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Physical fitness in relation to later body composition in pre-school children

Pontus Henriksson[a,b,c,*], Marja H. Leppänen[d], Hanna Henriksson[b,c], Christine Delisle Nyström[a,e], Cristina Cadenas-Sanchez[c], Anna Ek[a,f], Jonatan R. Ruiz[a,c], Francisco B. Ortega[a,c], Marie Löf[a,b]

[a] Department of Biosciences and Nutrition, Karolinska Institutet, Sweden
[b] Department of Medical and Health Sciences, Linköping University, Sweden
[c] PROFITH "PROmoting FITness and Health Through Physical Activity" Research Group, Department of Physical Education and Sports, Faculty of Sport Sciences, University of Granada, Spain
[d] Faculty of Sport and Health Sciences, University of Jyvaskyla, Finland
[e] Healthy Active Living and Obesity (HALO) Research Group, Children's Hospital of Eastern Ontario Research Institute, Canada
[f] Division of Pediatrics, Department of Clinical Science, Intervention and Technology, Karolinska Institutet, Sweden

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ABSTRACT

Objectives: Although physical fitness is considered a marker of health in youth, little is known whether physical fitness in pre-school age is related to later body composition. Thus, this study investigated (i) associations of physical fitness at 4.5 years of age with body composition 12 months later and (ii) whether improvements in physical fitness during the 12-month follow-up were associated with changes in body composition.
Design: This study included 142 children, measured at 4.5 and 5.5 years, from the control group of the MINISTOP trial.
Methods: Physical fitness (cardiorespiratory fitness, lower- and upper-body muscular strength and motor fitness) was measured using the PREFIT test battery. Body composition was assessed using air-displacement plethysmography.
Results: In adjusted regression analyses, greater cardiorespiratory fitness, lower-body muscular strength and motor fitness at 4.5 years were associated with a lower fat mass index at 5.5 years (standardized $\beta = -0.182$ to -0.229, $p \leq 0.028$). Conversely, greater cardiorespiratory fitness, lower- and upper-body muscular strength as well as motor fitness at 4.5 years of age were associated with a higher fat-free mass index (standardized $\beta = 0.255$–0.447, $p \leq 0.001$). Furthermore, improvements in cardiorespiratory fitness, lower-body muscular strength and motor fitness during the 12-month follow-up period were associated with decreases in fat mass index and/or % fat mass.
Conclusions: In conclusion, the results of this study provide evidence of the importance of physical fitness early in life. Nevertheless, further studies are needed in order to clarify the influence of physical fitness in the pre-school age with later health outcomes.

Practical implications

- Greater physical fitness 4.5 years of age was related to a healthier body composition (i.e. less fat mass and/or more fat-free mass) at the 12 months follow-up.
- Improvements in physical fitness was related to decreases in fat mass during the follow-up period.
- These results highlight the relevance of physical fitness already in pre-school age and motivates efforts to improve physical fitness in this age-group.

1. Introduction

The escalating prevalence of childhood obesity is a concern globally.[1] This is alarming, since childhood obesity generally tracks into adulthood[2] and is also related to premature death, diabetes and cardiovascular disease later in life.[3] Physical fitness has been found to counteract some of the negative health consequences of

* Corresponding author.
E-mail address: pontus.henriksson@ki.se (P. Henriksson).

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obesity on health[4] and is considered to be a powerful marker of health in youth.[5] For instance, greater cardiorespiratory fitness has been found to be associated with a lower risk of later premature death[6], and cardiovascular diseases[7] both in normal-weight and overweight/obese adolescents.

Greater physical fitness has also been consistently associated with lower body fatness and body mass index (BMI) in school-aged children and adolescents.[5,8–12] Interestingly, several cross-sectional studies have also reported that greater physical fitness already in the pre-school age is related to lower levels of adiposity or BMI.[13–17] For instance, in our previous study,[14] physical fitness in 4-year-olds was inversely associated with fat mass, but positively associated with fat-free mass. The knowledge based on these cross-sectional studies indicates that physical fitness and body composition is correlated already in early ages. However, whether physical fitness in preschool-aged children is associated with body composition later in life, and whether improvements in fitness are associated with improvements in body composition remains to be investigated. Such studies would be of great importance to further clarify the role of fitness in the preschool-age for later health.

Therefore, the aim of this study was to examine the associations of physical fitness (cardiorespiratory fitness, muscular strength and motor fitness) in 4.5-year-olds with body composition 12 months later. Additionally, we also studied whether the improvements in physical fitness during the 12-month follow-up period were associated with improvements in body composition during the corresponding time period.

2. Methods

This study utilized data from the MINISTOP trial (Mobile-based INtervention Intended to STop Obesity in Preschoolers) conducted between 2014 and 2015. This trial aimed to promote healthy diet, physical activity and body fatness in preschool-aged children through a mobile health (mHealth) application targeting their parents.[18] After a population-based recruitment,[18] a total of 315 children were included in the trial, and 156 children were randomized into the intervention group and 159 children into the control group. The main results were that the MINISTOP app improved a composite score of dietary and physical activity habits and it appeared that the effect was strongest for the dietary components.[18] Thus, in order to avoid any interventional effects on the results in the present analysis (for instance, an effect on diet which in turn would influence body composition), the analyses were restricted to children in the control group only. Of the 159 children in the control group, a total of 145 were measured at the 12-month follow-up. In this analysis, we included the 142 children with complete body composition data at 4.5 and 5.5 years of age that had any physical fitness component measured at 4.5 years of age. The MINISTOP trial received ethical approval by the Research Ethics Committee, Stockholm, Sweden (2013/1607–31/5; 2013/2250–32) and was prospectively registered as a clinical trial (https://clinicaltrials.gov/ct2/show/NCT02021786). The study was conducted according to the Declaration of Helsinki and informed consent, witnessed and formally recorded, was obtained from the parents.

Physical fitness was measured using the PREFIT battery (FITness testing in PREschool children).[19,20] This fitness battery includes tests covering cardiorespiratory fitness, muscular strength and motor fitness (speed-agility). *Cardiorespiratory fitness* was assessed by means of the 20 m shuttle run, which started at 8.5 km/h with the speed increasing by 0.5 km/h each minute during the test.[21] Briefly, children ran back and forth between two lines which were 20 m apart. Children ran the test individually together with one person from the trained research staff and they were paced by an audio signal. The test was completed when the child failed to reach the line concurrent with the audio signal or finished due to exhaustion. Given the maximal nature of this test, it was performed once and placed last in the physical fitness measurement session. *Upper-body muscular strength* was measured using a handgrip strength test. Children squeezed an analog dynamometer (TKK 5001, Grip-A, Takei, Tokyo) gradually and continuously for at least 2 s. Grip span was set at 4.0 cm. The test was performed twice for each hand. The highest value for each hand was retained and then the average for these two results was used in the analyses as a measure of upper-body muscular strength. *Lower-body muscular strength* was assessed using the standing long jump test. Briefly, children jumped as far as possible with their feet together while remaining upright. The better of two attempts was used in the analyses. *Motor fitness* (speed-agility) was measured by means of the 4×10 m shuttle run test. In this test, the children ran as fast as possible between two lines that were 10 m apart covering a total of 40 m. In this test, lower scores indicate higher performance. This test was performed twice and the quickest time was used in the analyses.

Anthropometry and body composition were measured before the physical fitness testing and all measurements were taken without shoes and in tight fitting underwear. Height of the children was measured using a wall stadiometer (Tillquist, Spånga, Sweden) to the nearest 0.1 cm. Weight and body composition were assessed using the pediatric option for BodPod (COSMED USA, Concord, CA, USA) as previously described.[22] This methodology has been found to provide accurate estimates of body fatness in 2–6-year-old children.[23] Overweight and obesity were classified according to the BMI cut-offs by Cole and Lobstein.[24] Body composition was described using BMI, % fat mass (%FM), fat mass index (FMI) and fat-free mass index (FFMI). BMI was calculated as body weight (kg) divided by height squared (m^2). FMI and FFMI were calculated as fat mass or fat-free mass (kg) divided by height squared (m^2), respectively.

Independent t-tests were used to examine the differences between boys and girls in regards to age, body composition and physical fitness. In the analyses, times for the 4×10 m shuttle run were inverted (i.e. multiplied by -1) as a lower time in this test indicates a higher performance. To examine linear associations between physical fitness and body composition, we applied linear regression analysis. Two regression models were created; one unadjusted and one adjusted for potential confounders, i.e. maternal BMI, maternal educational attainment (university degree vs. no university degree), age at the measurements, sex, and baseline values of exposures and outcomes (only in change vs. change analysis in Table 3). In the fully adjusted models, we examined interaction terms (physical fitness x sex) to examine whether the associations between physical fitness and body composition differed between boys and girls. Overall, there was very little evidence for any sex-interactions and thus, results are presented with boys and girls combined. The study size of the entire MINISTOP trial (n = 315) was based on a previous power calculation for the primary intervention outcomes which were FMI and a composite score comprised of diet and physical activity variables.[18] Although this is a secondary analysis, it is noteworthy that a sample size of 133 participants provides 80% power ($\alpha = 0.05$, two-tailed) to detect associations with a standardized regression coefficient of 0.24. Furthermore, we also applied analysis of covariance (ANCOVA) to investigate whether there were any differences in body composition at 5.5 years of age between the children that had physical fitness levels above and below the sex-specific median at 4.5 years of age. All hypothesis tests were two-sided and $p < 0.05$ was considered statistically significant. The statistical analysis was conducted using SPSS Statistics 22 (IBM, Armonk, NY, USA).

3. Results

Mothers of the participating children were on average 35 ± 4 years with an average BMI of 23.8 ± 4.1 kg/m^2 and 68% (n = 97) of the mothers had a university degree. Descriptive data for the 142 preschool-aged children in the study are provided in Table S1 in Supplementary material. At 4.5 years of age children were on average 107.6 ± 4.4 cm tall, and weighed on average 18.2 ± 2.4 kg. Corresponding figures at 5.5 years of age were: 115.3 ± 4.9 cm and 20.5 ± 3.0 kg. At 4.5 years and 5.5 years of age, 11 children (7 boys and 4 girls) and 9 children (5 boys and 4 girls) were overweight/obese, respectively.

Associations of physical fitness at 4.5 years of age with body composition at 5.5 years of age are presented in Table 1. Greater cardiorespiratory fitness, lower-body muscular strength and motor fitness at 4.5 years were associated with lower FMI, %FM, but not with BMI, at 5.5 years of age. More specifically, in adjusted analyses, each standard deviation (SD) greater cardiorespiratory fitness, lower-body muscular strength and motor fitness were associated with 0.229, 0.182 and 0.184 SD (all $p \leq 0.028$) lower FMI, respectively. Conversely, greater cardiorespiratory fitness (adjusted standardized $\beta = 0.265$, $p = 0.001$), lower-body muscular strength (adjusted standardized $\beta = 0.303$, $p < 0.001$) and motor fitness (adjusted standardized $\beta = 0.255$, $p = 0.001$) were related to a higher FFMI. Upper-body muscular strength at 4.5 years of age was not related to FMI at the 12-month follow-up, but it was positively related to BMI (adjusted standardized $\beta = 0.385$, $p < 0.001$) and FFMI (adjusted standardized $\beta = 0.447$, $p < 0.001$).

As shown in Fig. 1, children whose physical fitness levels were above the sex-specific median at 4.5 years of age generally had a more favorable body composition at the 12-month follow-up. For instance, children whose cardiorespiratory fitness and motor fitness were above the sex-specific median at 4.5 years of age had a lower FMI and %FM, but a higher FFMI at 5.5 years of age (all $p < 0.05$). Furthermore, greater lower-body muscular strength was associated with a lower FMI and a higher FFMI at the 12-month follow-up (all $p < 0.05$). Finally, children who had upper-body muscular strength above the sex-specific median at the age of 4.5 years also had a greater FFMI at 5.5 years of age ($p < 0.001$).

Associations of changes in physical fitness between 4.5 and 5.5 years of age with changes in body composition during the corresponding time period are presented in Table 2. In these analyses, improvements in cardiorespiratory fitness, lower-body muscular strength and motor fitness were associated with decreases in FMI or %FM during the 12-month follow-up period. However, there were no statistically significant associations between the changes in any of the physical fitness components and the change in FFMI (Table 2).

A supplementary analysis (Table S2) examining associations of body composition at 4.5 years with physical fitness at 5.5 years shows that these associations were generally weaker and less consistent than the ones between physical fitness at 4.5 years of age and body composition at the 12-month follow-up (i.e. Table 1). Thus, FMI was inversely associated with later lower-body muscular strength and motor fitness ($p \leq 0.022$), but not with cardiorespiratory fitness or upper-body muscular strength (Table S2). Furthermore, a higher FFMI was positively associated with upper-body and lower-body muscular strength ($p \leq 0.014$), but not with cardiorespiratory or motor fitness, respectively.

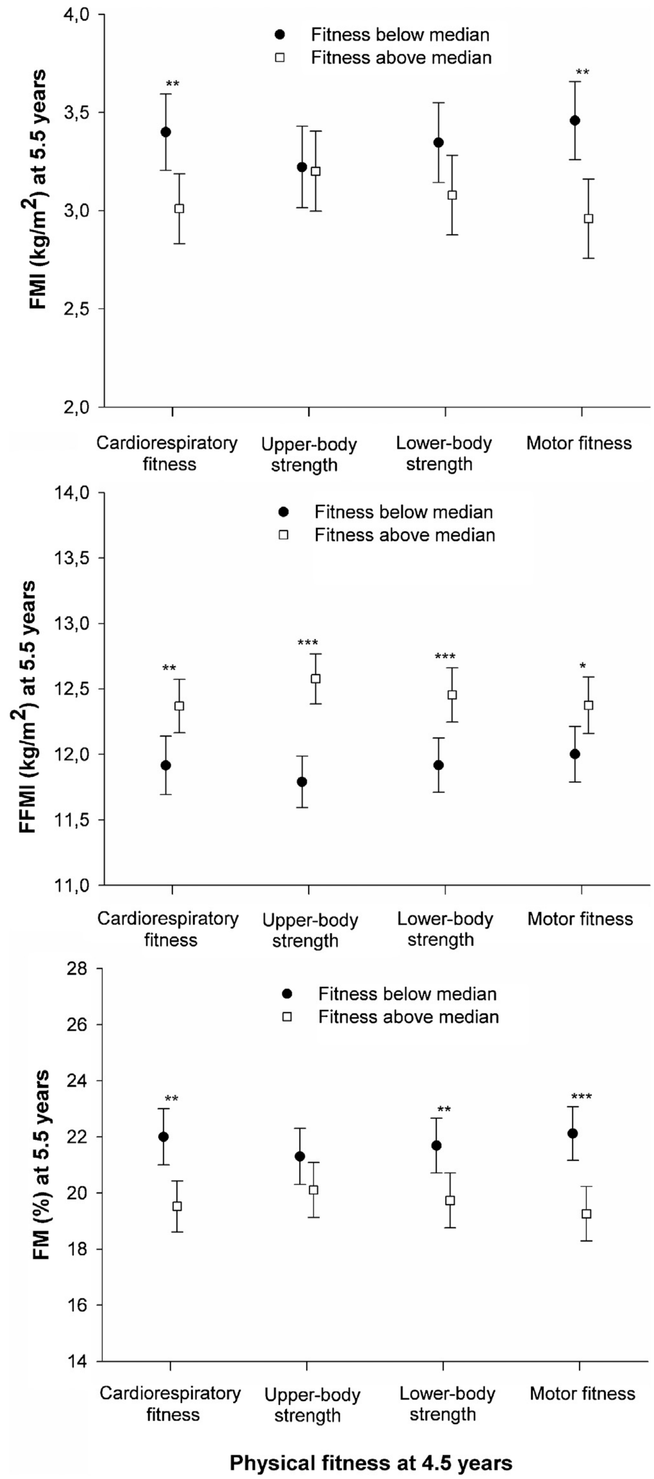

Fig. 1. Association of physical fitness below or above the sex-specific median at 4.5 years with body composition at 5.5 years. Analyses were conducted using analysis of covariance (ANCOVA) adjusting for maternal BMI, maternal educational attainment, childs sex and age, at the measurements. Data are presented as estimated marginal means with their 95% confidence intervals. FFMI, fat-free mass index; FM, fat mass; FMI, fat mass index. Differences between the two groups: *$p < 0.05$, **$p < 0.01$, *** $p < 0.001$.

4. Discussion

The main findings of this study were that better physical fitness at 4.5 years of age was associated with lower fat mass and higher fat-free mass at 5.5 years of age, and that improvements in physical fitness during the 12-month follow-up period was associated with decreases in fat mass. These results motivate efforts to promote physical fitness through increasing physical activity levels already early in life. Our findings are novel, since to the best of our knowledge, this is the first study investigating associations of physical fitness in preschool-aged children with later body composition.

Table 1
Associations of physical fitness at 4.5 years with body composition at 5.5 years (n = 138–142).

	Physical fitness[a] at 4.5 years (x)							
	Cardiorespiratory fitness		Upper-body muscular strength		Lower-body muscular strength		Motor fitness	
Body composition at 5.5 years (y)	β	p	β	p	β	p	β	p
BMI (kg/m^2)								
Unadjusted	0.055	0.52	0.389	<0.001	0.105	0.21	0.058	0.49
Adjusted[b]	0.064	0.48	0.385	<0.001	0.112	0.20	0.074	0.40
FMI (kg/m^2)								
Unadjusted	−0.306	<0.001	−0.025	0.77	−0.265	0.001	−0.242	0.004
Adjusted[b]	−0.229	0.007	0.061	0.47	−0.182	0.028	−0.184	0.026
FFMI (kg/m^2)								
Unadjusted	0.318	<0.001	0.531	<0.001	0.370	<0.001	0.288	0.001
Adjusted[b]	0.265	0.001	0.447	<0.001	0.303	<0.001	0.255	0.001
FM (%)								
Unadjusted	−0.362	<0.001	−0.170	0.043	−0.346	<0.001	−0.311	<0.001
Adjusted[b]	−0.272	0.001	−0.066	0.41	−0.245	0.001	−0.245	0.001

BMI, body mass index; FFMI, fat-free mass index; FM, fat mass; FMI, fat mass index; β, standardized regression coefficient.
[a] Physical fitness was measured using the PREFIT battery, i.e. 20 m shuttle run test (cardiorespiratory fitness), handgrip strength test (upper-body muscular strength), standing long jump test (lower-body muscular strength) and 4 × 10 m shuttle run test (motor fitness).
[b] Adjusted for maternal BMI, maternal educational attainment, childs sex and age, at the measurements.

Table 2
Associations of change in physical fitness with change in body composition between the ages of 4.5 and 5.5 years (n = 133–140).

	Change[a] in physical fitness[b] (x)							
	Cardiorespiratory fitness		Upper-body muscular strength		Lower-body muscular strength		Motor fitness	
Change[a] in body composition (y)	β	p	β	p	β	p	β	p
BMI (kg/m^2)								
Unadjusted	−0.054	0.54	0.127	0.13	−0.035	0.68	−0.089	0.30
Adjusted[c]	−0.046	0.63	0.208	0.032	−0.001	0.99	−0.047	0.70
FMI (kg/m^2)								
Unadjusted	−0.160	0.066	0.021	0.81	−0.157	0.064	−0.058	0.49
Adjusted[c]	−0.200	0.015	0.130	0.13	−0.211	0.014	−0.188	0.089
FFMI (kg/m^2)								
Unadjusted	0.100	0.25	0.088	0.30	0.127	0.13	−0.011	0.90
Adjusted[c]	0.082	0.33	0.137	0.098	0.137	0.091	0.098	0.36
FM (%)								
Unadjusted	−0.174	0.045	−0.018	0.84	−0.181	0.033	−0.051	0.55
Adjusted[c]	−0.198	0.011	0.064	0.43	−0.263	0.001	−0.222	0.032

BMI, body mass index; FFMI, fat-free mass index; FM, fat mass; FMI, fat mass index; β, standardized regression coefficient.
[a] Refers to the change in physical fitness and body composition between the measurements at 4.5 and 5.5 years of age.
[b] Physical fitness was measured using the PREFIT battery, i.e. 20 m shuttle run test (cardiorespiratory fitness), handgrip strength test (upper-body muscular strength), standing long jump test (lower-body muscular strength) and 4 × 10 m shuttle run test (motor fitness).
[c] Adjusted for maternal BMI, maternal educational attainment, child's sex, age at the measurements and baseline values of exposures and outcomes.

Importantly, the associations of physical fitness with later BMI were not statistically significant. This is likely due to the fact that the direction of the associations of physical fitness with FMI and FFMI go in opposite directions questioning the applicability of BMI in this age group. Indeed, BMI cannot differentiate between fat mass and fat-free mass and we have previously demonstrated that BMI is as strongly related to FFMI as it is to FMI in 4.5 year-olds.[25] Using accurate body composition methodology enabled us to identify the associations between physical fitness and body composition that BMI could not detect. This motivates the measure of detailed body composition in pre-school aged children. Another novel aspect of this study is that physical fitness and body composition were measured at 4.5 and 5.5 years of age which made it possible to test bidirectional associations between fitness and body composition. Interestingly, the associations between physical fitness and later body composition were more pronounced, more consistent, and by extension likely to be more practically meaningful than corresponding associations of body composition and later physical fitness. Indeed, physical fitness is positively related to physical activity[26] which may stimulate both increases in fat-free mass as well as decreases in fat mass due to increased activity energy expenditure. Even though no previous study has examined the association of physical fitness in preschool-aged children with later body composition, our results may be compared with studies conducted in slightly older children. For instance, Rodrigues et al.[27] reported that 6-year-olds with a greater performance in the 20 m shuttle run test, standing long jump test and 50 m dash test were all associated with decreased body fat growth over the 9-year follow-up. In a large study of 4878 Cypriot adolescents, the odds of becoming overweight during a 4-year follow-up was 60% lower in the participants in the highest quartile of cardiorespiratory fitness as compared to the participants in the lowest quartile.[12] Also, several other studies have concluded that changes in cardiorespiratory fitness and/or motor competence in childhood are inversely associated with the risk of becoming overweight or obese.[9–11] Thus, the results from this study builds upon previous studies by demonstrating that the association of physical fitness with later adiposity is present already in preschool-aged children.

The results of this study may have implications for public health. Firstly, it provides further evidence that physical fitness already in preschool-aged children may be a marker of current or future health, which already has been established in older children.[5] By examining both BMI and accurately measured FMI in this study, we could clearly point out the limitations of BMI in this age category, considering that the observed associations of physical fitness with later FMI would not have been identified if BMI was used as a proxy for adiposity. Thus, interventions that aim to reduce fat mass through physical activity and/or diet should consider accurate measurements of body composition. Generally, the strength of the identified associations of physical fitness with FMI and FFMI may be considered as weak-to-moderate.[28] For instance, the standardized regression coefficients show that each 1 SD greater cardiorespiratory fitness at 4.5 years of age was associated with approximately 0.23 SD lower FMI and 0.27 SD higher FFMI at 5.5 years of age. However, considering that both low fat mass and adequate fat-free mass may be of importance for health,[29] we believe that the identified associations between physical fitness and body composition in this study are strong enough to be of some public health importance. However, it is possible that the strength of the associations between physical fitness in the preschool age with later body composition weakens over time. Thus, the relatively short follow-up (12 months) in our study should be noted which also motivates further studies with longer follow-ups.

This study has several important strengths such as accurately measured body composition and physical fitness.[19,20,23] Furthermore, as stated previously,[18] the population-based sampling resulted in a study sample which was very comparable to the invited sample and/or Swedish children in general, although parents were slightly more well-educated than the Swedish adults on average.

There are also limitations that need to the recognized. Firstly, this is an observational study which does not prove causality. Secondly, although consistent associations were observed between physical fitness at 4.5 years and body composition 12-months later, there is a need for studies with a longer follow-up. Such studies may also include additional health outcomes such as cardiometabolic risk factors and bone health. Furthermore, our study included relatively few children with overweight and obesity which motives further studies in samples with greater prevalence of overweight/obesity. Other limitations of our study is that it lacked adjustments for dietary changes as well as a comprehensive measure of motor competence, both which should be considered in future studies. Finally, although the tests in the PREFIT battery are considered as reliable and feasible,[19] they are performance-based which comes with inherent limitations. For instance, previous studies have suggested caution and proper scaling when relating fitness to health outcomes e.g. Ref. 30. Thus, although our results are the first to demonstrate the association of physical fitness with later body composition in preschool-aged children, further studies are needed to expand our knowledge regarding the influence of early fitness with later health.

5. Conclusion

Physical fitness at 4.5 years of age was associated with less fat mass and more fat-free mass 12-months later. Furthermore, improvements in physical fitness during this time period were associated with decreases in fat mass. Thus, this study provides evidence for the relevance of physical fitness early in life. Nevertheless, further studies are needed in order to clarify the influence of physical fitness in the pre-school age with health outcomes later in life.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.jsams.2018.11.024.

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