast, Lockie et al. [35] reported correlations between individual components of the FMS™, such as deep squat (DS) and in-line lunge (ILL) with performance measures such as vertical jump (VJ) ($r=0.428$) and agility as measured by the modified *t*-test ($r=0.582$) in 22 male recreational team sport athletes. The same authors also reported

negative relationships between individual tests such as active straight-leg raise (ASLR) with VJ ($r=-0.376$ to -0.731) in 9 female team sport athletes [34]. It is important to recognise the differences in the approach when incorporating both sexes (e.g., splitting or pooling the data), the training status of the individuals being assessed [50, 51], their sporting background [33], and key study limitations (e.g., experience of assessors and sample size). As such, there is a need to establish sex-specific norms in Touch given the single- and mixed-sex aspect of the sport as well as to understand the movement patterns and relationship with anthropometric and physical characteristics. Insight into sex-specific norms for anthropometric and physical characteristics, and movement patterns, will support practitioners future screening practices and programme design.

The aim of the study was to describe and compare the movement patterns, anthropometric and physical characteristics of male and female Touch players, and examine the relationship between FMS™ scores and the anthropometric and physical characteristics. It was hypothesised that males would achieve superior results in the assessment of physical characteristics, and that females would demonstrate greater flexibility within the individual FMS™ tests for this quality.

Methods

Using a cross-sectional study design, male and female Touch players completed assessments of anthropometric and physical characteristics, and movement patterns using the FMS™ battery [13, 14]. All data were collected across two consecutive days on a natural grass pitch or hard flat surface and took approximately 60 min to complete. Each playing group was assessed at a different location within England, as this corresponded with a squad training camp. On arrival at the facility, players' body mass (SECA scales, 813, Hamburg, Germany), stature (SECA stadiometer, Leicester Height Measure, Hamburg, Germany) and countermovement jump (CMJ) performance were recorded. Thereafter, all players completed the full FMS™ battery with scores recorded by a single researcher to ensure consistency. Players then completed a standardised warm up led by a strength and conditioning coach before completing two 10 m sprints, a single glycolytic change of direction test, and the Yo–Yo Intermittent Recovery Test Level 1. Across the two testing days, mean temperature was 12.5 ± 2.1 °C and humidity was $70.1 \pm 5.6\%$.

Participants

A non-probability, purposive sampling approach was used. Potential participants were identified by the authors through consultation with England Touch Association. Those that

met the inclusion criteria (i.e., affiliated with the open category, aged over 16 years, and free of injury) were provided with a participant information sheet. Forty-eight elite Touch players from the England National team were identified as eligible and invited to take part. A total of 35 players (18 male, age = 24.7 ± 4.9 years; stature = 177.6 ± 4.6 cm; body mass = 73.4 ± 6.6 kg and 17 female, age = 26.7 ± 5.2 years; stature = 162.5 ± 5.0 cm; body mass = 59.8 ± 6.7 kg) participated in this study. An *a-priori* power calculation was performed using G*Power (3.1.9.4) [21] to determine the required sample for assessing both mean differences and relationships. To determine a between-sex difference in the TFMS™ score, it was estimated that 20 participants per group would be required using a standardised mean difference of 0.82 [7] with α set at 0.05 and β set at 0.80. To determine the correlation between physical characteristics and movement patterns, an estimated total sample of 29 was required based on a correlation between FMS™ and a composite score of three physical fitness tests [30]. Whilst an *a-priori* calculation was used, it is recognised that the sample was limited to those selected for the national team representing a hard-to-reach population. Institutional ethics approval for the study was provided by Manchester Metropolitan University (No. 1187, 2016), with participants giving written informed consent/assent and caregiver's consent for those under 18 years.

Procedures

Countermovement Jump

All participants performed two countermovement jumps on a 60×60 cm portable force platform (HUR Labs, FP4, Tampere, Finland) sampling at 1200 Hz. Participants were given a clear explanation and demonstration of the required technique, which included placing their hands on the hips, using a self-selected depth, and ensuring their legs were straight during flight. Jumps that did not meet the criteria were not recorded and participants were asked to complete an additional jump. Recovery time between jumps was ~60 s. Flight time was displayed on custom software (HUR Labs Force Platform Software Suite) where the start of the jump was defined as < 5 N and landing as > 50 N. Peak power output (PPO) was calculated from the inbuilt equation that uses the force impulse equation and is expressed relative to body mass. The reliability for the countermovement jump [flight time, coefficient of variation (CV) = 8.3%; PPO CV = 4.7%] [18].

Glycolytic Change of Direction Test

The glycolytic change of direction test [44] required players to complete a series of forward, backward, and lateral movements totalling 177 m. Initially, players completed

three 10 m forward sprints, each interspersed with three 5 m backward jogs. A 5 m lateral shuttle to the right was then performed, followed by three 10 m forward sprints and two 5 m backward jogs. This was followed by another 5 m shuttle to the right and a 35 m maximal forward sprint. Finally, a 7 m diagonal shuttle to the left, a 15 m forward sprint, a 5 m jog backwards and a 20 m forward sprint were performed (Fig. 1). All participants were habituated to the test having completed this previously on several occasions. The total time to complete the trial was recorded to the nearest 0.01 s using single-beam electronic timing gates (Brower, Speedtrap 2, Brower, Utah, USA) (in-house CV = 2.5%).

Sprint Test

Sprint time was measured using a single-beam electronic timing gates (Brower Speedtrap 2, Brower, Utah, USA) positioned at 0 and 10 m, with gates placed 150 cm apart and at a height of 90 cm [17]. Participants began each sprint from a two-point stance 0.3 m behind the starting line. Participants completed two maximal sprints with the time recorded to the nearest 0.01 s and the lowest 10 m sprint time used for analysis. Sprint performance over these distances has been shown to be reliable with similar athletes (CV = 4.2% [17]).

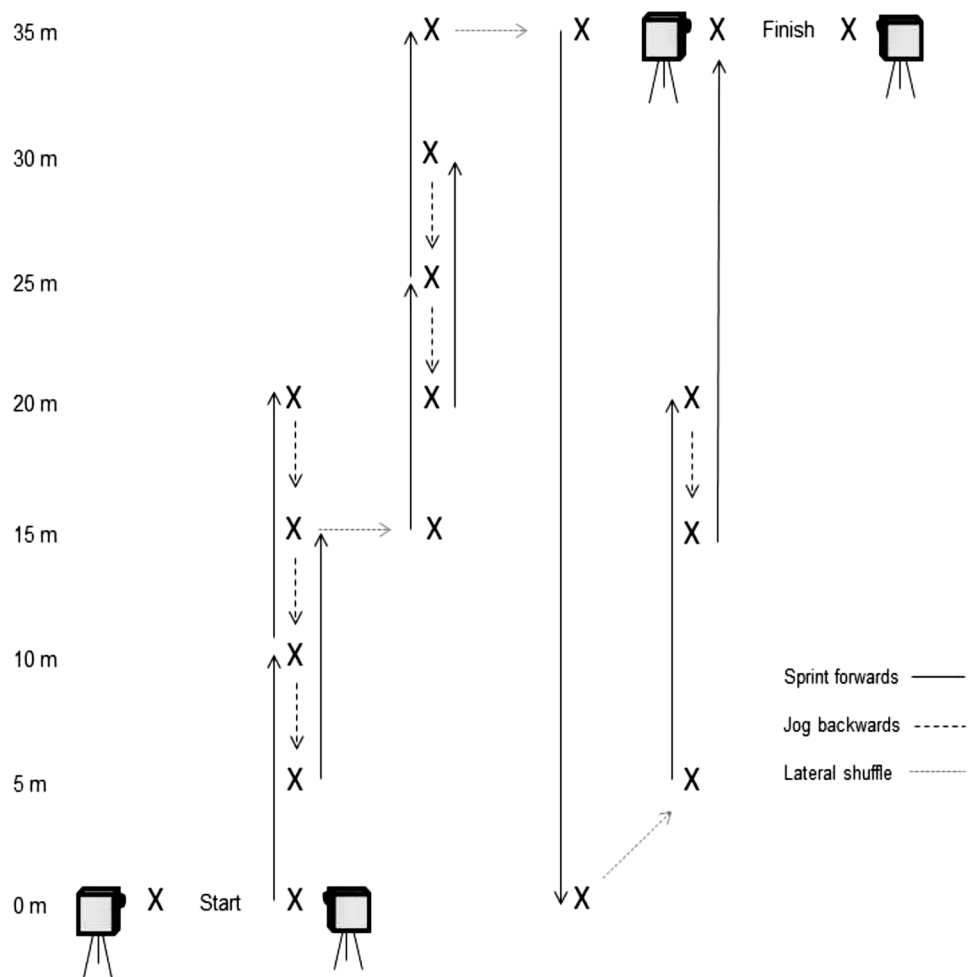
Yo-Yo Intermittent Recovery Test Level 1

During the Yo-Yo Intermittent Recovery Test Level 1, players completed as many 40 m (2×20 m) shuttles as possible interspersed with 10 s active recovery (walking) [4]. Running speed started at 10 km/h and increased 0.5 km/h every ~60 s. Participants were only allowed one failed attempt to complete the shuttle after which they were withdrawn from the test. The final distance was recorded as the last successfully completed shuttle (CV = 4.9%) [31].

Functional Movement Screen™

All participants completed the seven fundamental movements patterns of the FMS™ including deep squat, hurdle step (HS), in-line lunge, shoulder mobility (SM), active straight leg raise (ASLR), trunk stability push-up (TSPU) and rotary stability (RS) [13, 14]. Each participant received verbal instructions and a demonstration before each movement. Participants performed the movement twice, to allow observations from sagittal and frontal planes. Movement quality was assessed against pre-defined criteria and scored on a 0–3 scale [13, 14]. A score of 3 describes that the individual achieved all the defined criteria. A score of 2 denotes that movements were completed but required compensatory movements to perform, and a score of 1 indicates that the individual was not able to perform the task. Participants unable to perform the task due to pain were given a score of 0.

Fig. 1 Glycolytic change of direction test



The same researcher with 20 years of experience in musculoskeletal physiotherapy conducted all assessments. Several studies have reported *ICC* values of ≥ 0.75 for both intra- and inter-rater reliability of the FMSTM [6, 15, 42] demonstrating that the FMSTM can be scored consistently.

Statistical Analysis

Descriptive statistics are presented as the mean \pm standard deviation (SD). Data for FMSTM are presented as median and interquartile ranges given the data is ordinal. The Shapiro–Wilk test was used to assess assumptions of normality for continuous variables. Multiple *t*-tests were used to determine if a difference in physical characteristics was observed between male and female groups. The Mann–Whitney U test was used to assess total and individual FMSTM scores. Standardised mean differences (SMD) were calculated using the difference in the means (male and female) over the pooled standard deviation. SMDs and 95% confidence limits (CL) were calculated and interpreted using the following thresholds where; ≤ 0.20 , trivial; 0.21–0.60, small; 0.61–1.20, moderate; 1.21–2.00, large; > 2.0 , very large [26]. Total and

individual tests (i.e., hurdle step) for the FMSTM battery as well as the left and right scores for HS, ILL, ASLR, SM, RS were correlated with each physical characteristic using Spearman's Rho correlation with an alpha level of 0.05. Thresholds for correlations were: ≤ 0.10 trivial, 0.11–0.30 small, 0.31–0.50 moderate, 0.51–0.70 large, 0.71–0.90 very large, 0.91–0.99 nearly perfect, 1 perfect [26]. Statistical significance was set at $P < 0.05$. All statistical analyses were performed using SPSS (IBM SPSS Statistics for Windows, Version 25.0, Armonk, NY, USA).

Results

Thirteen participants were not involved due to injury and availability at the time of testing, resulting in a final sample of 35 participants. All continuous variables met the assumptions of normality (0.871–0.987, $P > 0.05$). Results indicated between-sex differences in body mass ($t = 6.082$, $P < 0.001$), stature ($t = 9.247$, $P < 0.001$), CMJ flight time ($t = 3.576$, $P = 0.001$), relative CMJ peak power ($t = 6.578$, $P < 0.001$), 10 m sprint time ($t = 15.861$, $P < 0.001$), glycolytic change

of direction test time ($t = -11.831, P < 0.001$) and Yo–Yo IR1 ($t = 6.842, P < 0.001$), with SMDs ranging from -3.91 to 2.26 (Table 1).

The relative frequencies of scores for the individual tests were similar between males and females, except for ASLR (Fig. 2). Whilst there was no difference in the mean score between males and females for hurdle step ($Z = 0.000, P = 1.000$), there were trivial to small (see Fig. 2) differences found for deep squat ($Z = -1.036, P = 0.443$), in-line lunge ($Z = -1.284, P = 0.303$), shoulder mobility ($Z = -0.173, P = 0.883$), trunk stability push up ($Z = -0.896, P = 0.483$) and rotary stability ($Z = -1.537, P = 0.273$). A moderate difference was observed for ASLR between sexes ($Z = -3.298, P = 0.010$). There was small difference between male (16.6 ± 2.3 AU) and female (17.7 ± 2.2 AU) for TFMS™ score [$t = -1.526, P = 0.137, SMD = -0.50$ (-1.21 to 0.17)].

The scores for the relative frequencies when considering right and left limbs were similar between males and females. A moderate difference was observed for ASLR with 100% of females achieving a score of 3 for both limbs (left, $Z = -3.398, P = 0.010$; right, $Z = -3.073, P = 0.025$) (Fig. 3). Mean between-sex differences were minimal for HS (left, $Z = 0.000, P = 1.000$; right, $Z = -0.582, P = 0.636$), ILL (left, $Z = -1.167, P = 0.424$; right, $Z = -0.15, P = 0.935$), SM (left, $Z = -0.022, P = 0.987$; right, $Z = -0.101, P = 0.961$) and RS (left, $Z = -0.789, P = 0.568$; right, $Z = -0.411, P = 0.757$).

The relationships between total and individual FMS™ scores with anthropometric and physical characteristics ranged from a trivial to a moderate correlation (Table 2). The relationships between individual limb scores (FMS™) with anthropometric and physical characteristics ranged from trivial to large (Table 3).

Table 1 Between-sex differences in age, anthropometric and physical characteristics of elite touch rugby players

Characteristic	Females	Males	Standardised mean difference (95% CI)
Age (years)	26.7 ± 5.2	24.7 ± 4.9	-0.39 (-1.04–0.72)
Body mass (kg)	59.8 ± 6.7	73.5 ± 6.6*	2.01 (1.19–2.81)
Stature (cm)	162.5 ± 5.0	177.6 ± 4.6*	3.06 (2.07–4.02)
CMJ flight time (ms)	479 ± 32	529 ± 48*	1.18 (0.47–1.88)
Relative CMJ peak power (W/kg)	42 ± 3	53 ± 7*	2.13 (1.30–2.95)
10 m sprint time (s)	2.09 ± 0.17	1.82 ± 0.09*	-1.94 (-2.73–1.13)
Change of direction time (s)	46.62 ± 1.56	40.8 ± 1.34*	-3.91 (-5.04–2.76)
Yo–Yo IR1 (m)	903 ± 354	1868 ± 469*	2.26 (1.41–3.10)

*Significant at 0.05

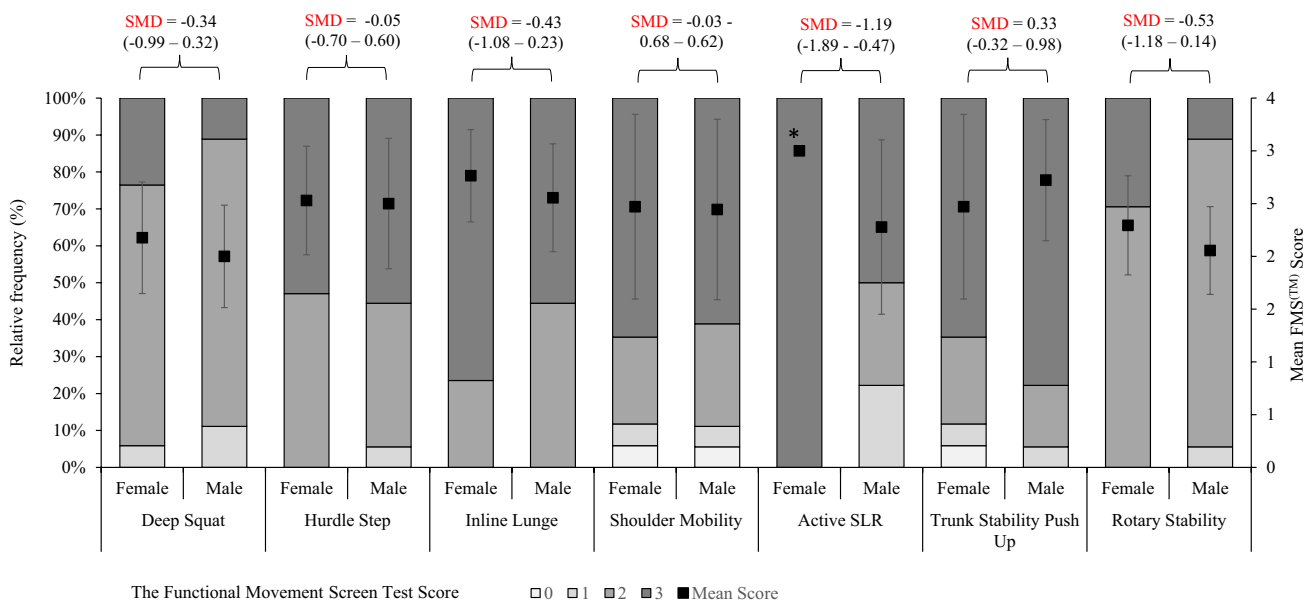


Fig. 2 Between-sex differences of in the relative frequency and mean composite FMS™ Scores

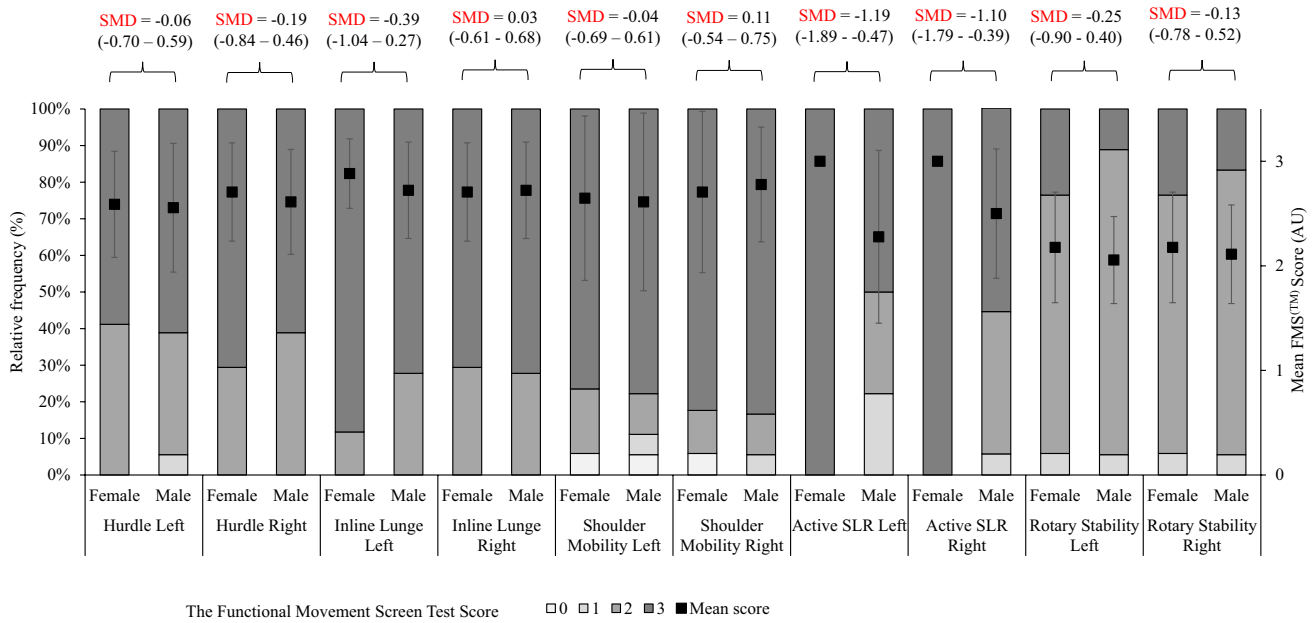


Fig. 3 Between-sex differences of in the relative frequency and mean individual FMS™ Scores for left and right

Table 2 The relationship between combined FMS score and tests of anthropometric and physical characteristics

Variable	Deep squat (AU)	Hurdle step (AU)	Inline lunge (AU)	Shoulder mobility (AU)	Active SLR (AU)	Trunk stability push up (AU)	Rotary stability (AU)	Total (AU)
Age (years)	0.146 (0.02)	0.022 (0.00)	0.036 (0.00)	-0.001 (0.00)	0.039 (0.00)	0.075 (0.01)	0.151 (0.02)	0.197 (0.04)
Stature (cm)	-0.273 (0.07)	-0.11 (0.01)	-0.131 (0.02)	-0.008 (0.00)	-0.502* (0.25)	-0.072 (0.01)	-0.294 (0.09)	-0.352* (0.12)
Body mass (kg)	-0.328 (0.11)	-0.085 (0.01)	-0.150 (0.02)	-0.172 (0.03)	-0.367* (0.13)	0.245 (0.06)	-0.279 (0.08)	-0.223 (0.05)
CMJ flight time (ms)	0.048 (0.00)	0.221 (0.05)	-0.009 (0.00)	-0.137 (0.02)	-0.134 (0.02)	0.297 (0.09)	-0.122 (0.01)	0.066 (0.00)
CMJ relative peak power (W/kg)	-0.210 (0.04)	0.024 (0.00)	-0.256 (0.07)	-0.201 (0.04)	-0.413* (0.17)	0.377* (0.14)	-0.389* (0.15)	-0.199 (0.04)
10 m sprint time (s)	0.216 (0.05)	-0.028 (0.00)	0.355* (0.13)	0.142 (0.02)	0.379* (0.14)	-0.071 (0.01)	0.427* (0.18)	0.356* (0.13)
Change of direction time (s)	0.143 (0.02)	-0.046 (0.00)	0.173 (0.03)	0.100 (0.01)	0.488* (0.24)	-0.372* (0.14)	0.192 (0.04)	0.145 (0.02)
Yo-Yo IR1 distance (m)	-0.244 (0.06)	-0.036 (0.00)	-0.268 (0.07)	0.015 (0.00)	-0.436* (0.19)	0.117 (0.01)	-0.045 (0.00)	-0.194 (0.04)

*Significant at 0.05

Discussion

In this study we described and compared the movement patterns, anthropometric and physical characteristics of male and female Touch players. We also examined the relationship between anthropometric and physical

characteristics with individual and TFMS™ scores. Differences were observed between males and females for all anthropometric and physical characteristics, with males being heavier, taller, and demonstrating superior physical performance. There were trivial to small differences between males and females for total and individual FMS™ scores except for ASLR where females achieved a

Table 3 The relationship between individual limb scores of FMS and tests of anthropometric and physical characteristics

Variable	Hurdle step (AU)		Inline lunge (AU)		Shoulder mobility (AU)		Active straight leg raise (AU)		Rotary stability (AU)	
	L	R	L	R	L	R	L	R	L	R
Age (years)	-0.082 (0.01)	0.137 (0.02)	0.043 (0.00)	-0.075 (0.01)	-0.124 (0.02)	-0.104 (0.01)	0.039 (0.00)	-0.020 (0.00)	-0.017 (0.00)	0.013 (0.00)
Stature (cm)	-0.017 (0.00)	-0.122 (0.01)	-0.096 (0.01)	0.097 (0.01)	0.081 (0.01)	0.018 (0.00)	-0.502* (0.25)	-0.425* (0.18)	-0.164 (0.03)	-0.101 (0.01)
Body mass (kg)	0.006 (0.00)	-0.161 (0.03)	-0.145 (0.02)	0.153 (0.02)	-0.119 (0.01)	-0.167 (0.03)	-0.367* (0.13)	-0.390* (0.15)	-0.138 (0.02)	-0.071 (0.01)
CMJ flight time (ms)	0.206 (0.04)	0.06 (0.00)	-0.057 (0.00)	0.091 (0.01)	-0.086 (0.01)	-0.163 (0.03)	-0.134 (0.13)	-0.116 (0.01)	-0.108 (0.01)	-0.029 (0.00)
CMJ relative peak power (W/kg)	0.062 (0.00)	-0.113 (0.01)	-0.127 (0.02)	0.081 (0.01)	-0.036 (0.00)	-0.082 (0.01)	-0.404* (0.16)	-0.350* (0.12)	-0.207 (0.04)	-0.156 (0.02)
10 m sprint time (s)	0.016 (0.00)	0.122 (0.01)	0.223 (0.05)	0.213 (0.05)	0.017 (0.00)	-0.093 (0.01)	0.379* (0.14)	0.331 (0.11)	0.268 (0.07)	0.263 (0.07)
Change of direction time (s)	0.05 (0.00)	0.113 (0.01)	0.255 (0.07)	-0.063 (0.00)	0.038 (0.00)	-0.004 (0.00)	0.488* (0.24)	0.510* (0.26)	0.042 (0.00)	0.012 (0.00)
Yo-Yo IR1 distance (m)	-0.084 (0.01)	0.078 (0.01)	-0.212 (0.04)	-0.022 (0.00)	-0.092 (0.01)	0.062 (0.00)	-0.436* (0.19)	-0.361* (0.13)	0.105 (0.01)	0.184 (0.03)

*Significant at 0.05

moderately higher mean score. There were thirteen significant correlations between anthropometric and physical characteristics with individual and total FMSTM, though many were considered trivial to small.

The results highlight large to very large differences between male and female elite Touch players in all measured physical characteristics, reaffirming previous observations in team sport athletes [16, 27, 39]. Differences between males and females for CMJ [32] and Yo-Yo IR1 have been highlighted for both rugby sevens [11] and football [43]. Superior performance by males compared to females in the assessed physical characteristics are mainly explained by the sex-related differences in physiological and neuromuscular characteristics that are well-established [8, 9, 39]. For example, a higher Yo-Yo IR1 distance in male Touch players would be influenced by their higher VO_{2max} that is attributed to a greater muscle and fat free mass compared to females [9].

Whilst differences in physical characteristics agree with data reported previously, minimal between-sex difference in total FMSTM or individual scores were observed except for ASLR. Small differences were observed for deep squat, trunk-stability push-up, and rotary stability between sexes, with females scoring better in 6 of the 7 tests, and only trivial differences noted in hurdle step and shoulder mobility. Males only scored higher in the trunk-stability push-up. Much of the literature published is conflicting, and differences between sexes in the TFMSTM is highlighted mainly in active children and adolescents [1, 3]. As well as the total score (male = 15.3 ± 2.1 AU *cf.* female = 13.8 ± 1.8 AU), Anderson et al. [3] also found differences between healthy male and female school-aged athletes (13–18 years of age) in inline lunge and trunk-stability push-up, but did not find a difference between sexes for ASLR. Conversely, differences between sexes in the composite score were not observed in an adult population (18+ years of age), differences in the individual test movements of trunk-stability push-up in favour of males and ASLR in favour of females have been shown [7, 49]. Whilst similar differences with ASLR were observed in this study, it is not possible to determine the magnitude of difference within the previous studies, as appropriate descriptive statistics were not provided for each sex. Additionally, populations within these studies are not reflective of an athletic population who have likely been exposed to sport-specific training programmes. Equally, the lack of statistical difference within our study maybe attributable to the homogenous sample whereby all players complete a standardised training programme delivered by the same strength and conditioning coach as well as slightly smaller sample size than required. Overall, these findings generally agree with previous findings [3, 7, 41, 49], however it

is difficult to make direct comparisons due to the variation in statistical reporting, age and activity of the participants.

The use of movement screening to highlight deficiencies in stability, flexibility and neuromuscular function can potentially identify factors associated with injury risk and guide sport-specific training programmes. The results of this study showed that the difference in total FMS™ scores for male (16.6 AU) and female (17.7 AU) were small. However, for both groups, the total score did exceed those suggested within the literature (< 14 AU) as a suitable cut-off score for risk of injury [24, 28, 52], with only 2 individuals scoring below this value. The variation in study characteristics (activity, sex and injury definition) within the population and the cut-off range (11–18 AU) for total FMS™ score used by Trinidad-Fernandez et al. [52] highlights the need for normative data for specific sporting populations and subgroups. This is the first study in Touch offering normative data for players within the elite game that can be used to inform training programmes, selection, or talent identification as well as return to play after injury.

Much of the current literature has focused on either male or female athletes which likely reflects the single-sex nature of most team sports; however, Touch is played by both sexes individually and as a mixed team. In many team sports, these differences would be of no consequence because of same sex grouping. In Touch, female players would be competing with and against males in the mixed-sex squads. However, the lack of difference within the composite score, and small to trivial differences in individual scores, allows a comparison between mixed populations within the sport of Touch. This suggests that standardisation of normative data, training programmes and screening practices would be appropriate withing the Touch population.

In all, thirteen out of the sixty-four correlations between anthropometric and physical characteristics with total FMS™ and individual scores were deemed to be significant, which supports existing literature [34, 47, 48, 53]. The results suggest limited association overall between movement quality and physical characteristics, which may be partially explained by the speed of the execution of movement during the FMS™ compared to sporting actions. However, poor movement patterns, compensatory movements, lack of stability and control remain important measures to consider in relation to an athlete's ability to perform many tasks within training programmes that might subsequently improve on-field performance.

The observed relationships for all participants ranged from trivial to moderate. Total FMS™ was only associated with stature and 10 m sprint time, however it is important to consider the individual components. For example, trunk-stability push-up and glycolytic change of direction time had a moderate negative correlation, with 13% of the variance in time explained. These findings suggest that the core features

enabling athletes to achieve a 3-in TSPU, including upper body strength, core stability and control may transfer into stabilising the trunk whilst accelerating, decelerating, and changing direction during the glycolytic change of direction test. These findings agree with Lockie et al. [34] who also reported negative (small) correlations between the TSPU and *t*-test performance time. The difference in the magnitude in correlations could be explained by the number of accelerations (5 *cf.* 17), decelerations (4 *cf.* 13) and changes of direction (4 *cf.* 4) between this study and Lockie et al. [34]. The ASLR was associated with 6 out of 7 anthropometric and physical characteristics when considering the combined and the individual limb scores. It was negatively associated with stature, body-mass, CMJ peak power and Yo–Yo IR1, but positively associated with 10 m-sprint time and glycolytic change of direction time. Collectively these findings suggest that the components of ASLR that allow an individual to score highly on the FMS™ may negatively impact markers of athletic performance, as seen in previous research [34, 35], potentially due to increased muscle length resulting in lack of power and greater risk of fatigue. These findings may also be explained by the approach of pooling male and female participants, as all female participants achieved a 3 on ASLR and inferior physical characteristics to their male counterparts.

In summary, most of the correlations were trivial to small, but do highlight some potential sex-related differences that warrant consideration when implementing a training programme within Touch. Some of these correlations also suggest that aspects of performance could possibly be improved by addressing an individual's deficiencies in FMS™.

Limitations

Data presented in this study reflected the player pool within England at open age; however, this represents only 7.3% of the open age playing population within Northern Hemisphere, potentially limiting the generalisability of the findings. Further, we do note the slightly smaller sample size than was required for 80% statistical power suggesting emphasis should be placed on the SMDs/correlations and that the probability be interpreted with caution. Finally, it may be worth future research exploring the association between FMS™ and its individual components with anthropometric and physical characteristics, using partial correlations. That said, this is an elite sporting population, who were preparing for international competition making data collection challenging. It is also important to note that this study was cross-sectional, with data collected over a 2-day period. Changes in the anthropometric, physical and movement characteristics over the duration of a tournament or an entire Touch season remain unknown.

Conclusions

The study shows all physical characteristics were superior in males compared to their female counterparts, whilst only trivial to small associations were observed for all FMS™ tests. There were, however, trivial to moderate relationships observed for both males and females between FMS™ and the physical characteristics. This study provides normative data on anthropometric and physical characteristics as well as movement quality for elite Touch players. These data have implications for injury moderation as some athletes failed to achieve a score of 3 on various components of the FMS™. Whilst literature does provide cut-off scores for other populations concerned with injury prediction, this might not be suitable for elite Touch players as they exceed the consensus cut-off of 14, with only 14% scoring 14 or below in this study. These findings also provide scores that can be used to support the return to play of athletes after injury, be used as normative data in talent identification, and aid in the development training programmes for other Touch populations (e.g., sub-elite, juniors).

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Data Availability Data is not available publicly, however, an anonymised version can be provided upon reasonable request.

Declarations

Conflict of interest The authors report no conflict of interest.

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