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ORIGINAL ARTICLE

Determinant factors of physical fitness in European children

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Abstract

Objectives This study was designed to explore the determinants of physical fitness in European children aged 6–11 years, cross-sectionally and longitudinally.

Methods There were sufficient data on 4903 children (50.6 % girls) on measured physical fitness (cardio-respiratory, muscular strength, flexibility, balance, and speed) and possible determinants related to child characteristics, child lifestyle and parental factors. Multivariate and mixed linear regression models were conducted.

Results Age, sex, children's BMI and physical activity were independent and strong determinants of children's fitness. Significant but small effects were found for low maternal BMI, high psychosocial well-being and fruit and vegetable intake as protective determinants. Sleep duration, breakfast intake, parental age and education and paternal BMI did not have a consistently significant effect on physical fitness. The role of determinants depended on children's sex and the specific PF component. Longitudinal analyses especially highlighted the importance of child's BMI as physical fitness determinant, independent of physical activity.

Conclusions BMI together with physical activity, diet and psychosocial factors are modifiable targets to enhance physical fitness. This calls for policy approaches that combine these factors in a systematic way.

Keywords Physical fitness · Children · Lifestyle · Parental determinants · Body mass index · IDEFICS

On behalf of the IDEFICS consortium.

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Introduction

Physical fitness (PF) is considered to be one of the most important health markers across the life course (Ortega et al. 2008), since it is not only a predictor of cardiovascular and all-cause mortality (Blair et al. 1989), but also of academic performance and psychosocial problems (Ortega et al. 2008). PF, physical exercise and physical activity (PA) are sometimes used as interchangeable concepts in the literature and must be distinguished from each other (Caspersen et al. 1985). PF is the capacity to perform PA and refers to a full range of physiological and psychological qualities. PA is any body movement produced by muscle action that increases energy expenditure, whereas physical exercise refers to planned, structured, systematic and purposeful physical activity. In contrast with PA, which is related to the movements that people perform, PF is a set of attributes that people have or achieve (Caspersen et al. 1985) and consequently has a more direct link with the overall health. Numerous studies have been conducted to identify the determinants of PA in children and adolescents, although with mixed findings (Sallis et al. 2000; Van Der Horst et al. 2007; Craggs et al. 2011). Nevertheless, we are not aware of a study that explores the main determinants of PF components. Understanding PF determinants in children and their dependence on PA will lead to future opportunities for intervention and prevention programs targeting metabolic health in early life. Thus, the aim of this study is to explore several putative determinants of PF in European children aged 6–11 years, taking their PA levels into account. To assess PF, six fitness tests that cover the different domains of PF (cardio-respiratory fitness, muscular fitness and speed/agility) were administered. Sex differences were tested and some determinants were also examined from a longitudinal perspective.

Methods

Study population

The current study is based on data derived from the IDEFICS ("IDentification and prevention of dietary and lifestyle induced health EFfects In Children and infantS") study, which was conducted in eight European countries (Belgium, Cyprus, Estonia, Germany, Hungary, Italy, Spain, Sweden) and aimed to determine the etiology of overweight, obesity and related disorders in children and to evaluate a tailored primary prevention program (Ahrens et al. 2011). The cities recruited in the study were not always representative of the country. Data were collected from a baseline survey (T0; $N = 16{,}228$; children aged 2–9 years) and 2-year follow-up survey (T1; $N = 13{,}622$). From the follow-up sample (T1), 4903 (50.6 % girls) children had valid data for all tested determinants: body mass index (BMI), psychosocial well-being, dietary habits, parental age, parental BMI and educational attainment. Included versus excluded subjects did not differ significantly in age, sex, parental educational attainment and BMI. Since PF can only be measured accurately starting at the age of 6 years (Eurofit tests 1988), only children 6–11 years were included in this study and therefore the cross-sectional analysis was based on T1, while a longitudinal analysis was based on change between T0 and T1 (supplementary Fig. 1 for flow chart). The study was approved by the research ethics committees at each study center involved and was performed following the ethical guidelines of the Declaration of Helsinki 1961 (revision of Edinburgh 2000). Written informed consent was obtained from all parents or guardians.

Measurement protocol

For quality management, all measurements followed detailed standard operating procedures that were pretested in children aged 2–9 years (Suling et al. 2011). Field personnel from each study center participated in the central training (Ahrens et al. 2011). The measurements were collected at participating schools and questionnaires were filled in by the parents at home.

Physical fitness assessment

PF components were mostly adapted from the ALPHA health-related fitness test battery. Its validity and reliability in young people has been previously published (Ruiz et al. 2011).

Cardio-respiratory fitness

Cardio-respiratory fitness (CRF) was measured by the progressive 20mSRT shuttle run test (Leger et al. 1988). Participants were required to run between two lines 20 m apart while keeping pace with audio signals emitted from a prerecorded CD. The initial speed was 8.5 km/h and increased by 0.5 km/h per minute (Leger et al. 1988). The test was finished when the participant stopped because of fatigue or failed to reach the end lines concurrent with the audio signals on two consecutive occasions. The test was performed once and the amount of shuttles was registered. Shuttles were converted to stages to calculate maximal oxygen consumption (VO_{2max}) using Legeŕs equation (Leger et al. 1988). A greater number of shuttles and higher VO_{2max} indicate better CRF. This test was not performed in Italian children ($N = 574$).

Muscular strength of the lower and upper limb

Upper-limb isometric strength was measured with the handgrip strength test using a hand dynamometer with adjustable grip (TKK 5101 Grip D; Takei). The child had to stay in a standard bipedal position with the arms in complete extension holding the dynamometer. The dynamometer was adjusted to sex and hand size for each child (España-Romero et al. 2008). The score was calculated as the average of the right and left handgrip strength. Higher scores indicate better performance.

Lower-limb explosive strength was evaluated with the standing long jump test (Castro-Pinero et al. 2010). The child jumped as far as possible with feet together on a nonslip hard surface. The test was performed twice and the best score was recorded in centimeters. Higher scores indicate better performance.

Speed and agility

The 40 m sprint test measured the maximum running speed. Two attempts were allowed, and the best score was retained. In this test, lower scores indicate better performance.

The flamingo balance test measured the ability to balance successfully on a single leg. The child has to bend his/her free leg backward and grip the back foot with his/her hand on the same side. The child was given one try to become familiar with the test. The number of attempts needed to stand on one leg for 1 min was counted for each leg. Children were excluded if they had put down the other foot 15 times or more within the first 30 s. The test score was calculated as the sum of attempts with both legs. Lower scores indicate better performance.

The back-saver sit-and-reach test measures the flexibility of the hamstring muscles (Meredith and Welk 2007). The participant was required to sit with the untested leg bent at the knee; the tested leg was placed straight with the foot placed against the box. The participant slowly reached forward as far as possible. The score was recorded to the nearest centimeter, twice for each leg. The score was calculated as the average of both sides. Higher scores indicate better performance.

Anthropometric measurement

International guidelines for anthropometry in children were used (Stomfai et al. 2011). Body weight (kg) and height (cm) were measured in barefoot children, clothed in underwear. An adapted version of the electronic TANITA scale (Tanita BC 420 SMA, Tanita Europe GmbH, Sindelfingen, Germany) was used to measure weight to the nearest 0.1 kg and a portable stadiometer (Seca 225, Birmingham, UK) to measure height at the nearest 0.1 cm. BMI was calculated as body weight (kg) divided by height (m) squared. Age- and sex-adjusted BMI z-scores were calculated following Cole's method and obesity/overweight classification was done using the extended IOTF cutoffs (Cole and Lobstein 2012).

Physical activity

Actigraph accelerometers (Actigraph MTI; FL, USA) were worn at the right hip to measure physical activity. Recordings were considered reliable if the device was worn for at least 6 h/day during at least 3 days (2 weekdays and 1 day of the weekend or holiday) (Ojiambo et al. 2011). PA was categorized as sedentary, light, moderate or vigorous PA according to the Evenson cutoff points (Evenson et al. 2008).

Psychosocial well-being

Questions were included from the proxy-reported KINDL for parents of children aged 7–17 years, a validated questionnaire for measuring health-related quality of life in children (http://www.kindl.org). Answers were given according to a four-point Likert scale (never, rarely, sometimes, often/all the time) that was adapted from the original five-point Likert scale of the KINDL. Only psychosocial well-being was considered, including the score of subscales on emotional well-being, self-esteem, family and friends. Higher scores indicate better well-being.

Dietary habits

Information on dietary habits was obtained from a validated standardized Food Frequency Questionnaire which was parentally reported. Only frequency data were available and not the portion (Bel-Serrat et al. 2014). We considered the reported frequency of breakfast consumption (Papoutsou et al. 2014) as well as fruits and vegetables as a marker of healthy dietary intake (Ciliska et al. 2000).

Sleep duration

Information on sleep duration was collected by questionnaire from parental-reported bedtime and get-up time, separately for weekdays and weekends. The average sleep duration was calculated as follows: $1/7 \times (2 \times \text{weekend} + 5 \times \text{weekday})$.

Parental factors

Parental BMI was calculated using self-reported height and weight of the mother and father. Self-reported parental age was included. Parental education as an indicator of socioeconomic status was categorized using the International Standard Classification of Education (ISCED 2006). The ISCED level was derived for the highest qualification levels of both parents using a scale from 0 to 6, but a re-categorization was done as follows: low education attainment (ISCED level 0–3) and high educational attainment, i.e., post-secondary education (ISCED level 4–6).

Statistical analysis

All statistical calculations were performed in SPSS software, version 22.0 (IBM, New York, NY, USA), with a significance set at $P < 0.05$. Independent sample-T test and Chi-square tests were used to give full description about predictor and outcome variables and sex differences. The cross-sectional associations between determinant factors and PF components based on data derived from follow-up study (T1) were analyzed by linear regression using two separate analyses. In the first analysis, all PF components were tested together as one outcome using multivariate regression analyses. The effect size (partial eta squared) was interpreted as follows: 0.14 low; 0.39 moderate; 0.59 large (Cohen et al. 2003). In the second analysis, linear mixed models were used to investigate the influence of predictors on each component outcome separately. This multilevel method enables a two-level model to adjust for the clustered design (children within countries) by using country as a random factor and to test the longitudinal change (two measurements within the individual) by including predictor and outcome factors of the two time points. In addition, the mixed models were also performed separately by sex, since (1) theoretically, different relations might exist, e.g., maternal characteristics might be more important for girls' PF than for boys' PF and (2) empirically, significant sex interaction terms were noticed for some predictors (psychosocial well-being, fruits and vegetables, PA, parental age). Furthermore, these linear mixed models were used to test some predictors longitudinally which might be changed over 2 years (lifestyle and BMI change between the T0 and T1 measurement wave). To get

Table 1 Descriptive table including determinant and outcome variables in the follow-up survey (T1) ("IDentification and prevention of dietary and lifestyle induced health Effects In Children and infantS" (IDEFICS) study; Belgium, Cyprus, Estonia, Germany, Hungary, Italy, Spain, Sweden; 2006–2012)

	Boys			Girls			Sex difference (P value)
	N	Mean	Std. deviation	N	Mean	Std. deviation	
Determinant variables							
Age (years)	2422	8.6	1.2	2481	8.7	1.2	0.089
BMI z-score	2422	0.4	1.2	2481	0.4	1.1	0.878
Parental educational attainment (level)	2422	4.0	1.0	2481	4.1	1.0	0.726
Psychosocial well-being score	2422	38.8	4.9	2481	39.1	5.0	0.033*
Breakfast frequency (time/week)	2422	6.1	1.9	2481	6.0	1.9	0.374
Fruits and vegetables frequency (time/week)	2422	17.7	11.6	2481	18.9	12.5	<0.001*
Sleep duration (h/day)	2422	9.7	0.7	2481	9.7	0.7	0.246
Mother's age (years)	2422	37.8	4.9	2481	38.2	5.0	0.008*
Father's age (years)	2422	40.7	5.5	2481	41.0	5.7	0.032*
BMI mother	2422	23.9	4.1	2481	23.9	4.1	0.917
BMI father	2422	26.5	3.6	2481	26.4	3.5	0.275
MVPA (% of time)	1227	6.0	3.0	1330	5.0	2.0	<0.001*
Outcome variables							
VO_{2max} (ml kg^{-1} min^{-1})	1542	46.3	4.2	1630	44.7	3.4	<0.001*
20 m shuttle run test (N shuttles)	1542	25.4	13.3	1630	19.8	10.2	<0.001*
Handgrip strength (kg)	2412	13.6	3.6	2448	12.4	3.5	<0.001*
Standing long jump (cm)	2422	120.6	24.6	2471	110.9	24.0	<0.001*
40 m sprint (s)	911	8.5	1.0	989	8.9	1.0	<0.001*
Back-saver sit and reach flexibility test (cm)	2415	18.7	5.7	2481	21.6	5.5	<0.001*
Flamingo balance test (attempts)	1734	3.4	3.1	1875	2.4	2.3	<0.001*

BMI body mass index, *VO_{2max}* maximal oxygen consumption, *MVPA* moderate-to-vigorous physical activity

* $P < 0.05$ statistically significant association

more insight in the role of PA in these relations, PA was included in the models in a second step. For all mentioned analyses, all predictor variables were included at once in the model and adjustment was done for the control versus intervention region to adjust for the IDEFICS intervention.

Results

Descriptive statistics are shown in Table 1. Although boys performed better than girls in CRF, upper- and lower-limb strength and speed, girls were better in balance and flexibility.

Multivariate regression analysis for the determinants of PF (Table 2) showed significant associations with children's age, sex, BMI, PA, psychosocial well-being and frequency of fruits and vegetables intake. The effect size (partial eta squared) was highest for age, moderate for sex, BMI and PA, and low for the other determinants.

All PF components were significantly associated with children's BMI and age, except flexibility which was not associated with the child's BMI (Tables 3, 4). While CRF and flexibility decreased by increasing age, muscular strength, speed and balance increased. Higher child's BMI was associated with lower CRF, higher upper-limb strength, less lower-limb strength, less speed and less balance. CRF was better in those with higher parental educational attainment, higher psychosocial well-being and lower maternal BMI. The upper-limb strength was positively associated with the child's age and BMI. Lower-limb strength was positively associated with age, psychosocial well-being and maternal age, while it was negatively associated with parental educational attainment, parental BMI and paternal age. While speed was higher in children with high psychosocial well-being and less maternal BMI, flexibility was better in children with only higher psychosocial well-being. Balance was significantly better in children with higher parental educational attainment and less maternal BMI.

Interestingly, some non-linearity was found in the effect of BMI (Fig. 1): a U-shape form was seen for speed in which the normal weight group was the best and balance was only worse in the obese group. In contrast, a perfect linear amelioration was seen with increasing BMI for upper-limb strength and an almost linear deterioration was seen for CRF and lower-limb strength.

As presented in supplementary Table 1, the significance of PF determinants could be different between sexes. The detected directions were similar to those in Tables 3 and 4. Maternal BMI had a significant association with CRF, lower-limb strength, speed and balance in boys, but not in girls. In contrast, psychosocial well-being was associated with speed and flexibility in girls, but not boys.

Next, the role of PA was examined. All outcome variables had significant association with PA ($P < 0.001$), except for balance ($P = 0.863$ and $P = 0.702$ in boys and girls, respectively). After adjusting for PA, data were available in 2557 children for the multivariate analyses, but higher sample sizes were available for the separate PF outcomes. The results of the multivariate model (Table 2) remained the same, except that psychosocial well-being was not a significant predictor any more. Changes were also noticed in the mixed model's results (Tables 3, 4).

Finally, Table 5 presents the results of 2-year longitudinal analyses for specific determinants which might be changed over time (BMI, psychosocial well-being, breakfast, frequency of fruits and vegetables intake and PA). It revealed that change in all PF components could be predicted by the child's BMI. With increasing BMI, upper-limb strength and balance improved, but all other PF components diminished. The effects were strongest for CRF and lower-limb strength. PA, psychosocial well-being and breakfast had a positive longitudinal effect on CRF. Speed deteriorated with increased breakfast frequency, while balance improved with increased frequency of fruit and vegetable intake.

Table 2 The association between overall physical fitness (outcome) and determinant factors using multivariate regression ("IDentification and prevention of dietary and lifestyle induced health EFfects In Children and infantS" (IDEFICS) study; Belgium, Cyprus, Estonia, Germany, Hungary, Italy, Spain, Sweden; 2006–2012)

Determinants	Partial eta squared (=effect size)	*P* value
Country	0.116	<0.001*
Sex	0.316	<0.001*
Age (years)	0.649	<0.001*
BMI z-score	0.269	<0.001*
Parental educational attainment (low–high)	0.008	0.271
Psychosocial well-being score	0.016	0.012[a]
Breakfast (time/week)	0.005	0.727
Fruits and vegetables (time/week)	0.014	0.037*
Sleep duration (h/day)	0.010	0.164
Age mother (years)	0.006	0.511
Age father (years)	0.004	0.715
BMI mother	0.009	0.198
BMI father	0.006	0.492
MVPA (% of time)	0.144	<0.001*

BMI body mass index, *MVPA* moderate-to-vigorous physical activity

* $P < 0.05$, statistically significant association

[a] Disappearance of the significance after adjustment for moderate-to-vigorous physical activity

Table 3 The association between cardio-respiratory fitness and muscular strength and determinant factors ("IDentification and prevention of dietary and lifestyle induced health EFfects In Children and infantS" IDEFICS study; Belgium, Cyprus, Estonia, Germany, Hungary, Italy, Spain, Sweden; 2006–2012)

	Cardio-respiratory fitness				Muscular strength			
	VO_{2max} (ml kg^{-1} min^{-1}) $N = 3172$		20 m shuttle run (shuttles) $N = 3172$		Handgrip strength (kg) $N = 4860$		Standing long jump (cm) $N = 4893$	
	β	P	β	P	β	P	β	P
Age	−0.273	<0.001*	0.354	<0.001*	0.620	<0.001*	0.349	<0.001*
Sex of the child (girls as reference)	0.391	<0.001*	0.472	<0.001*	0.369	<0.001*	0.434	<0.001*
BMI z-score	−0.219	<0.001*	−0.245	<0.001*	0.240	<0.001*	−0.166	<0.001*
Parental educational attainment (high as reference)	−0.142	0.001*	−0.095	0.019[a]	−0.011	0.072	−0.074	0.007*
Psychosocial well-being	0.051	0.009[a]	0.040	0.029[a]	0.016	0.247	0.042	0.001*
Breakfast (t/week)	−0.003	0.932	−0.011	0.532	0.001	0.818	−0.002	0.822[b]
Fruits and vegetables (t/week)	0.020	0.741	0.021	0.257	0.012	0.155	0.019	0.111[b]
Sleep duration (h/day)	−0.017	0.436	−0.011	0.605	0.017	0.167	−0.017	0.214
Age mother	0.022	0.449	0.022	0.813	0.008	0.979	0.053	0.004*
Age father	0.036	0.169	0.038	0.127[b]	−0.002	0.531	−0.035	0.042[a]
BMI mother	−0.041	0.049*	−0.046	0.013	−0.019	0.261	−0.037	0.004*
BMI father	−0.027	0.163	−0.027	0.139	−0.012	0.430	−0.025	0.043*

All determinants were added to the model at once

VO_{2max} maximal oxygen consumption, β standardized regression coefficient

* $P < 0.05$ statistically significant association

[a] Disappearance of the significance after adjustment for moderate-to-vigorous physical activity

[b] Significant after adjustment for moderate-to-vigorous physical activity

Discussion

PA and PF among children and adolescents have been an increasing public health concern during the last decades, with health effects already in early life (Sallis et al. 2000; Van Der Horst et al. 2007; Craggs et al. 2011). Previously published studies on PF determinants resulted in mixed findings which could be related to the great diversity in research designs, measurement approaches, populations studied, tested variables and PA outcomes. The specific/additional value of our study is the use of several objectively measured PF components in a heterogeneous group and the longitudinal analyses for some determinants which could change over 2 years. Children's characteristics, their lifestyle and parental factors were considered in the present analyses.

Children's characteristics

Findings of the current study revealed significant differences in PF between boys and girls. Boys performed better than girls in CRF, upper- and lower-limb strength and speed, while girls were better in agility (balance and flexibility). Older children performed better than younger children in all tests, except for CRF and flexibility. These findings were consistent with literature, which highlighted sex and age differences in children and adolescents in PF (Dumith et al. 2010; De Miguel-Etayo et al. 2014). The sex and age differences in PF performance in our study might hence be related to the effects of genetics, anatomy, physiology, behavior and social and physical environments.

BMI z-score was the only determinant which had very strong and consistent significant associations with PF in both cross-sectional and longitudinal analyses. The strongest BMI effects were seen on CRF and lower-limb strength. These significances and the effect size (partial eta squared = 0.269) show that BMI reduction was a very important factor to prevent or improve low PF, except for upper-limb strength and balance. Our findings concur with cross-sectional studies which have found an inverse correlation between PF and BMI (Dumith et al. 2010; Fogelholm et al. 2008), but an advantageous effect on

Table 4 The association between speed and agility and determinant factors ("IDentification and prevention of dietary and lifestyle induced health EFfects In Children and infantS" (IDEFICS) study; Belgium, Cyprus, Estonia, Germany, Hungary, Italy, Spain, Sweden; 2006–2012)

	Speed and agility					
	40 m sprint (s) $N = 1900$		Sit-and-reach flexibility test (cm) $N = 4896$		Flamingo balance (attempts) $N = 3609$	
	β	P	β	P	β	P
Age	−0.503	<0.001*	−0.116	<0.001*	−0.352	<0.001*
Sex of the child (girls as reference)	−0.398	<0.001*	−0.493	<0.001*	0.339	<0.001*
BMI z-score	0.139	<0.001*	0.030	0.065	0.099	<0.001*
Parental educational attainment (high as reference)	0.061	0.170	0.006	0.856	−0.122	0.001*
Psychosocial well-being	−0.061	0.005[a]	0.036	0.020*	−0.025	0.229
Breakfast (t/week)	0.028	0.225	−0.010	0.514	−0.010	0.541
Fruits and vegetables (t/week)	−0.036	0.092	−0.010	0.501	−0.023	0.377
Sleep duration (h/day)	0.003	0.906	−0.032	0.074[b]	−0.009	0.602
Age mother	−0.000	0.979	0.007	0.741	−0.037	0.106
Age father	−0.016	0.583	−0.040	0.066	−0.003	0.884
BMI mother	0.072	0.002*	0.010	0.506	0.040	0.014[a]
BMI father	0.026	0.224[b]	0.006	0.687	0.002	0.847

All determinants were added to the model at once

VO_{2max} maximal oxygen consumption, β standardized regression coefficient

* $P < 0.05$, statistically significant association

[a] Disappearance of the significance after adjustment for moderate-to-vigorous physical activity

[b] Significant after adjustment for moderate-to-vigorous physical activity

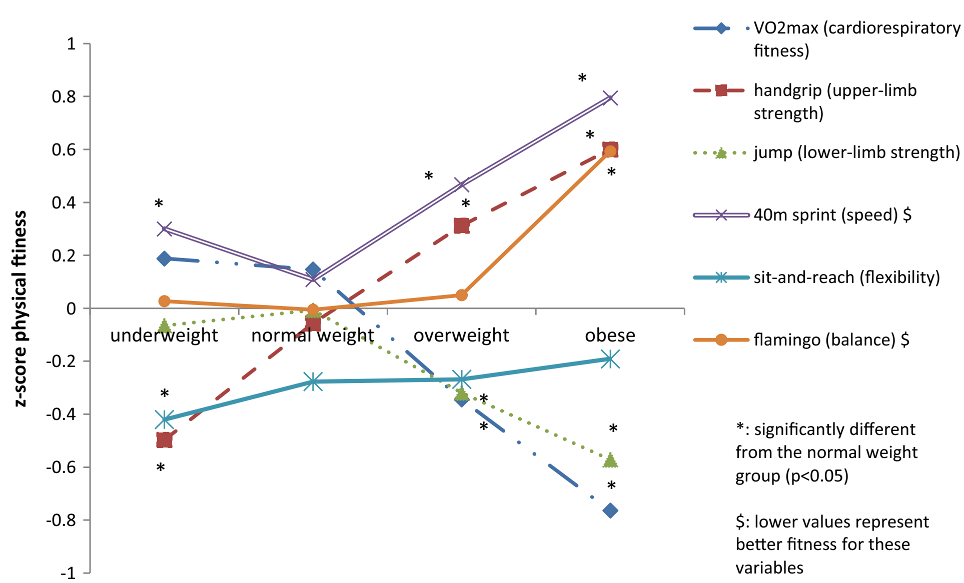

Fig. 1 Patterns of physical fitness over the different body mass index categories using cross-sectional mixed model regression ["IDentification and prevention of dietary and lifestyle induced health EFfects In Children and infantS" (IDEFICS) study; Belgium, Cyprus, Estonia, Germany, Hungary, Italy, Spain, Sweden; 2006–2012], VO_{2max} maximal oxygen consumption

handgrip (Deforche et al. 2003). Our findings also show that PA is an important predictor of PF and that the association of PF and obesity remains after adjusting for PA. But what do these complex PA–PF–obesity relations now mean for public health? A recent review has detected a lot of uncertainty until now (Rauner et al. 2013). For improvement of PF in a preventive perspective, overweight-related lifestyle should be targeted. For intervention, it has previously been recommended to encourage obese youth in PA to start with static strength exercise (Deforche et al. 2003). After all, overweight people cannot directly achieve better PF values because of their overweight status giving problems to perform well on PF tests and to practice high-intensity cardio-respiratory activities.

Table 5 Longitudinal effect of five determinants on change in physical fitness ("IDentification and prevention of dietary and lifestyle induced health EFfects In Children and infantS" IDEFICS study; Belgium, Cyprus, Estonia, Germany, Hungary, Italy, Spain, Sweden; 2006–2012)

	VO_{2max} (ml kg^{-1} min^{-1}) $N = 1433$		20 m shuttle run (shuttles) $N = 1433$		Handgrip strength (kg) $N = 2245$		Standing long jump (cm) $N = 2263$		40 m sprint (s) $N = 948$		Sit-and-reach flexibility test (cm) $N = 1231$		Flamingo balance test (attempts) $N = 1809$	
	β	Sig.	β	Sig.	β	Sig.	β	Sig.	β	Sig.	β	Sig.	β	Sig.
BMI z-score	−0.091	0.003*	−0.178	<0.001*	0.070	<0.001*	−0.127	<0.001*	0.060	0.036*	−0.066	0.003*	−0.068	0.004*
Psychosocial well- being	0.080	0.008*	−0.110	0.002	0.024	0.136	0.025	0.174	0.001	0.953	0.034	0.132	0.000	0.974
Breakfast (time/week)	0.063	0.031	−0.047	0.203	−0.002	0.875	−0.019	0.309	0.076	0.008*	−0.021	0.364	−0.001	0.944
Fruits and vegetables (time/week)	0.062	0.106	0.007	0.841	−0.012	0.449	0.022	0.206	−0.044	0.114	−0.022	0.307	−0.079	0.002*
MVPA (%)	0.161	<0.001*	0.120	<0.001*	0.040	0.078	0.011	0.664	0.021	0.555	0.016	0.588	0.023	0.473

Results are based on mixed model analyses using baseline survey (T0) and follow-up survey (T1) data for determinants and outcome

BMI body mass index, VO_{2max} maximal oxygen consumption, β standardized regression coefficients, *MVPA* moderate-to-vigorous physical activity

* $P < 0.05$, statistically significant association

Children's lifestyle

A daily breakfast might be considered as a healthy dietary habit. Indeed, daily reported breakfast consumption was associated with a healthier BMI, healthier lipid profiles and higher PA in European children (Papoutsou et al. 2014). However, skipping breakfast was not associated with lower PA, lower PF or higher sedentary time in European adolescents (Cuenca-García et al. 2013) and similar results were also published on British adolescents (Corder et al. 2011). Findings in the present study revealed no association between reported breakfast consumption and PF overall. Surprisingly, after adjustment for sex and PA, even an unfavorable effect of breakfast intake was found in boys (more frequent breakfast consumption, less speed performance). However, the longitudinal analyses detected a positive association of reported breakfast with CRF. This shows that the effect might differ depending on the type of PF. Insufficient data about the quality of reported breakfast consumption limits the discussion of these results.

Our findings showed that a higher reported intake of fruits and vegetables (as a marker for healthy dietary habits) was associated with better PF. This was the case for lower-limb strength and balance, mainly in girls. The longitudinal analyses revealed that fruit and vegetable intake was only important for a better balance. Since some significances remained after adjustment for PA, these relations are not solely explained by a healthier lifestyle but perhaps might be related to a better nutrient availability for muscle growth and related physiology (Lampe 1999).

Sleep duration has been tested as a determinant for PF, since some studies have reported an association between short sleep duration and obesity in adults (Kohatsu et al. 2006). Moreover, longer sleep duration might result in less possibilities for being active. The National Sleep Foundation (2011) in Washington, USA, recommends children aged 5–12 years to have 10–11 h of sleep. Our cohort had a mean sleep duration of 9.7 h, showing that half of our population may have at least some lack of sleep. This suggests that lack of sleep is an important public health problem that might influence PF. Longer sleep duration was indeed associated with stronger lower limbs in boys, but also with worsened flexibility in girls. To the best of our knowledge, no previous study has investigated the influence of sleep duration on PF. Some authors have studied the effect of sleep duration on PA and have found that children who spent more time sleeping spent less time being physically active (Laurson et al. 2014); however, other authors did not find any association between PA and sleep duration (Ortega et al. 2011). Consequently, more in-depth studies are necessary, also taking into account sleep quality.

Psychosocial well-being was a last lifestyle-related determinant that was tested since low well-being might decrease the motivation to participate in activity. Indeed, cross-sectionally, well-being was beneficial for fitness, especially for CRF, lower-limb strength, speed and flexibility. This association was observed in boys and girls, but more prominently in girls. After adjustment for PA, some of the associations disappeared, especially the relation with CRF and speed. Longitudinal analyses confirmed the important impact of psychosocial well-being on CRF.

Parental factors

Parents are important influencers of children's behavior. There is inconclusive information about whether associations exist between children's PF and parental age and BMI.

Results from the current study showed only few associations between parental age and children's PF. In addition, almost all significances disappeared after adjustment for PA. Parental age was also not significant in the multivariate analysis.

Maternal BMI had an important effect on PF in our sample. Lower maternal BMI resulted in higher CRF, higher speed and stronger upper and lower limbs in both sexes, but more specific in boys. Most of these associations were independent of the child's PA. Paternal BMI did not show an effect on children's PF. These results highlighted a major maternal influence in the determination of children's PF. Less maternal BMI might be due to their healthy diet and PA which affect their children.

Some uncertainties surround educational attainment differences in PF. Men and women from higher educational attainment are involved in more sport and recreational activity (Macintyre and Mutrie 2004) and are probably more aware of the health effects. Indeed, a significant positive association between parental educational level and their child's PA level has previously been found (Kimm et al. 2002). In contrast, another study found that maternal education was not cross-sectionally or longitudinally predictive of children's PA or sedentary behaviors (Ball et al. 2009). In the present study, the findings revealed better CRF, lower-limb strength and balance in both boys and girls with high parental educational attainment. Most of these significances can be explained by higher PA in high educational attainment, since the significant association disappeared after adjustment for PA. In contrast, socioeconomic status influenced PF in European adolescents independently of PA (Jiménez Pavón et al. 2010).

Strengths and limitations

The main strengths of the current study are: (a) a large sample of European children; (b) the standardized use of different fitness components; (c) a well-balanced sex distribution which enables sex-specific data; (d) longitudinal analyses to explore some determinants which could change over 2 years; (e) an adjustment for PA to see the effects independent of PA; (f) the use of validated questionnaires (e.g., well-being, diet) and objective methods (e.g., physical activity, BMI). To our knowledge, no similar studies have been conducted yet.

The current study is subject to certain limitations. Many children did not have valid and complete data for all necessary variables. Thus, the number of included children dramatically decreased which lowered our power for the longitudinal analyses and PA adjustments. Concerning reported breakfast intake, information was not available on what children usually eat as breakfast, making it difficult to discuss our findings in the context of 'a healthy dietary routine'. Parental proxy reporting of child's diet and well-being are prone to error. Finally, parental PA was not tested due to insufficient data.

Conclusion

This study identified some unmodifiable but more importantly also some modifiable predictors of PF to be included in prevention and intervention. Moreover, the determinants differ depending on the type of PF and the child's sex. Age, sex, children's BMI and PA were the strongest determinants of children's PF, independent of each other. Older children performed better than younger children, except in CRF and flexibility. Boys performed better than girls in CRF, upper- and lower-limb strength and speed, while girls were better in balance and flexibility. Longitudinally, a high BMI was associated with a decline in CRF, speed, flexibility and lower-limb strength and with an increase in upper-limb strength and balance. PA was associated with higher PF components except for balance. Significant but small effects were found for low maternal BMI, high psychosocial well-being and high fruit and vegetable intake as protective determinants.

A new strong perspective of this study is that PF can be an important health factor separate from PA, since many determinants (e.g., fruit/vegetables and BMI) still had an effect on PF independent of PA. Especially for BMI, there are complex implications for intervention, since PF cannot be improved without increasing PA. Consequently, BMI and PA together should be taken into account when designing interventions to improve PF as a general health marker, but also nutritional interventions might decrease BMI and consequently increase PF.

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References

Ahrens W, Bammann K, Siani A et al (2011) The IDEFICS cohort: design, characteristics and participation in the baseline survey. Int J Obes 35:S3–S15

Ball K, Cleland VJ, Timperio AF et al (2009) Socioeconomic position and children's physical activity and sedentary behaviors: longitudinal findings from the CLAN study. J Phys Act Health 6(3):289–298

Bel-Serrat S, Mouratidou T, Pala V et al (2014) Relative validity of the children's eating habits questionnaire-food frequency section among young European children: the IDEFICS Study. Public Health Nutr 17(2):266–276

Blair SN, Kohl HW, Paffenbarger RSJR et al (1989) Physical fitness and all-cause mortality. A prospective study of healthy men and women. JAMA 262:2395–2401

Caspersen CJ, Powell KE, Christenson GM (1985) Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. Public Health Rep 100(2):126–131

Castro-Pinero J, Ortega FB, Artero EG et al (2010) Assessing muscular strength in youth: usefulness of standing long jump as a general index of muscular fitness. J Strength Cond Res 24:1810–1817

Ciliska D, Miles E, O'Brien M et al (2000) Effectiveness of community-based interventions to increase fruit and vegetable consumption. J Nutr Educ 32:341–352

Cohen J, Cohen P, West SG et al (2003) Applied multiple regression/correlation analysis for the behavioral sciences, 3rd edn. Routledge, New York

Cole TJ, Lobstein T (2012) Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. Pediatr Obes 7(4):284–294

Corder K, van Sluijs EM, Steele RM et al (2011) Breakfast consumption and physical activity in British adolescents. Br J Nutr 105(2):316–321

Council of Europe Committee for the Development of Sport. Eurofit (1988) Handbook for the EUROFIT tests of physical fitness. Edigrafeditorialegrafica, Rome

Craggs C, Corder K, van Sluijs EM et al (2011) Determinants of change in physical activity in children and adolescents: a systematic review. Am J Prev Med 40(6):645–658

Cuenca-García M, Ruiz JR, Ortega FB, Labayen I et al (2013) Association of breakfast consumption with objectively measured and self-reported physical activity, sedentary time and physical fitness in European adolescents: the HELENA Study. Public Health Nutr 11:1–11

De Miguel-Etayo P, Gracia-Marco L, Ortega FB et al (2014) Physical fitness reference standards in European children: the IDEFICS study. Int J Obes 38(Suppl 2):S57–S66

Deforche B, Lefevre J, De Bourdeaudhuij I et al (2003) Physical fitness and physical activity in obese and nonobese Flemish youth. Obes Res 11:434–441

Dumith SC, Ramires VV, Souza MA et al (2010) Overweight/obesity and physical fitness among children and adolescents. J Phys Activity Health 7(5):641–648

España-Romero V, Artero EG, Santaliestra-Pasias AM et al (2008) Hand span influences optimal grip span in boys and girls aged 6 to 12 years. J Hand Surg Am 33(3):378–384

Evenson KR, Catellier DJ, Gill K et al (2008) Calibration of two objective measures of physical activity for children. J Sports Sci 26:1557–1565

Fogelholm M, Stigman S, Huisman T et al (2008) Physical fitness in adolescents with normal weight and overweight. Scand J Med Sci Sports 18(2):162–170

Jiménez Pavón D, Ortega FP, Ruiz JR et al (2010) Socioeconomic status influences physical fitness in European adolescents independently of body fat and physical activity: the HELENA study. Nutr Hosp 25(2):311–316

Kimm SY, Glynn NW, Kriska AM et al (2002) Decline in physical activity in black girls and white girls during adolescence. N Engl J Med 347(10):709–715

Kohatsu ND, Tsai R, Young T et al (2006) Sleep duration and body mass index in a rural population. Arch Intern Med 166(16):1701–1705

Lampe JW (1999) Health effects of vegetables and fruit: assessing mechanisms of action in human experimental studies. Am J Clin Nutr 70(3 Suppl):475S–490S

Laurson KR, Lee JA, Gentile DA et al (2014) Concurrent associations between physical activity, screen time, and sleep duration with childhood obesity. Obesity 9(2014):204540

Leger LA, Mercier D, Gadoury C et al (1988) The multistage 20 meter shuttle run test for aerobic fitness. J Sports Sci 6:93–101

Macintyre S, Mutrie N (2004) Socio-economic differences in cardiovascular disease and physical activity: stereotypes and reality. J R Soc Health 124(2):66–69

Meredith M, Welk G (2007) Fitness gram-activity gram test administration manual. Human Kinetics, Champaign, IL, USA

National Sleep Foundation (2011) Children and sleep—information on sleep health and safety. https://sleepfoundation.org/media-center/press-release/national-sleep-foundationrecommends-new-sleep-times. Accessed 2 Feb 2015

Ojiambo R, Cuthill R, Budd H et al (2011) Impact of methodological decisions on accelerometer outcome variables in young children. Int J Obes 35:S98–S103

Ortega FB, Ruiz JR, Castillo MJ et al (2008) Physical fitness in childhood and adolescence: a powerful marker of health. Int J Obes 32:1–11

Ortega FB, Ruiz JR, Labayen I et al (2011) Sleep duration and activity levels in Estonian and Swedish children and adolescents. Eur J Appl Physiol 111(10):2615–2623

Papoutsou S, Briassoulis G, Wolters M et al (2014) No breakfast at home: association with cardiovascular disease risk factors in childhood. Eur J Clin Nutr 68(7):829–834

Rauner A, Mess F, Woll A (2013) The relationship between physical activity, physical fitness and overweight in adolescents: a systematic review of studies published in or after 2000. BMC Pediatr 1(13):19

Ruiz JR, Castro-Pinero J, Espana-Romero V et al (2011) Field-based fitness assessment in young people: the ALPHA health-related fitness test battery for children and adolescents. Br J Sports Med 45:518–524

Sallis JF, Prochaska JJ, Taylor WC (2000) A review of correlates of physical activity of children and adolescents. Med Sci Sports Exerc 32:963–975

Stomfai S, Ahrens W, Bammann K et al (2011) Intra and inter observer reliability in anthropometric measurements in children. Int J Obes 35:S45–S51

Suling M, Hebestreit A, Peplies J et al (2011) Design and results of the pretest of the IDEFICS study. Int J Obes 35:S30–S44

United Nations Educational Scientific and Cultural Organization International Standard Classification of Education (ISCED) (2006). http://www.uis.unesco.org/Education/Pages/international-standard-classification-of-education.aspx. Accessed 2 Feb 2012

Van Der Horst K, Paw MJ, Twisk JW et al (2007) A brief review on correlates of physical activity and sedentariness in youth. Med Sci Sports Exerc 39(8):1241–1250