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Motor Competence, Physical Fitness, Psychosocial, and Physical Activity Characteristics in 9- to 14-Year-Olds: Sex Differences and Age and Maturity Considerations

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ABSTRACT

Sex, chronological age, and maturity potentially impact multidimensional health-related characteristics (i.e. motor competence, physical fitness, psychosocial, physical activity), which adds to the challenges of reversing current youth health-related concerns. Previous research fails to optimally assess such characteristics and consider sex, age, and maturity among youth. Therefore, the aims were to 1) present the multidimensional health-related characteristics of 9–14-year-olds from the UK, 2) examine sex differences, and 3) account for the effect of age and maturity on such characteristics. Eighty-one girls (mean age = 12.8 ± 1.2 years) and 136 boys (mean age = 13.1 ± 1.2 years) were purposively sampled and assessed across each of the four health-related domains. Multiple ANCOVA analyses examined sex differences among characteristics while accounting for chronological age. Pearson's correlations were used to evaluate the associations between maturity and multidimensional health-related characteristics. Multidimensional health-related characteristics were lower than similar populations and highly variable. Boys outperformed girls on most physical measures (ES = −0.76 to 0.76), elicited greater self-determined motivation (ES = 0.36), greater perceived competence (ES = 0.54), and engaged in more vigorous physical activity (ES = 0.78). Small age effects were present across some characteristics (e.g. isometric mid-thigh pull). Associations between maturity and multidimensional health-related characteristics were different for boys and girls (e.g. maturity offset positively associated with motor competence scores in girls only). Results suggest that multidimensional health-related characteristics of 9- to 14-year-olds are a concern, and are impacted by sex, age, and maturity. Identifying methods to improve multidimensional health-related characteristics which considers sex, age, and maturity are required. Assessing multidimensional health-related characteristics across youth is recommended to inform and measure interventions.

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Health; physical education; sport; youth

The development of motor competence (i.e., an individual's ability to perform a variety of motor skills, where outcomes are influenced by movement quality, control, and coordination), physical fitness, and psychosocial (i.e., the interrelation between individual psychological traits that have social influences and how these factors guide behaviors, Gledhill et al., 2017) characteristics throughout childhood and adolescence are important for health and performance (Lloyd et al., 2016). Recent evidence suggests these characteristics are declining among youth (Sandercock & Cohen, 2019) (i.e., pre-pubertal children and circa/post-pubertal adolescents, Lloyd et al., 2015; Towlson et al., 2020), which is confounded by fewer youth meeting worldwide physical activity recommendations (Aubert et al., 2018), reduced sports participation trends (Visek et al., 2015), alongside increasing obesity rates (Health and Social Care Information Centre, 2017) and mental health conditions (Murphy et al., 2020). Whilst these concerns exist, compared to child populations, limited research is available that collectively presents the motor competence, physical fitness, psychosocial and physical activity characteristics (from this point forward referred to as multidimensional health-related characteristics) within adolescents. As highlighted by Burton et al. (2023) the aim of studies that have examined multidimensional health-related characteristics among adolescents (e.g., Britton et al., 2019), has been to examine the efficacy of the developmental model proposed by Stodden et al. (2008). This model suggests that motor competence, physical fitness, perceived competence, and physical activity interact to induce positive (healthy weight status, positive spiral of engagement) or negative (unhealthy weight status, negative spiral of disengagement) trajectories. In support of this model, Britton et al. (2019) identified that health-related fitness and perceived actual competence mediated the association between motor competence and physical activity in both directions. Similarly, Jekauc et al. (2017) highlighted that physical self-concept mediated the association between motor abilities (in this case motor competence and physical fitness) and physical activity, while Haugen et al. (2013) identified associations between physical activity and perceived athletic competence which were mediated by physical fitness

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characteristics. However, by utilizing data to examine the efficacy of the Stodden model, such studies may overlook and underreport descriptive findings. Such information is important to assess current trends, to inform the development of health-related characteristics in youth, and to provide recommendations for future research. Furthermore, these studies, along with most of the papers included in the Burton et al. (2023) systematic review assessed motor competence via process [technique] or product [outcome] measures rather than the recommended combined assessment of both process and product. Consequently, key information may be overlooked when using process or product measures in isolation (Rudd et al., 2016).

Whilst research presenting the multidimensional health-related characteristics of adolescents is important, factors including sex, chronological age, and biological maturation may compound these characteristics. For example, across stages of maturity (i.e., pre-, circa-, post-peak height velocity [PHV], Lloyd & Oliver, 2012), there is considerable inter-individual variability in the timing (i.e., the onset of change), magnitude (i.e., level of change), and tempo (i.e., rate) of biological maturation (Towlson et al., 2020). Growth rates rapidly increase during the adolescent growth spurt, with girls typically reaching PHV approximately two years before boys (Lloyd et al., 2015). Furthermore, boys experience a greater magnitude of growth, while girls undergo sex-specific physiological changes (e.g., increased fat mass, joint laxity, knee valgus angle). Consequently, the transition across stages of maturity represents a complicated period of change that can disrupt motor competence (e.g., adolescent awkwardness, Quatman-Yates et al., 2012) and increase injury risk (Murphy et al., 2003). Psychosocial maturation occurs simultaneously, which includes pre-frontal cortex executive function development (Nigg, 2017) and increased information processing ability (Strandjord & Rome, 2016). These changes suggest that youth are developing problem solving and self-evaluation techniques regarding their own physical development (Harter, 2012). However, research to date exploring the impact of sex, age, and maturity on multidimensional health-related characteristics across youth is limited. From studies which have collectively explored the Stodden et al. (2008) model, Haugen et al. (2013) compared sex differences among the associations between multidimensional health-related characteristics, while Britton et al. (2019) highlighted sex differences across individual health-related characteristics. Across two time-points, boys had greater moderate-vigorous physical activity engagement, greater object control competence, and greater physical fitness than girls (Britton et al., 2019). Jekauc et al. (2017) did not consider the effects of sex, age, or maturity on multidimensional health-related characteristics within their study. Pullen et al. (2022) did assess the effects of maturity on multidimensional health-related characteristics of adolescents. This study found that maturity offset was associated with BMI in boys and girls (negative), and with standing long jump in girls only (positive). The authors also identified sex differences in push-up and tuck jump competence, physical self-efficacy, and global self-esteem (all in favor of boys). However, this study did not include physical activity engagement (Pullen et al., 2022) among the characteristics explored. Therefore, to the authors knowledge, no previous study has collectively investigated sex differences, age, and maturity considerations across all multidimensional health-related characteristics of youth within a single cohort. Understanding the impact of compounding variables on these characteristics may help inform specific interventions to support positive outcomes for youth (Burton et al., 2023; Lloyd et al., 2015).

Based on the limitations of previous research, this study aimed to 1) present the multidimensional health-related characteristics (i.e., motor competence, physical fitness, psychosocial, and physical activity characteristics) of 9- to 14-year-olds from the United Kingdom; 2) examine sex differences; and 3) account for the effect of chronological age and biological maturity on multidimensional health-related characteristics. It is hypothesized that current multidimensional health-related characteristics of boys and girls are suboptimal, that boys will present greater scores across characteristics than girls, and that age and maturity have an influence on the multidimensional health-characteristics of youth.

Materials and methods

Participants

Two hundred and seventeen youth aged 9 to 14 years (UK school years 5–9) from one primary and one secondary state school participated in this cross-sectional study (girls $n = 81$; mean age = 12.8 ± 1.2 years; boys $n = 136$; mean age = 13.1 ± 1.2 years). This age range allowed participants to be recruited across the childhood-adolescent transition and at each stage of maturity (i.e., pre-, circa-, and post-PHV, Lloyd & Oliver, 2012). On that basis, participants were purposively sampled from a local state secondary school and one primary school that fed into the secondary school. This sampling procedure served the purpose of 1) bridging the age-gap required for each stage of maturity; and 2) maintaining a similar socioeconomic status across participants that might otherwise be different if sampling two random schools. Ethics was granted by Leeds Beckett Universities Research Ethics Committee (ref: 98965) with gatekeeper, parent, and participant consent/assent obtained.

Protocols

All participants undertook a multidimensional assessment across three PE lessons over a two-week period between June and September 2022 (1: anthropometrics, lower body power, muscular strength; 2: speed, change of direction [COD], cardiovascular endurance; 3: motor competence). At the start of each lesson, participants completed a five-minute standardized warm up (Jeffreys, 2006). Participants were given three separate questionnaires to complete on one occasion outside of PE lessons to evaluate their motivation for exercise, physical self-perceptions, and physical activity engagement.

Anthropometrics and body composition

Standing and sitting height was measured to the nearest 0.1 cm using a portable stadiometer (Seca 213, Hamburg, Germany).

Body mass, fat mass, fat-free mass (all to the nearest 0.1 kg), and body fat percentage were collected using bioelectrical impedance scales (Tanita DC-360, Tokyo, Japan). Participants were measured barefoot wearing standard PE kit (i.e., shorts and t-shirt). Similar bioelectrical impedance devices have presented excellent test-retest reliability (intraclass correlation [ICC] = 0.98) (Loenneke et al., 2013).

Stage of maturity

Standing and sitting heights, body mass and the participants' dates of birth were used to estimate maturity offset (i.e., years from PHV) via the Mirwald et al. (2002) predictive equations for boys and girls, which have a standard error of ±6 months. This method was selected due to being noninvasive, time efficient, and convenient to administer within a school context in comparison to other approaches (e.g., measuring skeletal age via a hand-wrist radiograph, clinical assessment of genital/pubic hair development, Malina et al., 2012). Age at peak height velocity (APHV) was calculated by subtracting the participants maturity offset from their chronological age.

Motor competence

Motor competence was assessed using the Dragon Challenge (Tyler et al., 2018). This continuous circuit-based assessment measures process, product, and time to complete nine fundamental movement skills (*stability*: balance bench, core agility, wobble spot; *object control*: overarm throw, basketball dribble, underarm throw and catch; *locomotor*: T-run, jumping patterns, sprint) overcoming limitations of previous motor competence assessments. Each motor skill was demonstrated prior to assessment and participants practiced each skill independently. Participants then attempted the full assessment, which was video recorded for retrospective scoring, using tripod mounted GoPro Hero9 cameras (GoPro Inc, San Mateo, USA) positioned in view of the whole circuit.

Dragon Challenge videos were scored retrospectively by four scorers. Each process criterion (two per skill) was scored zero (not achieved) or one (achieved) with the total process score ranging from 0 to 18. Each product criterion (one per skill) was scored zero (not achieved) or two (achieved) with the total product score ranging from 0 to 18. Time to complete the circuit was also converted to a score ranging from 0 to 18. The overall score is the sum of process, product, and time elements (ranging from 0 to 54). Stability, object control, and locomotor skill scores equal the sum of process and product elements from the relevant motor skills (scores range from 0 to 9 per domain). The inter-rater reliability between the four scorers was assessed across 10 randomly selected videos and was deemed good (ICC = 0.80–1.00; supplementary Table S1). The Dragon Challenge has acceptable to excellent construct validity, good concurrent validity, good test–retest reliability, and good inter- and intra-rater reliability among 10–14-year-olds (Tyler et al., 2018).

Muscular strength

Full body muscular strength (i.e., isometric mid-thigh pull [IMTP]) was measured using a dynamometer (T.K.K.5402, Takei Scientific Instruments Co. Ltd, Niigata, Japan) attached to a wooden platform, as this approach provides a safe and reliable measure of maximal force production among similarly aged youth (Moeskops et al., 2018; Till et al., 2018). Following the validated protocol outlined by Till et al. (2018) participants stood on the wooden platform over the dynamometer in a hip-width stance. Participants assumed a shoulder-width, double overhand grip on a latissimus pulldown bar (attached to the dynamometer via a chain) and were positioned on each repetition to represent the second pull phase of the power clean (shoulders placed over the bar which was in a mid-thigh position with knees and hips slightly flexed). Prior to pulling, participants maintained tension with the bar and chain to prevent a jerking action, and were then instructed to pull maximally and as quick as possible after a 3-s countdown. Participants performed one familiarization trial, followed by two maximal efforts. Peak force (N) was calculated using the highest score in a correction equation (Till et al., 2018). Relative peak force ($N{\cdot}kg^{-1}$) was calculated by dividing peak force by body mass. The peak force ICC and coefficient of variation (CV) were 0.94 and 5.3% (boys = 0.94 and 5.8%; girls = 0.95 and 4.2%). The ICC and CV for relative peak force was 0.94 and 5.3% (boys = 0.93 and 5.6%; girls = 0.93, 4.5%).

Lower body power

Lower body power was assessed via a countermovement jump (CMJ) using the Optojump Next photocell system (Microgate Bolzano, Italy) to the nearest 0.1 cm. Participants stood with their legs fully extended, feet at a self-selected width, and hands on their hips and were instructed to jump as high as possible, with no attempt to control the depth or speed of the countermovement. During the flight, participants kept their hands on their hips and their legs extended (Glatthorn et al., 2011). Two warm-up jumps were completed, before two maximal efforts. The CMJ measured by the Optojump system has demonstrated good concurrent validity compared to force plates (ICC > 0.90), and test–retest reliability (ICC > 0.90, CV < 4%) (Glatthorn et al., 2011). The ICC and CV for jump height were 0.88 and 9.3% (boys = 0.89 and 9.5%; girls = 0.83 and 8.8%).

Speed and change of direction

Speed and COD were measured via the 5-0-5 agility test, using Witty photocell timing gates (Microgate, Bolzano, Italy). Photocell technology presents a small typical error of the estimate for 10 m sprint (2.5%) and 505 COD times (left = 4.1%, right = 5.4%) (Sawczuk et al., 2017). The 5-0-5 test also presents acceptable reliability (CV < 4%) among boys (Dugdale et al., 2019) and girls (Emmonds et al., 2018) and is validated against other change of direction measures (e.g., T-run, Illinois test; $r > 0.60$, Stewart et al., 2014). Participants started 0.5 m behind the first timing gate, at a self-selected time, and sprinted maximally through a second timing gate at 10 m. Participants continued sprinting maximally, before decelerating and planting their foot at a 15 m marker, and turning 180° to sprint back 5 m through the timing gates at the 10 m marker (Sawczuk et al., 2017). Two full trials were conducted (one turn on each foot). The fastest 10 m time, and the average COD time (to the nearest 0.01 s) between left and right foot attempts were used for analysis. For the 10 m sprint, the ICC and CV were 0.87 and 3.6% (boys = 0.90 and 3.4%;

girls = 0.76 and 4.0%). The ICC and CV for the 5-0-5 test was 0.70 and 5.3% (Boys = 0.77 and 4.9%; girls = 0.54, 5.9%).

Cardiovascular endurance

Cardiovascular endurance was assessed using the multi-stage fitness test (MSFT, Leger et al., 1998). Participants ran 20 m shuttles at a pace dictated by audio beeps, which increased running velocity by 0.5kph every minute. When participants failed to reach the end lines in time with two consecutive audio beeps, their test was terminated. The number of completed levels and shuttles were recorded, and converted to total distance covered (i.e., total shuttles × 20 m distance) for analysis. The MSFT is a reliable and valid measure of cardiovascular endurance in adolescents, is time-efficient for assessing large groups, and is used in large scale surveillance research (Ortega et al., 2023).

Motivation for exercise

Motivation for exercise was evaluated via the Behavioural Regulation in Exercise Questionnaire-2 (BREQ-2, Markland & Tobin, 2004). The BREQ-2 evaluates intrinsic (four items; e.g., "I exercise because it's fun"), identified (four items; e.g., "I value the benefits of exercise"), introjected (three items; e.g., "I feel guilty when I don't exercise"), and external (four items; e.g., "I exercise because other people say I should") regulations, as well as amotivation (four items; e.g., "I don't see why I should have to exercise") using a 5-point Likert scale (0="Not true for me" 4 = "Very true for me"). The mean of the items was calculated for each subscale. All subscales present acceptable factorial validity and reliability has been previously reported among adolescents (Gillison & Standage, 2005). The internal consistency (Cronbach alphas) of each subscale ranged from 0.73 to 0.83 in this cohort.

Physical self-perceptions

Physical self-perceptions were evaluated using the physical self-perception profile (PSPP, Fox & Corbin, 1989). The PSPP has five, six-item scales which evaluate global self-esteem, perceived sports competence, perceived physical condition, perceived body image, and perceived physical strength. Exploratory and confirmatory factor analysis shows that all items of the PSPP contributed well to each subscale (Fox & Corbin, 1989). Moreover, the PSPP has good reliability and stability (coefficient alphas = 0.81–0.91; test–retest reliability = 0.74–0.92). The Cronbach alphas for the PSPP subscales ranged from 0.81 to 0.84 in this cohort.

Physical activity engagement

The Adolescent Physical Activity Recall Questionnaire (APARQ, Booth et al., 2002) was utilized to assess physical activity engagement. The APARQ presents acceptable validity and good reliability (weighted kappa = 0.44–0.89; percentage agreement = 67–97%) in adolescents (Booth et al., 2002). Participants were required to record the frequency, duration, and type of any organized (i.e., regular training, practice, or competition, which is somewhat supervised by adults) and unorganized (i.e., unsupervised activities that do not involve training or competition, e.g., casual ball games, walking) physical activities that they participate in during a normal week for summer and winter. Frequency, duration, and type of physical activity for summer and winter was calculated. Activities were assigned MET values (1 MET = 3.5 mL of oxygen·kg^{-1} body weight·min^{-1}) using an up-to-date compendium of physical activities (Ainsworth et al., n.d.). Summer and winter physical activity was averaged for low, moderate, moderate-vigorous (MVPA) and vigorous physical activity.

Statistical analysis

Means and 95% confidence intervals (95% CIs) are presented separately for boys and girls across all characteristics. Multiple analysis of covariance (ANCOVA) were conducted to determine sex differences (independent variable) across multidimensional health-related characteristics (dependent variables) while controlling for chronological age (covariate). Where age had an insignificant effect on model outcomes, the covariate was removed from the model (Owen et al., 2022). Maturity offset was not included in the models due to sex differences in maturity. Normality of residuals were checked visually via Q-Q plots. Where a model presented non-normality of residuals, the dependent variable underwent log transformation prior to analysis and was subsequently back transformed to interpret the results. Collinearity of fixed effects were assessed using a variable inflation factor (values >5 indicated substantial collinearity). The estimated effect of age and the 95% were reported for each dependent variable and should be interpreted as the effect of a one-unit change in age on the estimated means. Post-hoc pairwise comparisons were conducted using Tukey's Honest Significant Difference adjustment to identify differences between boys and girls for each dependent variable while controlling for type I error. Cohen's d effect sizes (ES) were also reported as: <0.2 (trivial), 0.2 (small), 0.6 (moderate), 1.2 (large), >2.0 (very large) (Hopkins et al., 2009). Pearson's correlation coefficients (r) were calculated to identify the association between dependent variables, maturity offset and APHV for boys and girls and were reported as: <0.10 (trivial), 0.10 (small), 0.30 (moderate), 0.50 (high), 0.70 (very high), and >0.90 (nearly perfect) (Hopkins et al., 2009). All data analysis was conducted in R (version 4.3.16, R Core Team, Vienna, Austria) using the performance (Lüdecke et al., 2021) and emmeans packages (Lenth, 2023).

Results

Table 1 presents the multidimensional health-related characteristics of 9–14-year-old boys and girls and the sex differences while controlling for chronological age. When controlling for chronological age, mean motor competence combined scores (the sum of process, product, and time scores) were 35.3 points (95% CI = 34.4–36.3 points) for boys, and 33.5 points (95% CI = 32.2–34.8 points) for girls. Isometric mid-thigh pull scores were 1355N (95% CI = 1315–1396N) for boys, and 1293N (95% CI = 1243–1344N) for girls, which equated to relative scores of 28.6N.kg^{-1} (95% CI = 27.8–29.5N.kg^{-1}) and 25.3N.

Table 1. Sex differences in multidimensional health characteristics (accounting for age), and the associations between maturation and health-related characteristics in 9- to 14-year-olds.

Multidimensional health-related characteristics	Estimated marginal means: Boys (95% CI)	Estimated marginal means: Girls (95% CI)	Boys vs. girls: Difference	Boys vs. girls: Effect size	Boys vs. girls: P value	Age (covariate): Estimated effect (95% CI)	Age (covariate): P value
Motor competence							
Dragon Challenge combined score	35.3 (34.4, 36.3)	33.5 (32.2, 34.8)	1.8 (5.2%)	0.35 (Small)	.03*	1.04 (0.43, 1.66)	0.01*
Dragon Challenge process score	12.1 (11.7, 12.5)	10.9 (10.4, 11.5)	1.2 (10.4%)	0.54 (Small)	<.01**	N/A	0.09
Dragon Challenge product score	10.5 (9.96, 11.10)	10.7 (9.89, 11.40)	−0.2 (−1.9%)	−0.05 (Trivial)	.77	0.44 (0.09, 0.80)	0.02*
Dragon Challenge completion time (s)	126 (123, 129)	135 (130, 139)	−9.0 (−6.9%)	−0.53 (Small)	<.01**	−2.6%[a] (−4.1%, −1.2%)	<0.01**
Dragon Challenge Stability score	5.2 (4.7, 5.7)	5.8 (5.1, 6.5)	−0.6 (−10.9%)	−0.21 (Small)	.19	N/A	0.45
Dragon Challenge object control score	8.6 (8.2, 9.0)	7.2 (6.6, 7.8)	1.4 (17.7%)	0.61 (Moderate)	<.01**	0.47 (0.20, 0.74)	<0.01**
Dragon Challenge locomotor score	8.8 (8.5, 9.2)	8.6 (8.2, 9.1)	0.2 (2.3%)	0.11 (Trivial)	.51	N/A	0.46
Physical fitness							
Body mass (kg)	48.5 (46.9, 50.2)	52.4 (50.1, 54.8)	−3.9 (−7.7%)	−0.38 (Small)	<.01**	11.2%[a] (8.6%, 13.8%)	<0.01**
Body composition (%)	14.5 (13.6, 15.5)	23.5 (21.6, 25.6)	−9.0 (−47.4%)	−1.23 (Large)	<.01**	−5.0%[a] (−9.1%, −0.6%)	0.03*
Fat mass (kg)	7.1 (6.4, 7.8)	12.4 (10.9, 14.0)	−5.30 (−54.6%)	−1.00 (Moderate)	<.01**	N/A	0.07
Lean mass (kg)	40.7 (39.7, 41.7)	39.0 (37.8, 40.3)	1.7 (4.3%)	0.28 (Small)	.048*	11.8%[a] (9.9%, 13.6%)	<0.01**
Isometric mid-thigh pull (N)	1355 (1315, 1396)	1293 (1243, 1344)	62 (4.7%)	0.26 (Small)	0.60	11.5%[a] (9.2%, 13.7%)	<0.01**
Relative isometric mid-thigh pull ($N \cdot kg^{-1}$)	28.6 (27.8, 29.5)	25.3 (24.2, 26.5)	3.3 (12.2%)	0.64 (Moderate)	<.01**	N/A	0.83
Countermovement jump height (cm)	24.9 (24.0, 25.9)	22.2 (20.9, 23.4)	2.7 (11.5%)	0.45 (Small)	<.01**	1.85 (1.22, 2.49)	<0.01**
10 m sprint time (s)	2.10 (2.07, 2.13)	2.21 (2.18, 2.25)	−0.11 (−5.1%)	−0.76 (Moderate)	<.01**	−2.50%[a] (−3.3%, −1.6%)	<0.01**
Average 505 change of direction time (s)	2.88 (2.84, 2.92)	2.98 (2.92, 3.03)	−0.10 (−3.4%)	−0.45 (Small)	<.01**	N/A	0.94
Multistage fitness test distance (m)	799 (727, 876)	517 (442, 599)	−282 (42.9%)	0.76 (Moderate)	<.01**	N/A	0.12
Psychosocial							
Controlled regulations	1.19 (1.06, 1.33)	1.29 (1.12, 1.46)	−0.10 (−8.1%)	−0.15 (Trivial)	.37	N/A	0.88
Self-determined regulations	3.00 (2.86, 3.13)	2.75 (2.56, 2.93)	0.25 (8.7%)	0.36 (Small)	.01*	N/A	0.08
Global self-esteem	16.9 (16.2, 17.7)	15.2 (14.2, 16.2)	1.7 (10.6%)	0.49 (Small)	<.01**	N/A	0.45
Perceived sports competence	17.0 (16.1–17.8)	15.0 (14.0–15.9)	2.0 (12.5%)	0.54 (Small)	<.01**	N/A	0.86
Perceived physical condition	16.9 (16.1–17.7)	15.6 (14.7–16.5)	1.3 (8.0%)	0.36 (Small)	.04*	N/A	0.59
Perceived body image	14.9 (14.0–15.7)	13.6 (12.6–14.6)	1.3 (9.1%)	0.33 (Small)	.06	N/A	0.57
Perceived physical strength	16.2 (15.4–17.1)	14.6 (13.6–15.6)	1.6 (10.4%)	0.42 (Small)	.02*	N/A	0.93
Physical activity							
Average moderate physical activity ($mins \cdot week^{-1}$)	254 (205, 309)	291 (225, 365)	−37 (−13.6%)	−0.14 (Trivial)	.33	N/A	0.77
Average vigorous physical activity ($mins \cdot week^{-1}$)	390 (323, 463)	164 (112, 226)	226 (81.6%)	0.78 (Moderate)	<.01**	N/A	0.42
Average moderate-vigorous physical activity ($mins \cdot week^{-1}$)	733 (644, 827)	506 (416, 607)	227 (36.6%)	0.54 (Small)	<.01**	N/A	0.90

Note. 95% CI = 95% confidence interval; *$p < .05$; **$p < .01$. [a]Estimated effect of age on log transformed dependent variable, represented as the percentage change in the dependent variable for every one unit change in age. N/A = age covariate removed from the model due to insignificant effect.

kg^{-1} (95% CI = 24.2–26.5N.kg^{-1}), respectively. During the MSFT, mean distance was 799 m (95% CI = 727–876 m) for boys and 517 m (95% CI = 422–599 m) for girls. Boys and girls presented more self-determined regulations (boys = 3.0AU, girls = 2.8AU) than controlled regulations (boys = 1.2AU, girls = 1.3AU). Mean global self-esteem scores were 16.9AU (95% CI = 16.2–17.7AU) for boys, and 15.2AU (95% CI = 14.2–16.2AU) for girls. Mean MVPA was 733 mins.$week^{-1}$ for boys (95% CI = 644–827 mins.$week^{-1}$) and 506 mins.$week^{-1}$ (95% CI = 416–607 mins.$week^{-1}$) for girls.

Table 2 presents the associations between maturity offset and APHV with each characteristic for boys and girls.

Table 2. The associations between maturation and multidimensional health-related characteristics in 9- to 14-year-olds.

	Correlation coefficients *(p value)*			
	Years from PHV		*Age at PHV*	
Multidimensional health-related characteristics	*Boys*	*Girls*	*Boys*	*Girls*
Motor competence				
Dragon Challenge combined score	0.02 (0.79)	0.40 (<0.01**)	0.18 (0.06)	0.16 (0.21)
Dragon Challenge process score	−0.03 (0.78)	0.29 (0.02*)	0.13 (0.18)	0.03 (0.80)
Dragon Challenge product score	−0.03 (0.76)	0.34 (0.01*)	0.17 (0.07)	0.17 (0.19)
Dragon Challenge completion time (s)	−0.17 (0.07)	−0.25 (0.05)	−0.14 (0.14)	−0.24 (0.07)
Dragon Challenge Stability score	−0.11 (0.25)	0.15 (0.24)	0.11 (0.23)	0.34 (0.01*)
Dragon Challenge object control score	0.15 (0.11)	0.42 (<0.01**)	0.10 (0.27)	−0.01 (0.93)
Dragon Challenge locomotor score	−0.06 (0.56)	0.18 (0.18)	0.12 (0.22)	0.01 (0.91)
Physical fitness				
Body mass (kg)	0.80 (<0.01**)	0.70 (<0.01**)	−0.44 (<0.01**)	−0.30 (0.01*)
Body composition (%)	−0.12 (0.17)	0.31 (0.01*)	−0.29 (<0.01**)	−0.32 (<0.01**)
Fat mass (kg)	0.25 (<0.01**)	0.50 (<0.01**)	−0.40 (<0.01**)	−0.31 (<0.01**)
Lean mass (kg)	0.93 (<0.01**)	0.83 (<0.01**)	−0.38 (<0.01**)	−0.26 (0.02*)
Isometric mid-thigh pull (N)	0.77 (<0.01**)	0.61 (<0.01**)	−0.22 (0.01*)	−0.09 (0.45)
Relative isometric mid-thigh pull (N·kg^{-1})	−0.05 (0.60)	−0.23 (0.04*)	0.19 (0.03*)	0.30 (0.01*)
Countermovement jump height (cm)	0.39 (<0.01**)	0.26 (0.03*)	0.09 (0.34)	0.18 (0.14)
10 m sprint time (s)	−0.52 (<0.01**)	−0.10 (0.40)	0.06 (0.53)	−0.19 (0.11)
Average 505 change of direction time (s)	−0.05 (0.60)	0.13 (0.28)	−0.01 (0.89)	0.21 (0.09)
Multistage fitness test distance (m)	0.09 (0.32)	−0.04 (0.74)	0.08 (0.41)	0.26 (0.03*)
Psychosocial				
Controlled regulations	−0.09 (0.33)	0.28 (0.02*)	−0.12 (0.23)	0.12 (0.39)
Self-determined regulations	−0.09 (0.37)	−0.10 (0.44)	−0.05 (0.63)	0.07 (0.60)
Global self-esteem	−0.15 (0.19)	−0.14 (0.31)	0.10 (0.41)	0.26 (0.06)
Perceived sports competence	0.03 (0.81)	−0.11 (0.41)	0.07 (0.54)	0.13 (0.33)
Perceived physical condition	0.00 (1.00)	0.03 (0.85)	−0.03 (0.81)	0.32 (0.02*)
Perceived body image	0.00 (0.99)	0.04 (0.76)	−0.05 (0.67)	0.29 (0.03*)
Perceived physical strength	0.13 (0.25)	−0.12 (0.40)	−0.18 (0.13)	−0.02 (0.90)
Physical activity				
Average moderate physical activity (mins·week^{-1})	0.04 (0.70)	−0.07 (0.60)	0.02 (0.84)	0.17 (0.17)
Average vigorous physical activity (mins·week^{-1})	−0.19 (0.06)	0.11 (0.39)	0.04 (0.68)	0.25 (0.05)
Average moderate-vigorous physical activity (mins·week^{-1})	−0.12 (0.22)	0.03 (0.81)	0.05 (0.65)	0.30 (0.02*)

Note. *$p < .05$; **$p < .01$. PHV = Peak height velocity.

Sex differences in multidimensional health-related characteristics

Sex differences were found across several health-related characteristics. Boys outperformed girls for Dragon Challenge process, time, object control, and combined scores (ES = −0.53 to 0.61). Boys were lighter, had lower body fat percentage, lower fat mass, and greater fat-free mass than girls (ES = −1.23 to 0.28). For physical fitness, boys outperformed girls for relative peak force, CMJ, speed, COD, and MSFT (ES = −0.76 to 0.64). For psychosocial measures, boys presented greater self-determined motivation for physical activity, global self-esteem, and perceived sports competence, physical condition, and physical strength (ES = 0.36–0.54). Boys also spent more time participating in vigorous, and moderate-vigorous physical activities than girls (ES = 0.54–0.78).

The effect of chronological age on multidimensional health-related characteristics

Positive age effects were found for Dragon Challenge combined, product, time, and object control scores, body composition (except for body fat percentage), peak force, CMJ, and self-determined regulation; a negative age effect was present for speed. No age effects were identified for any other characteristic.

Associations between maturity offset and multidimensional health-related characteristics

Maturity offset had significant small to moderate positive associations with Dragon Challenge combined, process, product, and object control scores in girls ($r = 0.29$–0.42), but no association with Dragon Challenge scores in boys. All weight status variables were positively associated (small to large) with maturity offset in boys ($r = 0.25$–0.80) and girls ($r = 0.31$–0.83) except for body fat percentage in boys ($r = -0.12$). Both sexes had a large positive association between maturity offset and peak force (boys $r = 0.77$; girls $r = 0.61$), while there was a small negative association between maturity offset and relative peak force in girls ($r = -0.23$). The association between CMJ and maturity offset was positive in girls ($r = 0.26$; small), and boys ($r = 0.39$; moderate). There was a moderate negative association between maturity offset and speed in boys ($r = -0.52$). Finally, girls presented a small positive association between controlled regulations and maturity offset ($r = 0.28$).

Associations between age at peak height velocity and multidimensional health-related characteristics

Stability/balance score was the only Dragon Challenge variable associated with APHV in girls ($r = 0.34$) with none associated in boys. All weight status variables presented significant small to moderate negative associations with APHV in both sexes (boys r = −0.29 to −0.44; girls r = −0.26 to −0.32). Peak force had a small negative association with APHV in boys (r = −0.22), while relative peak force had a small (boys r = 0.19) and moderate (girls r = 0.30) positive association with APHV. There was a small positive association between girls APHV and MSFT distance (r = 0.26). Perceived physical condition (moderate positive; r = 0.32) and perceived body image (small positive; r = 0.29) were the only psychosocial variables associated with APHV in girls. Moderate-vigorous physical activity was moderately and positively associated with APHV in girls (r = 0.30).

Discussion

This study aimed to 1) present the multidimensional health-related characteristics (i.e., motor competence, physical fitness, psychosocial, and physical activity) of youth; 2) examine sex differences; and 3) account for the effect of chronological age and biological maturation. To the authors' knowledge, no previous study has presented the multidimensional health-related characteristics of youth using a combined assessment of motor competence while accounting for age and maturity. Results indicate that the multidimensional health-related characteristics (e.g., motor competence) of this cohort are low compared to similar populations, which is impacted by sex, age, and maturity.

Multidimensional health related characteristics

This study is one of the first to present multidimensional health-related characteristics across four domains (i.e., motor competence, physical fitness, psychosocial characteristics, physical activity). From the data presented, there is evidence indicating that multidimensional health-related characteristics are low among 9- to 14-year-old boys and girls. For example, with the Dragon Challenge, a combined product and process motor competence assessment, scores were lower (boys = 35.3, girls = 33.5) than upper tertial values (i.e., combined score > 37) of a comparable Welsh sample (Stratton et al., 2015) supporting other studies showing low motor competence among similarly aged youth (e.g., Pullen et al., 2022). Similarly, findings from the MSFT showed that boys and girls covered a mean distance of 799 and 517 m, respectively. Compared to European surveillance data, these distances align with the 50th percentile of similarly aged youth (Ortega et al., 2023) with the UK ranking 15th out of 30 countries for MSFT performance (Ortega et al., 2023). Furthermore, boys (2.10 s) and girls (2.21 s) presented lower 10 m sprint times compared to separate samples of boys (1.96s, Pichardo et al., 2019) and girls (2.06s, Sommerfield et al., 2022) from New Zealand, whilst girls perceived competence was lower in this sample (15.0 vs. 16.7AU) compared to similarly aged Australian girls (Rogers et al., 2018). Both boys and girls presented lower physical activity engagement (733 [boys] and 505 [girls] mins.week^{-1} vs. 845 mins.week^{-1}) compared to Australian boys and girls (Barnett et al., 2011).

High variability was also present across multidimensional health-related characteristics. For example, 95% CI's appeared to be large across some characteristics (e.g., relative strength boys = 27.8–29.5N·kg^{-1}, girls = 24.2–26.5N·kg^{-1}; global self-esteem boys = 16.2–17.7AU, girls = 14.2–16.2AU; MVPA boys = 644–827 mins.week^{-1}, girls = 416–607 mins.week^{-1}), which mirrors similar populations (e.g., Barnett et al., 2011). However, the current study sampled boys and girls across numerous age groups, which increases sample heterogeneity. Nevertheless, the variability highlighted across youth multidimensional health-related characteristics shows that youth are very different, meaning an individual approach is required to maximize health outcomes. Such variability among youth signifies the challenge that PE and sport face when attempting to provide well-rounded curricula and may explain why a gap exists within the UK's PE curricula (i.e., technical and tactical focus over multidimensional health-related characteristics). Moreover, if similar gaps exist across multiple contexts, youth may experience fewer opportunities to enhance their multidimensional health-related characteristics. Together, these descriptive findings indicate that several health problems and challenges are present among this cohort 9–14-year-olds which may exist among other youth contexts. Therefore, this study highlights the importance of regularly assessing multidimensional health-related characteristics in order to understand the current health status of youth, and to inform and monitor future interventions.

Sex differences

The participants within this study included mainly circa- (48%) and post-PHV (47%) girls, and pre- (47%) and circa-PHV (50%) boys. During circa-PHV, sex differences in neuromuscular strength, power, and coordination emerge in favor of boys (Beunen & Malina, 1988). Current findings demonstrated sex differences, when controlling for chronological age, whereby boys had greater motor competence, physical fitness, motivation, self-esteem, and perceived competence alongside increased vigorous and moderate-vigorous physical activity. This is consistent with previous research evidence (e.g., Britton et al., 2019). Motor competence and physical fitness differences likely reflect hormonal changes in girls that leads to sex-specific fat and muscle mass distribution (Roemmich & Rogol, 1995) and consequently reduced relative strength (Quatman et al., 2006) during adolescence. Previous evidence among children suggests that those who lack sufficient strength may present lower competence during playground and sports-based movement skills (Hands, 2008). Youth who have fewer opportunities to develop motor competence and strength may also be less physically active throughout life (Faigenbaum et al., 2013). Motor competence and fitness differences within the present sample may therefore explain why boys showed greater psychosocial and physical activity characteristics than girls. In addition, these sex difference may be due to non-biological factors such as an individual's social and physical environment that may impact engagement in physical activity (Sherar et al., 2010). Understanding sex differences is vital to start to understand the multidimensional health-related characteristics of youth and therefore make appropriate interventions to support the development of these characteristics in boys and girls. However, further research is required to better understand the relationships across all domains for boys and girls (e.g., motor competence vs. psychosocial characteristics) to understand this complex topic (Burton et al., 2023).

Age effect on multidimensional health-related characteristics

Small age effects were found for motor competence (combined, product, time, and object control scores), weight status (body mass, body composition, lean mass), and physical fitness (peak force, CMJ, sprint time). Developmental trajectories suggest that motor competence is dependent upon multiple internal (e.g., biological) and external (e.g., social) factors, with development requiring structured programs and diverse physical activity experiences (Hardy et al., 2010). Strength progresses linearly for boys and girls pre-PHV but during puberty, boys experience accelerated strength increases while girls progress at pre-pubertal rates (Bergeron et al., 2015; Lloyd & Oliver, 2012). Cardiovascular endurance development is mainly linear for 8–18-year-old boys, whereas girls experience a plateau by their mid-teens (Bergeron et al., 2015). Previous theory suggests that children lack the ability to accurately determine their motor competence (Goodway & Rudisill, 1997) compared to adolescents (Harter, 1999) likely due to psychosocial maturation (Nigg, 2017; Strandjord & Rome, 2016). Moreover, self-determination theory suggests that increased competence is a requirement for obtaining autonomous motivation (Deci & Ryan, 2000). Consequently, older individuals may present more autonomous motivation due to their enhanced ability to determine their own competence. Based on these developmental trajectories and the small age effects presented across youth multidimensional health-related characteristics, targeted interventions are required to maximize developmental outcomes. Understanding the relationships between multidimensional health-related characteristics while accounting for chronological age and maturity will be important because stronger relationships between characteristics may indicate where further interventions are required across youth. For example, during adolescence, motor competence is positively associated with several physical fitness components (Burton et al., 2023). Consequently, resistance training interventions may be beneficial as they have positive effects on numerous physical fitness measures (e.g., strength, power, throwing) among children and adolescents (strongest for adolescents) (Lesinski et al., 2020).

Associations between multidimensional health-related characteristics and maturity status

Maturity offset was positively associated with combined, process, product, and object control motor competence scores in girls, while no associations were identified in boys. These findings support previous research in boys (Pichardo et al., 2019) but not in girls (Pullen et al., 2022). Although central nervous system and motor competence changes occur at different stages (de Graaf-Peters & Hadders-Algra, 2006) central nervous system development is key for motor competence progression (Dayan & Cohen, 2011). From the onset of puberty, peak synapse elimination occurs along with physical signs of neuromuscular disfunction (de Graaf-Peters & Hadders-Algra, 2006). Within this study, girls were more mature than boys. Subsequently, it is plausible that girls had experienced these central nervous system changes, allowing for their motor competence to progress. Moreover, a study of adolescent male footballers highlighted that post-PHV scores were higher than pre- and circa-PHV (Ryan et al., 2018). This adolescent awkwardness (Quatman-Yates et al., 2012) among pre- and circa-PHV boys may partially explain the trivial associations identified between maturity offset and Dragon Challenge scores. Therefore, practice, encouragement, and instruction is recommended in order for youth to progress their motor competence (Clark & Metcalfe, 2002; Gallahue & Ozmun, 2006).

Among girls, APHV had a moderate positive association with stability/balance scores, suggesting that later maturing girls have greater stability/balance competence compared to earlier maturing girls. During adolescence, weight status is negatively associated with stability/balance competence (Burton et al., 2023). Indeed, in this study, APHV was negatively associated with weight status variables in girls. Therefore, a clear link exists between weight status, maturation, and stability/balance development which is important for PE teachers, sports providers, researchers, and others to consider when designing interventions for girls transitioning across stages of maturity.

Among girls only, APHV was positively associated with perceived physical condition, perceived body image and MVPA. These positive associations suggest that earlier maturing girls have lower perceptions of physical fitness and body image, resulting in less weekly MVPA engagement compared to later maturing girls. Such findings are understandable as earlier maturing girls will have experienced the hormonal and physiological changes associated with female peak growth (e.g., sex-specific distribution of fat and muscle mass) (Roemmich & Rogol, 1995). Furthermore, research shows that increased weight status is associated with reduced cardiovascular endurance (Petrovics et al., 2020) self-perceptions (Pullen et al., 2022) and physical activity engagement (Garcia-Hermoso & Marina, 2017). Therefore, understanding maturity-related changes among girls is important for mitigating negative perceptions, increasing physical activity, and enhancing health-related outcomes.

Strengths and limitations

This study provides a broad overview of multidimensional health-related characteristics across youth but has some limitations. Firstly, pre-PHV girls and post-PHV boys were underrepresented compared to other stages of maturity. Secondly, this study represents one primary and one secondary school cohort meaning that findings cannot be generalized. Future research should investigate such characteristics across multiple contexts (e.g., state/independent schools, grassroots/professional sport). Nonetheless, the present study contributes to the international priority of surveying multidimensional health-related characteristics (Lang et al., 2023) provides comprehensive youth data, and mitigates for limitations of previous literature by utilizing a combined motor competence assessment (process and product).

Practical applications

Several practical applications can be adopted from this study. Firstly, the multidimensional health-related characteristics of 9- to 14-year-old boys and girls are low, which adds evidence to the problem of declining health among today's youth. For example, motor competence is low among the present sample of boys and girls. A recent survey of physical education teachers showed that fewer motor competencies are perceived as important during circa- and post-PHV compared to pre-PHV (Burton et al., 2022) which may contribute to this finding. Therefore, interventions such as upskilling PE teachers (McGrane et al., 2018), strength and conditioning (Pullen et al., 2020), or implementing motor competence-based curriculums (e.g., MOGBA, Morley et al., 2021; RAMPAGE, Till et al., 2021) may be beneficial as these have been shown to improve motor competence among youths. Secondly, study findings highlight how age and maturity influence multidimensional health-related characteristics, which could inform the timing of interventions to develop these characteristics (e.g., motor competence development across stages of maturity in boys; stability/balance interventions in circa-PHV girls). Thirdly, the high variability presented across multidimensional health-related characteristics signifies the challenges faced by PE and sport policy makers. This challenge is compounded by sex differences among multidimensional health-related characteristics and maturity-related considerations meaning that boys and girls have different needs across childhood and adolescence. Such differing needs should therefore be reflected within any intervention. Finally, this study highlights the importance of assessing health-related characteristics across youth and provides a comprehensive testing battery for assessing these characteristics within youth contexts. Future research should consider assessing relationships between multidimensional health-related characteristics while accounting for sex, age, and maturity, as well as longitudinal methods and surveillance-based research among larger cohorts.

Conclusion

This study aimed to 1) present the multidimensional health-related (i.e., motor competence, physical fitness, psychosocial, and physical activity) characteristics among youth; 2) examine sex differences; and 3) account for the effect of chronological age and biological maturity. Findings showed that multidimensional health-related characteristics (e.g., motor competence, cardiovascular endurance) are low compared to similar populations, and that there is high variability among youth multidimensional health-related characteristics. Sex differences showed that boys outperformed girls on most physical measures, and that they presented greater self-determined motivation, greater physical self-perceptions, and engaged in more vigorous physical activities compared to girls. The effect of age, and associations between maturation and multidimensional health-related characteristics suggest that youth need exposure across all domains to enhance health outcomes. Combined, these findings highlight the need to continually develop motor competence across youth, while boys and girls may have different health-related needs. Therefore, assessing youth multidimensional health-related characteristics is recommended to better inform intervention decision-making.

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Data availability statement

The data that supports the findings of this study are available from the corresponding author, AB, upon reasonable request.

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