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Exploring the Relationship between Adiposity and Fitness in Young Children

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Running head: Adiposity and fitness in children

Abstract

Purpose: High levels of cardiorespiratory fitness (CRF) may attenuate the association between excessive adiposity and the risks of cardiovascular and metabolic disease. The purpose of this study was to stratify children according to their BMI and adiposity (body fat percentage, BF%) and compare levels of CRF across subgroups. **Methods:** This prospective cohort study comprises a cross-sectional and longitudinal analyses of data collected at baseline (n=641) and two years later (n=579) on children (7.4-11.6y) attending public school in Denmark. Levels of CRF were measured using the Andersen test, while BF% was measured by dual-energy x-ray absorptiometry (DXA). **Results:** There were 560 (87.4%) children classified as normal weight according to BMI at baseline, of which 46 (7.4%) were identified as having excessive BF%. These children had significantly lower CRF (mean [95% Confidence Interval]: -63.1m [-100.2,-25.9]) than children with normal BMI and normal BF%; and the effect of BF% on CRF was significantly worse in boys than girls. Overweight children with high BF%, had significantly lower prospective (2 years) CRF levels (-34.4m [-58.0,-10.7]) than children with normal BMI and BF%. Though children who improved their BMI and/or BF% classification over the two year period achieved CRF levels (8.9m [-30.2,47.9]) which were comparable to children with normal BMI and BF% at both measurement time points. **Conclusion:** The CRF levels in children are impacted by BMI and BF%, although BF% appears to play a greater role. This association between BF% and CRF is sex-dependent, with CRF levels in boys being impacted to a greater extent by BF%. Children identified as 'normal weight' by BMI but presenting with excessive BF% had significantly lower CRF than 'normal weight' children with low BF%.

Introduction

Global estimates using objectively measured physical activity data in children (4-11 y.o.) indicate they perform between 22 min (95% CI, 19.9-24.1) and 45 min (95% CI, 39.6-50.4) of moderate-to-vigorous physical activity (MVPA) per day (13), which falls well below the recommended 60 min of daily MVPA (34). The low levels of physical activity in children correspond with a high prevalence of overweight and obesity (6, 20, 23) as well as low levels of cardiorespiratory fitness (CRF) (23). This is alarming considering both low CRF and high adiposity are associated with increased cardiovascular and metabolic disease risk (4, 8, 9, 11, 15, 16, 18, 27).

While the association between low CRF and adiposity is well recognised (21, 25-27, 29), the magnitude of this association remains equivocal. This is due in part to the differences in the techniques used to measure adiposity, which range from the direct measurement of body fat using dual energy x-ray absorptiometry (DXA) to the adoption of a combination of anthropometric techniques (i.e. height and weight; waist circumference; skinfolds). Of these techniques, body mass index (BMI) or BMI z-score are most commonly employed as the outcome measure (17). This is despite the growing number of studies reporting substantial variance in the adiposity of children within given BMI categories (32), with a particular concern being the concealment of excessive adiposity in children categorised as "normal" by BMI (the so-called "thin-fat" phenotype). This is a concern since total body fat percentage (BF%) has been identified as a stronger predictor of composite and single cardiovascular risk factors than either BMI or waist circumference in children (18).

The purpose of the present study therefore was to stratify children according to BMI and DXA-derived adiposity, and identify differences in the children's CRF. We hypothesized that children identified as being of "normal weight" (BMI) and low BF% would have the highest CRF, while those with high BF% - irrespective of their BMI - would have the lowest CRF. Children were then tested two years later to explore the effect of an increase (considered detrimental; increasing adiposity or shifting into the overweight/obese BMI category) or decrease (considered beneficial; decreasing adiposity or shifting into the normal-weight BMI category) in weight-status on their CRF. We hypothesized that children who demonstrated a beneficial shift in their weight status would demonstrate similar CRF to those children who were constantly 'normal weight' and 'low adiposity'; but that these children would have significantly higher CRF than those who maintained a high adiposity at each time-point.

Methods

Study design

This prospective cohort study is nested in the Childhood Health, Activity, and Motor Performance School Study in Denmark (CHAMPS study-DK; (31)). The study herein comprises two discrete analyses of data collected from children attending public school in the municipality of Svendborg, Denmark. The first analysis is a cross-sectional analysis of data collected during testing in 2008 (T1). This analysis was conducted to determine the association of CRF with weight-status and adiposity (four categorical levels). The second analysis comprised two separate longitudinal models to determine whether baseline (T1) weight-status or adiposity effected children's CRF two years later (T2). Only children with complete data sets were included in the longitudinal analysis.

Participants

Children from the CHAMPS study-DK who were in 2nd to 4th grade (7.4–11.6 years) at baseline were enrolled in this study which has previously been described in detail (30). This subsample was chosen because these children had whole-body dual-energy x-ray absorptiometry (DXA; GE Lunar Prodigy, GE Medical Systems, Madison, WI) scans during T1 and T2 which allowed the direct measure of total body fat percentage. All children and parents from the 10 participating schools received information about the study through school meetings and additional written information and all examinations took place at *The Hans Christian Andersen Children's Hospital* (Odense, Denmark). Participation in the study was voluntary and all parents provided their written informed consent. Permission to conduct the CHAMPS study-DK was granted by the Regional Scientific Ethical Committee of Southern Denmark (ID S-20080047).

Fitness Assessment

Cardiorespiratory fitness was measured using the Andersen test (2). The test was conducted indoor on one-half of a handball court (wood flooring) with 20m running lanes marked by cones. Participants were required to run from one line to the other, where they had to touch the floor behind the line with one hand, turn around and run back. At 15s, the test leader blew a whistle and the participants stop as quickly as possible and rest for 15s. This procedure was repeated for 10 min. The test leader announced the end of each resting period by counting backwards from 3 to 0. The laps and distance covered by each child were counted by research staff with groups of 6 -10 children running at the same time. The total distance measured in meters was the test result. This test has previously been shown to demonstrate good test-retest performance (988±77 and 989±87

m; $r^2=0.86$; CV=3%; n=31) and concurrent validity when compared to VO_2max testing ($r^2=0.85$) in this age group (6-9 y.o.; (1)).

Anthropometrics and adiposity

Weight was measured to the nearest 0.1 kg on an electronic scale (Tanita BWB-800S, Tanita Corporation, Tokyo, Japan) wearing light clothes. Height was measured to the nearest 0.5 cm using a portable stadiometer (SECA 214, Seca Corporation, Hanover, MD, USA). Both anthropometrics were conducted barefoot and the BMI subsequently calculated (kg/m^2) and defined according to the International Obesity Task Force criteria (10).

Fat mass and body fat percentage (BF%) was measured by DXA (GE Lunar Prodigy, GE Medical Systems, Madison, WI, USA) only in the children in 2nd to 4th grade. Participants were instructed to lie still in a supine position wearing underwear, a thin T-shirt and stockings, and a blanket was provided for the duration of the scan. All scans were performed by the same two operators and analysed by one using the ENCORE software (version 12.3, Prodigy, Lunar Corp, Madison, WI, USA). The total body composition was calculated after exclusion of the head. We adopted percentage body fat measures of 25% and 30% as the cut-points for categorisation of adiposity in boys and girls respectively, which was based on the findings of Williams et al. (33). The DXA machine was calibrated each day in accordance with the standardized procedures.

Pubertal stage

The Tanner pubertal stages self-assessment questionnaire was used to determine pubertal status (30). Boys and girls were presented with five pictures of Tanner staging for pubic hair development, and children were asked to indicate which stage best referred to their own pubertal

stage with explanatory text in Danish supporting the self-assessment. The procedure took place in a private setting with sufficient time to allow for the self-assessment. The accuracy of this technique has previously been shown to be sufficient in a similar cohort and setting (28).

Data Analysis

The cross-sectional analysis and estimate of prospective fitness was performed on stratified data comprising 'overweight or obese' (OW/OB) or 'normal weight' (NW) classification according to BMI, and 'higher%BF' (BF% greater than pre-defined cut-points) or 'lower%BF' (BF% less than pre-defined cut-points) classification based on DXA measurement of total body-fat. The children were then stratified into categories consisting of NW+lower%BF, NW+higher%BF, OW/OB+lower%BF and OW/OB+higher%BF. For inclusion in the cross-sectional analysis, BMI, adiposity, age, sex and CRF test score during T1 was required. For inclusion in the prospective fitness assessment, BMI, adiposity, age, sex and CRF test score at T1 was required, and CRF test score at T2 (outcome measure) required. Children with complete data sets (T1: BMI, adiposity, age, sex, CRF; T2: BMI, adiposity, age, sex, CRF) were included in the longitudinal analysis and classified as (i) constant NW+lower%BF; (ii) constant NW+higher%BF; (iii) constant OW/OB+higher%BF; (iv) improving BMI or %BF; (v) worsening BMI or %BF. The classifications of 'constant', 'improving' and 'worsening' in the longitudinal data set refer to categorical changes in BMI or Adiposity.

Association of adiposity and BMI with fitness was examined using multilevel mixed-effects analyses using the xtmixed procedure in STATA, with school class and school modelled as random effects to comply with the cluster structure of the school-based design (30). Each

(cross-sectional and longitudinal) model was also adjusted for sex, age, pubertal status, testing time-point and fitness as indicated, and the beta coefficients calculated. Where an interaction on sex was identified, a separate analysis was performed. Sex-based differences in CRF within each category of interest were further explored using the marginsplot command in STATA and contrasts computed (fixed portion: distance covered in metres; Figure 1a, 1b and 2). All analyses were conducted using NW+lower%BF as the reference group and children with missing data were excluded from relevant analysis. Additional "post hoc" analyses were conducted to further explore the associations between the independent variables BMI-z scores (s.d.) and BF% with CRF, using the multilevel mixed-effects analyses (adjusted for age, sex and puberty). The interaction term of sex and the independent variable were included when significant. Data are presented as means and standard deviation (SD) or (95% confidence intervals; [95% CI]). All analyses were completed in STATA version 12.1 (StataCorp, College Station, TX, USA) with α=0.05 (two sided).

Results

Descriptive data for all children are presented in Table 1. Between T1 and T2, the children demonstrated an increase in their BMI (mean [95% C.I.]; boys: 0.98 kg.m^{-2} [0.86, 1.09]; girls: 1.10 kg.m^{-2} [0.98, 1.22]), BF% (mean [95% C.I.]; boys: 1.92% [1.47, 2.37]; girls: 1.58% [1.12, 2.04]) and CRF (mean [95% C.I.]; boys: 64.1m [54.6, 73.5]; girls: 70.5m [61.8, 79.2]), with no significant between sex differences observed in any of these outcome measures.

Cross-sectional analysis of fitness with weight-status and adiposity

Data from 322 girls and 319 boys at T1 were included in the cross-sectional analysis (Table 2). Sex and age were identified as significant variables in the regression model, with boys running further (74.9m; $p<0.001$) than girls and older children running further (24.1m; $p<0.001$) than the younger children. Puberty status was not a significant variable in the model ($p=0.957$). When children from each category were stratified by sex, the associations followed similar trends for girls and boys (Figure 1a). However, a higher BMI and higher BF% was significantly more detrimental on CRF in boys than girls (OW/OB+higher%BF: -55.8m, $p=0.009$).

Effect of weight-status and adiposity at baseline on prospective fitness

Data from 579 children (boys: n=290; girls=289; age: 11.3±0.8 y) was used in the analysis (Table 3). Children increased the distance they ran in the CRF test between T1 (930.2±101.8 m) and T2 (997.1±100.3 m). Sex, age and CRF (run distance) at T1 were identified as significant variables impacting the prediction of CRF at T2 (All $p<0.001$) while puberty status was not significant ($p=0.677$). Boys ran further (34.3m) than girls, while older children ran further (14.6m/year) than the younger children in the CRF test at T2. After adjusting for sex, age and CRF at T1, children categorised as OW/OB+higher%BF at T1 ran significantly less distance (34.4m; $p=0.004$) during the CRF test at T2 than individuals categorised as NW+lower%BF at baseline. When children were stratified by sex (Figure 1b), the associations followed similar trends for girls and boys. However, BF% had a significantly greater detrimental effect on CRF in boys than in girls categorised as NW+higher%BF (-65.1m, $p=0.002$), but this was not observed in the other categories (OW/OB+higher%BF: -32.3m, $p=0.071$; OW/OB+lower%BF: 6.6m, $p=0.882$).

Effect of longitudinal weight-status and adiposity on prospective fitness

Data from 502 children (boys: n=254; girls=248; age: 11.3±0.9 y) was used in this analysis (Table 4). As expected, children increased the distance they ran during the CRF at T2 (1003.0±100.1 m) when compared to T1 (934.5±100.9 m). Children maintaining a normal BMI and BF% (constant NW+lower%BF; Table 4) ran significantly further than those identified as being constantly NW+higher%BF (-52.4m; p=0.015) and constantly OW/OB+higher%BF (-56.0m; p<0.001). There was an interaction of sex in this association with boys classified as constantly NW+higher%BF and constantly OW/OB+higher%BF having their CRF affected significantly more (constantly NW+higher%BF: -69.4m, p=0.014; constantly OW/OB+higher%BF: -45.4m, p=0.021) than girls (Figure 2). Puberty status was not a significant variable in the model (p=0.602)

Post-hoc Analysis

The cross-sectional relationship between CRF and BMI was explored further using the BMI z-scores which showed that for every 1-point increase in the child's BMI z-score, the child ran 32.7m less ([95% C.I.]; [-38.9, -26.6]), but there was no significant (p=0.305) interaction with sex. When the association between CRF and BF% was calculated, every 1% increase in BF was associated with the child running 5.6m less ([95% C.I.]; [-6.5, -4.7]), and a significant (p=0.003) interaction between sex and BF% on CRF was identified, with higher BF% affecting boys to a greater extent (mean [95% C.I.]; -1.9m [-3.2, -0.7]).

When the longitudinal relationship between CRF and BMI z-scores was explored, the child's BMI z-score during T1 did not affect the child's CRF at T2 (mean [95% C.I.]; -7.2m [-15.5, 1.2]);

although a significant interaction with sex was observed with boys being affected to a greater extent (mean [95% C.I.]; -13.5m [-25.0, -2.0]). When the longitudinal association between CRF and BF% was calculated, every 1% increase in BF% at T1 was associated with the child running 2.1m less ([95% C.I.]; [-3.1, -1.0]) at T2. A significant (p=0.003) interaction between sex and BF% on CRF was identified, with higher BF% at T1 affecting the CRF at T2 in boys to a greater extent (mean [95% C.I.]; -2.1m [-3.5, -0.7]).

Discussion

The main findings of the present study were i) a higher than expected proportion (7.2%) of children who were normal weight by BMI had a high BF% (NW+higher%BF); ii) children classified as NW+higher%BF demonstrated a significantly lower CRF than children classified as NW+lower%BF; iii) the detrimental effects of high BF% or OW/OB classification on CRF were similar and appeared to be additive with OW/OB+higher%BF children having the lowest CRF; iv) children OW/OB+higher%BF at T1, had significantly lower CRF at T2, even when adjusted for baseline fitness (CRF at T1); v) children who improved either their BMI or BF% between T1 and T2 no longer had a significantly lower CRF than children maintaining a constant NW+lower%BF phenotype; vi) high levels of BF% were more detrimental on CRF in boys than in girls.

A longstanding concern with adoption of BMI as a diagnostic tool for the classification of obesity-which is defined as abnormal or excessive fat accumulation that may impair health (34)- is the concealment of individuals with excessive adiposity and increased cardio-metabolic risk factors within the "normal" category; the so-called "thin-fat" phenotype which includes individuals with "metabolic obesity" (14). This phenotype, characterized by a greater fat mass at any given BMI

level, is believed to be more prevalent in some ethnicities (e.g. South Asians versus Europeans) (12) and appears already in early childhood (32, 36). In the present study, 7.2% of children were identified as being NW+higher%BF ("thin-fat" phenotype); this is despite the children in this study being primarily Caucasian. This prevalence of the "thin-fat" phenotype is comparable to the 10.8% of children identified as being OW/OB+higher%BF and when considered another way, 40% of children who were considered to have a high BF% were considered normal weight by BMI.

Evidence from studies in adults (5, 22) and children (4, 7) suggests higher levels of CRF attenuate the health risks associated with obesity. In the current study, the cross-sectional analysis revealed significantly lower CRF in children categorized as being OW/OB (OW/OB+lower%BF) or having high BF% (NW+higher%BF) when compared to children categorized as NW+lower%BF. However the combination of high BF% with OW/OB was most detrimental, with children identified as OW/OB+higher%BF performing worst in the CRF test. This detrimental effect of BF% on CRF was significantly greater in boys than in girls. To provide some context, the CRF of NW+higher%BF or OW/OB+lower%BF children was similar to the CRF of NW+lower%BF children who were two years younger, while OW/OB+higher%BF children had a CRF similar to NW+lower%BF children who were three and a half years younger. Considering BF% has previously been shown to be a stronger predictor of composite and individual CVD risk factors in this population than BMI or waist circumference (18) and that high CRF may attenuate this risk; the poor CRF in children with high BF% is concerning, particularly in children classified as NW+higher%BF since typical screening measures (i.e. BMI classification) are unlikely to identify these children as being at-risk.

To the authors' knowledge, no studies have previously examined prospective CRF based on DXA derived adiposity and weight-status. In the current study, 579 children had complete data to conduct this analysis (Table 3). Children classified as OW/OB+higher%BF at baseline (T1) had significantly lower CRF two years later (during T2) than children classified as NW+lower%BF at baseline (T1) even when adjusted for baseline CRF (T1). This difference was not observed in other categories. When stratified by sex, the detrimental effect of BF% on CRF was more profound in boys than girls.

When children were classified according to their BF% and BMI across both measurement times (T1 and T2; n=502), children identified as constant NW+higher%BF and constant OW/OB+higher%BF had significantly lower CRF than the constantly NW+lower%BF children (table 4). Consistent with our previous findings (18), this detrimental effect of adiposity on CRF was worse for boys than girls (Figure 1). Girls in these categories ran on average 52.4m/5.3% (constant NW+higher%BF) and 56.0m/5.7% (constant OW/OB+higher%BF) less than girls in the constant NW+lower%BF categories; while boys ran on average 128.8m/12.1% (constant NW+higher%BF) and 101.4m/9.5% (constant OW/OB+higher%BF) less than boys in the constant NW+lower%BF categories. It is noteworthy that children identified as having an improved BMI or Adiposity classification between T1 and T2, achieved a CRF score which was no longer significantly different from children who were constantly NW+lower%BF. Additionally, no sex-based differences were apparent in this improvement (p=0.413).

The current study had several strengths and limitations which informed the interpretation of these results. The major study strengths include that we directly measured BF% by DXA in this large cohort of children, using standardised procedures. Weight and height were measured using the

same equipment, and our multilevel modelling accounted for several potential sources of confounding in the analyses. In the present study, CRF was directly assessed using a valid and reproducible intermittent running test (1, 2), which showed the general fitness of the cohort was comparable to those previously reported (mean VO_2 peak range: 36.8-66.0 ml.min.$^{-1}$kg^{-1}) (19). A limitation of the study was despite the large study sample, some of the subgroup analyses requiring stratification by sex were limited in size therefore increasing the risk of model overfit. Although not a limitation, it is important to note that current evidence suggests the use of continuous scores for risk factors of disease classification and prognostic prediction in children (3). However this study dichotomised adiposity and BMI according to pre-determined cut-points. This decision was based on aligning the major findings of the study with the current application of these measures. With respect to the BF% cut-offs, these were chosen since they were shown to be indicative of increased risk for elevated BP and lipoprotein ratios in a study conducted in over 3300 children and adolescents (1667 males; 1653 females; (33)). Whilst the percentage body fat cut-offs in that study were calculated using skinfold thickness, to the authors' knowledge, there are currently no large cohort studies which have assessed associations between cardio-metabolic risk factors and BF% measured by DXA in this age group. Finally, there were significant differences in the BMI of children in respective categories, and in particular, in the BMI of children classified as 'normal weight' (i.e. NW+lower%BF versus NW+higher%BF). However, when children with the lowest BMI in the NW+lower%BF category were removed from the analysis, such that the mean BMI was no longer different, the main findings remained consistent with those reported herein (results not shown).

In summary, we show not only that the "thin-fat" phenotype is present (~7.2%) in this European cohort, but also that these children have lower CRF levels than children considered normal weight by BMI. Adiposity is known to strongly contribute to metabolic disease risk in prepubescent children, while CRF is protective against metabolic disease risk when adiposity is high (27). Further, the addition of CRF as a risk factor for metabolic syndrome in children improves diagnostic criteria (3). For these reasons, the finding of low CRF in children with normal BMI but high BF% is concerning, since these children are not identified as being at risk during routine diagnostic screening. Data from the longitudinal analyses revealed that an improvement in BF% or BMI classification is associated with an improvement in CRF; indicating the importance of early detection and intervention for children with high BF% or BMI. The proportion of children with low levels of CRF who maintain these low levels of CRF into adolescents and adulthood is currently unknown, and the associated clinical implications remain to be resolved.

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Conflict of interest

The authors declare no conflict of interest.

The results of the present study do not constitute endorsement by the American College of Sports Medicine.

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Figure Description

Figure 1   Comparison of the mean (± 95% CI) distance covered during CRF testing by girls (▲) and boys (•) stratified by BMI and adiposity based on (a) data from the cross-sectional analysis of children from each category (NW+higher%BF, girls: n=21, boys: n=25; OW/OB+higher%BF, girls: n=39, boys: n=30; OW/OB+lowerBF%, girls: n=9, boys: n=3) compared with the reference category (NW+lower%BF, girls: n=253, boys: n=261; indicated by dashed line); (b) data from the longitudinal analysis of prospective (two years later) CRF in children from each category (NW+higher%BF, girls: n=19, boys: n=21; OW/OB+higher%BF, girls: n=34, boys: n=25; OW/OB+lowerBF%, girls: n=7, boys: n=3) compared with the reference category (NW+lower%BF; girls: n=229, boys: n=241) indicated by the horizontal dashed line. NW=normal weight; OW/OB=overweight or obese; higher%BF=%BF above pre-determined cut-off; lower%BF=%BF below pre-determined cut-off.

Figure 2   Longitudinal comparison of the mean (± 95% CI) distance covered during CRF testing by girls (▲) and boys (•) stratified by their baseline and 2 year prospective BMI and adiposity. Comparison is made between categories of interest (constant NW+higher%BF, girls: n=9, boys: n=11; constant OW/OB+higher%BF, girls: n=28, boys: n=18; improving BMI or %BF, girls: n=10, boys: n=7; worsening BMI or %BF, girls: n=4, boys: n=9) with the reference category (constant NW+lower%BF, girls: n=197, boys: n=209; indicated by the dashed line). NW=normal weight; OW/OB=overweight or obese; higher%BF=%BF above pre-determined cut-off; lower%BF=%BF below pre-determined cut-off; Constant=remaining in the same category at the second testing time-point; Improving=shifting into more favourable category at the second testing time-point; Worsening=shifting into less favourable category at the second time-point.
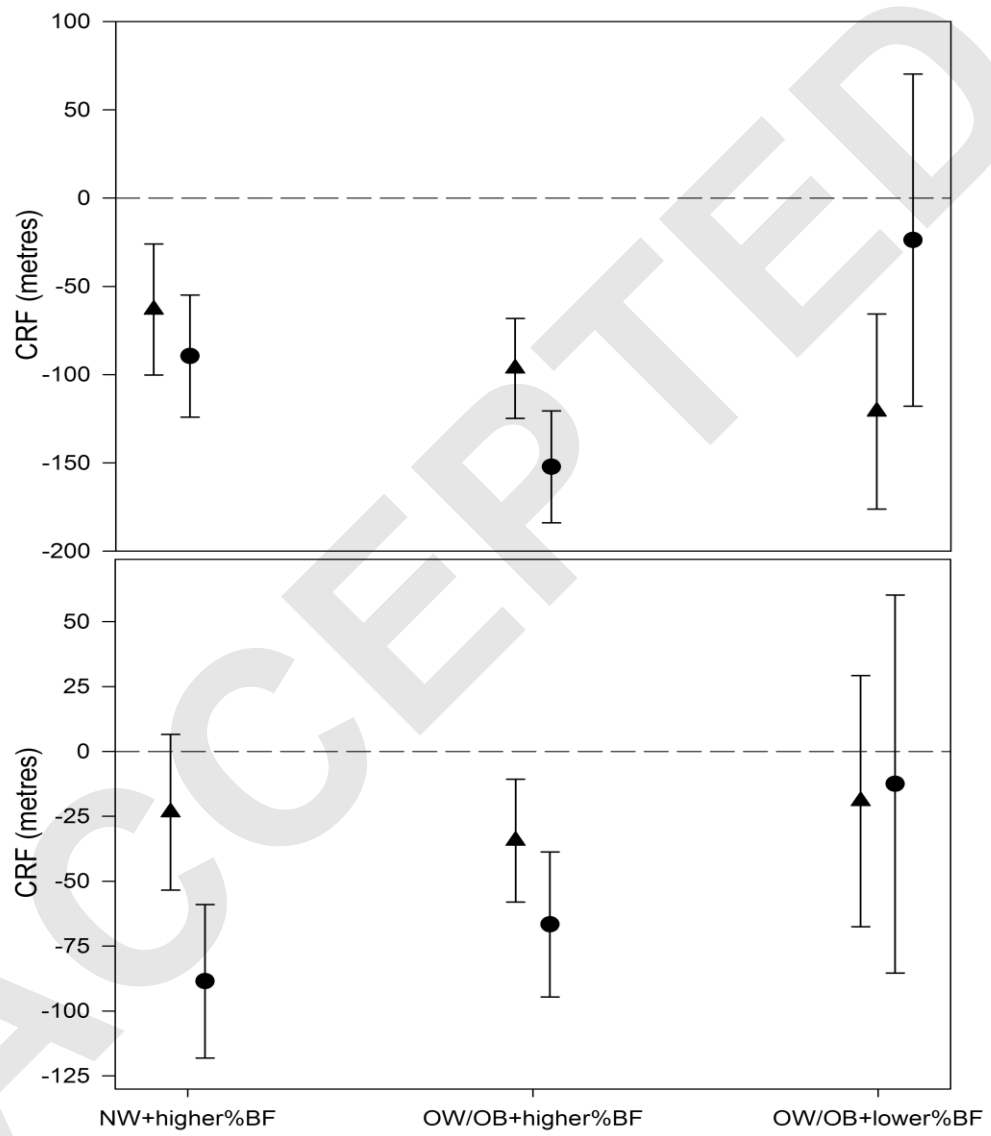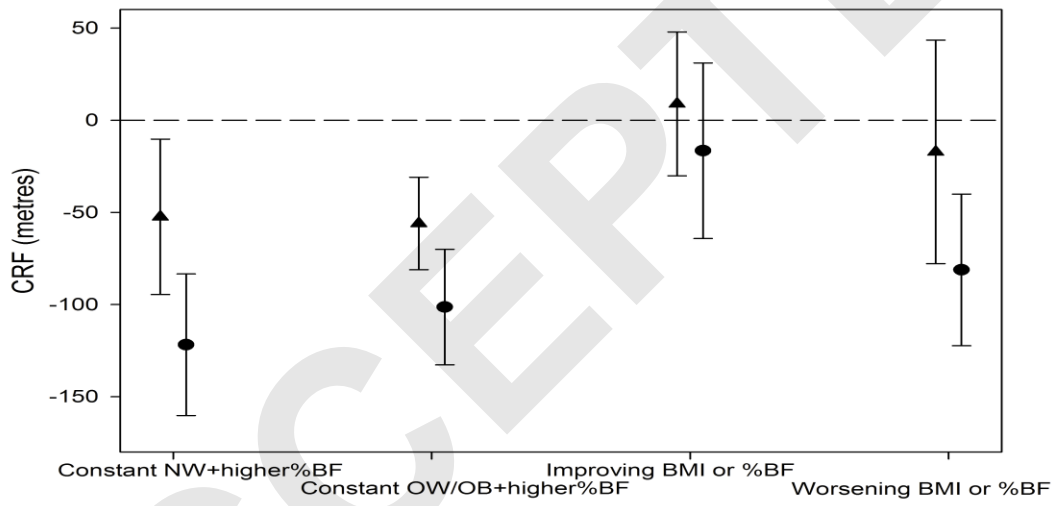
Figure 1

Figure 2

TABLE 1. Summarized data for each variable stratified by measurement-time.

		Time 1			Time 2	
	obs	Mean (SD)	**Range** Min - Max	obs	Mean (SD)	**Range** Min - Max
All Particpants						
Age (y)	834	9.3 (0.9)	7.4 – 11.6	834	11.3 (0.9)	9.3 – 13.6
Height (cm)	732	137.9 (7.6)	120.5 – 171	729	149.8 (8.6)	130 – 185
Weight (kg)	731	32.3 (6.5)	19.6 – 61.6	729	40.4 (8.5)	23.9 – 79.5
BMI (m.kg^{-2})	731	16.9 (2.3)	12.7 – 26.9	729	17.8 (2.5)	12.8 – 28.5
Lean body mass	717	24.1 (3.3)	16.3 – 40.1	682	29.6 (5.2)	14.0 – 62.9
Fat percentage (%)	717	20.6 (8.1)	5.9 – 42.9	682	22.0 (8.1)	5.4 – 46.3
Fitness (m)	692	926.1 (103.3)	576 – 1221	746	992.2 (101.7)	600 – 1247
Fitness (m) across: BMI/BF% Categories						
NW+normal%BF	522	949.2 (91.0)	590 – 1221	483	1019.5 (89.9)	600 – 1247
NW+higher%BF	47	877.9 (105.4)	621 – 1052	70	928.3 (93.4)	698.5 – 1107.5
OW/OB+normal%BF	71	821.4 (97.2)	616 – 1005	72	892.1 (92.1)	627 – 1060
OW/OB+higher%BF	12	823.3 (103.1)	660 – 1000	6	977.1 (41.8)	920 – 1017
VO$_2$ peak (ml.min^{-1}.kg^{-1})	692	46.8 (6.2)	25.7 – 64.5	746	50.7 (6.1)	27.2 – 66.0
VO$_2$ peak across: BMI/BF% Categories						
NW+normal%BF	522	49.8 (5.7)	33.8 – 64.3	483	50.6 (6.0)	31.7 – 64.8
NW+higher%BF	47	44.7 (5.8)	31.2 – 55.2	70	44.4 (5.5)	33.4 – 56.6
OW/OB+normal%BF	71	39.7 (5.9)	23.2 – 51.7	72	39.9 (6.0)	23.5 – 53.0
OW/OB+higher%BF	12	40.3 (7.2)	31.2 – 53.4	6	43.9 (4.0)	39.1 – 48.5

[#]Fat percentage calculated from DXA measures. Obs, number of observations performed for each variable. Fat percentage calculated from DXA measures. VO2 peak calculated by the formula: (1.39x m run + 152.25 x sex + 41.37 x weight in kg – 1168.19)/weight in kg, (Data available upon request). Obs, number of children measured for each variable.

TABLE 2. Association of fitness[1] between the reference category (NW+NonAdipose; n=977) and each category of interest.

	β^2	P	[95% Conf. Interval]	
Cross Sectional (n=1247)				
NW+Adipose (n=114)	-45.6	>0.001	-67.0	-24.3
OW/OB+Adipose (n=138)	-93.9	>0.001	-115.5	-72.4
OW/OB+NonAdipose (n=18)	-64.2	0.002	-105.5	-22.9

[1]fitness based on distance (m) covered during the Andersen fitness test
[2]In addition to adjusting for schools and classes, the model was adjusted for subject id, sex, age, pubertal status and testing time-point.
NW, normal weight (according to BMI); OW/OB, overweight or obese (according to BMI); Adipose, excess body fat percentage (according to DXA); NonAdipose, normal body fat percentage.

TABLE 3. Association of prospective (T2) fitness[1] between the reference category (NW+NonAdipose; n=470) and each category of interest assessed at baseline (T1).

	β[2]	P	[95% Conf. Interval]	
Longitudinal (n=579)				
NW+Adipose (n=40)	-23.43	0.126	-53.43	6.57
OW/OB+Adipose (n=59)	-34.38	0.004	-58.04	-10.71
OW/OB+NonAdipose (n=10)	-19.16	0.437	-67.48	29.17

[1]fitness based on distance (m) covered during the Andersen fitness test
[2]In addition to adjusting for schools and classes, the model was adjusted for sex, age, pubertal status and baseline fitness.
NW, normal weight (according to BMI); OW/OB, overweight or obese (according to BMI); Adipose, excess body fat percentage (according to DXA); NonAdipose, normal body fat percentage.

TABLE 4. Association of fitness at the second testing period between the reference category (children maintaining normal weight and normal adiposity [constant NW+nonAdipose; n=406] at both time-points) and each category of interest. Fitness was based on the distance (m) covered during the Andersen fitness test.

	β^1	P	95% Conf. Interval	
Longitudinal (n=502)				
constant NW+Adipose (n=20)	-52.4	0.015	-94.6	-10.2
constant OW/OB+Adipose (n=46)	-56.0	0.001	-81.1	-30.9
Improving BMI or Adiposity (n=17)	8.9	0.656	-30.2	47.9
Worsening BMI or Adiposity (n=13)	-17.2	0.579	-77.9	43.5

[1]In addition to adjusting for schools and classes, the model was adjusted for baseline fitness, sex, age and pubertal status.
NW, normal weight (according to BMI); OW/OB, overweight or obese (according to BMI); Adipose, excess body fat percentage; NonAdipose, normal body fat percentage