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Title: A Cross-Sectional Study on the Deprivation and Sex Differences in Health-Related Fitness Measures in School Children

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ABSTRACT:

The aim of this study was to investigate deprivation and sex differences in selected health-related fitness measures in 9-12-year-old children. Data were captured on 3,407 children (49.3% boys; aged 10.5±0.6 years) as part of the serial Swan-Linx programme between 2013-2017. Three components of health-related fitness were measured, namely cardiorespiratory fitness (20m multistage shuttle run test; 20m MSRT), muscular strength (handgrip strength) and body mass index (stature and body mass; BMI). Participants' home postcodes were used to calculate Welsh Index of Multiple Deprivation (WIMD) scores, and to split participants into quintile groups. A two-way Analysis of Variance examined differences in BMI z-score by sex and WIMD quintiles. Two-way Analysis of Covariances investigated the effect of sex and WIMD quintiles on grip strength, adjusting for BMI z-score, and on shuttles achieved in the 20m MSRT, adjusting for maturation. Independent of sex, children in the middle quintile had a significantly higher mean BMI z-score (p=0.029) than their least deprived counterparts. There was a significant increase in grip strength (p=0.005) and 20m MSRT (boys p<0.001; girls p=0.028) between most and least deprived quintiles. Significant differences in 20m MSRT score were more apparent with decreases in deprivation in boys. The present study was one of the first large-scale studies to investigate differences in BMI, muscular strength and cardiorespiratory fitness by sex and different levels of deprivation. Overall, results showed that inequalities exist and should be used to inform focused services and interventions to improve current and future health inequalities.

Key words: cardiorespiratory fitness, muscular strength, body mass index, socioeconomic status, deprivation, children

INTRODUCTION:

The World Health Organization defines health inequalities as "the differences in health status or in the distribution of health determinants between different population groups"(World Health Organization, 2019, p.2). Health is not equally spread across UK society, with children from deprived areas at a higher risk of poor health (Public Health Wales Observatory, 2013), including poor health-related fitness outcomes (Brophy, Rees, Knox, Baker, & Thomas, 2012; Charlton et al., 2014; Nevill, Duncan, Lahart, & Sandercock, 2017; Noonan, Boddy, Knowles, & Fairclough, 2016, 2017; Noonan & Fairclough, 2018; Pearce et al., 2019). In children, many studies have reported strong associations between health-related fitness outcomes, including low cardiorespiratory fitness (McMurray & Andersen, 2010; Ortega, Ruiz, Castillo, & Sjöström, 2008; Ruiz et al., 2009), low muscular strength/fitness (Ortega et al., 2008; Ruiz et al., 2009; Volaklis, Halle, & Meisinger, 2015), and high body mass index (Griffiths, Parsons, & Hill, 2010; L'Allemand-Jander, 2010; Ruiz et al., 2009), with metabolic and cardiovascular disease risk, mental health problems, reduced quality of life and all-cause mortality later in life (Högström, Nordström, & Nordström, 2015; Ruiz et al., 2009; Volaklis et al., 2015). In addition to links to health, both cardiorespiratory fitness and muscular strength provide markers of vigorous-intensity physical activity, with muscular strength also being a product of activities that strengthen muscle and bone (Ortega et al., 2008; Tomkinson, Lang, et al., 2017; Wind, Takken, Helders, & Engelbert, 2010). Moreover, a high BMI is associated with a reduction in physical activity levels (Tremblay et al., 2011), increases in high-energy food consumption (Flatt, 2001), and, subsequently, an increase in overall energy intake (Livingstone, 2000). Health-related fitness therefore provides an indicator of both health status and physical activity levels.

Health-related fitness and physical activity are closely associated, with fitness mainly, albeit not completely, determined by physical activity levels (Blair, Cheng, & Holder, 2001). The physical activity levels of children and young people in Wales are low and lie in the bottom quartile for physical activity levels across very high Human Development Index (HDI) countries (Aubert et al., 2018; Tremblay et al., 2016; Tyler et al., 2016). In accord with health inequality research, physical activity levels in Wales have been reported to be higher in boys than girls; however, results display little difference in average levels between deprivation groups (Tyler et al., 2016; Welsh Government, 2015, 2017). Although physical activity levels and inequalities are well established in Wales (Aubert et al., 2018; Tremblay et al., 2016; Tyler et al., 2016; Welsh Government, 2015, 2017),the interpretation of these results are difficult given the varied measures of physical activity and socioeconomic status/deprivation used. Ultimately, health-related fitness has been shown to be a stronger indicator of health than physical activity (Andersen, Riddoch, Kriemler, & Hills, 2011), and so, identifying differences in health-related fitness levels among school children could indicate the need for focused services and interventions to improve health inequalities.

Whilst there are numerous environmental factors that affect children's levels of health-related fitness, the neighbourhood environment within which children live has been specifically highlighted (Noonan et al., 2016; Noonan & Fairclough, 2018). Indeed, children living in deprived neighbourhoods have been associated with decreased variation in physical activity as a result of safety concerns of the neighbourhood (Noonan et al., 2016; Noonan &

Fairclough, 2018). For example, children's independent active free play, which often involves moderate- and vigorous-intensity physical activity that improves health-related fitness (Janssen & Leblanc, 2010; Poitras et al., 2016), is regularly limited by parents in response to their negative perceptions of the safety of the neighbourhood (Lee et al., 2015; Noonan et al., 2016; Noonan & Fairclough, 2018). Restricting children's independent active free play can lead to children being limited to the home environment (Noonan et al., 2016), and therefore is more likely to increase their time spent in sedentary behaviours (e.g. TV viewing, videogaming) (Atkin et al., 2013; Tremblay et al., 2011). This can consequently increase the likelihood of poor health-related fitness outcomes (Tremblay et al., 2011), including low cardiorespiratory fitness, low muscular strength/fitness, and high body mass index (Noonan et al., 2016; Noonan & Fairclough, 2018; Ortega et al., 2008; Pearce et al., 2019; Ruiz et al., 2009). In comparison to more affluent neighbourhoods, more deprived neighbourhoods tend to be less walkable due to safety concerns (Noonan et al., 2016; Noonan & Fairclough, 2018), as well as have reduced access to self-contained gardens (Noonan et al., 2016; Noonan & Fairclough, 2018), and a higher concentration of fast-food outlets (Cummins & Macintyre, 2006), all of which increase the potential of the neighbourhood environment to negatively influence children's health-related fitness and overall health (Högström et al., 2015; Ortega et al., 2008; Ruiz et al., 2009; Tomkinson, Carver, et al., 2017; Tremblay et al., 2011; Volaklis et al., 2015). Therefore, investigations into the levels of health-related fitness in deprived areas in comparison to more affluent neighbourhoods is warranted, particularly in Wales.

Although some recent UK studies have considered health-related fitness measures and deprivation in statistical analyses (Brophy et al., 2012; Charlton et al., 2014; Nevill et al., 2017; Noonan et al., 2016, 2017; Noonan & Fairclough, 2018; Pearce et al., 2019), there were inherent limitations. Specifically, the predominant focus was not comparing multiple fitness measures across deprivation levels, and the variation in health-related fitness variables included in these studies limits inter-study comparisons (Nevill et al., 2017; Noonan et al., 2016, 2017; Noonan & Fairclough, 2018). Additionally, these studies neglected to include any measure of the muscular strength component of physical fitness (Brophy et al., 2012; Charlton et al., 2014; Nevill et al., 2017; Noonan et al., 2016, 2017). Research has purported the need to assess this component given its individual relationship with health outcomes (Ortega et al., 2008; Ruiz et al., 2009; Volaklis et al., 2015), with grip strength, specifically, having direct associations with cardio-metabolic disease risk and early mortality (Ortega et al., 2008; Volaklis et al., 2015). Moreover, Brophy et al. (2012) and Charlton et al. (2014)

used the number of children receiving free school meals and school's postcode as a proxy measure of deprivation. However, using a solely income-based proxy for deprivation (i.e. free school meals) overlooks the multiple dimensions/domains of deprivation that effect children (Noble, Wright, Smith, & Dibben, 2006), while using school postcodes has been shown to lack effectiveness as children may travel across postcodes to school (Boddy, Hackett, & Stratton, 2010). It is therefore postulated that levels of health-related fitness, particularly grip strength, should be measured across deprivation groups with use of the index of multiple deprivation (neighbourhood deprivation) to assess health inequalities in UK children.

The aim of this study was to investigate deprivation and sex differences in selected health-related fitness measures in 9-12-year-old children.

METHODS:

Participants and Settings

A sample of 3,407 children (49.3% boys; aged 10.5 ± 0.6 years) participated in the study. Data were collected on children as part of the Swan-Linx health, fitness and lifestyle programme (Sheldrick, Tyler, Mackintosh, & Stratton, 2018; Tyler, Mackintosh, Brophy, et al., 2015; Tyler, Mackintosh, Palmer, Jones, & Stratton, 2015), which includes selected measures from the Sportslinx project (Stratton et al., 2007; Taylor, Hackett, Stratton, & Lamb, 2004). Data were captured during Fitness Fun Days between 2013-2017, across 29 socio-demographically representative schools, in South Wales, UK. All measures were conducted in school sport halls or at Swansea University's Indoor Training Centre, by trained researchers, local community coaches and Active Young People officers. Written informed head teacher and parental consent, as well as child assent, were obtained prior to data collection. The Swan-Linx programme has institutional Research Ethics Committee approval (PG/2014/007; PG/2014/37) for its procedures and measures.

Measures and Procedures

Health-related Fitness:

Three components of health-related fitness were measured, namely cardiorespiratory fitness, muscular strength and body mass index, using standardised methods (Sheldrick et al., 2018; Taylor et al., 2004; Tyler, Mackintosh, Palmer, et al., 2015).

20m Multistage Shuttle Run Test (20m MSRT): The 20m MRST (Léger, Mercier, Gadoury, & Lambert, 1988), shown to be valid and reliable in similarly-aged children, assessed cardiorespiratory fitness (Mayorga-Vega, Aguilar-Soto, & Viciana, 2015). To ensure a consistent pace and to give encouragement, a researcher completed the test with the participants. The total number of completed shuttles was recorded.

Handgrip Strength Test: The Handgrip Strength test was used to measure upper body muscular strength and provide an indication of overall muscular strength (Ortega et al., 2008; Wind et al., 2010). Using hand dynamometers [Takei Corp Ltd., Tokyo, Japan], participant's strength was measured in kilograms. Each participant held the dynamometer at arm's length above their head and squeezed the dynamometer with maximum isometric effort for 5s, whilst bringing it down slowly towards their side.

Anthropometric Measures: All anthropometric measures were taken by the same trained researcher using standard techniques (Lohman, Roche, & Martorell, 1988). Participant's stature, sitting stature, and body mass were measured to the nearest 0.1cm and 0.1kg, using a portable stadiometer [Seca 213 portable stadiometer, Seca Ltd, Birmingham, UK], a sitting stature stadiometer [Harpenden Sitting Height Table, Holtain Ltd, Pembrokeshire, UK], and electronic weighing scales [Seca 876, Seca Ltd, Birmingham, UK]. Body Mass Index (BMI) was calculated (BMI = body mass (kg)/stature^2 (m)) as a proxy measure of body composition, and BMI z-scores were derived using the UK 1990 growth reference curves (Cole, Freeman, & Preece, 1995). Sex-specific maturation offset regression equations using interactions between body mass, stature, sitting stature, lower limb length (difference between stature and sitting stature) and decimal age, were used to predict participant's age from peak height velocity (Mirwald, Baxter-Jones, Bailey, & Beunen, 2002). This calculation was used as a proxy measure of biological maturation.

Deprivation:

Welsh Index of Multiple Deprivation (WIMD): The Welsh Index of Multiple Deprivation (WIMD) is used as the official measure of deprivation in Wales (Welsh Government, n.d.), in which eight domains of deprivation (employment; health; income; housing; community safety; access to services; education and the environment) are considered to provide an area-based deprivation measurement (Noble et al., 2006). WIMD ranks have been calculated for each of Wales 1,909 Lower-Layer Super Output Areas (LSOA), with the most deprived LSOA ranking 1, and the least deprived ranking 1,909. Participants' home postcodes were used to calculate WIMD scores, which were then split into WIMD quintile one (WIMD 23-226), two (WIMD 227-710), three (WIMD 711-982), four (WIMD 983-1604) and five (WIMD 1605-1908), with 20% of participants in each group.

Statistical Analyses

Descriptive statistical analysis, mean and standard deviation (mean±SD), were initially performed on all measures. Statistical analysis was completed using SPSS, version 25 (IBM SPSS Statistics Inc., Chicago, IL, USA), with a significance level of 0.05. Participant results were included in each respective analysis if there were no missing data for the variable concerned. Missing data were noted for BMI z-score (79 participants (2.32%)), grip strength (28 participants (0.82%)), and 20m MSRT (137 participants (4.02%)). Due to the nested nature of the data (i.e. participants nested within schools), intraclass correlation coefficients (ICC) were calculated prior to further analyses to determine the proportion of the total variability in BMI z-score, grip strength, and 20m MSRT that could be attributed to school. Subsequently, in-line with past studies (Freitas et al., 2007; Mutunga et al., 2006), a two-way Analysis of Variance (ANOVA) was conducted to examine whether there was a statistically significant difference in BMI z-score by sex and WIMD quintiles. A two-way Analysis of Covariance (ANCOVA) was used to investigate if there were differences in grip strength by sex and WIMD quintiles, while adjusting for BMI z-score. BMI z-score was chosen as a covariate due to the known positive correlation of BMI and grip strength during childhood, irrespective of sex (Milliken, Faigenbaum, Loud, & Westcott, 2008; Wind et al., 2010). A second two-way ANCOVA examined the effect of sex and WIMD quintiles on shuttles achieved in the 20m MSRT, after adjusting for maturation, given its potential confounding effect (Andersen et al., 2006; Katzmarzyk et al., 2012; Malina, Bouchard, & Bar-Or, 2004; Malina & Kozieł, 2014; Sherar, Cumming, Eisenmann, & Malina, 2010). The suitability of the covariates in each ANCOVA model was investigated by ensuring the homogeneity of regression slopes assumption was met, as determined by a comparison between the two-way ANCOVA model with and without interaction terms. If an interaction effect was present in the ANCOVA model, analysis of simple main effects of both WIMD quintiles and sex was performed, with statistical significance receiving a Bonferroni adjustment ($p<0.05 \div$ number of simple main effects made), to correct for the testing of multiple simple main effects. In the case of a non-significant interaction effect, analyses of main effects were performed. If a significant simple main effect or significant main effect was present, pairwise comparisons were run with p-values Bonferroni-adjusted ($p<0.05 \div$

number of comparisons). Hedges' *g* was used as a measure of effect size for pairwise comparisons.

RESULTS:

The descriptive characteristics of the study participants are presented in Table 1. Intraclass correlation coefficients for BMI z-score (ICC = 0.014), grip strength (ICC = 0.083), and 20m MSRT (ICC = 0.032) demonstrated little statistical dependency in the data, suggesting that the largest proportion of variance lies among participants.

[INSERT 'Table 1. Descriptive statistics for study participants' ABOUT HERE]

The interaction effect between WIMD quintiles and sex on BMI z-scores was not statistically significant ($F_{(4,3318)} = 1.240$, $p = 0.292$). Means ± SD for BMI z-scores, for boys and girls in WIMD quintile 1 to 5 are shown in Table 2. Main effects analysis displayed a significant main effect of WIMD quintiles on BMI z-scores ($F_{(4,3318)} = 3.488$, $p = 0.008$). Pairwise comparisons revealed a statistically significant difference of 0.215 (95% CI, 0.12 to 0.419; $p = 0.029$, $g = 0.170$) between mean BMI z-score in WIMD quintile 3 and WIMD quintile 5, but there were no other significant mean differences in BMI z-score between WIMD quintile groups. There was no significant main effect of sex on BMI z-scores ($F_{(4,3318)} = 0.811$, $p = 0.368$).

[INSERT 'Table 2. Mean ± SD BMI z-scores, adjusted mean ± SE grip strength and 20m MSRT for boys and girls by WIMD quintile (deprivation) groups' ABOUT HERE]

Given that there was homogeneity of regression slopes ($F_{(9,3281)} = 1.066$, $p = 0.385$), BMI z-scores were included as a covariate in the ANCOVA model for grip strength. Adjusted means ± SE (by BMI z-score) for grip strength are shown in Table 2. There was no statistically significant two-way interaction between WIMD quintiles and sex on grip strength, while adjusting for BMI z-scores ($F_{(4,3290)} = 0.696$, $p = 0.595$). The main effect of sex was statistically significant ($F_{(4,3290)} = 39.336$, $p < 0.001$, $g = 0.205$), with boys adjusted mean grip strength 0.823 (95% CI, 0.565 to 1.080) kg higher than girls. There was also a statistically significant main effect of WIMD quintile on grip strength ($F_{(4,3290)} = 3.919$, $p = 0.004$). Pairwise comparisons revealed a statistically significant difference of 0.718 (95% CI, 0.143 to 1.294; p = 0.005, g = 0.174) kg between adjusted mean grip strength in WIMD quintile 1 and WIMD quintile 5, but no other significant differences in grip strength between WIMD quintiles were found.

Given that the interaction term between 20m MSRT and maturation was not significant (p > 0.05), there was homogeneity of regression slopes and so maturation was included as a covariate in the ANCOVA model for 20m MSRT. Adjusted means ± SE (by maturation) for 20m MSRT score are presented in Table 2. There was a statistically significant interaction between WIMD quintiles and sex on 20m MSRT, while controlling for maturation ($F_{(4,3182)}$ = 2.659, p = 0.031,). Simple main effects revealed that sex was statistically significant in WIMD quintile group 1 ($F_{(1,3182)}$ = 11.437, p = 0.001, g = 0.319), group 2 ($F_{(1,3182)}$ = 35.100, p < 0.001, g = 0.534), group 3 ($F_{(1,3182)}$ = 11.560, p = 0.001, g = 0.297), group 4 ($F_{(1,3182)}$ = 32.391, p < 0.001, g = 0.475), and group 5 ($F_{(1,3182)}$ = 42.138, p < 0.001, g = 0.566), with boys achieving a significantly greater 20m MSRT score than girls in each WIMD quintile group. Moreover, simple main effects showed that WIMD quintile group was statistically significant in girls ($F_{(4,3182)}$ = 13.793, p < 0.001), and boys ($F_{(4,3182)}$ = 3.481, p = 0.008). For girls, WIMD quintile 1 had a significantly lower adjusted mean 20m MSRT score than WIMD quintile 5 (3.694 shuttles, 95% CI, 0.230 to 7.157; p = 0.028, g = 0.292), but there were no statistically significant differences between adjusted mean 20m MSRT scores when comparing all other WIMD quintiles. For boys, WIMD quintile 1 had a significantly lower adjusted mean 20m MSRT score than WIMD quintile 2 (4.380 shuttles, 95% CI, 0.969 to 7.792; p = 0.003, g = 0.251), WIMD quintile 4 (6.544 shuttles, 95% CI, 3.121 to 9.967; p < 0.001, g = 0.379), and WIMD quintile 5 (7.921 shuttles, 95% CI, 4.529 to 11.313; p < 0.001, g = 0.469). Further, boys' adjusted mean 20m MSRT score in WIMD quintile 2 was significantly lower than WIMD quintile 5 (3.541 shuttles, 95% CI, 0.066 to 7.016; p = 0.042, g = 0.200). Finally, boys' WIMD quintile 3 had a significantly lower adjusted mean 20m MSRT score than both WIMD quintile 4 (4.307 shuttles, 95% CI, 0.747 to 7.867; p = 0.007, g = 0.229) and WIMD quintile 5 (5.684 shuttles, 95% CI, 0.969 to 7.792; p = 0.003, g = 0.310). All other pairwise comparisons between quintiles for boys' adjusted mean 20m MSRT score were non-significant.

DISCUSSION:

The aim of this study was to investigate deprivation and sex differences in selected health-related fitness measures in 9-12-year-old children. In this study, there was a large variance in WIMD scores (SD = 598.6) to classify deprivation quintiles, with children living in one of the most deprived (WIMD = 23), to the most affluent areas (WIMD = 1908) in Wales.

The current results showed that, independent of sex, children in the middle quintile (quintile 3) had a significantly higher mean BMI z-score than their least deprived counterparts (quintile 5), in contrast to studies that have found no association between school deprivation (school postcode) or individual deprivation levels (free school meals) and weight status in children (Brophy et al., 2012; Dummer, Gibbon, Hackett, Stratton, & Taylor, 2005). Nonetheless, the current results are more in line with a recent study on school children in England, as well as a systematic review, that shows an inverse association between neighbourhood deprivation and BMI/weight status (Nevill et al., 2017; Shrewsbury & Wardle, 2008). A recent study analysing British longitudinal and observational data indicated that BMI and weight disparities have widened between socioeconomically disadvantaged children (those living in the most deprived neighbourhoods) and their more affluent peers (Bann, Johnson, Li, Kuh, & Hardy, 2018), and so it would be expected that BMI z-scores would be significantly higher in the least affluent quintile compared to all other quintiles. It is important to note, however, that the only significant mean difference in BMI z-score found in the current study was between quintile 3 and 5. In fact, there was little mean difference between quintiles 1, 2 and 3, as well as between quintiles 4 and 5. Given that Bann and colleagues (2018) asserted that BMI inequalities were larger at the higher end of the BMI distribution, a shift in focus to identifying children at this end of the distribution may have resulted in more apparent differences.

The current study highlights an apparent split in BMI z-scores, with children in the bottom 3 quintiles (middle to high deprivation), having a higher mean BMI z-score than the top 2 quintiles (least deprived). A similar split between high to middle deprivation and middle to low deprivation, was also apparent in a study that showed a significant difference between deprivation quartile 1 and 2 (least to middle affluent) and quartile 3 and 4 (middle to most affluent) (Fairclough, Boddy, Hackett, & Stratton, 2009). Such a divide in deprivation groups may reflect the fact that more deprived neighbourhoods tend to discourage physical activity, especially independent active free play (Noonan et al., 2016; Noonan & Fairclough, 2018). However, since national surveillance evidence shows little difference in physical activity levels across deprivation in Wales (Tyler et al., 2016; Welsh Government, 2015, 2017), it can be speculated that the divide in deprivation groups seen in the present study may be related to other factors. One such factor may be dietary intake, as a systematic review provided evidence that higher deprivation was associated with poorer diets (Hanson & Chen, 2007). It has also been reported that more deprived neighbourhoods have a higher concentration of fast-food outlets (Cummins & Macintyre, 2006; Noonan et al., 2016; Noonan & Fairclough, 2018), which may additionally play a part in this deprivation group divide. Further research investigating the concurrent effect of dietary consumption and possible other influencing factors on weight status and fitness by deprivation is warranted.

Congruent with previous studies conducted measuring muscular strength and cardiorespiratory fitness in children (Cohen et al., 2010; De Miguel-Etayo et al., 2014; Noonan et al., 2017), the current results showed that boys had a significantly higher grip strength and achieved a significantly greater 20m MSRT score than girls. Previous research has shown that boys have higher physical activity levels compared to girls (Tyler et al., 2016; Welsh Government, 2015, 2017). Given that physical activity has a reciprocal relationship with physical fitness levels (Janssen & Leblanc, 2010; Ortega et al., 2008), these reported differences may be a contributing factor to the differences in fitness levels between girls and boys seen in the current study.

While deprivation level (paternal professional and maternal professional level) has been shown to be positively associated with muscular strength in children (Jiménez-Pavón et al., 2010), our results were converse in that there was only a significant difference in grip strength between least deprived (quintile 5) and most deprived (quintile 1). However, the current results are consistent with previous research showing that grip strength was significantly higher in children from less deprived circumstances (parental occupation, education, income, housing, and residential area features) than more deprived children (Freitas et al., 2007). Moreover, both girls and boys had a significantly higher 20m MSRT score in the least deprived group (quintile 5) compared to most deprived group (quintile 1), which agrees with other work (Mutunga et al., 2006). It is noteworthy that significant differences in 20m MSRT score were more apparent with decreases in deprivation level in boys. Specifically, most deprived boys (quintile 1) had a significantly lower 20m MSRT score than all other groups of boys except for boys in the middle quintile (quintile 3), while boys in the middle quintile (quintile 3) had a significantly lower 20m MSRT score than their less deprived counterparts (quintile 4 and 5). While there is little difference in physical activity levels across deprivation in Wales, a difference in sport participation has been reported, with around ten percent more children hooked on sport (take part in sport on 3 or more occasions a week in an extracurricular (school-based) or a community club setting) in the least deprived compared to most deprived areas in Wales (Sport Wales, 2015; Tyler et al., 2016). Given that a recent study has shown that, regardless of deprivation, participation in sport is associated with better physical fitness when compared to non-participation (Golle, Granacher, Hoffmann, Wick, & Muehlbauer, 2014), the differences in fitness levels found between the least and most deprived children may be, at least in part, due to differences in sport participation. As previously discussed, another notion is that deprived neighbourhoods are restrictive in terms of physical activity and free play (Noonan et al., 2016; Noonan & Fairclough, 2018), and thus, the children in the least affluent quintile may be spending a disproportionate amount of time spent in sedentary behaviours (Atkin et al., 2013; Tremblay et al., 2011). Consequently, this could lead to poorer health-related fitness outcomes (Tremblay et al., 2011), including low cardiorespiratory fitness and muscular strength (Noonan et al., 2016; Noonan & Fairclough, 2018; Ortega et al., 2008; Pearce et al., 2019; Ruiz et al., 2009).

Although not the primary aim, the present study enabled comparisons of health-related fitness data obtained to international normative values. In comparison to European sex- and age-specific normative values on over 200,000 grip strength test performances of children and young people aged 9–17 years across 30 countries (Tomkinson, Carver, et al., 2017), girls' and boys' mean grip strength score in the present study were in the 50th and 40th centile, respectively. Further, in comparison to international sex- and age-specific normative values on over one million 20m MSRT performances of 9–17 year olds from 50 countries (Tomkinson, Lang, et al., 2017), girls and boys achieved a level commensurate with the 40th and 50th centile, respectively. Therefore, cardiorespiratory fitness and muscular strength levels of girls and boys in the current study were low to moderate in comparison to international norms.

The current study showed that inequalities exist in body size, muscular strength, and cardiorespiratory fitness across levels of deprivation and sex in children. Moreover, overall health-related fitness levels of children involved in the study were low to moderate in comparison to international normative values (Tomkinson, Carver, et al., 2017; Tomkinson, Lang, et al., 2017). Given the negative implications of low physical fitness levels on health, focused services and interventions should work to improve physical fitness levels, and specifically aim to close the gap in inequalities, particularly in areas of high deprivation and in girls. It should be noted that creating active communities or other settings/environments that increase physical activity to improve health-related fitness will generally require significant additional investment (Wickham, Anwar, Barr, Law, & Taylor-Robinson, 2016). However, there are other resources that may be influential, including evidence-based programmes using behaviour change techniques and social marketing tools within the targeted population group (Global Advocacy for Physical Activity (GAPA) the Advocacy Council of the International Society for Physical Activity and Health (ISPAH), 2011). Alternatively, facilitating and encouraging inexpensive independent active free play may also act as an effective strategy to enhance health-related fitness in children.

Limitations and Future Directions:

It is important to note that the current study is not without limitations. The cross-sectional study design of this study does not allow for causality to be determined, and therefore future investigations into the causes of (i) the deprivation group divide in BMI z-scores, (ii) the more pronounced differences in 20m MSRT by deprivation in boys compared to girls and (iii) the lack of significant difference in 20m MSRT between boys in most deprived and middle quintiles, perhaps considering any differences in physical activity, sport participation and exercise levels across specific groups. Moreover, although the measures used in this study are valid and used in many large-scale studies, future research should aim to include more objective measures of physical fitness (e.g. using treadmill based VO_2 peak assessments) and body composition (e.g. skinfolds and circumferences, or dual-energy X-ray absorptiometry (DEXA)), to assess fat and fat-free mass and percentage body fat. However, capturing this information on such large-scale data would be cost and time intensive.

Conclusion:

The present study was one of the first large-scale studies to investigate differences in body mass index, muscular strength and cardiorespiratory fitness by sex and different levels of deprivation. In accord with previous research, boys had significantly higher muscular strength and cardiorespiratory fitness than girls. Children in the middle quintile (quintile 3) had a significantly higher mean BMI z-score than those in the least deprived quintile (quintile 5). Most deprived children (quintile 1) had significantly lower muscular strength and cardiorespiratory fitness than their least deprived counterparts (quintile 5). Overall, these results show that inequalities exist between deprivation and sex in selected health-related fitness measures, and should be used to inform focused services and interventions to improve current health inequalities and future health implications.

SUMMARY BOX:

- The present study was one of the first large-scale studies to quantify differences in body mass index, muscular strength and cardiorespiratory fitness by sex and levels of deprivation. The study adds new findings to support the recent CMO physical activity guidelines review.
- Results show that inequalities exist between deprivation and sex in selected health-related fitness measures.
- Focused services and interventions to improve current health inequalities and future health implications is needed.
- Practitioners should aim to close the gap in inequalities, particularly in areas of high deprivation and in girls.

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CONFLICT OF INTEREST:

The authors declare there are no known conflicts of interest in the present study. The results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation.

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Table 1. Descriptive statistics (mean (± SD)) for study participants

	WIMD quintile 1[◊]			**WIMD quintile 2**			**WIMD quintile 3**			**WIMD quintile 4**			**WIMD quintile 5[†]**			**Overall**		
	Boys	**Girls**	**All**	**Boys**	**Girls**	**All**	**Boys**	**Girls**	**All**	**Boys**	**Girls**	**All**	**Boys**	**Girls**	**All**	**Boys**	**Girls**	**All**
Age(years)	10.6 ±0.6	10.6 ±0.7	10.6 ±0.6	10.6 ±0.6	10.6 ±0.7	10.6 ±0.7	10.6 ±0.6	10.6 ±0.7	10.6 ±0.7	10.5 ±0.6	10.5 ±0.6	10.5 ±0.6	10.5 ±0.6	10.5 ±0.6	10.5 ±0.6	10.6 ±0.6	10.5 ±0.6	10.5 ±0.6
Stature(cm)	141.7 ±7.4	142.6 ±8.1	142.1 ±7.7	142.0 ±6.9	143.6 ±8.3	142.8 ±7.7	142.7 ±7.4	142.6 ±7.5	142.6 ±7.5	142.6 ±7.21	143.2 ±8.0	142.9 ±7.7	142.6 ±7.4	142.1 ±7.4	142.3 ±7.4	142.3 ±7.3	142.8 ±7.9	142.6 ±7.6
Sitting Stature(cm)	74.1 ±4.2	74.7 ±4.6	74.4 ±4.4	74.0 ±4.2	75.2 ±4.6	74.6 ±4.4	74.3 ±5.0	74.9 ±5.1	74.6 ±5.0	74.9 ±3.5	75.0 ±4.0	74.9 ±3.8	74.7 ±3.8	74.5 ±4.3	74.6 ± 4.1	74.4 ±4.1	74.9 ±4.5	74.6 ±4.4
Body Mass(kg)	38.3 ±10.7	40.3 ±10.3	39.3 ±10.6	38.4 ±10.1	41.1 ±11.8	39.8 ±11.0	39.8 ±10.7	39.6 ±10.0	39.7 ±10.4	37.7 ±9.1	39.4 ±10.1	38.6 ±9.7	37.6 ±9.6	38.0 ±8.6	37.8 ±9.1	38.4 ±10.1	39.7 ±10.3	39.0 ±10.2
Lower Limb Length(cm)	67.6 ±4.9	67.9 ±5.0	67.8 ±5.0	68.1 ±5.1	68.4 ±4.9	68.2 ±5.0	68.4 ±5.7	67.7 ±5.6	68.0 ±5.7	67.7 ±4.5	68.2 ±5.0	68.0 ±4.8	67.9 ±4.8	67.5 ±5.1	67.7 ±5.0	67.9 ±5.0	68.0 ±5.1	67.9 ±5.1
BMI($kg \cdot m^{-2}$)	19.0 ±4.1	19.7 ±3.9	19.3 ±4.0	18.8 ±3.7	19.7 ±4.2	19.3 ±4.0	19.3 ±3.9	19.3 ±3.8	19.3 ±3.9	18.3 ±3.2	19.0 ±3.8	18.7 ±3.5	18.3 ±3.4	18.7 ±3.2	18.5 ±3.3	18.7 ±3.7	19.3 ±3.8	19.0 ±3.8
BMI z-score	0.6 ±1.3	0.7 ±1.3	0.6 ±1.3	0.6 ±1.3	0.7 ±1.4	0.6 ±1.3	0.8 ±1.4	0.6 ±1.3	0.7 ±1.3	0.5 ±1.3	0.5 ±1.3	0.5 ±1.3	0.5 ±1.2	0.4 ±1.2	0.5 ±1.2	0.6 ±1.3	0.6 ±1.3	0.6 ±1.3
Maturity Offset(years)	-2.8 ±0.6	-1.2 ±0.8	-2.0 ±1.1	-2.8 ±0.6	-1.2 ±0.8	-2.0 ±1.1	-2.8 ±0.7	-1.2 ±0.8	-2.0 ±1.1	-2.7 ±0.6	-1.2 ±0.7	-2.0 ±1.0	-2.7 ±0.6	-1.3 ±0.7	-2.0 ±1.0	-2.8 ±0.6	-1.2 ±0.7	-2.0 ±1.0
Deprivation Score(WIMD)	107.0 ±71.4	108.0 ±71.3	107.5 ±71.3	434.8 ±149.7	435.5 ±155.1	435.1 ±152.3	838.5 ±60.8	835.1 ±65.1	836.8 ±63.0	1245.5 ±204.0	1248.1 ±194.6	1246.8 ±199.0	1728.2 ±76.9	1731.9 ±80.0	1730.0 ±78.4	858.7 ±598.6	869.6 ±588.9	864.2 ±593.7
Grip Strength(kg)	16.5 ±3.9	16.0 ±4.0	16.3 ±4.0	16.8 ±4.2	16.0 ±4.0	16.4 ±4.1	17.0 ±3.9	15.7 ±4.0	16.3 ±4.0	16.8 ± 4.0	16.0 ±3.8	16.4 ±3.9	17.3 ±4.4	16.2 ±3.5	16.8 ±4.0	16.9 ±4.1	16.0 ±3.9	16.4 ±4.0
20m MSFT Score(shuttles)	29.0 ±16.2	22.6 ±12.2	26.8 ±15.0	35.4 ±18.9	23.3 ±11.4	29.2 ±16.7	33.0 ±19.0	24.8 ±13.0	28.8 ±16.7	37.5 ±18.7	26.2 ±14.2	31.6 ±17.4	38.7 ±17.9	26.6 ±13.2	32.7 ±16.9	35.0 ±18.3	24.7 ±12.9	29.8 ±16.6

Note: WIMD quintile 1[◊] = most deprived, WIMD quintile 5[†] = least deprived

Table 2. Mean ± SD BMI z-scores by WIMD, adjusted mean ± SE grip strength (adjusted by BMI z-scores), and adjusted mean ± SE 20m MSRT (adjusted for maturation) by WIMD quintile (deprivation) groups

BMI z-scores	**WIMD quintile 1◊** (n = 699, 51.9% boys)	**WIMD quintile 2** (n = 676, 49.1% boys)	**WIMD quintile 3** (n = 620, 48.7% boys)	**WIMD quintile 4** (n = 671, 48.0% boys)	**WIMD quintile 5†** (n = 662, 50.8% boys)
Boys	0.60 ± 1.34	0.61 ± 1.32	0.78 ± 1.37	0.53 ± 1.27	0.48 ± 1.21
Girls	0.66 ± 1.32	0.66 ± 1.36	0.56 ± 1.26	0.47 ± 1.30	0.44 ± 1.18
All	0.63 ± 1.33	0.63 ± 1.34	0.67 ± 1.32	0.50 ± 1.29	0.46 ± 1.19
Grip Strength (kg)	**WIMD quintile 1◊** (n = 695, 51.8% boys)	**WIMD quintile 2** (n = 672, 49.0% boys)	**WIMD quintile 3** (n = 616, 48.5% boys)	**WIMD quintile 4** (n = 660, 47.7% boys)	**WIMD quintile 5†** (n = 658, 51.1% boys)
Boys	16.4 ± 0.2	16.7 ± 0.2	16.7 ± 0.2	17.0 ± 0.2	17.4 ± 0.2
Girls	16.0 ± 0.2	16.0 ± 0.2	15.7 ± 0.2	16.0 ± 0.2	16.4 ± 0.2
All	16.2 ± 0.1	16.4 ± 0.2	16.2 ± 0.2	16.5 ± 0.2	16.9 ± 0.2
20m MSFT Score (shuttles)	**WIMD quintile 1◊** (n = 670, 51.6% boys)	**WIMD quintile 2** (n = 635, 49.4% boys)	**WIMD quintile 3** (n = 605, 48.8% boys)	**WIMD quintile 4** (n = 646, 48.0% boys)	**WIMD quintile 5†** (n = 637, 50.4% boys)
Boys	29.0 ± 0.9	33.4 ± 0.9	31.3 ± 1.0	35.6 ± 0.9	37.0 ± 0.9
Girls	24.4 ± 0.9	25.1 ± 0.9	26.5 ± 0.9	27.8 ± 0.9	28.1 ± 0.9
All	26.7 ± 0.6	29.3 ± 0.6	28.9 ± 0.6	31.7 ± 0.6	32.5 ± 0.6

Note: WIMD quintile 1◊ = most deprived, WIMD quintile 5† = least deprived