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Inter-participant variability in daily physical activity and sedentary time among male youth sport footballers: Independent associations with indicators of adiposity and cardiorespiratory fitness

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Running head: Physical activity, sedentary time and adiposity in youth sport footballers

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Abstract

Participation in youth sport is assumed to promote, and contribute towards more physically active lifestyles among children and adolescents. The aim of this study was to examine inter-participant variability in objectively measured habitual physical activity (PA) behaviours and sedentary time among youth sport participants and their implications for health. One-hundred-and-eighteen male youth sport footballers (Mage = 11.72 ± 1.60) wore a GT3X accelerometer for 7 days. Average daily PA [min/day, in light, (LPA), moderate (MPA), vigorous (VPA) and combined moderate-to-vigorous (MVPA)] and sedentary time were calculated. Participants' body-mass-index adjusted for age and sex (BMI-standard-deviation-score), percent body fat (BF%), waist circumference and cardiorespiratory fitness were assessed. Results revealed variability in daily PA behaviours and sedentary time (min/day) were associated with BMI-standard-devaition-score, [VPA (−), MVPA (−)], BF% [sedentary time (+), VPA (−), MVPA (−)], waist circumference [sedentary time (+), LPA (−)] and cardiorespiratory fitness [sedentary time (−), MPA (+), VPA (+), MVPA (+)]. Whilst sedentary time and MVPA were not related to health outcomes independent of one another, associations with markers of adiposity and cardiorespiratory fitness were stronger for sedentary time. Sedentary time was also significantly positively related to waist circumference independent of VPA. Results demonstrate inter-participant variability in habitual PA and sedentary time among youth sport participants which holds implications for their health. Thus, promoting PA and in particular, reducing sedentary time, may contribute towards the prevention of adverse health consequences associated with a physically inactive lifestyle for children and adolescents active in the youth sport context.

Key words: *Youth sport, MVPA, sedentary time, adiposity, cardiorespiratory fitness*

Introduction

In 2013, overweight and obesity were identified as the fifth leading risk for global deaths (World Health Organisation, 2013). Childhood overweight and obesity has reached epidemic proportions worldwide, with global prevalence estimates of 14% (overweight including obesity) and 4% (obesity), respectively (International Association for the Study of Obesity, 2014). Given that obesity and its associated co-morbidities track from childhood to adulthood (Reilly & Kelly, 2011), identifying preventative strategies to counteract this growing epidemic and associated negative health consequences in young people is a critical public health concern.

Low levels of engagement physical activity (PA) and an increase in engagement in sedentary pursuits have been implicated in the aetiology of childhood obesity (Must & Tybor, 2005). Specifically, population based studies of youth demonstrate negative associations between moderate-to-vigorous physical activity (MVPA) and indicators of adiposity, cardiovascular disease and type 2 diabetes (Chaput et al., 2012; Dencker & Andersen, 2008; Ekelund et al., 2012; Mark & Janssen, 2011), with the reverse evidenced for sedentary time (Tremblay et al., 2011). Vigorous physical activity (VPA) also demonstrates consistent associations with these same health outcomes, with relationships often reported to be stronger than observed for MVPA (Dencker & Andersen, 2008). Consequently, evidenced based guidelines for PA and sedentary time have been developed and endorsed by numerous health organisations across the globe. These guidelines hold that school-aged youth should engage in at least 60 minutes and up to several hours of MVPA per day (Mark & Janssen, 2011). In addition, it is recommended that children and adolescents should minimise time spent sedentary, and participate in VPA on at least 3 days per week (Australian Government: Department for Health and Ageing: 2004; Department of Health, 2011; US Department of

Health and Human Services, 2013). However, despite evidence demonstrating the health benefits of engaging in regular PA, population based research indicates school-aged youth across the globe are insufficiently active to meet recommended levels of MVPA and VPA, and also engage in high levels of sedentary time.

Youth sport: promoting, and contributing towards more physically active lifestyles?

Numerous government reports advocate increasing participation in youth sport as an avenue through which the growing obesity crisis may be addressed , via encouraging the adoption of a more physically active lifestyle (Centers for Disease Control and Prevention, 2000; Commission of the European Communities, 2007; NSW Department of Health, 2009). Certainly, research employing self-report methods to assess PA has demonstrated sport participants engage in higher levels of PA, and are more likely to meet recommended levels of MVPA than non-sport participants (Nelson et al., 2011; Silva et al., 2010). To date, only two studies have employed objective PA measurement methods to determine habitual levels of engagement in PA among youth sport participants. Machado-Rodrigues et al., (2012) and Van Hoye et al., (2013) reported average daily MVPA assessed by accelerometers to be above the recommended 60 minutes per day in male youth sport participants aged between 9 and 16 years, from Portugal, England, France and Greece (Machado-Rodrigues et al., 2012; Van Hoye et al., 2013). In addition, studies have reported youth sport to be particularly conducive towards accruing VPA. Certainly, research informs us participants average daily VPA to be above levels identified as relevant to the prevention of excess overweight and obesity among youth (Martinez-Gomez et al., 2010).

These recent findings serve to confirm previous reports regarding the benefits of youth sport participation for accruing higher levels of health enhancing PA. However, it is important to note that past studies have reported mean levels of PA engagement, calculated by averaging the daily MVPA (average minutes/day) across the sample, to reflect the habitual levels of PA participation among the population of interest. That is, inter-participant variability (i.e., variability between individuals) in habitual levels of MVPA and VPA were not examined in previous research. Indeed, it is likely that, for many children, participation in youth sport and engagement in health enhancing levels of PA are not one and the same. As such, there is a need for research which seeks to examine whether youth sport engagement is conducive towards habitual participation in recommended and health enhancing levels of objectively assessed MVPA and VPA for all youth. Moreover, where such variability is associated with variability in health outcomes (i.e., low PA is associated with higher adiposity), it would suggest that interventions targeting habitual PA behaviours of youth sport participants may contribute towards improved health and disease prevention among this cohort. Indeed, research has demonstrated participation in youth sport does not necessarily mitigate the health risks associated with low PA participation (e.g., excess adiposity) (BeLue, Francis, Rollins & Colaco, 2009).

A lack of research employing objective PA assessment methods among youth sport participants has also limited our investigation of levels of sedentary time participation in this population. The two extant studies examining sedentary time have revealed youth sport participants to spend between 8 and 11 hours per day sedentary (Machado-Rodrigues et al., 2012; Van Hoye et al., 2013). As such, whilst some youth sport participants may engage in recommended levels of MVPA, they may also be highly sedentary. Indeed, research reports a common correlate of male youth who present a high active/high sedentary behaviour profile is participation in organised sports (Jago, Fox, Page, Brockman, & Thompson, 2010). Given that some research has reported sedentary behaviour to be independently linked to health outcomes after adjusting for levels of engagement in MVPA (e.g., Henderson et al., 2012;

Mitchell, Pate, Beets, & Nader, 2013), the health implications of this high active/high sedentary behaviour typology which may be apparent for some youth sport participants warrants further attention. Accordingly, research is necessary to determine whether the high levels of sedentary time associated with engagement in youth sport may potentially negate any of the positive health benefits which may arise from PA engagement among this group of youth.

The overarching purpose of the present study was to more critically analyse the habitual PA behaviours and sedentary time of children and adolescents active in the youth sport setting and implications held for health. Accelerometers provide an advantage over self-report methods of PA, allowing more true determination of inter-participant variability in habitual PA engagement across the full spectrum of PA behaviours (i.e., light, moderate and vigorous). To this end, the primary aims of the present study were two fold. First, to determine inter-participant variability in average daily levels of PA (light, moderate, vigorous and combined MVPA) and sedentary time among youth sport football participants and associations with indicators of adiposity (i.e., body mass index (BMI), percent body fat (BF%), waist circumference and cardiorespiratory fitness). Second, to investigate whether associations between light, moderate, vigorous and MVPA with targeted health outcomes, were independent of sedentary time, and likewise, whether sedentary time is related to health outcomes independent of levels of MVPA and VPA engagement. In addition, given the greater health benefits reported to result from VPA participation (relative to other dimensions of PA), a second aim of the current study was to determine whether associations between VPA and health outcomes were independent of LPA and MPA. Grassroots football was the targeted youth sport in the present study given the popularity of this organised sport activity across the globe (Australian Bureau of Statistics, 2009; Kunz, 2007; National Council of Youth Sports, 2008; Womens Sports Foundation, 2008).

Method

Participants and recruitment

Participants were a subsample of grassroots football players (N = 149), recruited from the European PAPA project (Promoting Adolescent Physical Activity; www.projectpapa.org). As part of the project, objective PA data (via accelerometer) were collected in Greece, France and England (N = 417). The present study analysed data from the English sample (N = 149, 35.73%), representing grassroots footballers recruited from 39 teams across 18 clubs. The full protocol for the PAPA Project and the core objective PA measurement protocol are detailed elsewhere (Duda et al., 2013; Van Hoye et al., 2013). The following sections outline the protocol followed in England where supplementary measures were included (i.e., measurement of BF% and waist circumference).

Lead coaches at football clubs were contacted by a member of the research team. Interested coaches (N = 39) were provided with information sheets detailing the study protocol to be passed on to players and parents. Four willing participants per team were then recruited to the study (i.e., a striker, midfielder, defender and goal keeper). All participants were playing in recreational leagues (i.e., one training session and/or match per week). Only male participants were recruited to the present study as few female clubs were interested in taking part (N = 2). Informed consent and assent were obtained from all players and their parents before participating in the study. The study was approved by the local National Health Service Research Ethics Committee.

Protocol

A trained researcher visited football sessions to carry out the procedures. Accelerometers and PA diaries were distributed at the start of training sessions. During the session, participants' height, weight, BF% and waist circumference were measured. Participant ethnicity was also recorded via a questionnaire administered as part of the larger PAPA protocol. Participants were asked to wear the accelerometer for 7 days. Researchers returned one week later to collect accelerometers and PA diaries.

Measures

Physical activity and sedentary time. The GT3X accelerometer (Actigraph; Pensacola, FL) was used to measure daily PA and sedentary time. Actigraph accelerometers have been shown to be valid and reliable measures of PA and sedentary time in youth (de Vries, Bakker, Hopman-Rock, Hirasing, & van Mechelen, 2006). The GT3X detects movements over pre-specified time periods called epochs. Movement counts within each epoch are summed and converted to activity counts and interpreted to determine frequency, intensity and duration of physical activity engagement. Accelerometers were initialised to measure PA in 15 second epochs. Participants were asked to wear the accelerometer for 7 days during all waking hours, removing only for water-based activities (e.g., swimming and bathing). Trained researchers gave verbal and written instructions to players and their parents demonstrating how accelerometers should be worn. Participants were instructed to record daily participation in sport and physical activity (e.g., football, swimming, cycling) during the study week, and times when the accelerometer was removed/replaced (indicating reasons why) in PA diaries.

Anthropometrics. Height, weight, BF% and waist circumference were measured with participants being bare footed, and wearing light clothing (e.g., shorts and t-shirt). Height was measured using a portable stadiometer (SECA, Leicester height measure). Weight and BF%

were measured using bioelectrical impedance scales (Tanita, SC330). Bioelectrical impedance analysis has been validated against dual-energy x-ray absorptiometry estimates of adiposity in youth (Hosking, Metcalf, Jeffery, Voss, & Wilkin, 2006). BF% was measured following entry of the participant's height and weight into the bioelectrical impedance scales. For measurement of waist circumference, children were asked to stand with feet shoulder width apart and expose their waistline to enable measurement against bare skin. The uppermost lateral border of the iliac crest was identified on both sides of the waist as the measurement point. A non- elastic tape was wrapped snugly around the waist in a horizontal plane in line with these points. Measurement was taken at the end of expiration. Measurements were recorded in duplicate to the nearest 0.1cm or 0.1kg. Where the first two measures differed by more than 0.4 cm or 0.5 kg, a third measure was recorded. Body mass index (BMI, kg.m^2) was calculated using the equation: weight (kg) ÷ height (m^2). BMI adjusted for age sex (BMI-standard-deviation-score) was computed for use in subsequent analysis (Cole, Freeman, & Preece, 1998).

Cardiorespiratory fitness. Cardiorespiratory fitness was assessed using the 20 meter multi-stage shuttle run test (Léger, Mercier, Gadoury, & Lambert, 1988). This test is easy to administer in field based research, is frequently used to indicate cardiorespiratory fitness in children and adolescents worldwide (Olds, Tomkinson, Leger & Cazorla, 2006) and has been demonstrated to be a valid and reliable assessment of cardiorespiratory fitness in youth (Liu, Plowman & Looney, 1992). A shuttle was marked on the ground by two lines of cones 20 meters apart. Participants were asked to run back and forth between the 20 meter shuttle at a workload regulated by audio-signals emitted from a pre-recorded audio-CD. Players were asked to start at the first sound signal and follow the pre-scribed pace set by the audio-CD. Frequency of the sound signals was increased by 0.5 km/hour h-1 each minute from a starting speed of 8.5 km/hour. Participants were instructed to run in a straight line, pace themselves in accordance with the time intervals emitted from the audio-CD, and to pivot upon completing each shuttle. Testing was terminated when the player could no longer maintain the prescribed pace for 2 consecutive signals or withdrew due to exhaustion. The last stage number announced was used to predict maximal oxygen uptake (VO_2max (cardiorespiratory fitness) = Y, $ml \cdot kg^{-1} \ min^{-1}$) from the speed ($X$, $km \cdot hour^{-1}$) corresponding to that stage [speed = 8 + (0.5 x stage no.)] and age (A, year):

$$Y = 31.025 + 3.238X - 3.248A + 0.1536AX$$

Data processing

Physical activity data were downloaded from the GT3X and analysed using the Actilife software (Actilife version 6.2, Actigraph; Pensacola, FL). Data were cleaned and checked for spurious values and periods of non-wear. Non-wear time was determined by identifying strings of consecutive zeros recorded by the accelerometer for >30 minutes, allowing for 1 minute of counts <100 (Cain, Sallis, Conway, Van Dyck, & Calhoon, 2013). A day was considered valid where ≥ 8 hours of valid wear time data had been recorded on ≥ 4 days, including a weekend day (Cain et al., 2013). Cut points were <100, 100 – 2295, 2296 – 4011 and ≥ 4012 counts per minute for sedentary, light, moderate, and vigorous PA, respectively (Evenson, Catellier, Gill, Ondrak, & McMurray, 2006). MPA and VPA were also combined to represent MVPA (≥ 2296 counts per minute). Compliance to the protocol was 79.20%. Participants were excluded from subsequent analyses for failing to wear the accelerometer for ≥ 4 days (N = 21), failing to wear the accelerometer on a weekend day (N = 7) and for lack of anthropometric or cardiorespiratory fitness data (N = 3). To determine the extent to which accelerometers may have underestimated PA in this cohort, completed PA diaries (response rate = 70%, N = 83) were also examined to quantify time spent in activities for which the accelerometer is unable to record PA. Only nine and eight participants reported engaging in swimming (1 hour total duration) and cycling (maximum 30 minute total duration) during the study week, respectively. Participation in these activities was therefore unlikely to affect the present results reported.

Statistical analysis

Descriptive statistics (M ± SD) were calculated for all measured variables. Non-normally distributed data were log transformed using an LG10 transformation. One way analysis of variance was conducted to determine if excluded participants were significantly different from those included in terms of age, height, weight, anthropometrics and cardiorespiratory fitness. Multiple linear regressions (i.e., sequentially built models) were employed to investigate relationships between daily PA variables (LPA, MPA, MVPA, VPA), and sedentary time (min/day) with health outcomes [BMI-standard-deviation-score, BF %, waist circumference (cm) and cardiorespiratory fitness (ml.kg^{-1} min^{-1})]. All regressions were initially adjusted for age, ethnicity, valid wear time and season to account for seasonal variation in levels of PA participation (Rich, Griffiths, & Dezateux, 2012). The first step involved entering PA variables as single predictors into adjusted models (i.e., one model each for LPA, MPA, VPA and MVPA) (Table 2, model 1). To determine independent associations between PA variables and sedentary time to the targeted health outcomes, a series of second models were tested. Models 2[a] examined whether associations between LPA, MPA, VPA and combined MVPA were independent of sedentary time (i.e., sedentary time was entered separately into each model). Beta coefficients for sedentary time were also examined to determine whether sedentary time engagement was significantly related to health outcomes independent of LPA, MPA, VPA and MVPA.

Additional analyses were conducted to investigate whether levels of VPA engagement were related to health outcomes independent of MPA and LPA (models 2[b]). Specifically, VPA was entered into separate models with LPA and MPA. Analyses were also interpreted to determine whether LPA and MPA were significantly related to health outcomes independent of VPA.

Results

Participant characteristics

Descriptive statistics for all measured variables are displayed in Table 1. Means and standard deviations are presented for the total sample and the subsample of participants with valid daily PA data. Ranges (min-max) are also reported to demonstrate inter-participant variability in levels of PA engagement (LPA, MPA, VPA and combined MVPA, min/day) and health indicators (BMI, BMI-standard-deviation-score, BF%, waist circumference and cardiorespiratory fitness) within the sample. One way analysis of variance demonstrated age, height, weight and anthropometric measurements (i.e., BMI, BMI-standard-deviation-score, BF% and waist circumference) of included and excluded participants were not significantly different. Significant differences between included and excluded participants were observed only for cardiorespiratory fitness (F (1, 143) = 4.55, p = .04).

Variability in habitual daily PA and sedentary time engagement

The average daily MVPA for the sample was above the recommended guideline of ≥ 60 min/day. However, ranges of 119.27 min/day (lower bound = 26.94) and 57.08 min/day (lower bound = 6.31) min/day were recorded for average daily MVPA and VPA, respectively. Examination of individual estimates for average daily MVPA (min/day) indicated 29.1% of participants did not meet guidelines for MVPA. In addition, where minutes of MVPA participation for every monitored day were examined separately for each participant (e.g., minutes of MVPA on day 1, 2 and 3 were observed individually), only 14.5% of participants (N = 17) met guidelines for MVPA on each day for which valid PA data (i.e., ≥ 8 hours) were recorded.

Results revealed participants spent between 7 and 8 hours per day sedentary on average. Average daily participation in sedentary time ranged between 5.10 and 9.81hours per day (range = 4.7 hours [282.21 minutes]). Of the total 118 participants, 99.15%, 83.90%, 44.07%, and 14.42%, engaged in ≥, 6, 7, 8 and 9 hours of sedentary time per day.

****Table 1 inserted here****

Relationships between PA and sedentary time with targeted health outcomes

Results from linear regressions examining relationships between habitual daily PA and sedentary time with health outcomes are displayed in Table 2. Covariates (age, ethnicity, valid wear time and season) accounted for 24.9%, 27.3%, 19.0% and 38.0% of the variance in BF%, waist circumference, BMI-standard-deviation-score and cardiorespiratory fitness, respectively.

Model 1

LPA (min/day) was significantly negatively associated with waist circumference. However LPA was not related to BF%, BMI-standard-deviation -score or cardiorespiratory fitness. Both MVPA and VPA (min/day) were significantly and negatively associated with BF% and BMI-standard-deviation-score. In addition, MPA, VPA and combined MVPA (min/day) all demonstrated significant positive relationships with cardiorespiratory fitness. However, neither MVPA nor VPA (min/day) were associated with waist circumference (model 1), and MPA (min/day) was unrelated to all other health indicators. Sedentary time (min/day) was significantly positively associated with BF% and waist circumference and significantly negatively associated with cardiorespiratory fitness. However no significant association was observed between sedentary time and BMI-standard deviation score (model 1).

Independent associations

Model 2[a]

Following adjustment for sedentary time (min/day), the previously significant association between LPA (min/day) with waist circumference was attenuated and no longer significant. In addition, MPA, VPA and MVPA (min/day) were no longer significantly related to cardiorespiratory fitness, and MVPA and VPA were no longer significantly associated with BMI-standard-deviation-score after adjusting for sedentary time.

Examination of the beta coefficients revealed the positive relationship between sedentary time (min/day) and waist circumference to remain stable following adjustment for VPA (min/day), and approach significance (p = .05). However, sedentary time was not significantly associated with BMI-standard deviation score, BF% or cardiorespiratory fitness independent of VPA, or any of the measured health outcomes independent of LPA, MPA or MVPA (min/day).

Model 2[b]

Results demonstrated VPA (min/day) was no longer significantly associated with BF%, BMI-standard-deviation-score or cardiorespiratory fitness after adjusting for MPA (min/day) (models 2b). However, VPA remained significantly and positively associated with cardiorespiratory fitness, and significantly negatively related to BF% and BMI-standard-deviation-score following adjustment for LPA, The relationship between MPA and cardiorespiratory fitness observed in model 1 was not independent of VPA. However, the significant negative relationship between LPA and waist circumference remained following adjustment for VPA.

****Table 2 inserted here****

Discussion

This is the first study to examine inter-participant variability in objectively assessed habitual PA and sedentary time among youth sport participants and their associations with health outcomes. Findings demonstrated variability in average daily PA and sedentary time were related to adiposity indices and cardiorespiratory fitness in this cohort. Specifically, results revealed higher levels of daily PA (LPA, VPA and MVPA) to be linked to lower levels of adiposity, and PA above a moderate intensity (MPA, VPA and MVPA) to be positively associated with cardiorespiratory fitness among male youth sport footballers. However these associations were not independent of daily sedentary time. In addition, whilst daily sedentary time was also not independently associated with most health outcomes, relationships were stronger than reported for all PA behaviours. Moreover, daily sedentary time demonstrated a positive relationship with waist circumference independent of VPA, that approached significance ($p = .05$). Results suggest that promoting PA and in particular, reducing sedentary time might hold implications for the health of children and adolescents whom participate in youth sport. Accordingly, PA and sedentary time interventions focused within the youth sport context may be relevant towards preventing excess adiposity and improving cardiorespiratory fitness for these young people.

Variability in daily PA and sedentary time engagement

Aligned with previous studies, current findings indicated that average daily levels of MVPA to be above the recommended 60 minutes per day in male youth sport footballers (Machado-Rodrigues et al., 2012; Van Hoye et al., 2013; Wickel & Eisenmann, 2007). However, a more critical examination of individual estimates for daily MVPA indicated 29% of participants did not accrue an average of ≥ 60 minutes of MVPA per day, and only 14.5% achieved this guideline on every valid PA measurement day. Moreover, average daily MVPA and VPA were reported to be as low as 27 and 6 minutes per day respectively for some participants. Findings therefore denote a certain level of variability to exist with respect to habitual levels of engagement in MVPA and VPA among males active in the youth sport football setting. Thus, participation in youth sport may not necessarily encourage regular engagement in health enhancing levels of MVPA and VPA across the broad spectrum of children who participate in youth sport at the grassroots level.

With regards to daily sedentary time, current findings indicated average daily participation to range between 5 and 10 hours in the current sample of male youth sport footballers, with 44% of participants engaging in more than 8 hours sedentary time per day. Thus, whilst daily sedentary time also appears to be variable among this group of children and adolescents, results suggest children who participate in youth sport are likely to spend large proportions of their day sedentary. Indeed, findings support recent observations indicating participation in youth sport may be associated with engagement in high amounts of sedentary time (Machado-Rodrigues et al., 2012; Van Hoye et al., 2013). The high levels of sedentary time observed among this cohort may partly be attributable to compensatory behaviours. That is, youth may compensate for the energy expended during PA (e.g., sport participation) by reducing their energy expenditure (via increased sedentary time) in other periods of the day or on consecutive days. Certainly, studies in adults have documented increases in sedentary time following structured exercise interventions (Kozey-Keadle et al., 2013; Rosenkilde et al., 2012) and a recent study demonstrated that for every additional 10 minutes in MVPA per day, children reduced their PA engagement (MVPA and LPA) by 30 minutes the following day (Ridgers, Timperio, Cerin, & Salmon, 2014).

The levels of PA and sedentary time engagement observed herein are comparable to findings from recent population based studies (Griffiths et al., 2013; Pate, Mitchell, Byun, & Dowda, 2011; Woods, Tannehill, Quinlan, Moyna, & Walsh, 2010). For example, a recent study indicated only 19% of Irish youth aged 10 to18 years met guidelines for MVPA (assessed via accelerometers) on every day of the week (Woods et al., 2010). In addition, average daily sedentary time reported for over 40% of youth in the present sample was higher than average estimates observed in studies of English and American youth (e.g., 6 to 8 hours) (Pate et al., 2011). Importantly, the levels of adiposity observed in the current study are also comparable to those reported in epidemiological studies of youth across Europe (Collings et al., 2014; Ekelund et al., 2012). As such, present results indicate that, in terms of their patterns of engagement in PA and sedentary time, and adiposity status, youth sport participants may be more representative of the general population of children and adolescents that initially thought.

The present associations reported between inter-participant variabilities in habitual PA and sedentary time, with adiposity indices and cardiorespiratory fitness, add further support to this contention. Indeed, where population based studies have demonstrated associations between daily PA engagement, and more recently, daily sedentary time with adiposity indices and cardiorespiratory fitness (Basterfield et al., 2012; Dencker & Andersen, 2008; Ekelund et al., 2012; Fisher et al., 2011; Gutin & Owen, 2011), present results indicated average daily LPA, MVPA and VPA to be significantly and negatively associated with indicators of adiposity, with the reverse true for sedentary time. In addition, PA above a moderate intensity was positively linked, and sedentary time negatively related to cardiorespiratory fitness Thus, the health implications arising from promoting higher levels of overall PA engagement and reducing sedentary time among children active in the youth sport context are likely similar to those reported for the general population of school aged youth. Evidence for the associations between PA, sedentary time and health among youth have resulted in a considerable number of PA and sedentary time interventions aimed at preventing obesity and related diseases in young people. To date, such interventions have largely targeted the school setting due to their ability to impact upon the PA and sedentary time behaviours of almost all school-aged children and adolescents (i.e., including those whom may engage in low levels of PA and high sedentary time) (Jago & Baranowski, 2004; Lonsdale et al., 2013). However, the variability in daily PA and sedentary time and associations with health outcomes reported herein, suggest PA advancement and sedentary time reduction strategies focused within the youth sport context also hold promise for health promotion (i.e., preventing excess adiposity and improving cardiorespiratory fitness) among school-aged youth.

Recently, research has begun to investigate the independent influences of MVPA and sedentary time on health outcomes among youth. Increasingly, studies are reporting daily MVPA participation to be related to indicators of adiposity and cardiorespiratory fitness after adjusting for levels of sedentary time engagement (Chaput et al., 2012; Ekelund et al., 2012; Steele, van Sluijs, Cassidy, Griffin, & Ekelund, 2009). Consequently, the health benefits of promoting at least moderate intensity PA, rather than reducing sedentary time, have been emphasised (Ekelund et al., 2012; Steele et al., 2009). Whilst some studies have also reported sedentary time to exert independent effects on obesity and disease related health outcomes after adjusting for levels of engagement in MVPA (Henderson et al., 2012; Hsu et al., 2011; Mitchell et al., 2013), these findings have been inconsistent.

Present findings indicated MVPA was not related to any of the targeted health outcomes independent of sedentary time, and vice versa. As such, results suggest that the observed relationships between MVPA and sedentary time with adiposity indices and cardiorespiratory fitness are somewhat co-dependent in youth sport football participants. That is, increasing MVPA and reducing sedentary time may hold comparable health benefits for young male sport participants in terms of obesity linked disease prevention. Still, it is important to consider that whilst not significantly related to health outcomes independent of MVPA, sedentary time was more strongly associated with waist circumference, BF% and cardiorespiratory fitness than MVPA. Thus, whilst results indeed highlight the importance of increasing habitual MVPA participation among youth sport football participants, our findings imply that reducing sedentary time may hold greater implications for obesity and related disease prevention in this group of children. A recent study has demonstrated that the social environment created by the interpersonal behaviours of the youth sport coach is associated with daily levels of sedentary time engagement among youth sport participants (Fenton, Duda, Quested, & Barrett, 2014a). Specifically, Fenton et al., (2014a) reported more adaptive social environments that foster autonomous motivation towards sport and PA related to lower levels of habitual sedentary time among male youth sport footballers. Thus, the social environment may offer an attractive target for interventions seeking to reduce sedentary time among youth active in the youth sport context.

Further underlining the importance of reducing sedentary time engagement among the present population, current analysis also revealed the a positive association between sedentary time and waist circumference to remain stable (approaching significance (p = .05), after adjusting for VPA, Moreover, the previously significant associations between VPA with BF%, BMI-standard-deviation-score and cardiorespiratory fitness (see Table 2, model 1) were reduced and no longer significant. Studies have underlined the value of participation in youth sport for encouraging higher levels of engagement in VPA, and consequently, the positive health implications which may arise from sport involvement (e.g., reduced risk of excess adiposity) (Leek et al., 2014, Fenton et al., 2014b). However, for male youth sport footballers, current results suggest that some of the health benefits which may result from participation in youth sport and associated higher levels of VPA engagement may be negated by the high levels of sedentary time which also appear characteristic of these young people. In particular, the high levels of sedentary time associated with sport participation may have negative implications for levels of central adiposity among youth active in this context, regardless of levels of VPA engagement. Interestingly, LPA was also negatively associated with waist circumference after adjusting for VPA. Results therefore point to the value of concurrently promoting engagement in LPA and reducing sedentary time (e.g., encouraging sedentary breaks) in this cohort. Indeed, waist circumference is evidenced to be a marker of cardiometabaolic health, on which interruptions in sedentary time have been demonstrated to have a positive effect (Saunders et al., 2013).

A secondary aim of the present study was to investigate whether associations between VPA with adiposity indices and cardiorespiratory fitness were independent of LPA and MPA. Indeed, evidence that points to the importance of examining the independent relationships between VPA engagement (relative to sedentary time and other PA dimensions) with health outcomes among different populations is compelling (e.g., Steele et al., 2009). Present results reporting daily VPA engagement to be independently related to markers of general adiposity (i.e., BF%, BMI-standard-deviation-score) and cardiorespiratory fitness, following adjustment for LPA are therefore of interest. In particular, such findings may suggest that, for male youth sport footballers, whilst VPA is not related to health outcomes independent of sedentary time, encouraging engagement in this behaviour (relative to advancing engagement in LPA and MPA), may hold value when considering the prevention of excess adiposity and improving cardiorespiratory fitness. Indeed, results also revealed LPA was not significantly associated with cardiorespiratory fitness, and MPA to be unrelated to both BMI-standard-deviation-score and BF% following baseline adjustment for potential confounders.

Strengths of the present study involve the use of accelerometers to assess engagement in health-related PA behaviours and sedentary time in the targeted population of children. Further, measures of both central and general adiposity were assessed. Central adiposity is more closely associated with cardiometabolic risk factors than general adiposity (Klein et al., 2007). Thus, results from this study may help contribute towards determining the potential value of PA promotion and sedentary time reduction strategies towards improving cardiometabolic health among youth sport participants. Moreover, this is the first study to employ a combination of objective assessments to measure PA, cardiorespiratory fitness and adiposity via bioelectrical impedance analysis in youth sport participants. Previous studies have assessed adiposity largely via measurements of BMI and waist circumference. Thus, the present study adds a novel contribution to literature, characterising levels of PA engagement, adiposity and cardiorespiratory fitness in youth sport participants as well as examining associations between these variables.

Important to note is that the cross-sectional nature of the present study limits the extent to which we can make inferences regarding the direction of causality. For example, a recent longitudinal study reported that BF% predicted daily levels of PA engagement (Kwon, Janz, Burns, & Levy, 2011). Nevertheless, longitudinal studies demonstrate PA engagement and sedentary time to predict health outcomes related to obesity and cardiovascular disease (Mitchell et al., 2013; Must & Tybor, 2005), and exercise interventions targeting increases in moderate intensity PA engagement have demonstrated decreases in adiposity among youth (Lemura & Maziekas, 2002). Longitudinal studies examining the associations between daily PA and sedentary time with indicators of adiposity and cardiovascular risk in groups of youth sport participants are necessary in order to first determine the fuller potential of PA and sedentary time interventions targeting the behaviours of youth sport participants for obesity and disease prevention. Also interesting to determine would be the extent to which youth sport contributes towards levels of LPA, MPA and VPA across the week. Such research would serve to answer interesting questions related to the direct benefits of sport participation for health among this cohort. In line with this suggestion, it would also be interesting to determine the extent to which popular screen-based sedentary behaviours identified as being relevant to health (e.g., TV viewing), might contribute towards total sedentary time and related health among this cohort.

A further limitation to the present study is the possibility of sample bias. Participants were male footballers recruited from England. As such, results presented may not be generalisable to young people representing the wider ethnic distribution of the English population, females and children and adolescents who participate in other youth sports. However, the global popularity of youth sport football means findings may be applicable to large numbers of children worldwide (Kunz, 2007). In addition, associations between PA, sedentary time and health have been reported to occur in both males and females, and in different cultures and ethnic groups (Janssen & Leblanc, 2010; Tremblay et al., 2011). Nevertheless, further research that includes samples comprising girls, different ethnic groups and different youth sports, are required before the conclusions drawn can be generalised to the wider population of youth sport participants. Finally, we were unable to adjust for maturity status in the present research. Consequently, we are unable to determine the extent to inter-participant variability in pubertal development may have influenced variability in the presently assessed health outcomes. However, pubertal status is reported to be highly correlated with age (Booth, Johnson, Granger, Crouter, & McHale, 2003; Patia-Spear, 2007). As such, adjustment for age in the present analysis is likely to have somewhat accounted for the variance in health outcomes attributable to participants' maturity status. Nevertheless, future studies are required in order to discern the extent to which pubertal status is associated with the presently assessed health outcomes among youth sport participants.

Conclusion

Present results indicate a certain level of variability to exist with respect to habitual levels of engagement in PA and sedentary time among those males active in grassroots football setting. Moreover, this inter-participant variability is associated with obesity linked health outcomes and cardiorespiratory fitness. Whilst longitudinal studies are necessary, current findings highlight there is likely a need to increase levels of engagement in PA, and reduce engagement in sedentary time even in these groups of children traditionally considered to be among the most active (Nelson et al., 2011). Further, whilst not independently related, sedentary time appears to be more strongly associated with markers of adiposity than MVPA, and is positively related to central adiposity after adjusting for VPA engagement. Consequently, high levels of sedentary time associated with youth sport participation may negate some of the benefits associated with engaging in MVPA and VPA among this cohort. Findings therefore suggest the way in which we appraise the role of youth sport as a vehicle for PA promotion and related obesity prevention should perhaps be readdressed. That is, simply encouraging participation in youth sport alone may not be enough to promote PA engagement towards level required to accrue positive benefits to health (i.e., the prevention of overweight and obesity). Rather, youth sport may offer a setting through which to target the PA and sedentary behaviours of school-age youth who may be at risk of engaging in levels of PA and sedentary time that are adversely associated with markers of obesity and related diseases.

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Table 1. Descriptive statistics for the total sample and participants with valid PA data

	Total Sample (N = 149)		Valid PA data (N = 118)	
	Mean ± SD	Range (min – max)	Mean ± SD	Range (min – max)
Physical Characteristics				
Age (years)	11.72 ± 1.60	9 – 15	11.70 ± 1.62	9 –15
Height (m)	1.53 ± 0.13	1.29 – 1.90	1.53 ± 0.14	1.29 – 1.90
Weight (kg)	45.15 ± 13.44	24.90 – 92.30	44.76 ± 13.94	24.90 – 92.30
BMI (kg.m^2)	18.81± 3.14	13.81 – 29.90	18.66 ± 3.21	13.81 – 29.90
BMI-SDS	0.32 ± 1.10	-.2.46 – 2.81	0.24 ± 1.13	-.2.46 – 2.81
¶BF%	15.22 ± 5.54	5.30 – 41.70	14.88 ± 5.73	5.30 – 41.70
¶WC (cm)	68.32 ± 8.10	55.50 – 91.80	67.99 ± 8.12	55.50 – 91.80
CRF (ml.kg^{-1} min^{-1})	43.64 ± 8.23	29.95 – 71.15	44.33 ± 8.32	29.95 – 71.15
Physical activity				
ST (min/day)	465.07 ± 62.33	260.33 – 588.39	472.43 ± 56.64	306.18 – 588.39
LPA (min/day)	220.26 ± 38.00	132.00 – 323.64	220.59 ± 37.20	132.00 – 323.64
MPA (min/day)	46.11 ± 11.98	20.63 – 82.82	46.35 ± 11.93	20.63 – 82.82
VPA (min/day)	26.55 ± 11.57	6.31 – 63.39	27.29 ± 11.92	6.31 – 63.39
MVPA (min/day)	72.67 ± 21.22	26.94 – 146.21	73.64 ± 21.67	26.94 – 146.21
Valid hours (hours/day)	12.63 ± 0.96	9.23 – 14.91	12.78 ± 0.79	11.01 – 14.91

Note: Time restrictions placed on researchers at training sessions resulted in missing BF% and WC data for N = 11 and N = 26 participants, respectively (final sample sizes; valid accelerometer data and (1) BMI = 118 (2) BF, N = 107, (3) WC, N = 92 and (4) CRF, N = 118).

¶ = Non-normally distributed variables. These variables were log transformed and used in subsequent regression analysis. Average daily PA/ST were calculated by summing total minutes of PA/ST accrued across all valid days (i.e., ≥ 8 wear time/day), divided by the total number of valid days (e.g., total MVPA ÷ number of valid days = average daily MVPA).

BF% = percent body fat, WC = waist circumference, CRF = cardiorespiratory fitness
BMI-(SDS) = body mass index (standard deviation score), ST = sedentary time, LPA = light physical activity, MPA = moderate physical activity, VPA = vigorous physical activity, MVPA = moderate-to-vigorous physical activity.

Table 2. Results of regression analysis investigating the associations between objectively measured daily LPA, MPA, VPA, MVPA and ST with indicators of adiposity and CRF

	BF (%)					**WC (cm)**					**BMI-SDS**					**CRF (ml.kg^{-1} min^{-1})**				
	β	*p*	R^2	$R^{2\Delta}$	95% CI [lower, upper]	β	*p*	R^2	$R^{2\Delta}$	95% CI [lower, upper]	β	*p*	R^2	$R^{2\Delta}$	95% CI [lower, upper]	β	*P*	R^2	$R^{2\Delta}$	95% CI [lower, upper]
Model 1																				
ST	.32	.01**	.30	.05	.00, .00	.29	.02**	.41	.04	.00, .00	.16	.22	.20	.01	.00, .01	−.28	.01**	.42	.04	−.08, −.01
LPA	−.20	.07	.27	.03	.00, .00	−.23	.04*	.41	.03	.00, .00	−.02	.84	.19	.00	−.01, .01	.12	.22	.39	.01	−.02, .07
MPA	−.14	.11	.27	.02	.00, .00	−.12	.20	.39	.01	.00, .00	−.14	.12	.21	.02	−.03, .00	.21	.01**	.42	.04	.05, .25
VPA	−.19	.04*	.28	.03	−.01, .00	−.11	.24	.38	.01	.00, .00	−.18	.04*	.22	.03	−.03, .00	.21	.01**	.42	.04	.05, .25
MVPA	−.18	.04*	.28	.03	.00, .00	−.12	.18	.39	.01	.00, .00	−.17	<.05*	.22	.03	−.02, .00	.23	.01**	.43	.05	.03, .15
Model 2[a]																				
LPA	.11	.57	.30	.03	.00, .00	−.08	.70	.41	.00	.00, .00	.30	.12	.22	.03	.00, .02	−.30	.07	.44	.05	−.14, .01
ST	.43	.06			.00, .00	.21	.36			.00, .00	.45	.05¶			.00, .02	−.58	.00**			−.14, −.03
MPA	.03	.82	.30	.03	.00, .00	.05	.69	.41	.03	.00, .00	−.12	.34	.21	.00	−.04, .01	.14	.17	.43	.01	−.05, .25
ST	.35	.05†			.00, .00	.33	.06			.00, .00	.04	.83			−.01, .01	−.14	.35			−.06, .02
VPA	−.10	.31	.30	.02	.00, .00	−.01	.92	.41	.03	.00, .00	.17	.10	.22	.00	−.04, .00	.15	.08	.43	.01	−.01, .22
ST	.25	.08			.00, .00	.28	.05†			.00, .00	.04	.78			−.01, .01	−.18	.14			−.06, .01
MVPA	−.06	.59	.30	.02	.00, .00	.02	.88	.41	.03	.00, .00	−.18	.12	.22	.00	−.02, .00	.18	.07	.44	.00	−.01, .14
ST	.26	.11			.00, .00	.30	.07			.00, .00	−.01	.96			−.01, .01	−.12	.39			−.06, .02
Model 2[b]																				
LPA	−.20	.06	.31	.04	.00, .00	−.23	.03*	.42	.01	.00, .00	−.03	.80	.22	.03	−.01, .01	.12	.19	.43	.04	−.01, .07
VPA	−.19	.03*			−.01, .00	−.11	.21			.00, .00	−.18	.04*			−.03, .00	.21	.01**			.05, .25
MPA	−.03	.79	.28	.01	.00, .00	−.08	.50	.39	.00	.00, .00	−.03	.82	.22	.01	−.02, .02	.13	.20	.43	.01	−.05, .23
VPA	−.17	.17			−.01, .00	−.05	.67			.00, .00	−.16	.17			−.04, .01	.13	.21			−.05, .23

Note: * $p < .05$,** $p < .01$, † $p = .05$.

Models 2[a] and 2[b]: PA variables entered into separate regression models. Model 2[a]: adjustment for ST, Model 2[b]: adjustment for VPA. $R^{2\Delta}$ = Change in R^2; Model 1 $R^{2\Delta}$ indicates change (i.e., variance explained) following inclusion of PA variables after baseline adjustment for age, ethnicity, season and valid wear time, Models 2a and 2b $R^{2\Delta}$ indicates change following adjustment for ST and VPA, respectively. 95% confidence intervals are reported in their unstandardised form.

BF% = percent body fat, WC = waist circumference, CRF = cardiorespiratory fitness, BMI-(SDS) = body mass index (standard deviation score), ST = sedentary time, LPA = light physical activity, MPA = moderate physical activity, VPA = vigorous physical activity, MVPA = moderate-to-vigorous physical activity