Motor competence and cardiorespiratory fitness have greater influence on body fatness than physical activity across time

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We investigated the longitudinal associations among physical activity (PA), motor competence (MC), cardiorespiratory fitness (VO2peak), and body fatness across 7 years, and also analyzed the possible mediation effects of PA, MC, and VO2peak on the relationships with body fatness. This was a seven-year longitudinal study with three measuring points (mean ages [in years] and respective sample size: 6.75±0.37, n=696; 9.59±1.07, n=617; 13.35±0.34, n=513). PA (moderate-to-vigorous PA—MVPA and vigorous PA—VPA) was monitored using accelerometers. MC was assessed by the “Körperkoordinationstest für Kinder—KTK” test battery. VO2peak was evaluated using a continuous running protocol until exhaustion. Body fatness was determined by the sum of four skinfolds. Structural equation modeling was performed to evaluate the longitudinal associations among PA, MC, VO2peak, and body fatness and the potential mediation effects of PA, MC, and VO2peak. All coefficients presented were standardized (z-scores). MC and VO2peak directly influenced the development of body fatness, and VO2peak mediated the associations between MVPA, VPA, MC, and body fatness. MC also mediated the associations between MVPA, VPA, and body fatness. In addition, VO2peak had the largest total association with body fatness ($\beta$=−0.431; $P<.05$), followed by MC ($\beta$=−0.369; $P<.05$) and VPA ($\beta$=−0.112; $P<.05$). As PA, MC, and VO2peak exhibited longitudinal association with body fatness, it seems logical that interventions should strive to promote the development of fitness and MC through developmentally appropriate physical activities, as the synergistic interactions of all three variables impacted body fatness.

KEYWORDS
children, health behaviors, longitudinal studies, motor activity, obesity, physical fitness

1 | INTRODUCTION

The worldwide increase in childhood obesity prevalence has attracted the attention of public health professionals. Obesity is one of the major causes of morbidity and mortality, and is associated with increasing medical expenditures. Additionally, obese children are more likely to be obese adults, and obesity is linked to several health issues (eg, type 2 diabetes, cardiovascular diseases, and various types of cancer). While a wealth of research has been conducted to provide better understanding about causal factors related to childhood obesity, alleviating this growing problem has been limited; thus, examining factors related to obesity requires further investigation.

Stodden et al. published a conceptual framework that hypothesizes how physical activity (PA), motor competence...
(MC), and health-related fitness could longitudinally influence obesity risk. According to the framework, PA, MC, and health-related fitness are suggested to demonstrate reciprocal longitudinal relationships with strengths of associations increasing across childhood and into adolescence. The framework also indicates that health-related fitness mediates the relationship between PA, MC, and obesity risk. Substantial research has been published evaluating the longitudinal impact of PA, MC and fitness on body fatness, and the mediation role of physical fitness. However, most studies investigated the relationships individually, not taking into account how those components interact and predict later body fatness in children and adolescents.

There is strong evidence linking MC to PA, fitness, and weight status, both in childhood and adolescence. Cairney and Veldhuizen analyzed the literature to evaluate whether motor coordination disorder could cause physical inactivity, poor physical fitness, and body fatness, using Hill’s causal criteria. MC fulfilled four of nine criteria of causality regarding PA (biological plausibility, coherence, consistency, and strength of association). According to the Cairney and Veldhuizen evaluation, the major factors in favor of the causal relationship between poor MC and inactivity are the biological and behavioral plausibility and coherence, especially as developed by the conceptual models of Stodden et al. and Hands and Larkin. Both frameworks suggest that children with poor MC find it difficult and unpleasant to participate in activities for which MC is required, which in turn influences PA level, fitness, and body fatness. Reciprocally, increased body fatness and low fitness hinders participation in PA and decreases the likelihood that individuals will develop MC.

Likewise, the logical influence that the development of MC has on fitness levels has strong empirical support. Despite the fact that MC has been linked to three different components of health-related fitness (aerobic capacity, anaerobic capacity, and strength), only aerobic fitness has been investigated in longitudinal studies. Overall, the strength of the association between MC and fitness variables varied widely across the three components of fitness, but it was stronger for the influence on aerobic fitness. Cairney and Veldhuizen characterized the evidence of a causal relationship between MC and fitness as relatively strong. Additionally, Ortega et al. systematically reviewed evidence of the longitudinal association between physical fitness and obesity. According to the review, high physical fitness level in childhood and adolescence is inversely associated with current and future adiposity levels.

Similarly, MC fulfilled six of nine Hill’s criteria for causality in relation to body fatness (biological plausibility, coherence, consistency, experimentation, dose-response, and strength of association) in Cairney and Veldhuizen. The influence of MC on body fatness has been investigated across several studies, with different age ranges, different methods, and techniques to measure body fatness. In addition, the influence of MC on body fatness has biological and behavioral plausibility and coherence. Researchers have also acknowledged the increase in the strength of associations between MC and body fatness in both cross-sectional and longitudinal studies. Specifically, poor motor coordinated children have a much higher risk of becoming overweight/obese.

Higher PA and physical fitness levels have been longitudinally associated with lower body fatness levels in children and adolescents. Ortega et al. summarized the evidence on the relationships between PA, physical fitness, and body fatness. The authors observed that high levels of PA and physical fitness (especially aerobic fitness) during childhood and adolescence were associated with lower body fatness during childhood and adolescence. Moore et al. followed preschool children for 8 years and observed that children in the highest PA tertile during the follow-up had smaller gains in BMI, and body fatness (sum of five skinfolds) throughout childhood. Pate et al. summarized the evidence that evaluated the prospective association between objectively measured PA and body fatness. From the seven studies evaluated, six observed that higher PA level was related to a decrease in body fatness, with only one study finding no association.

Overall, evidence demonstrating longitudinal associations among PA, physical fitness, and body fatness (assessed simultaneously) is scarce. A systematic review found only two longitudinal studies that investigated associations among PA, physical fitness, and body fatness. To the best of our knowledge, only Martins et al. and Lopes et al. have investigated how PA, MC, and physical fitness were longitudinally associated with body fatness. Lopes et al. observed both MC and physical fitness were associated with body fatness (sum of two skinfolds). Martins et al. demonstrated that, among MC, PA, and fitness, only MC was negatively associated with BMI across 3 years. However, the authors used indirect measures of PA and were limited to a three-year follow-up in childhood. Neither of the two aforementioned studies addressed potential mediation pathways among those factors included in the conceptual framework. Therefore, long-term longitudinal studies analyzing the combined impact of objectively measured PA, MC, and physical fitness on body fatness across childhood and adolescence are needed. Thus, the aims of this study were to (a) investigate the longitudinal associations among PA (ie, moderate-to-vigorous PA and vigorous PA), MC, cardiorespiratory fitness, and body fatness across 7 years; and (b) understand the extent to which VOpeak, PA, and MC each would be potential mediators within the combination of these variables to predict body fatness.

We hypothesized that PA, MC, and cardiorespiratory fitness would be longitudinally associated with body fatness and that cardiorespiratory fitness, PA, and MC would mediate the other relationships with body fatness.
2 | MATERIALS AND METHODS

This study was based on longitudinal data from the “Copenhagen School Child Intervention Study,” which began in 2001. Children attending preschool class in two communities in the area of Copenhagen (46 preschool classes in 18 schools [mean age=6.75±0.37]) were recruited to participate in the study. Written informed consent was obtained from the parents/guardians of 706 children (69% of the sample), and 696 actually participated in the study at baseline. The original intervention consisted of four components: (a) an increase in the amount of physical education (PE) lessons from 90 to 180 min/wk; (b) lessons in health education, focusing on the importance of PA and healthy eating; (c) three to four full days a year of supplementary training for the PE teachers that focused on didactic tools to enhance the children’s motivation for and enjoyment of PA and, at the same time, keeping the intensity in PE lessons moderate-to-vigorous; (d) upgrades to indoor and outdoor PE and playing facilities in all intervention schools. Following the intervention, which lasted 3 years, the children were retested at 9 years of age (mean age=9.59±1.07) and followed up again in 2008 at 13 years (mean age=13.35±0.34). The study was approved by the ethical committee, University of Copenhagen.

Because the complete methodology has been previously published,27–29 the methodology here presents only those variables of interest. Pubertal status was assessed by self-report of sexual maturation using a scale of pictures of breast development for girls and genital development for boys. Numbers were rated 1-5, according to criteria described by Tanner.30 Biceps, triceps, subscapular, and suprailiac skinfolds were measured on the self-reported non-dominant side of the body by the same two skilled researchers with a Harpenden skinfold caliper (Harpenden, West Sussex, UK), and the body fatness was computed as the sum of the four skinfolds (S4SF).

Cardiorespiratory fitness (VO2peak) was assessed in mL/(kg·min) using a continuous running protocol on a treadmill until exhaustion. VO2peak was measured directly on an AMIS 2001 Cardiopulmonary Function Test System (Innovision, Odense, Denmark) at 6 and 9 years of age, and using a COSMED K4b2 portable metabolic system (COSMED, Rome, Italy) at 13 years of age. Both systems provide valid measure of VO2 when validated against the Douglas bag method.28,31,32 We tested whether VO2peak scaled in mL/min or in mL/height/min would change the interpretation of the results because of the weight component included in the VO2peak unit of measurement in mL/(kg·min). However, no significant difference in the association between VO2peak and body fatness was observed regardless of the VO2peak unit. Thus, we used VO2peak in mL/(kg·min) in our analyses.

In this study, the term MC is defined as “the degree of skilled performance in a wide range of motor tasks as well as the movement coordination and control underlying a particular motor outcome.”33 MC was assessed using the “Körperkoordinationstest für Kinder” (KTK), which is a standardized, normative, German test battery.34,35 The KTK has high test-retest reliability (0.90-0.97).34,35 The KTK consists of four independent tests: (a) walking backwards on balance beams of decreasing width: 6.0, 4.5, and 3.0 cm; (b) moving sideways on wooden boards for 20 seconds; (c) one-legged hopping over a foam obstacle with increasing height in consecutive steps of 5 cm; and (d) two-legged jumping from side to side for 15 seconds. The KTK battery test was originally developed to identify children with motor disorders and behavioral disorders; however, the KTK battery has been used in numerous studies to evaluate MC performance levels in normally developing children and adolescents up to 15 years of age.17,36–38 In our study, MC is the sum of the four KTK tests for each age of measurement (6, 9, and 13 years of age).

Physical activity was measured using Actigraph 7164 accelerometer (ActiGraph LLC, Pensacola, FL, USA) at baseline and Actigraph GT1M at the two follow-ups in epochs of 10 seconds. All the devices were calibrated in a motor-driven vertical acceleration machine before use. The participants wore an elastic belt with the accelerometer on the right side of the waist, close to the center of gravity. The device was only supposed to be removed while sleeping and during activities involving water. Periods with 30 or more minutes with consecutive zeros counts were considered as non-wear periods. A valid day was noted at a minimum of 10 hours of wear time. Children with four or more valid days were included in the analyses. To calculate the minutes spent in moderate-to-vigorous physical activity (MVPA) and vigorous physical activity (VIG PA) we used Evenson’s cut-points39 because of its valid estimation for the age range of the participants in the present study40—sedentary≤100 counts per minute (cpm); light>100 cpm; moderate≥2296 cpm; vigorous≥4012 cpm.39 We created the variable “valid PA weekend days” (yes and no) to adjust the analyses because we did not require one of the four valid accelerometry days to be a weekend day.

2.1 | Statistical analysis

In all analyses, we used STATA version 14.0 (StatCorp LP, College Station, TX, USA). We based our analysis in the conceptual framework first proposed by Stodden et al.8 in which PA, MC, and physical fitness all interact synergistically and influence the development of body fatness across time. Therefore, we used structural equation modeling (SEM) to analyze (a) whether PA, MC, and VO2peak longitudinally influence body fatness; and (b) the possible mediation effects of VO2peak, PA, and MC on their relationships with body fatness. The results were presented in three different components: direct association—straight association coefficient between two variables; indirect association—association
between two variables that is mediated by a third variable; and total association—the sum of the direct and indirect association between variables.

Figure 1 presents the pathways examined in the analysis. In summary, we tested whether all variables influenced PA, MC, VO$_{2peak}$, and body fatness. We also examined whether PA, MC and VO$_{2peak}$ influenced body fatness, and whether “valid PA weekend days” influenced PA level in our model. Sex, valid PA weekend days (valid PA weekend day monitored—yes and no), pubertal status (prepubertal and pubertal), follow-ups (age at the measurements—6, 9, and 13 years of age) and intervention (enrolled in the intervention schools—yes and no) were controlled in all the analyses. In addition, PA and MC were examined with VO$_{2peak}$ as a mediating variable leading to body fatness (dotted arrows). Complementarily, MC was also evaluated as a mediating component on the relationship between PA and body fatness, whereas PA was evaluated as a mediating component on the relationship between MC and body fatness. Independent of the PA outcome used (vigorous or moderate-to-vigorous PA), the model adequately fit the data: CFI=.99, TLI=.98, RMSEA=.02, SRMR=.01. Note that all follow-up measures were included as one box (“follow-ups”) in Figure 1 because it is difficult to show the complexity of all variables assessed at all time points within one figure. Thus, Figure 2 shows a simplified version of how longitudinal relationships were assessed, and it does not include the covariates or show potential mediation paths. It specifically depicts the mathematical calculation of the longitudinal association between MVPA and body fatness (S4SF) taking into consideration the three data collection time points. Importantly, this example applies to the calculation of the coefficients between
any variables in our model. In this example, to present the overall association between MVPA and body fatness, SEM calculated the association between MVPA at 6 years of age and body fatness at 6 years of age. At the same time, the association between MVPA at 6 years of age and body fatness at 9 years of age was calculated, taking into account the body fatness at 6 years of age (dotted arrow from body fatness at 6 years of age to body fatness at 9 years of age). Additionally, the association between MVPA at 9 years of age and body fatness at 9 years of age was calculated, taking into account both MVPA (dotted arrow from MVPA at 6 years of age to MVPA at 9 years of age) and body fatness at 6 years of age (dotted arrow from body fatness at 6 years of age to body fatness at 9 years of age). The same calculation was performed between MVPA at six and 9 years of age and body fatness at 13 years of age (see Figure 2). Any of the coefficients on the longitudinal association between two variables presented in the results section are an aggregate coefficient based on the calculations described previously. The associations coefficients presented in the results section were standardized to directly compare different variables and their association between them in standard deviation (SD).

In order to take into account the fact that data were clustered by school and classes within school, we completed a separate analysis to calculate the variance related to the clusters of nested data and the intraclass correlation coefficient (ICC) for each model to interpret the variation between school classes, classes, and individuals. In all the models, the majority of the variation (ICC) was based on the individual level; the ICCs from school and classes were always below 5%. Because the STATA software does not concomitantly calculate the ICC in each nesting structure and the post-estimation model fit parameters using SEM, we decided not to adjust the model for the nesting structure in order to evaluate whether the proposed model adequately fitted the data. In other words, given the limitations of STATA and the fact that the ICC among schools and classes barely contributed variance to the model, we felt it was more important to be able to estimate model fit parameters instead of accounting for the clustering effect.

3 | RESULTS

Boys spent more time in MVPA and VPA and exhibited higher VO\textsubscript{2peak} than girls at each time point. Girls presented higher body fatness than boys at each time point. No differences between boys and girls were observed in the KTK scores at any age (see Table 1).

Moderate-to-vigorous physical activity was not directly associated with body fatness ($\beta\text{MVPA} = 0.044$ SD; 95% CI: $-0.017$ to 0.105). However, MVPA was associated with body fatness via MC ($\beta\text{MVPA} = -0.033$ SD; 95% CI: $-0.053$ to 0.001 SD).
and fitness ($\beta_{\text{MVPA}}=-0.060 \text{ SD}; 95\% \text{ CI: } -0.092: -0.029$) as mediators. The total association between MVPA and body fatness was not significant ($\beta_{\text{MVPA}}=-0.049 \text{ SD}; 95\% \text{ CI: } -0.118: 0.020$). MC was directly associated with body fatness ($\beta_{\text{MC}}=-0.230 \text{ SD}; 95\% \text{ CI: } -0.287: -0.173$). In addition, the association between MC and body fatness was mediated only via fitness ($\beta_{\text{MC}}=-0.147 \text{ SD}; 95\% \text{ CI: } -0.181: -0.113$), not via MVPA ($\beta_{\text{MC}}=0.005 \text{ SD}; 95\% \text{ CI: } -0.002: 0.012$). MC also presented a total association with body fatness ($\beta_{\text{MC}}=-0.337 \text{ SD}; 95\% \text{ CI: } -0.437: -0.318$). Finally, fitness was associated with body fatness directly ($\beta_{\text{FIT}}=-0.229 \text{ SD}; 95\% \text{ CI: } -0.279: -0.180$) and totally ($\beta_{\text{FIT}}=-0.437 \text{ SD}; 95\% \text{ CI: } -0.497: -0.376$; see Figure 3).

Similar to MVPA, VPA was not directly associated with body fatness ($\beta_{\text{VPA}}=0.004 \text{ SD}; 95\% \text{ CI: } -0.057: 0.065$), but VPA was associated with body fatness as mediated by MC ($\beta_{\text{VPA}}=-0.042 \text{ SD}; 95\% \text{ CI: } -0.063: -0.022$) and fitness ($\beta_{\text{VPA}}=-0.074 \text{ SD}; 95\% \text{ CI: } -0.105: -0.042$). Moreover, VPA showed total association with body fatness ($\beta_{\text{VPA}}=-0.112 \text{ SD}; 95\% \text{ CI: } -0.180: -0.043$). In the analyses with VPA in the model, MC was directly associated with body fatness ($\beta_{\text{MC}}=-0.228 \text{ SD}; 95\% \text{ CI: } -0.285: -0.171$). Additionally, MC exhibited a significant association with body fatness as mediated by fitness ($\beta_{\text{MC}}=-0.141 \text{ SD}; 95\% \text{ CI: } -0.174: -0.108$), but not VPA ($\beta_{\text{MC}}=0.001 \text{ SD}; 95\% \text{ CI: } -0.008: 0.010$). MC also presented total association with body fatness ($\beta_{\text{MC}}=-0.369 \text{ SD}; 95\% \text{ CI: } -0.429: -0.309$). Fitness was associated with body fatness directly ($\beta_{\text{FIT}}=-0.216 \text{ SD}; 95\% \text{ CI: } -0.264: -0.169$) and totally ($\beta_{\text{FIT}}=-0.431 \text{ SD}; 95\% \text{ CI: } -0.492: -0.370$) (see Figure 4).

### DISCUSSION

To the best of our knowledge, this is the first study to evaluate the longitudinal impact of PA, MC and VO$_{2\text{peak}}$ on body fatness in a seven-year follow-up, specifically using an a priori conceptual approach. All exposure variables were longitudinally associated, either directly or indirectly, with body fatness, and VO$_{2\text{peak}}$ had the strongest longitudinal total impact on body fatness. Around 50% of the association between VO$_{2\text{peak}}$ and body fatness was explained via the mediation

![Figure 3](image-url)

**Figure 3** Standardized parameter estimates of the slope for the total, direct, and indirect association between moderate-to-vigorous physical activity (MVPA), motor competence, VO$_{2\text{peak}}$, and body fatness. (a) Black solid line and coefficients: direct impact of the exposures on body fatness; (b) blue dotted line and coefficients: the indirect impact of MVPA and motor competence on body fatness mediated by VO$_{2\text{peak}}$; (c) green dotted line and coefficients: indirect impact of MVPA and motor competence on body fatness mediated by motor competence and MVPA, respectively; (d) red coefficients: the total impact of physical activity, motor competence, and VO$_{2\text{peak}}$ on body fatness.
role of VO\textsubscript{2peak} on the associations between PA (MVPA and VPA) and body fatness and MC and fatness. Furthermore, MC exhibited direct and mediated, via VO\textsubscript{2peak}, association with body fatness. Moreover, MC mediated the association between PA (MVPA and VPA) and body fatness. In addition, PA was not directly associated with body fatness, or mediated the association between MC and body fatness. PA was only associated with body fatness via VO\textsubscript{2peak} mediation. In conclusion, MC and VO\textsubscript{2peak} work in conjunction with PA to affect body fatness throughout childhood and early adolescence.

Physical activity (MVPA or VIG PA) was associated with body fatness, as proposed by Stodden et al.,\textsuperscript{8} but only via mediation by VO\textsubscript{2peak}. Likewise, Martins et al.\textsuperscript{26} did not find an association between self-reported PA levels and body fatness when controlling for MC and cardiorespiratory fitness. Thus, the aforementioned results are similar to the non-significant direct impact of PA on body fatness observed in our analysis. These data also agree with the two other longitudinal studies that included both PA and cardiorespiratory fitness with body fatness (but not MC). PA had either no impact or a weak longitudinal impact on body fatness when controlling for physical fitness.\textsuperscript{24,25} This is in contrast to data from several other longitudinal studies where PA was directly associated with decreased body fatness (six out of seven studies reviewed). However, physical fitness and MC were not included in the analysis of those six studies.\textsuperscript{6} In summary, our results indicated that PA and MC contributed to the development of VO\textsubscript{2peak} and impacted body fatness due to their relationship with VO\textsubscript{2peak} (mediation results).

Motor competence had both a direct and indirect (mediated by VO\textsubscript{2peak}) inverse longitudinal impact on body fatness. These data agree with previous longitudinal data that used BMI as a weight status predictor.\textsuperscript{17,26,44} Specifically, Martins et al.\textsuperscript{26} assessed MC, self-reported PA and cardiorespiratory fitness (via 1 mile run/walk) and found that MC was the only variable to significantly influence BMI. D’Hondt et al.\textsuperscript{44} demonstrated a weaker effect of MC on BMI (\(\beta=-0.003\) BMI \(z\)-scores), but only across 2 years of monitoring. It is likely that our measure of body fatness (skinfolds) allowed us to observe stronger relationships with MC than BMI would, as BMI is only a proxy for percent fat. PA was not a mediator.
of the relationship between MC and BMI study, which it is similar to the non-significant mediation component of PA in the relationship between MC and body fatness shown in the current study. Thus, it appears that MC has independent, direct, longitudinal relationships with body fatness.

From the three exposure variables tested in our model, VO\textsubscript{2peak} had the highest total impact on body fatness, and it also mediated the impact that PA and MC had on body fatness. However, around 50% of the total impact of VO\textsubscript{2peak} on body fatness was explained by VO\textsubscript{2peak} mediating the effect of PA and MC on body fatness. Thus, the Stodden et al.\textsuperscript{8} conceptual framework has correctly predicted the mediation role of physical fitness in the relationships between MC, PA, and body fatness as shown in these longitudinal data. According to our results, it seems plausible that while developing MC is inherently associated with PA, the capability to successfully participate in many different activities that inherently require adequate levels of MC probably generates more opportunities to be physically active, thus leading to higher cardiorespiratory fitness and decreased body fatness.\textsuperscript{8} Subsequently, higher cardiorespiratory fitness would allow for longer participation, specifically in activities associated with moderate and vigorous activity. In fact, Ré et al.\textsuperscript{45} demonstrated that higher fitness has a major impact on soccer participation in recreational level adolescents, and the mediation role of fitness observed in our study supports this finding. Concomitantly, increased PA and increased MC likely function to assist in the development of cardiorespiratory fitness as PA and MC demonstrate consistent positive associations with fitness across childhood. Thus, the synergetic associations among PA, MC, VO\textsubscript{2peak} and body fatness across childhood into adolescence noted in this study suggest the need to intervene in early childhood, by providing an environment where physical activities promote both MC and physical fitness might have greater sustained impact across childhood and into adolescence on unhealthy weight gain.

Our study has limitations to be considered in the interpretation of the results. While accelerometry is considered a reference method measure for PA in epidemiological studies, the limited measurement time of PA (four to 7 days at each age—six, nine, and 13 years of age) may not demonstrate true PA habits of children and may have influenced the strength of association with body fatness. In addition, from the three exposure variables, PA accelerometry represents the largest measurement error, which could have weakened the strength of relationships with PA and body fatness. Data from this study also might have been influenced by the intervention project that occurred in the initial 3 years of the project. However, compared to participants in the control arm of the original intervention study, the intervention demonstrated no significant impact on PA, MC, VO\textsubscript{2peak} or body fatness levels\textsuperscript{27} and the longitudinal results presented in this study were adjusted for the intervention factor. Unfortunately, we only have three time points of monitoring, which does not provide a truly clear picture of how the longitudinal associations among all the factors developed and how the strength of associations developed across time, and perceived MC was not collected as part of this study.

In terms of strengths, it should be noted that this is the first longitudinal study to test the conceptual framework first proposed by Stodden et al.,\textsuperscript{8} which intended to describe how PA, MC, and health-related fitness would influence obesity risk across childhood and adolescence. In addition, the assessments in this study (actual VO\textsubscript{2peak}, MC, body fatness, and accelerometer-derived PA) are the most complete and most objective set of measures for all variables that have been used in one study. Importantly, we were able to follow children for 7 years during their childhood until early adolescence, which is the longest time frame where these types of data have been collected. This time frame also represents a period where obesity trajectories are solidified, and thus track into adulthood.\textsuperscript{4}

5 | PERSPECTIVE

Physical activity (only indirectly), MC, and cardiorespiratory fitness collectively demonstrated a strong longitudinal impact on body fatness. PA only influenced body fatness through VO\textsubscript{2peak} and MC, while MC presented direct and indirect (also mediated by VO\textsubscript{2peak}) impact on body fatness. From the three exposure variables, VO\textsubscript{2peak} demonstrated the greatest total impact on body fatness. Therefore, PA interventions focusing on the development MC and cardiorespiratory fitness in early childhood could have a sustainable impact on maintaining a healthy weight status, or even reducing adiposity across childhood and adolescence. Overall, it seems logical, as well as feasible, that interventions should strive to promote the development of fitness and MC through developmentally appropriate physical activities, as the synergistic interactions of all three variables are more likely to impact body weight status than focusing on only one variable.

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