Fairchild, T. J., Klakk, H., Heidemann, M., Andersen, L. B., Wedderkopp, N. (2016). Exploring the relationship between adiposity and fitness in young children. *Medicine & Science in Sports & Exercise*, 48, s. 1708-1714.

Exploring the relationship between adiposity and fitness in young children.

Authors: **Timothy J. Fairchild**[1] t.fairchild@murdoch.edu.au
Heidi Klakk[2,3]
Malene Heidemann[4]
Lars B. Andersen[2,5]
Niels Wedderkopp[1,2,6]

Affiliations: 1. School of Psychology and Exercise Science, Murdoch University, Murdoch, Australia.
2. Centre of Research in Childhood Health, Department of Sports Science and Clinical Biomechanics, University of Southern Denmark, Odense M, Denmark
3. University College Lillebaelt, Odense, Denmark
4. Hans Christian Andersen, Children's Hospital, Odense University Hospital, Odense, Denmark
5. Department of Sport Medicine, Norwegian School of Sport Sciences, Oslo, Norway
6. Orthopedic Department, Institute of Regional Health Services Research, University of Southern Denmark, Hospital of Middelfart, Middelfart, Denmark.

Abstract

Objective: 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 and two years later on children (7.4-11.6 y) 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: Of the 87.5% (n=1091) of children classified as being normal weight according to BMI, 9.5% (n=114) were identified as having excessive BF%. These children had significantly lower CRF (mean [95% Confidence Interval]: -45.6m [-67.0, -24.3]) than children with normal BMI and normal BF%. The detrimental effect of BF% on CRF was significantly worse in boys than girls (-37.4m [-67.4, -7.3]). 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%. However, 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: A large proportion of children identified as being 'normal weight' according to BMI present with excessive BF%. These children have low levels of CRF, a known risk factor for cardiovascular and metabolic disease; and this association between BF% and CRF appears to be sex-dependent, with CRF levels in boys being impacted to a greater extent by BF%.

Keywords: physical activity, obese, weight, exercise, running

Introduction

Global estimates in children (4-14 y.o.) indicate they perform only 22–44 min {Niederer, 2009 #470;Eiberg, 2005 #471;Zahner, 2006 #483;Reilly, 2006 #487;Ekelund, 2012 #488} of moderate-to-vigorous physical activity (MVPA) per day, which falls well below the recommended 60 min of daily MVPA required to achieve physical and psychological benefits {Strong, 2005 #425} {Organization, 2010 #468}. The low levels of physical activity in children correspond with a high prevalence of overweight and obesity {Lobstein, 2004 #498;Bibiloni Mdel, 2013 #499;Novotny, 2015 #502} as well as low levels of cardiorespiratory fitness (CRF) {Olds, 2006 #415}. Alarmingly, the prevalence of childhood overweight and obesity has demonstrated a steady increase {Ng, 2014 #489} while CRF has steadily declined over the past few decades {Tomkinson, 2007 #416}. This is alarming since both low CRF and high adiposity are associated with cardiovascular and metabolic disease risk {Andersen, 2008 #474;Brothers, 2013 #391;Brouwer, 2013 #390;Cummings, 2010 #399;Hurtig-Wennlof, 2007 #473;Jago, 2010 #401;Klakk, 2014 #112;Parrett, 2011 #394}; wherein a high CRF is thought to attenuate the association between adiposity and cardiovascular and metabolic disease risk {Brouwer, 2013 #390;Cummings, 2010 #399;Jago, 2010 #401;Klakk, 2014 #112;Parrett, 2011 #394}.

While the inverse association between CRF and adiposity is well recognised {Magnusson, 2008 #403;Ostojic, 2010 #397;Ostojic, 2011 #392;Parrett, 2011 #394;Stigman, 2009 #404}, 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) used as surrogate measures of body fat. Of these techniques, body mass index (BMI) or BMI z-score are most commonly employed as the outcome measure {Jimenez-Pavon, 2010 #517} despite a growing number of studies reporting substantial variance in the adiposity of children within given BMI categories {Wells, 2014 #9}. A particular concern with the use of BMI in children relates to the concealment of excessive adiposity within the "normal" category (the so-called "thin-fat" phenotype) thereby missing individuals with increased cardio-metabolic risk factors.

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 adiposity would have the highest CRF, while those with high adiposity- irrespective of their BMI- would have the lowest CRF. Children were then tested two years later to explore the effect of a negative (increasing adiposity or shifting into the overweight/obese BMI category) or positive (decreasing adiposity or shifting into the normal-weight BMI category) shift in weight-status on their CRF. We hypothesized that children who demonstrated a positive 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; Wedderkopp et al., 2012). The study comprises analyses of data collected at baseline (T1) and two years later (T2) on children attending public school in the municipality of Svendborg, Denmark. The first analysis is a cross-sectional analysis of all data (all students present at T1 and T2; Table 1) 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 weight-status or adiposity effect CRF two years later.

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 {Wedderkopp, 2012 #139}. This subsample was chosen because these children had whole-body dual-energy x-ray absorptiometry (DXA) scans to provide a direct measure of total body fat percentage (TBF%; T1: n=717; T2: n=682). All children and parents from the 10 participating schools received information about the study through school meetings and additional written information. 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 {Andersen, 2008 #374}. 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 15 s. This procedure was repeated for 10 minutes. 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.; {Ahler, 2012 #375}).

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 {Cole, 2000 #373}.

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. {Williams, 1992 #716}. 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 {Tanner, 1962 #377}. 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 {Rasmussen, 2015 #711}.

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 'Adipose' (BF% greater than pre-defined cut-points) or 'NonAdipose' (BF% less than pre-defined cut-points) classification based on DXA measurement of total body-fat. The children were therefore stratified into categories consisting of NW+NonAdipose, NW+Adipose, OW/OB+NonAdipose and OW/OB+Adipose. For inclusion in the cross-sectional analysis, BMI, adiposity, age, sex and CRF test score during a single testing period 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+nonAdipose; (ii) constant NW+Adipose; (iii) constant OW/OB+Adipose; (iv) improving BMI or Adiposity; (v) worsening BMI or Adiposity. 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-effect 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 {Wedderkopp, 2012 #139}. 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. In the cross-sectional analyses where each individual was potentially included more than once in the analyses, the individual was included as random variable as well as school class and school. 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+nonAdipose as the reference group and children with missing data were excluded from relevant analysis. 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 collected from children at T1 and T2 are presented in Table 1. When all children (n=1247) with a complete set of data at T1 or T2 were categorised, 78.4% (n=977) were classified as NW+NonAdipose, while 9.1% (n=114), 10.9% (n=138) and 1.3% (n=18) were classified as NW+Adipose, OW/OB+Adipose and OW/OB+NonAdipose respectively. There were differences in the BMI range between respective categories, where children categorised as NW+NonAdipose had a lower BMI (16.4±1.5 kg.m^{-2}) than NW+Adipose

(18.7±1.2 kg.m^{-2}), and those children identified as being OW/OB+Adipose (21.8±2.1 kg.m^{-2}) had a higher BMI than children identified as being OW/OB+NonAdipose (20.2±1.4 kg.m^{-2}). Of the 1247 children with complete data (BMI, BF%, CRF) at either T1 or T2, there were 561 children (boys: n=279; girls: n=282) with a complete set of data at both measurement time-points. These children increased 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]) from T1 to T2, 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 1247 observations at T1 and T2 were included in the cross-sectional analysis (Table 2). Sex and age were identified as significant variables in the regression model, with boys (n=615) running further (77.9m; $p<0.001$) than girls (n=632) and older children running further (25.9m; $p<0.001$) than the younger children. After adjusting for sex, age, subject id, measurement-time, school type and class, children categorised as NW+NonAdipose covered significantly more distance than children categorised as NW+Adipose (-45.6m; $p<0.001$), OW/OB+Adipose (-93.9m; $p<0.001$) and OW/OB+NonAdipose (-64.2m; $p=0.002$). When children were stratified by sex, the associations followed similar trends for girls and boys (Figure 1a). However, adiposity had a significantly greater effect on CRF in boys than girls (NW+Adipose: -37.4m, $p=0.015$; OW/OB+Adipose: -35.8m, $p=0.026$) while this sex-based difference was not observed in the OW/OB+NonAdipose children (-3.5m, $p=0.927$).

When the cross-sectional analysis was repeated following exclusion of children with a BMI of 15.9 kg.m^{-2} or less (386 children removed from the NW+NonAdipose group only), the NW+NonAdipose children were still the best performing children in the CRF test running 43.0m, 89.6m and 59.6m further than NW+Adipose, OW/OB+Adipose and OW/OB+nonAdipose children (All $p\leq0.007$) respectively.

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 $p<0.001$). 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+Adipose at T1 ran significantly less distance (34.4m; $p=0.004$) during the CRF test at T2 than individuals categorised as NW+NonAdipose at baseline. When children were stratified by sex (Figure 1b), the associations followed similar trends for girls and boys. However, adiposity had a significantly greater detrimental effect on CRF in boys than in girls categorised as NW+Adipose (-65.1m, $p=0.002$), but this was not observed in the other categories (OW/OB+Adipose: -32.3m, $p=0.071$; OW/OB+NonAdipose: 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+nonAdipose; Table 4) ran significantly further than those identified as being constantly NW+Adipose (-52.4m; $p=0.015$) and constantly OW/OB+Adipose (-56.0m; $p<0.001$). There was an interaction of sex in this association with

boys classified as constantly NW+Adipose and constantly OW/OB+Adipose having their CRF affected significantly more (constantly NW+Adipose: -69.4m, p=0.014; constantly OW/OB+Adipose: -45.4m, p=0.021) than girls (Figure 2).

To adjust for the lower BMI in the constantly NW+NonAdipose group (15.9±1.3 kg.m^{-2}), the longitudinal analysis was repeated following exclusion of children with a BMI of 17.5 kg.m^{-2} or less. The overall results were similar to those described above, with the remaining children in the constantly NW+nonAdipose category running 95.9m (p=0.007) and 74.8m (p<0.001) further than those identified as being constantly NW+Adipose (BMI: 18.0±0.9 kg.m^{-2}) and OW/OB+Adipose (BMI: 21.2±2.0 kg.m^{-2}) respectively.

Discussion

The main findings of the present study were i) a large proportion of children who were normal weight by BMI had a high BF% (NW+Adipose); ii) children classified as NW+Adipose demonstrated a significantly lower CRF than children classified as NW+nonAdipose; iii) the detrimental effects of high BF% or OW/OB classification on CRF were similar and appeared to be additive with OW/OB+Adipose children having the lowest CRF; iv) children OW/OB+Adipose 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+nonAdipose 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 which presents a risk to health {, 1996 #566}- 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" {Hamdy, 2006 #567}. 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) {Deurenberg, 2002 #24} and appears already in early childhood {Wells, 2014 #9;Yajnik, 2003 #571}. In the present study, 9.1% of children were identified as being NW+Adipose ("thin-fat" phenotype). This prevalence of the "thin-fat" phenotype is comparable to the 10.9% of children identified as OW/OB+Adipose, suggesting a significant number of children in European countries may present with this phenotype.

Evidence from studies in adults {McAuley, 2014 #615;Barry, 2014 #616} and children {Andersen, 2008 #474;Brage, 2004 #29} suggests higher levels of CRF attenuates the health risk associated with obesity. In the current study, the cross-sectional analysis revealed significantly lower CRF in children categorized as being OW/OB (OW/OB+nonAdipose) or having high BF% (NW+Adipose), when compared to children categorized as NW+nonAdipose. However the combination of high BF% with OW/OB was most detrimental, with children identified as OW/OB+Adipose 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+Adipose or OW/OB+nonAdipose children was similar to the CRF of NW+nonAdipose children who were two years younger, while OW/OB+Adipose children had a CRF similar to NW+nonAdipose 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 {Klakk, 2014 #112} and that high CRF may attenuate this risk; the poor CRF in children with high BF% is concerning, particularly in children classified as NW+Adipose 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+Adipose at baseline (T1) had significantly lower CRF two years later (during T2) than children classified as NW+nonAdipose 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, particularly in the NW+Adipose category (p=0.002).

When children were classified according to their BF% and BMI across both measurement times (T1 and T2; n=502), children identified as constant NW+Adipose and constant OW/OB+Adipose had significantly lower CRF than the constantly NW+nonAdipose children (table 4). Consistent with our previous findings {Klakk, 2014 #112}, 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+Adipose) and 56.0m/5.7% (constant OW/OB+Adipose) less than girls in the constant NW+nonAdipose categories; while boys ran on average 128.8m/12.1% (constant NW+Adipose) and 101.4m/9.5% (constant OW/OB+Adipose) less than boys in the constant NW+nonAdipose 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+nonAdipose. Additionally, no sex-based differences were apparent in this improvement (p=0.413), indicating both boys and girls who improved their BF% or BMI between T1 and T2, achieved a CRF comparable to children who were constantly NW+nonAdipose.

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 was 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 {Andersen, 2008 #374;Ahler, 2012 #375}. 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 {Andersen, 2015 #718}. 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. This approach resulted in significant differences in the mean BMI of children classified as 'normal weight' (NW+nonAdipose versus NW+ Adipose). However, when children with the lowest BMI in the NW+nonAdipose category were removed from the analysis, the main findings remained consistent with those reported herein.

In summary, we show not only that a large proportion of children in Denmark display a "thin-fat" phenotype but also, that these children present with low CRF levels. 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 {Parrett, 2011 #394}. Further, the addition of CRF as a risk factor for metabolic syndrome in children improves diagnostic criteria {Andersen, 2015 #718}. For these reasons, the finding of low CRF in children with normal BMI but high adiposity (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. This finding underpins the importance of appropriate diagnostic screening incorporating measures of adiposity, to ensure children with high levels of adiposity are identified during diagnostic screening so that early intervention can proceed. 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.

Acknowledgements
The authors gratefully acknowledge the work of numerous research staff and PhD students who have participated in the data collection for the CHAMPS study-DK. We thank children, parents, and teachers in the schools involved in the project, and we are grateful for the cooperation with the Svendborg Project, Sport Study Sydfyn, and the municipality of Svendborg.

Funding for the study has been provided by The TRYG Foundation, University College Lillebaelt, University of Southern Denmark, The Nordea Foundation, The IMK Foundation, The Region of Southern Denmark, The Egmont Foundation, The A.J. Andersen Foundation, The Danish Rheumatism Association, Østifternes Foundation, Brd. Hartmann's Foundation, TEAM Denmark, The Danish Chiropractor Foundation, and The Nordic Institute of Chiropractic and Clinical Biomechanics. Finally, the authors wish to acknowledge the members of the CHAMPS study-DK not listed as coauthors of this paper: C. T. Rexen, E. Jespersen, NC Moller and C. Franz.

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.

TABLE 1. Summarized data for each variable in the cross-sectional and longitudinal analyses stratified by measurement-time.

	Time 1			**Time 2**		
	obs	Mean (SD)	**Range** Min - Max	obs	Mean (SD)	**Range** Min - Max
Variables						
Fitness (m)	692	926.1 (103.3)	576 - 1221	746	992.2 (101.7)	600 – 1247
Age (y)	834	9.3 (0.9)	7.4 - 11.6	834	11.3 (0.9)	9.3 – 13.6
Fat percentage (%)	717	20.6 (8.1)	5.9 – 42.9	682	22.0 (8.1)	5.4 – 46.3
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

[#]Fat percentage calculated from DXA measures. Obs, number of observations performed 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

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 compared with the reference category (NW+NonAdipose; indicated by dashed line); (b) data from the longitudinal analysis of prospective (two years later) CRF in children from each category compared with the reference category (NW+NonAdipose) indicated by the horizontal dashed line. NW=normal weight; OW/OB=overweight or obese; Adipose=%BF above pre-determined cut-off; nonAdipose=%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 with the reference category (constant NW+Adipose; indicated by the dashed line). NW=normal weight; OW/OB=overweight or obese; Adipose=%BF above pre-determined cut-off; nonAdipose=%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.

Fig 1a and b

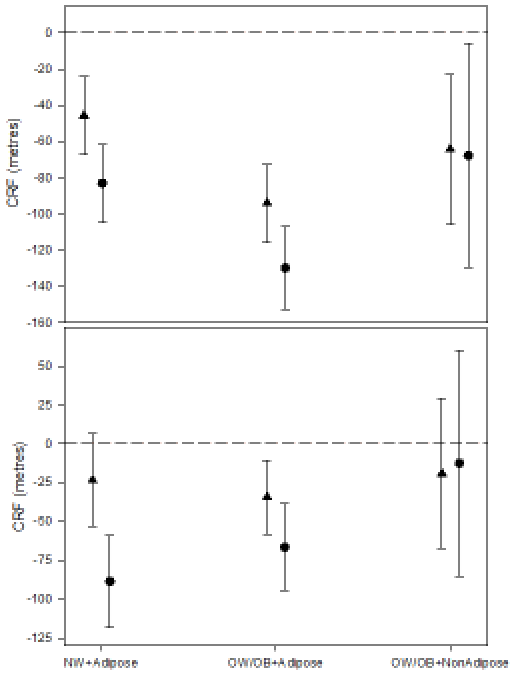
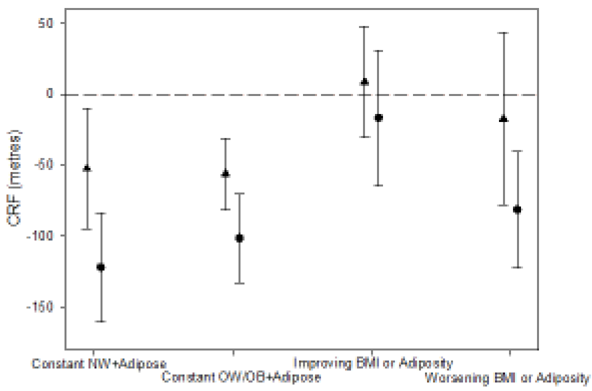


Figure 2



References

1. Ahler T, Bendiksen M, Krustrup P, Wedderkopp N. Aerobic fitness testing in 6- to 9-year-old children: reliability and validity of a modified Yo-Yo IR1 test and the Andersen test. *Eur J Appl Physiol*. 2012;112(3):871–6.

2. Andersen LB, Andersen TE, Andersen E, Anderssen SA. An intermittent running test to estimate maximal oxygen uptake: the Andersen test. *J Sports Med Phys Fitness*. 2008;48(4):434–7.

3. Andersen LB, Lauersen JB, Brønd JC, et al. A new approach to define and diagnose cardiometabolic disorder in children. *J Diabetes Res*. 2015;2015:539835.

4. Andersen LB, Sardinha LB, Froberg K, Riddoch CJ, Page AS, Anderssen SA. Fitness, fatness and clustering of cardiovascular risk factors in children from Denmark, Estonia and Portugal: the European Youth Heart Study. *Int J Pediatr Obes*. 2008;3(1 Suppl):58–66.

5. Barry VW, Baruth M, Beets MW, Durstine JL, Liu JH, Blair SN. Fitness vs. fatness on all-cause mortality: a meta-analysis. *Prog Cardiovasc Dis*. 2014;56(4):382–90.

6. Bibiloni Mdel M, Pons A, Tur JA. Prevalence of overweight and obesity in adolescents: a systematic review. *ISRN Obes*. 2013;2013:392747.

7. Brage S, Wedderkopp N, Ekelund U, et al. Features of the metabolic syndrome are associated with objectively measured physical activity and fitness in Danish children: the European Youth Heart Study (EYHS). *Diabetes Care*. 2004;27(9):2141–8.

8. Brothers J, McBride M, Paridon A, Zhang X, Paridon S. Fatness is not a factor of fitness: analysis of cardiorespiratory data from healthy children over an 8-year period. *Cardiol Young*. 2013;23(1):47–53.

9. Brouwer SI, Stolk RP, Liem ET, Lemmink KA, Corpeleijn E. The role of fitness in the association between fatness and cardiometabolic risk from childhood to adolescence. *Pediatr Diabetes*. 2013;14(1):57–65.

10. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ*. 2000;320(7244):1240–3.

11. Cummings DM, Dubose KD, Imai S, Collier DN. Fitness versus fatness and insulin resistance in U.S. adolescents. *J Obes*. 2010:2010.

12. Deurenberg P, Deurenberg-Yap M, Guricci S. Asians are different from Caucasians and from each other in their body mass index/body fat per cent relationship. *Obes Rev*. 2002;3(3):141–6.

13. Ekelund U, Luan J, Sherar LB, et al. Moderate to vigorous physical activity and sedentary time and cardiometabolic risk factors in children and adolescents. *JAMA*. 2012;307(7):704–12.

14. Hamdy O, Porramatikul S, Al-Ozairi E. Metabolic obesity: the paradox between visceral and subcutaneous fat. *Curr Diabetes Rev*. 2006;2(4):367–73.

15. Hurtig-Wennlof A, Ruiz JR, Harro M, Sjostrom M. Cardiorespiratory fitness relates more strongly than physical activity to cardiovascular disease risk factors in healthy children and adolescents: the European Youth Heart Study. *Eur J Cardiovasc Prev Rehabil*. 2007;14(4):575–81.

16. Jago R, Drews KL, McMurray RG, et al. Fatness, fitness, and cardiometabolic risk factors among sixth-grade youth. *Med Sci Sports*. 2010;42(8):1502–10.

17. Jiménez-Pavón D, Kelly J, Reilly JJ. Associations between objectively measured habitual physical activity and adiposity in children and adolescents: systematic review. *Int J Pediatr Obes*. 2010;5(1):3–18.

18. Klakk H, Grøntved A, Møller NC, Heidemann M, Andersen LB, Wedderkopp N. Prospective association of adiposity and cardiorespiratory fitness with cardiovascular risk factors in healthy children. *Scand J Med Sci Sports*. 2014;24:e275–82.

19. Krahenbuhl GS, Skinner JS, Kohrt WM. Developmental aspects of maximal aerobic power in children. *Exerc Sport Sci Rev*. 1985;13:503–38.

20. Lobstein T, Baur L, Uauy R, IASO International Obesity TaskForce. Obesity in children and young people: a crisis in public health. *Obes Rev*. 2004;5(1 Suppl):4–104.

21. Magnusson KT, Sveinsson T, Arngrimsson SA, Johannsson E. Predictors of fatness and physical fitness in nine-year-old Icelandic school children. *Int J Pediatr Obes*. 2008;3(4):217–25.

22. McAuley PA, Artero EG, Sui X, Lavie CJ, Almeida MJ, Blair SN. Fitness, fatness, and survival in adults with prediabetes. *Diabetes Care*. 2014;37(2):529–36.

23. Novotny R, Fialkowski MK, Li F, et al. Systematic review of prevalence of young child overweight and obesity in the United States–affiliated Pacific Region compared with the 48 contiguous states: the Children's Healthy Living Program. *Am J Public Health*. 2015;105(1):e22–35.

24. Olds T, Tomkinson G, Leger L, Cazorla G. Worldwide variation in the performance of children and adolescents: an analysis of 109 studies of the 20-m shuttle run test in 37 countries. *J Sports Sci*. 2006;24(10):1025–38.

25. Ostojic SM, O'Neil M, Calleja J, Terrados N, Stojanovic M. Cardiorespiratory fitness and adiposity in overweight and nonoverweight 8-year-old school children. *Minerva Pediatr*. 2010;62(6):537–43.

26. Ostojic SM, Stojanovic MD, Stojanovic V, Maric J, Njaradi N. Correlation between fitness and fatness in 6–14-year old Serbian school children. *J Health Popul Nutr*. 2011;29(1):53–60.

27. Parrett AL, Valentine RJ, Arngrímsson SA, Castelli DM, Evans EM. Adiposity and aerobic fitness are associated with metabolic disease risk in children. *Appl Physiol Nutr Metab*. 2011;36(1):72–9.

28. Rasmussen AR, Wohlfahrt-Veje C, Tefre de Renzy-Martin K, et al. Validity of self-assessment of pubertal maturation. *Pediatrics*. 2015;135(1):86–93.

29. Stigman S, Rintala P, Kukkonen-Harjula K, Kujala U, Rinne M, Fogelholm M. Eight-year-old children with high cardiorespiratory fitness have lower overall and abdominal fatness. *Int J Pediatr Obes*. 2009;4(2):98–105.

30. Tanner JM. *Growth at Adolescence: With a General Consideration of the Effects of Hereditary and Environmental Factors upon Growth and Maturation from Birth to Maturity*.

Blackwell Scientific Publications; 1962.

31. Wedderkopp N, Jespersen E, Franz C, et al. Study protocol. The Childhood Health, Activity, and Motor Performance School Study Denmark (The CHAMPS-study DK). *BMC Pediatr*. 2012;12:128.

32. Wells JC. Toward body composition reference data for infants, children, and adolescents. *Adv Nutr*. 2014;5(3):320S–9.

33. Williams DP, Going SB, Lohman TG, et al. Body fatness and risk for elevated blood pressure, total cholesterol, and serum lipoprotein ratios in children and adolescents. *Am J Public Health*. 1992;82(3):358–63.

34. World Health Organization. *Global Recommendations on Physical Activity for Health*. World Health Organization Geneva (Switzerland). 2010. pp. 17–21.

35. Yajnik CS, Fall CH, Coyaji KJ, et al. Neonatal anthropometry: the thin–fat Indian baby. The Pune Maternal Nutrition Study. *Int J Obes Relat Metab Disord*. 2003;27(2):173–80.