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Objectively measured physical activity, body composition and physical fitness: Cross-sectional associations in 9- to 15-year-old children

LAURA JOENSUU [1,2], HEIDI SYVÄOJA [2], JOUNI KALLIO[2], JANNE KULMALA [2], URHO M. KUJALA [1], & TUIJA H. TAMMELIN[2]

[1]*Faculty of Sport and Health Sciences, University of Jyväskylä, Jyväskylä, Finland &* [2]*LIKES Research Centre for Physical Activity and Health, Jyväskylä, Finland*

Abstract

The aim of this study was to examine and quantify the cross-sectional associations of body composition (BC), physical activity (PA) and sedentary time (ST) with physical fitness (PF) in children and adolescents. A sample of 594 Finnish students (56% girls), aged 9–15 (12.4 ± 1.3 years) were selected for a study performed in 2013. The measurements of the Move! monitoring system for physical functional capacity were used to measure cardiorespiratory and musculoskeletal fitness and fundamental movement skills. Moderate-to-vigorous PA (MVPA) and ST were measured objectively with an accelerometer and BC by a bioelectrical impedance analysis. Fat mass index (FMI) and fat-free mass index (FFMI) were calculated to represent height-adjusted BC. Associations were explored with a linear regression model. In general, FMI had statistically significant negative associations, while FFMI and MVPA had positive associations with PF. No statistically significant associations were observed between ST and PF. In general, FMI had the strongest association with PF, although some variation occurred with sex and PF component. However, associations were practically relevant only in 20-m shuttle run, push-up, curl-up and 5-leaps test. For example, approximately 5 kg increase in fat mass in 155 cm tall children was estimated to correspond to 8 laps in 20-m shuttle run. Similar increase in fat-free mass corresponded to +4 and +6 laps, and 10 min increase in daily MVPA +3 and +2 laps in 20-m shuttle run, in boys and girls, respectively. Understanding these associations is necessary when interpreting children's PF and designing interventions.

Keywords: *Physical fitness, physical activity, body composition, children, adolescents*

Highlights

- This study aimed to examine and quantify the associations of body composition, physical activity and sedentary timewith different components of field-based measured PF.
- Interpretation of the results suggests that adiposity had the strongest and adverse association with PF. However, the positive associations of fat-free mass and MVPA were also considerable.
- For example, 5 kg kilograms increase in fat mass in 155 cm tall child was estimated to correspond 8 laps (one stage) weaker result in 20m shuttle run, while similar increase in fat-free mass and 10 minutes increase in daily MVPA corresponded to 2–6 laps better results.
- Understanding these associations is necessary when interpreting children's PF and designing interventions.

Introduction

Physical fitness (PF) consists of cardiorespiratory, musculoskeletal (including muscular fitness and flexibility) and neuromotor fitness (Garber et al., 2011). Childhood PF has been found to be associated with positive health outcomes during childhood (Bea, Blew, Howe, Hetherington-Rauth, & Going, 2016; Ruiz et al., 2016) and adulthood (Eisenmann, Wickel, Welk, & Blair, 2005). The evidence is especially strong for cardiorespiratory (Pate, Oria, & Pillsbury, 2012) and muscular fitness (Smith et al., 2014), while the direct health benefits of the motor

Correspondence: Laura Joensuu, Faculty of Sport and Health Sciences, University of Jyväskylä, Rautpohjankatu 8, 40700 Jyväskylä, Finland. Email: laura.p.joensuu@jyu.fi; @laurajoensuu

skill domain (Lubans, Morgan, Cliff, Barnett, & Okely, 2010) and flexibility (Plowman, 2014) are less evident.

PF measurements have recently been suggested as surrogate measures of health risks in children (Bangsbo et al., 2016; Ruiz et al., 2016). Several PF testing batteries are available for this population (Ruiz et al., 2011), although not all measurements have had their validity evaluated against laboratory measurements. Recently in Finland, a novel monitoring system for physical functional capacity (Jaakkola, Sääkslahti, Liukkonen, & Iivonen, 2012) was launched under the name of Move!, where the PF of every 5th- and 8th-grade (approximately 11 and 14 years old) child is assessed in comprehensive schools and the results are discussed individually with the child and their parent during health examinations (The Finnish National Board of Education).

Previous studies have shown that body composition (BC) (Ortega, Ruiz, Castillo, & Sjöström, 2008) and physical activity (PA) (Strong et al., 2005) have considerable associations with PF in children and adolescents. Although these direct associations have previously been studied, less is known about their interrelationships and practical associations with PF. Previous studies have shown inconsistent results about the scope of PA and BC on children's PF (Dencker et al., 2007; Lintu et al., 2016; Rauner, Mess, & Woll, 2013).

As PF measures are increasingly used as a tool to identify children with possible health risks, it is important to understand the associations of major modifiable correlates of PF. Determining the associations of PA and BC help us not only to understand the PF of children and adolescents better, but also to find the central variables for interventions. Moreover, the measurements used in health screening usually have a cross-sectional design and professionals are obligated to interpret and make primary decisions of child's health and well-being based on corresponding data. Therefore, the studies with this design are justified.

It is important to note that also age is a major correlate with PF as age-related growth, maturation and development have significant associations with PF (Malina, Bouchard, & Bar-Or, 2004). Therefore, age-adjusted analyses are required to achieve general recommendations for different aged children and adolescents.

This study aimed to examine and quantify the associations of BC, PA and sedentary time (ST) with different components of field-based measured PF. To our knowledge, this is the first study examining these associations with the full range of PF using objective measures of PA, ST and BC in children and adolescents.

Methods

Study design and participants

A total of 1778 students from 9 Finnish schools from grades 4 to 7 were invited to participate in a longitudinal study (2013–2015) which was part of research related to Finnish Schools' on the Move programme (LIKES Research Centre for Physical Activity and Health). A total of 971 students participated in the study (55%) and delivered a signed written consent with their main carer. Participation was voluntary and could be discontinued at any point during the research. A cross-sectional sample of baseline measurements from spring 2013 was used in this study. After excluding students with no valid PA data ($n = 204$), missing PF measurements ($n = 76$) and possible confounding factors (reported injuries, illnesses, learning difficulties or disabilities, $n = 97$), the final study population consisted of 594 apparently healthy students (56%), aged 9–15 (12.4 ± 1.3) years old.

The study setting for the measurements was approved by the Ethics Committee of the University of Jyväskylä. All measurements were carried out in accordance with the Declaration of Helsinki.

PA and ST measures

Objective measurements of PA and ST were conducted by using an accelerometer (ActiGraph GT3X +, wGT3X+, Pensacola, Florida, USA) for seven consecutive days. Participants were advised to continue their ordinary daily routines during the measurement period and instructed to wear the accelerometer on the right side of the hip during waking hours, except for water activities (e.g. shower, swimming). Data were collected in raw 30 Hz acceleration, standardly filtered and converted into 15 s epoch counts. ST (≤100 cpm) and moderate-to-vigorous PA (MVPA, ≥2296 cpm) (Evenson, Catellier, Gill, Ondrak, & McMurray, 2008) were defined from the data. Periods longer than 30 min of consecutive zero counts were defined as non-wear time (Domazet et al., 2016). Data over 20,000 cpm were considered as spurious acceleration and excluded (Heil, Brage, & Rothney, 2012). The minimum amount of adequate data was set as 500 min day^{-1} (between 7 am and 11 pm) (Cooper et al., 2015) for at least two weekdays and one weekend day. MVPA and ST were converted into a weighted mean value of MVPA and ST per day (e.g. [(average MVPA min/day of weekdays × 5 + average MVPA min/day of weekend × 2)/7]).

PF measures

PF was measured with the measurement battery included in the novel Move! monitoring system for physical functional capacity (Jaakkola et al., 2012). For more detailed descriptions of the measurements, see Supplement Document 1.

Cardiorespiratory fitness was evaluated with 20-m shuttle run where running speed is increased in 1-min interval until maximal voluntary exhaustion. Initial speed was $8.0\ \text{km h}^{-1}$, following speed $9.0\ \text{km h}^{-1}$ and following increment of $0.5\ \text{km h}^{-1}$ per stage (Nupponen, Soini, & Telama, 1999). The result was counted as the number of laps run.

Muscular fitness measurements included push-up and curl-up. Push-up (Malmberg, 2011; Pihlainen et al., 2008) measures upper-body muscular strength. Boys performed push-ups with hands and toes and girls with hands and knees on the ground. Students completed as many push-ups as possible during 1 min. The number of correctly performed repetitions was counted. Curl-up (Jaakkola et al., 2012; Plowman & Meredith, 2013) is a modified version of FitnessGram curl-up. The number of correctly performed repetitions was counted with maximal number of repetitions limited to 75.

Flexibility (Jaakkola et al., 2012) is a composite score comprised of four different multi-joint flexibility measurements. Measurements included squat, lower back extension and left and right shoulder stretch. Each student received 1 point out of each measurement that he/she performed according to the selected criteria. The maximum score in flexibility is 4 and minimum 0.

Fundamental movement skills (FMS) were selected as the representatives of the motor skills domain. FMS were evaluated with 5-leaps test and throwing–catching combination test. In the 5-leaps test (Jaakkola, Kalaja, Arijutila, Virtanen, & Watt, 2009), students performed five consecutive leaps. The first leap was performed with both legs, followed by four following alternating single-leg leaps. Landing was performed on both legs. Each student had two attempts to jump as far as they can and the best score was recorded in meters with 0.1 m accuracy. In the throwing–catching combination test (Jaakkola et al., 2012), students threw a tennis ball from 7 to 10 m distance (distance was selected according to their age and gender) to a 1.5 m × 1.5 m sized target area situated on the wall 0.9 m above the floor. Students had 20 attempts to throw the ball behind the marked line, hit the target area and catch the ball after one bounce. The number of correctly performed repetitions were counted.

The reliability (Intraclass correlation coefficient, ICC or Correlation coefficient, r) of the measurements are: push-up ICC: 0.76–0.94, curl-up ICC: 0.67, squat ICC: 0.62, lower back extension ICC: 0.81, shoulder stretch ICC: 0.82–0.85, 5-leaps test r: 0.84 and throwing–catching combination test ICC: 0.69 (Jaakkola et al., 2012).

The measurements were conducted in school's gym halls by educated research personnel. Measurements were performed on one student group (avg. 25 persons) during a 1.5 h session. The measurement techniques were explained and rehearsed prior to the official assessment.

Anthropometric and BC measurements

Body height was measured with an accuracy of 0.1 cm (Charder HM 200P scale). BC and weight were measured in light clothing using bioelectrical impedance analysis (InBody 720, Biospace Co., Ltd) prior to participating in the PF measurements. The validity of the InBody 720 has been shown to be reasonable for measuring BC in children: the Intraclass and Pearson correlation coefficients against dual-energy X-ray absorptiometry were >0.92 (Tompuri et al., 2015).

Fat percentage, body mass index (BMI, kg m^{-2}), fat mass index (FMI, kg m^{-2}) and fat-free mass index (FFMI, kg m^{-2}) were calculated (mass in kilograms divided by height in meters squared).

Questionnaire to guardians

The main carer was asked to report any injuries, illnesses or disabilities affecting the child's physical activity, physical fitness and/or school performance.

Statistical analysis

The IBM© SPSS© Statistics was used (IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.) for the analysis. Basic analyses were performed to test and obtain normally distributed data, means, standard deviations and correlations. For PF measures where the testing procedures varied between age groups, the results were initially transformed into a standardised z-score. The untransformed data is shown for clarity. Characteristics were compared between sex groups using independent t-test for continuous variables.

A linear regression model was used to explore associations of selected variables and PF. Analyses were performed separately for boys and girls. The final multivariable model consisted of age, FMI, FFMI, MVPA and ST with PF component as the dependent factor. FMI and FFMI were chosen for indicators of BC as these measures were not too highly correlated and could be placed in the same regression model. The ST was proportioned to device-wearing time. Additionally, the variation produced by MVPA was removed from the ST variable, i.e. the shared variance between MVPA and ST, resulting into an ST residual variable that is no longer correlated with MVPA. With this procedure, the collinearity of the model can be controlled and the independent associations of the ST explored (Sequential regression, Dormann et al., 2013).

Standardised regression coefficients (Stand. β) were used to indicate the direction of the associations and their comparable strength, and coefficients of determination (R^2) to indicate the model's robustness. The unstandardised regression coefficients (Unstand. β) were used to calculate practically relevant associations between BC, PA and PF. Statistical significance level was set at $p < .05$.

Results

Participant characteristics and group differences between boys and girls are shown in Table I.

Direction, significance and comparable strength for the associations of FMI, FFMI, MVPA and ST can be seen in boys (Table II) and girls (Table III) from standardised regression coefficients (Stand. β). For boys and girls, respectively, the regression model explained (R^2) 45.5% and 34.1% of the variance in cardiorespiratory fitness, 18.0–37.4% and 13.8–30.2% of the variance in muscular fitness, 6.1% and 5.1% of the variance in flexibility and 17.6–67.8% and 11.6–47.4% of the variance in FMS. In general, FMI was negatively associated, while FFMI, MVPA and age had positive associations with PF. Sedentary time had no statistically significant association with any of the PF components (Tables II and III). Correlation coefficients for boys and girls between used variables are shown in Supplement Table I.

Measurement-specific associations

20-m shuttle run. FMI had the strongest association with 20-m shuttle run in boys and girls ($p < .001$ and $p < .001$, respectively). MVPA ($p < .001$, $p < .001$) and FFMI ($p = .003$, $p < .001$) had also significant associations in both genders (Tables II and III).

Based on unstandardised regression coefficients of the linear regression model, the estimated practical associations (Table IV) showed that approximately 5 kg increase in fat mass in 155 cm tall children was equivalent of −8 laps in the 20-m shuttle run in boys and girls. Similar increase in fat-free mass corresponded to +4 and +6 laps and 10 min increase in daily MVPA +3 and +2 laps, in boys and girls, respectively.

Push-up. FMI had the strongest association in boys and girls ($p < .001$ and $p < .001$, respectively). In addition, only FFMI ($p < .001$) was associated with push-up in boys, while in girls, FFMI ($p < .001$) and MVPA ($p = .005$) had significant associations (Tables II and III).

Approximately 5 kg increase in fat mass in 155 cm tall children was equivalent of −6 repetitions in push-up in boys and girls (Table IV). Similar increase in fat-free mass corresponded to +5 and +8 repetitions, in boys and girls, respectively. Ten minutes increase in daily MVPA was equivalent of +1 repetition in girls, while in boys the association was not statistically significant.

Curl-up. FFMI had the strongest association with curl-up in boys ($p = .001$). In girls, FMI had the strongest association ($p < .001$), although FFMI was quite equally associated ($p < .001$). No other statistically significant associations were observed in girls. In boys, in addition, FMI ($p = .003$) and MVPA ($p = .002$) were associated with curl-up (Tables II and III).

Approximately 5 kg increase in fat mass in 155 cm tall children was equivalent of −4 and −6 repetitions in curl-up in boys and girls, respectively (Table IV). Similar increase in fat-free mass corresponded to +6 and +9 repetitions, in boys and girls, respectively. Ten minutes increase in daily MVPA corresponded to +2 repetitions in boys, while in girls, the association was not statistically significant.

Flexibility. FMI was the only factor associated with flexibility both in boys and girls ($p = .001$, $p = .001$, respectively) (Tables II and III).

Practical associations of fat were minor and corresponded to less than one (< −1) score point in flexibility.

5-leaps test. FMI had the strongest association in boys and girls ($p < .001$ and $p < .001$, respectively). FFMI ($p < .001$, $p < .001$) and MVPA ($p = .005$, $p = .030$) were also associated in both genders (Tables II and III).

Approximately 5 kg increase in fat mass in 155 cm tall children was equivalent of −60 cm in 5-leaps test in boys and girls (Table IV). Similar increase in fat-free mass was equivalent of +60 cm in boys and girls. Ten minutes increase in daily MVPA corresponded to +10 cm in boys and girls.

Throwing–catching combination test. In boys, MVPA had the strongest association ($p < .001$), with FMI ($p < .001$) and FFMI ($p = .030$) also associated. In girls, only FFMI ($p < .001$) had a statistically significant association.

Table I. Participant descriptives and group differences in characteristics between sexes

Descriptives	All subjects ($n = 971$)	Apparently healthy subject group ($n = 594$) Mean (SD)	Boys ($n = 263$) Mean (SD)	Girls ($n = 331$) Mean (SD)	p-Value[a]
Age	12.6 (1.3)	12.4 (1.3)	12.4 (1.3)	12.4 (1.3)	.79
Physical fitness					
Cardiorespiratory fitness					
20-m shuttle run (laps)	41.6 (19.0)	42.6 (18.2)	48.3 (19.5)	38.0 (15.6)	<.001
Muscular fitness					
Push-up (repetitions)	20.1 (13.2)	21.0 (12.9)	16.8 (11.5)	24.4 (12.9)	[b]
Curl-up (repetitions)	36.8 (20.6)	37.6 (20.7)	39.8 (20.9)	35.9 (20.3)	.02
Flexibility					
Flexibility score (0–4)	3.2 (0.9)	3.3 (0.9)	3.1 (1.0)	3.5 (0.7)	<.001
Fundamental movement skills					
5-leaps test (m)	8.2 (1.2)	8.2 (1.1)	8.5 (1.2)	8.0 (0.9)	<.001
Throwing–catching combination test (repetitions)	12.0 (4.9)	12.1 (4.9)	12.7 (5.1)	11.6 (4.7)	[b]
Physical activity					
MVPA (min·day-1)	52.7 (21.7)	52.1 (21.2)	58.2 (23.3)	47.3 (18.0)	<.001
ST (min·day-1)	499.7 (70.1)	499.7 (71.4)	485.5 (74.9)	511.0 (66.6)	<.001
Prevalence of MVPA ≥ 60min·day-1 (%)	34.0	33.7	44.9	24.2	<.001
Accelerometer wear time	769.9 (55.0)	769.6 (55.9)	765.9 (57.8)	772.5 (54.2)	.16
Anthropometrics and body composition					
Height (cm)	156.1 (10.4)	155.2 (10.1)	155.2 (11.1)	155.1 (9.3)	.85
Weight (kg)	46.5 (11.6)	45.2 (11.0)	44.6 (11.9)	45.7 (10.2)	.26
BMI (kg m^{-2})	18.9 (3.2)	18.6 (3.0)	18.2 (3.1)	18.8 (3.0)	.03
FMI (kg m^{-2})	3.7 (2.4)	3.5 (2.2)	2.9 (2.2)	4.0 (2.1)	<.001
FFMI (kg m^{-2})	15.2 (1.7)	15.1 (1.5)	15.4 (1.7)	14.8 (1.4)	<.001
Fat% (%)	18.4 (8.4)	17.9 (7.9)	14.7 (7.8)	20.4 (6.9)	<.001

Notes: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); FMI, fat mass index (calculated as fat mass in kilograms divided by height in meters squared); FFMI, fat-free mass index (calculated as fat-free mass in kilograms divided by height in meters squared); MVPA, moderate-to-vigorous physical activity; SD, standard deviation.
[a]*p*-Value, statistical significance value for group difference between sexes measured with independent samples *t*-test.
[b]Measurement method differed between boys and girls.

Although these associations were statistically significant, the practical associations were minor and corresponded to 1–2 repetitions in throwing–catching combination test in boys and girls (Table IV).

Discussion

Main findings

The results of our study are consistent with previous findings showing that adiposity has a strong negative association with PF (Ortega et al., 2008), while fat-free mass (Malina, 2014) and MVPA (Strong et al., 2005) have positive associations with PF. ST was not associated with any of the PF components after adjusting for age, BC and MVPA. This result was also consistent with the previous findings (Cliff et al., 2016). Interpretation of the results suggests that adiposity has the strongest and adverse association with PF. However, the positive associations of fat-free mass and MVPA are also considerable.

Previously, the possible confounding effect of adiposity with PF has been discussed. Adjusting fitness measures for body weight and/or BC have been considered (Plowman, 2014) and favourable scaling methods were recommended (Armstrong, 2017). It has been suggested that adjusting results with body weight and especially with adiposity would give more unbiased assessment of fitness (Lloyd, Bishop, Walker, Sharp, & Richardson, 2003). On the other hand, it is unclear whether adjusted results would give an accurate picture of adolescents' daily physical functional capacity (the ability to perform tasks that require physical effort) and how adjustments may affect the health-related criteria (Plowman, 2014) that has been recently developed (Ruiz et al., 2016). However, it is important to note that adiposity is highly associated with children's PF when explored with weight-bearing measures. More research is needed to achieve feasible, valid and coherent evaluation of PF in children (Armstrong, 2017; Plowman, 2014).

There was some variation, however, in the associations depending on sex and PF component. For example, fat-free mass had the strongest association with curl-up in boys and with throwing–catching combination test in girls. MVPA had the strongest association with throwing–catching combination test in boys. These anomalies can be explained by

Table II. The unstandardised regression coefficients (Unstand. β), standardised regression coefficients (Stand. β), 95% confidence intervals (CI 95%), statistical significance level (Sig.) and the total coefficient of determination (R^2) of FMI, FFMI, MVPA and ST in relation to physical fitness with boys

Boys	Unstand. β	Stand. β	CI (95%)	Sig.
Cardiorespiratory fitness				
20-m shuttle run (laps)				
FMI (kg m^{-2})	−4.203	−0.471	−5.134 to −3.272	<.001
FFMI (kg m^{-2})	1.970	0.172	0.669 to 3.270	.003
MVPA (min day^{-1})	0.269	0.321	0.187 to 0.350	<.001
Sedentary time (residual)	0.012	0.003	−0.361 to 0.384	.951
R^2	45.5%			
Muscular fitness				
Push-up (repetitions)				
FMI (kg m^{-2})	−2.846	−0.537	−3.439 to −2.254	<.001
FFMI (kg m^{-2})	2.691	0.395	1.863 to 3.519	<.001
MVPA (min day^{-1})	0.043	0.086	−0.009 to 0.095	.106
Sedentary time (residual)	−0.069	−0.033	−0.306 to 0.169	.568
R^2	37.4%			
Curl-up (repetitions)				
FMI (kg m^{-2})	−1.889	−0.197	−3.117 to −0.662	.003
FFMI (kg m^{-2})	3.016	0.244	1.300 to 4.732	.001
MVPA (min day^{-1})	0.173	0.192	0.065 to 0.280	.002
Sedentary time (residual)	0.189	0.050	−0.302 to 0.681	.449
R^2	18.0%			
Flexibility				
Flexibility score (0–4)				
FMI (kg m^{-2})	−0.107	−0.232	−0.170 to −0.044	.001
FFMI (kg m^{-2})	−0.022	−0.037	−0.110 to 0.067	.627
MVPA (min day^{-1})	0.001	0.015	−0.005 to 0.006	.823
Sedentary time (residual)	−0.018	−0.099	−0.043 to 0.007	.160
R^2	6.1%			
Fundamental movement skills				
5-leaps test (m)				
FMI (kg m^{-2})	−0.305	−0.538	−0.351 to −0.260	<.001
FFMI (kg m^{-2})	0.305	0.417	0.241 to 0.369	<.001
MVPA (min day^{-1})	0.006	0.109	0.002 to 0.010	.005
Sedentary time (residual)	0.001	0.005	−0.017 to 0.019	.910
R^2	67.8%			
Throwing–catching combination test (repetitions)				
FMI (kg m^{-2})	−0.572	−0.244	−0.873 to −0.272	<.001
FFMI (kg m^{-2})	0.464	0.154	0.044 to 0.884	.030
MVPA (min day^{-1})	0.058	0.263	0.031 to 0.084	<.001
Sedentary time (residual)	−0.053	−0.057	−0.173 to 0.068	.390
R^2	17.6%			

Notes: All models were controlled for age. FMI, fat mass index; FFMI, fat-free mass index; MVPA, moderate-to-vigorous physical activity; ST residual, sedentary time value where variation produced by MVPA and device-wearing time is removed. Coefficient of determination (R^2) represents the proportion of the variance in the fitness variable that was able to be predicted with the model.

the differences in the type of the measurement and subject group characteristics.

The pronounced role of muscle mass to curl-up, i.e. muscular fitness is logical. However, the findings from the other muscular fitness measurement (push-up) did not support this finding (where adiposity was the strongest correlate in both sexes). This is perhaps because the curl-up is less of a weight-bearing measurement than push-up, where body weight and excessive adiposity adds loading and impairs performance.

The throwing–catching combination test showed fat-free mass to have the strongest association in girls. The observations from the PF measurements showed that girls struggled to throw the ball far enough. These findings might indicate that the separative factor in girls was actually muscle strength instead of FMS. However, in boys, the strongest correlation with this task was MVPA. As Finnish boys' leisure time PA includes ball games more frequently than girls (Aarnio, Winter, Peltonen, Kujala, & Kaprio, 2002) and most ball games are considered MVPA in children (Ridley & Olds, 2008), it is logical that a higher volume of MVPA correlated with better FMS, as measured by object control skills.

Only adiposity was associated with flexibility. Although the flexibility measure included several

Table III. The unstandardised regression coefficients (Unstand. β), standardised regression coefficients (Stand. β), 95% confidence intervals (CI 95%), statistical significance level (Sig.) and the total coefficient of determination (R^2) of FMI, FFMI, MVPA and ST in relation to physical fitness with girls

Girls	Unstand. β	Stand. β	CI (95%)	Sig.
Cardiorespiratory fitness				
20-m shuttle run (laps)				
FMI (kg m^{-2})	−3.821	−0.509	−4.599 to −3.043	<.001
FFMI (kg m^{-2})	3.193	0.278	1.980 to 4.406	<.001
MVPA (min day^{-1})	0.206	0.237	0.124 to 0.288	<.001
Sedentary time (residual)	0.075	0.026	−0.249 to 0.399	.651
R^2	34.1%			
Muscular fitness				
Push-up (repetitions)				
FMI (kg m^{-2})	−3.209	−0.517	−3.872 to −2.546	<.001
FFMI (kg m^{-2})	3.792	0.400	2.759 to 4.826	<.001
MVPA (min day^{-1})	0.100	0.138	0.030 to 0.169	.005
Sedentary time (residual)	0.010	0.004	−0.266 to 0.286	.943
R^2	30.2%			
Curl-up (repetitions)				
FMI (kg m^{-2})	−3.155	−0.324	−4.312 to −1.998	<.001
FFMI (kg m^{-2})	4.642	0.311	2.838 to 6.445	<.001
MVPA (min day^{-1})	0.102	0.090	−0.020 to 0.223	.101
Sedentary time (residual)	0.344	0.091	−0.138 to 0.825	.161
R^2	13.8%			
Flexibility				
Flexibility score (0–4)				
FMI (kg m^{-2})	−0.077	−0.216	−0.122 to −0.033	.001
FFMI (kg m^{-2})	0.018	0.033	−0.052 to 0.087	.614
MVPA (min day^{-1})	0.002	0.046	−0.003 to 0.007	.423
Sedentary time (residual)	0.002	0.011	−0.017 to 0.020	.868
R^2	5.1%			
Fundamental movement skills				
5-leaps test (m)				
FMI (kg m^{-2})	−0.273	−0.612	−0.315 to −0.232	<.001
FFMI (kg m^{-2})	0.313	0.458	0.248 to 0.377	<.001
MVPA (min day^{-1})	0.005	0.093	0.000 to 0.009	.030
Sedentary time (residual)	0.012	0.071	−0.005 to 0.029	.165
R^2	47.4%			
Throwing–catching combination test (repetitions)				
FMI (kg m^{-2})	−0.266	−0.119	−0.535 to 0.002	.052
FFMI (kg m^{-2})	0.864	0.253	0.446 to 1.282	<.001
MVPA (min day^{-1})	0.021	0.080	−0.008 to 0.049	.150
Sedentary time (residual)	−0.025	−0.029	−0.137 to 0.086	.656
R^2	11.6%			

Notes: All models were controlled for age. FMI, fat mass index; FFMI, fat-free mass index; MVPA, moderate-to-vigorous physical activity; ST residual, sedentary time value where variation produced by MVPA and device-wearing time is removed. Coefficient of determination (R^2) represents the proportion of the variance in the fitness variable that was able to be predicted with the model.

assessments and indicated overall flexibility, the selected linear regression model could detect only 5.1–6.1% of the variance in flexibility, leaving 94.9–93.9% of the variance unexplained. This largely unexplained variance indicates that flexibility has other correlates than those covered in this study. This finding supports previous knowledge that flexibility is a highly specific characteristic (Plowman, 2014).

However, although the previously mentioned associations were statistically significant, they were practically relevant only in 20-m shuttle run, push-up, curl-up and 5-leaps test. The results of the linear regression model estimated that approximately 5 kg increase in fat mass content of a 155 cm tall child was equivalent of 8 laps lower performance (approximately 1 min or one stage) in 20 m shuttle run. Similar increase in fat-free mass content and a 10 min increase in daily MVPA corresponded to approximately 2–6 laps better performance. Similar findings were found with push-up, curl-up and 5-leaps test and are presented in detail in the Results section (Table IV).

Consistency of evidence with previous studies

To our knowledge, this is the first study that examines and attempts to quantify the associations of

Table IV. Estimated practical associations of fat, fat-free mass and MVPA with PF

	Boys		Girls
Cardiorespiratory fitness			
20-m shuttle run		laps	
+5 kg Fat mass[a]	−8		−8
+5 kg Fat-free mass[a]	+4		+6
+10 min MVPA·day^{-1}	+3		+2
Muscular fitness			
Push-up		repetitions	
+5 kg Fat mass[a]	−6		−6
+5 kg Fat-free mass[a]	+5		+8
+10 min MVPA·day^{-1}	ns		+1
Curl-up		repetitions	
+5 kg Fat mass[a]	−4		−6
+5 kg Fat-free mass[a]	+6		+9
+10 min MVPA·day^{-1}	+2		ns
Flexibility		flexibility score	
+5 kg Fat mass[a]	< −1		< −1
+5 kg Fat-free mass[a]	ns		ns
+10 min MVPA·day^{-1}	ns		ns
Fundamental movement skills			
5-leaps test		cm	
+5 kg Fat mass[a]	−60		−60
+5 kg Fat-free mass[a]	+60		+60
+10 min MVPA·day^{-1}	+10		+10
Throwing–catching combination test		repetitions	
+5 kg Fat mass[a]	−1		ns
+5 kg Fat-free mass[a]	+1		+2
+10 min MVPA·day^{-1}	+1		ns

Notes: Unstandardised regression coefficients of the linear regression model were transformed to relevant measurement related values and rounded to nearest integer. <1, indicates that the association is statistically significant but corresponds less than one unit in PF. ns, association was not statistically significant.

[a]Increase by two units in fat mass index or two units in fat-free mass index were equivalent of 4.8 kg (approximately 5 kg) of fat or correspondingly fat-free mass in a 155 cm tall child.

objectively measured PA, ST and BC with cardiorespiratory and musculoskeletal fitness and FMS in children and adolescents. A few studies have explored some of these associations with resembling methods. For example, Fogelholm, Stigman, Huisman, & Metsämuuronen, 2008; Lohman et al., 2008; Dencker et al., 2007 and Lintu et al., 2016 have previously explored the associations of BC, PA and PF in children. These cross-sectional studies have shown inconsistent results on these associations and found evidence supporting either the role of PA (Fogelholm et al., 2008; Lintu et al., 2016; Lohman et al., 2008) or BC (Dencker et al., 2007) with PF. The findings our study supports the importance of BC with PF. However, it is probable that these differences depend at least partially on the differences in subject groups and used methods. A systematic review from this field is needed to further understand these associations and differences according to used methods and subject groups. Furthermore, it needs to be acknowledged that BC and PA are representatives of fairly different dimensions; they describe the status of a physical characteristic and behaviour. This is an issue which is reasonable to consider when performing direct comparisons. Our study adds to previous research by quantifying the associations of BC and PA with various components of PF. Our study also showed that some variation exists in the roles of PA and BC with PF depending on sex, PF component and the type of PF measurement.

Thus, PA and BC have both positive and negative associations with PF in children and adolescents. Furthermore, these findings suggest that it might be beneficial to balance excess adiposity, support MVPA and gain muscle mass in order to promote PF. Previous findings from intervention studies support this interpretation. Systematic reviews have shown that exercise interventions have resulted into improved fitness in children (Kriemler et al., 2011). In addition, improving the status of these variables has also resulted into decreased health risks. Ho et al. (2013) showed in their review that dietary interventions and diet-plus-exercise interventions improve metabolic profiles in children and adolescents. Notably, combining diet and exercise was found to be more efficient than exercise alone. Similarly, García-Hermoso, Ramírez-Vélez, Ramírez-Campillo, and Peterson (2016) showed in their review that combining aerobic and resistance exercise resulted in greater improvements in metabolic profiles than aerobic exercise alone.

Notably, these findings show that promoting those factors which are associated with PF might contribute not only to PF but also to reduce health risks in children and adolescents. Therefore, it is favourable to support the positively associated factors and to improve the status of adversely associated factors, with effects possibly increasing when multi-purpose procedures are performed. This is a valuable aspect to recognise while designing interventions especially for those who are obese, have a low PF level and possible health risks.

We also want to acknowledge that although this study and previous findings have not observed associations between ST and PF or health (Cliff et al., 2016) in children and adolescents, there is evidence that high ST is associated with deleterious health outcomes in adults (Biswas et al., 2015); therefore, the possible negative long-term effects of ST should not be ignored.

Strengths and limitations

The major strengths of this study are the objective assessments of PA, ST and BC with the evaluation of a full range of PF components in a large sample of children and adolescents. BMI is commonly used in studies with large participant samples as a surrogate measure of adiposity, accompanied with subjective measures of PA. Using more definitive methods provides a more objective and accurate picture of these variables.

Several limitations are noted including the cross-sectional study design that makes it impossible to explore causalities. All PF measurements were measured on school premises with field-based measurements. Although the reliability of the measures used has been shown to be reasonable (Jaakkola et al., 2012) and measurements were performed by educated personnel, more accurate assessments of the characteristics might have been obtained in a laboratory setting. The selected variables (PA, ST and BC) explained 5–68% of the variance in PF in children and adolescents, leaving an additional 32–95% of the variance unexplained. This portion of the variance might include participant motivation, amount of practice, testing conditions and equipment, tester errors, differences in running economy and heritage (Pate et al., 2012; Plowman & Meredith, 2013), which could not be addressed in this study.

Finally, although accelerometers are commonly used to detect objective intensity and duration of PA, they do not record all PA (e.g. bike riding) or the quality of the activity (cardiorespiratory, musculoskeletal or neuromotor exercise).

Conclusions

This study aimed to explore and quantify the associations of BC and PA with PF in children and adolescents. In general, adiposity had a strong negative association with PF, while fat-free mass and MVPA had positive associations with PF. No associations were observed between ST and PF. The results of this study suggest that, in general, adiposity had the strongest association with PF. The positive associations of fat-free mass and physical activity were, however, also considerable. BC and PA could explain practically relevant associations in 20-m shuttle run, push-up, curl-up and 5-leaps test. For example, 5 kg increase in fat mass in 155 cm tall child was estimated to correspond to 8 laps (one stage) weaker result in 20-m shuttle run, while similar increase in fat-free mass and a 10 min increase in daily MVPA corresponded to 2–6 laps better results.

Understanding these associations is necessary when interpreting children's PF and designing interventions. Supporting the positively associated factors (PA and gain in muscle mass) and improving the status of adversely associated factors (adiposity) may contribute advantageously not only to children's and adolescents' PF but also to health.

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ORCID

Laura Joensuu http://orcid.org/0000-0002-9544-6552
Heidi Syväoja http://orcid.org/0000-0002-6068-9511
Janne Kulmala http://orcid.org/0000-0003-0402-7983
Urho M. Kujala http://orcid.org/0000-0002-9262-1992

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