Fitness, Stress, and Body Composition in Primary Schoolchildren

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ABSTRACT

GERBER, M., K. ENDES, C. HERRMANN, F. COLLEDGE, S. BRAND, L. DONATH, O. FAUDE, U. PÜHSE, H. HANSSEN, and L. ZAHNER. Fitness, Stress, and Body Composition in Primary Schoolchildren. *Med. Sci. Sports Exerc.*, Vol. 49, No. 3, pp. 581–587, 2017. **Purpose**: A better understanding of how social and environmental contexts affect childhood overweight/obesity is needed to develop more effective prevention strategies. Because the relationship between physical activity, stress, and obesity measures has received limited attention, this study examined for the first time in first-grade schoolchildren whether physical activity and fitness moderate the relationship between psychosocial stress and obesity-related measures. **Methods**: A total of 325 children (51% girls, M_{age} = 7.3 yr) took part in this cross-sectional study. Stress (critical life events, family, peer, and school-related stress) and vigorous physical activity were assessed via parental reports. Fitness was assessed with the 20-m shuttle run test. Body mass index, sum of skinfolds, and waist circumference were used as obesity-related outcomes. Hierarchical regression analyses were calculated to test whether fitness and physical activity act as stress buffers, using sex, age, and parental education as covariates. **Results**: Children experiencing elevated school-related stress had lower body mass index, body fat, and waist circumferences if they had high fitness and physical activity levels, as compared with their less active and fit peers. Few significant interaction effects occurred for the other stress measures, although the findings trended in a similar direction for peer stress. **Conclusion**: This study shows that high fitness is associated with less unfavorable body composition among children with elevated school stress. Our findings indicate that policies aimed at reducing overweight and obesity should include the promotion of physical activity both inside and outside the school context. Moreover, our findings highlight the importance of strengthening children's capacities to cope successfully with school-related pressures. **Key Words:** BODY MASS INDEX, CRITICAL LIFE EVENTS, OBESITY, OVERWEIGHT, SUM OF SKINFOLDS, WAIST CIRCUMFERENCE

Obesity represents an important hazard for children's health, and during recent years, an increase in pediatric obesity has been observed worldwide (12). For instance, a population-based study with more than 18,000 German children and adolescents (KiGGS) showed that 8.5% of all participants were overweight and 6% were obese (20). Obese children have an increased risk of developing endothelial dysfunction, hypertension, insulin resistance, cholecystolithiasis, nonalcoholic fatty liver disease, and respiratory and orthopedic disorders, as well as chronic pain (1,12). In many cases, obese children also reported a reduced quality of life (11,32), similar to children diagnosed with cancer (32). Moreover, childhood obesity constitutes a precursor for a range of adverse health effects during adulthood (4).

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Submitted for publication June 2016.
Accepted for publication October 2016.

0195-9131/17/4903-0581/0
MEDICINE & SCIENCE IN SPORTS & EXERCISE®

DOI: 10.1249/MSS.0000000000001123

Despite the widespread concern about the increase in childhood obesity (9), research into the underlying causes is still insufficient (2). As a consequence, many factors that may place children at risk for overweight and obesity remain undiscovered, a fact that limits the development of effective prevention strategies (2).

However, during the last few decades, research has accumulated which shows that increased physical activity and fitness are both associated with a greater likelihood of being normal weight (26,30). To illustrate, Colley et al. (5) showed that higher body mass index (BMI) was associated with lower physical activity in 6- to 11-yr-old children, irrespective of whether physical activity was measured by accelerometry or parental report. Importantly, several surveys reveal that many children in Western societies do not attain the recommended physical activity levels (39).

Besides lower physical activity levels, previous research has identified psychological stress as an important risk factor in the development of childhood overweight and obesity (18,40). Researchers have shown that psychological stress significantly contributed to obesity in 5- to 6-yr-old children (18) and caused more rapid weight gain in schoolchildren who were followed up from birth through 15 yr of age (25).

However, only two studies have focused on the question of whether physical activity and fitness can act as moderators of the relationship between children's and adolescents' stress and obesity-related measures. This is surprising given that stress-buffering effects among youngsters and adults have been investigated since the early 1980s (17). However, most of these studies have focused on mental health outcomes (e.g., depression and psychosomatic complaints) or self-reported health (10,36).

The first study with youngsters was based on a sample of 303 adolescents (M_{age} = 16.6 yr) from the United States (40). The findings revealed that higher perceived stress was associated with larger waist circumference, whereas higher physical activity was related to lower sum of skinfold measurements. Most importantly, the interaction between stress and physical activity predicted BMI, waist circumference, and sum of skinfold measurements, showing that physical activity buffers the effects of chronic stress on adiposity measures. However, a limitation of Yin et al.'s study was that all participants had a family history of early myocardial infarction or hypertension, and the average in BMI was high, which makes it difficult to generalize these findings to more "healthy" populations. In the second study, Holmes et al. (14) assessed several self-reported stress indicators in a small sample of 8- to 18-yr-old males (n = 37), which they correlated with a composite metabolic risk score (MRS). Their findings suggest that only school-related stress and weight-related teasing were associated with the MRS. Importantly, school-related stress was only correlated with MRS among students with low, but not high physical activity levels. However, no separate analyses were performed for the various MRS indicators, which precludes a judgment about whether physical activity has the potential to moderate the relationship between stress and children's BMI or other obesity-related measures.

Given that the etiology of childhood obesity is complex and multifaceted (16), both researchers and clinicians require a better understanding of how social and environmental contexts are associated with childhood overweight/obesity to develop more effective prevention methods (23). Because the relationships between physical activity, stress, and adiposity measures have received limited attention, the purpose of the present study was to test for the first time in first-grade schoolchildren whether physical activity and fitness moderate the relationships between different psychosocial stress indices and obesity-related measures.

METHODS

Participants and procedures. In 2014, all first-grade pupils (N = 1302) of public primary schools in the canton Basel-Stadt, Switzerland, were eligible to take part in a large-scale, cross-sectional study. Weight and height were assessed in 1255 children (96.4% of the total population). Of these, 540 children (43%) obtained parental informed consent to participate in additional tests assessing fitness, physical activity, psychosocial stress, and body composition. In total, 149 children dropped out because of relocation or illness at one of the two test dates. None of the children included in the analyses took medication or supplementation. Teachers and parents were informed in advance about the study and its objectives. The legal guardians provided information about children's psychosocial stress and physical activity levels. Given that questionnaires were unavailable for 66 children, the final sample consisted of 325 children with complete data sets (165 girls, 160 boys, M_{age} = 7.28 yr, SD = 0.36). This study followed the ethical guidelines of the Declaration of Helsinki (1964). The ethics committee of the University of Basel (EKNZ, Basel, No. 258/12) approved the study, and all children and their families provided written informed consent.

Minimal sample size was determined to be able to detect a small bivariate relationship between school-related stress and children's BMI. Using G-Power software for bivariate correlations, the estimated minimal sample size was 266 children (one tail, r = 0.20, power = 0.95, 5% level of significance).

Instruments. Parents completed a questionnaire to provide information about parental education, sex, and age of their children. Parental educational level was operationalized with the highest completed school level resulting in an index ranging from 1 (low = only one parent with vocational training, but no tertiary education) to 3 (high = both parents with tertiary education).

To assess recent critical life events, parents filled in a 16-item adapted version of the Life Events Checklist by Johnson and McCutcheon (15), covering to the past 3 months. Examples of life events are as follows: death of a loved one, illness or accident of a loved one, persistent quarrel with brothers/sisters, divorce/separation of parents, and father/mother lost job. This list is not exhaustive but provides a sample of significant life events common during childhood. This instrument has been used previously in child stress research (7,33). Parents rated the effect of each event on their children's life using a four-point scale from 0 (no effect) to 3 (large negative effect). The mean influence of all negative events was summed to build a trauma-indicator.

In addition, three subscales (family, friends, and school) of the KINDL-R questionnaire (Fragebogen für KINDer und Jugendliche zur Erfassung der gesundheitsbezogenen Lebensqualität—Revised Version = Questionnaire for Children and Adolescents for the Assessment of Health-Related Quality of Life—Revised Version) were used to assess specific sources of stress in the lives of the involved schoolchildren (31). Parents were asked to respond on a five-point Likert scale from 0 (never) to 4 (all the time). All items started with the anchor: "During the past week …" The subscales used in this study were family (e.g., "my child got on well with us as parents," "we quarreled at home"), friends (e.g., "my child got along well with his friends," "my child felt different from other children"), and everyday functioning at school (e.g., "my child easily coped with schoolwork," "my child worried about his/her future"). The KINDL-R subscales have a high degree of reliability and satisfactory convergent validity (31). Positively poled items were recoded before computing the subscale mean scores. Higher scores reflected increased psychosocial stress throughout all dimensions.

To assess children's physical activity, a previously developed single-item proxy measure was used (28). The parents were asked to interview their child to obtain information about vigorous physical activity (defined as time spent in vigorous activities and sport, except physical education lessons [$min{\cdot}d^{-1}$]). Similar proxy measures have been used previously in studies with German speaking samples of young children (21).

Children's endurance performance was assessed during a physical education lesson with the 20-m shuttle run test. A 5-min standardized warm-up was performed with all children. The validity of this test has been established previously (38). During the test, the children run back and forth for 20 m, with initial running speed (8.0 $km{\cdot}h^{-1}$) being increased by 0.5 $km{\cdot}h^{-1}$ every minute, paced by beeps on a stereo. If a child was unable to cross the 20-m line at the moment of the beep for two successive 20-m distances, the individual maximum was reached and the test ended. The number of stages, with one stage corresponding to 1 min, was counted with a precision of 0.5 stages.

Body height was measured with a wall-mounted stadiometer, without shoes and to the nearest 0.2 cm (Seca 206; Seca, Basel, Switzerland). Body weight was assessed with an electronic scale, in light clothing, without shoes and to the nearest 50 g (Seca 899, Seca). Body weight was divided by height in meters squared to obtain BMI. A flexible tape at the natural waist (half way between the ribcage and the iliac crest) was used to determine waist circumference. Skinfold thickness was assessed based on standard procedures (6) with Harpenden Calipers (HSK-BI; British Indicators, UK) at two sites (triceps and subscapular), in triplicate to the nearest 0.5 mm. The devices were calibrated to exert a pressure of 10 $g{\cdot}cm^{-2}$. The mean of the two skinfold measures was calculated to obtain percent body fat. The prediction equations of Slaughter et al. (35) for white prepubescent males and females were used to estimate body fat based on the two skinfolds.

Statistical analyses. Descriptive statistics (*M* and SD) were calculated to describe characteristics of the sample. Pearson product moment correlations were run to examine the bivariate relationships between age, parental education, predictor (critical life events, family stress, peer stress, and school stress), moderator (physical activity and fitness), and outcome variables (BMI, body fat, and waist circumference). Independent-sample *t*-tests were used to examine sex differences in the predictor, moderator, and outcome variables. Finally, hierarchical (four-stage) regression analyses were performed to determine whether stress interacted with physical activity and fitness in the prediction of obesity-related measures. To control for demographic and social background, sex (female = 0, male = 1), age, and parental education were entered in the first step in each regression, followed by stress (step 2), fitness or physical activity (step 3), and the interaction term between stress and fitness or physical activity (step 4). Stress, fitness, and physical activity were centered before the calculation of the interaction terms. The following coefficients are displayed in the results section: (i) the multiple correlation coefficient squared R^2 for the entire model after the final step, (ii) the stepwise changes in R^2 (ΔR^2), and (iii) the standardized regression weights (β) for each predictor variable (for the final model). Significant interaction effects are plotted to interpret the direction of the relationships. Alpha was set at $P < 0.05$ across all analyses. All statistical analyses were carried out using the Statistical Package for the Social Sciences (version 23; IBM Corporation, Armonk, NY) for Apple Mac®.

RESULTS

Descriptive statistics are displayed in Table 1 for all covariates, predictor, moderator, and outcome variables. According to CDC standards (taking into consideration children's date of birth and sex, see: https://nccd.cdc.gov/dnpabmi/calculator.aspx), 75% (n = 243) of the children were normal weight (5th percentile up to the 84th percentile), 12% (n = 38) were overweight (85th to the 94th percentile), and 9% (n = 28) were obese (equal to or greater than the 95th percentile), whereas 5% (n = 16) were underweight (below the 5th percentile). With regard to percentage of overweight and obesity, as well as stages achieved in the 20-m shuttle run test (M = 4.57), the children were comparable to other Swiss first graders (19). With a mean level of 56.66 $min{\cdot}d^{-1}$ of vigorous physical activity, based on

TABLE 1. Descriptive statistics and bivariate correlations.

	M	SD	1	2	3	4	5	6	7	8	9	10	11
1. Critical life events	1.54	2.58	–										
2. Family stress	0.70	0.47	0.23***	–									
3. Peer stress	0.90	0.50	0.13*	0.25***	–								
4. School stress	0.42	0.42	0.08	0.05	0.22***	–							
5. BMI ($kg{\cdot}m^{-2}$)	16.33	2.03	0.06	−0.08	−0.06	0.20***	–						
6. Body fat (%)	16.64	4.87	0.09	−0.03	−0.04	0.20***	0.80***	–					
7. Waist circumference (cm)	58.03	5.87	0.04	−0.08	−0.04	0.17**	0.87***	0.81***	–				
8. 20-m shuttle run test (stages)	4.57	1.64	−0.07	0.07	−0.01	−0.17**	−0.33***	−0.40***	−0.29***	–			
9. Vigorous physical activity ($min{\cdot}d^{-1}$)	56.66	38.59	−0.07	0.01	0.01	−0.02	−0.09	−0.11*	−0.11*	0.15**	–		
10. Sex (female = 1, male = 0)	–	–	0.00	0.03	−0.13*	−0.08	0.05	0.24***	0.11*	−0.23***	−0.09	–	
11. Age (yr)	7.28	0.36	0.05	−0.03	0.02	−0.02	0.09	0.06	0.15**	0.15**	0.04	0.00	–
12. Parental education	2.32	0.77	−0.04	0.13*	0.13*	−0.27***	−0.23***	−0.23***	−0.12*	0.29***	0.05	−0.01	−0.10

*P < 0.05. **P < 0.01. ***P < 0.001.

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parental report, 51% (n = 166) of the children met the standard of 60 min or more per day of vigorous activity recommended by the Swiss Federal Office of Sports (37). Forty-nine percent of the children (n = 159) did not meet this standard.

Table 1 shows the bivariate associations between all study variables. Small but significant associations were found between critical life events, family, and peer stress. Likewise peer stress was positively related to school stress. School stress was positively correlated with BMI, body fat, and waist circumference. No significant relationships emerged between other stress indices and body composition. BMI, body fat, and waist circumference were highly correlated with one another. Fitness was negatively associated with school stress, BMI, body fat, and waist circumference. Small inverse correlations were found for vigorous physical activity with BMI, body fat, and waist circumference. A weak but significant correlation occurred between children's fitness and physical activity.

As shown in Table 1, increasing age was correlated with higher waist circumference and fitness levels, whereas higher parental education was correlated with higher family and peer stress as well as augmented fitness. Inverse relationships occurred between parental education and school stress, BMI, body fat, and waist circumference.

Table 2 shows that compared with girls, male students had higher peer stress. Moreover, boys had higher performances in the 20-m shuttle run test. By contrast, girls had higher body fat and waist circumferences.

With regard to the question of whether physical activity and fitness act as stress buffers, with BMI as an outcome, Table 3 shows that after controlling for sex, age, and parental education, only school stress explained significant amounts of variance in the outcome (explaining 2.3% of variance in step 2). Whereas fitness proved to be a significant (negative) predictor of BMI across all analyses, physical activity was not (step 3). Finally, school stress interacted both with fitness and physical activity to explain an additional 2.7% of variance beyond the main effects. As shown in Figure 1, if children experienced low school stress, the relationship between fitness and BMI was weak, whereas among students with higher school stress, those with lower fitness had significantly higher BMI scores. A similar pattern was found with physical activity as predictor variable. For the other stress indices, none of the interaction terms were significant.

TABLE 2. Independent t-test to examine sex differences in the main study variables.

	Boys (n = 160)		Girls (n = 165)			
	M	SD	M	SD	t	Cohen's d
Critical life events	1.55	2.55	1.54	2.61	−0.04	0.00
Family stress	0.69	0.48	0.72	0.47	0.59	0.06
Peer stress	0.97	0.51	0.84	0.49	−2.29*	−0.26
School stress	0.45	0.41	0.38	0.43	−1.47	−0.17
BMI ($kg \cdot m^{-2}$)	16.23	1.98	16.42	2.08	0.83	0.09
Body fat (%)	15.43	5.02	17.80	4.43	4.49***	0.50
Waist circumference (cm)	57.36	5.47	58.68	6.17	2.04*	0.23
20-m shuttle run test (stages)	4.94	1.70	4.20	1.50	−4.14***	−0.46
Vigorous physical activity ($min \cdot d^{-1}$)	60.35	39.66	53.08	37.31	−1.70	−0.19

Cohen's d: ≥ │0.20│ = small difference, ≥ │0.50│ = moderate difference, ≥ │0.80│ = large difference.
*P < 0.05. **P < 0.01. ***P < 0.001.

A very similar pattern was found with waist circumference as outcome (Table 3). Again, among children with elevated school stress, those with higher fitness or physical activity had a lower waist circumference compared with their less active or fit peers, whereas the relationship between fitness and physical activity was weak in children with low stress levels (Fig. 1). No significant interaction effects were found for the other stress indicators.

For body fat, physical activity moderated the relationship between high levels of school stress and that outcome, whereas fitness did not (although the interaction term trended in the expected direction). However, high levels of fitness seemed to moderate the relationship between peer stress and body fat. When body fat was used as an outcome, the only significant interaction found was between fitness and peer stress, although it must be noted that the pattern of findings suggests similar (albeit not significant) relationships for BMI and waist circumference.

DISCUSSION

The key findings of the present study are that children experiencing elevated school-related stress have lower BMI, body fat, and waist circumferences if they have high fitness and physical activity levels, as compared with their less active and fit peers. By contrast, few significant interaction effects were found for the other stress measures, although the findings trended in a similar direction for peer stress.

Although both psychosocial stress, fitness, and physical activity have been identified as correlates of overweight and obesity, surprisingly little research has explored whether fitness and physical activity act as stress buffers (14,40). Therefore, this study explored new territory, as we examined for the first time in healthy young children whether higher levels of fitness and physical activity are associated with less unfavorable body composition in instances of exposure to elevated levels of family-, peer-, or school-related stress.

These findings are relevant because previous research has shown that the association between overweight, behavior problems, and decreased physical activity becomes stronger as children grow older (3). Moreover, there is abundant international evidence showing that childhood fitness and overweight/obesity are associated with adult overweight/obesity. To provide two examples, a prospective cohort-study with adults who formerly participated in the Australian School Health and Fitness Survey indicated that lower levels of child fitness were significantly linked with odds of adult obesity, and that declining fitness levels between childhood and adulthood were associated with increased adult obesity (8). Furthermore, data from the Canada Fitness Survey revealed a moderate-to-strong BMI tracking

TABLE 3. Regression analyses with stress as predictor, physical fitness/vigorous physical activity as moderators, and BMI, body fat, and waist circumference as outcomes.

Moderator	20-m Shuttle Run Test (Stages)								Vigorous Physical Activity (min·d^{-1})							
Type of Stress	Critical Life Events		Family Stress		Peer Stress		School Stress		Critical Life Events		Family Stress		Peer Stress		School Stress	
(Predictor)	ΔR^2	β	ΔR^2	β	ΔR^2	β	ΔR^2	β	ΔR^2	β	ΔR^2	β	ΔR^2	β	ΔR^2	β
BMI																
Step 1: covariates	0.061***	–	0.061***	–	0.061***	–	0.061***	–	0.061***	–	0.061***	–	0.061***	–	0.061***	–
Sex	–	−0.03	–	−0.02	–	−0.03	–	−0.02	–	0.03	–	0.04	–	0.03	–	0.04
Age	–	0.12*	–	0.13*	–	0.13*	–	0.14**	–	0.08	–	0.08	–	0.08	–	0.08
Parental education	–	−0.13*	–	−0.13*	–	−0.13*	–	−0.11*	–	−0.22***	–	−0.22***	–	−0.22***	–	−0.17**
Step 2: stress	0.003	0.04	0.002	−0.03	0.001	−0.07	0.023**	0.07	0.003	0.01	0.002	−0.04	0.001	−0.03	0.023**	0.17**
Step 3: moderator	0.083***	−0.32***	0.083***	−0.31***	0.086***	−0.33***	0.075***	−0.30***	0.006	−0.09	0.007	−0.09	0.007	−0.08	0.006	−0.08
Step 4: stress–moderator	0.000	0.01	0.000	−0.02	0.007	−0.09	_0.027**_	_−0.17**_	0.005	−0.08	0.006	−0.08	0.002	−0.05	_0.027**_	_−0.17**_
Total R^2	0.147***		0.147***		0.156***		0.187***		0.075***		0.059***		0.071**		0.118***	
n	325		325		325		325		325		325		325		325	
Body fat																
Step 1: covariates	0.114***	–	0.114***	–	0.114***	–	0.114***	–	0.114***	–	0.114***	–	0.114***	–	0.114***	–
Sex	–	0.17**	–	0.17**	–	0.17**	–	0.18**	–	0.23***	–	0.23***	–	0.24***	–	0.24***
Age	–	0.09	–	0.10	–	0.10	–	0.11*	–	0.04	–	0.05	–	0.04	–	0.05
Parental education	–	−0.12*	–	−0.12*	–	−0.13*	–	−0.10	–	−0.22***	–	−0.23***	–	−0.23***	–	−0.17**
Step 2: stress	0.006	0.08	0.000	0.00	0.000	−0.04	0.027**	0.12*	0.006	0.06	0.000	−0.01	0.000	0.01	0.027**	0.18**
Step 3: moderator	0.093***	−0.34***	0.096***	−0.34***	0.096***	−0.35***	0.086***	−0.32***	0.005	−0.07	0.005	−0.08	0.005	−0.08	0.005	−0.07
Step 4: stress–moderator	0.002	0.05	0.000	0.00	_0.013*_	_−0.12*_	0.003	−0.06	0.001	−0.03	0.005	−0.07	0.001	−0.03	_0.011*_	_−0.11*_
Total R^2	0.215***		0.195***		0.120***		0.230***		0.125***		0.108***		0.125***		0.157***	
n	325		325		325		325		325		325		325		325	
Waist circumference																
Step 1: covariates	0.047**	–	0.047**	–	0.047**	–	0.047**	–	0.047**	–	0.047**	–	0.047**	–	0.047**	–
Sex	–	0.04	–	0.05	–	0.04	–	0.05	–	0.10	–	0.10	–	0.10	–	0.11*
Age	–	0.20***	–	0.20***	–	0.20***	–	0.21***	–	0.15**	–	0.15**	–	0.15**	–	0.16**
Parental education	–	−0.01	–	0.00	–	−0.01	–	0.01	–	−0.10	–	−0.10	–	−0.10	–	−0.04
Step 2: stress	0.001	0.02	0.005	−0.06	0.000	−0.06	0.027**	0.08	0.001	−0.01	0.005	−0.07	0.000	−0.02	0.027**	0.18**
Step 3: moderator	0.079***	−0.32***	0.078***	−0.31***	0.082***	−0.32***	0.070**	−0.29***	0.009	−0.10	0.010	−0.11	0.010	−0.10	0.009	−0.09
Step 4: stress–moderator	0.000	0.01	0.000	0.00	0.009	−0.10	_0.034***_	_−0.19***_	0.006	−0.08	0.006	−0.08	0.005	−0.07	_0.029**_	_−0.17**_
Total R^2	0.128***		0.114***		0.138***		179***		0.064**		0.068**		0.062**		0.112***	
n	325		325		325		325		325		325		325		325	

Significant two-way interactions are italicized. $*P < 0.05$. $**P < 0.01$. $***P < 0.001$.

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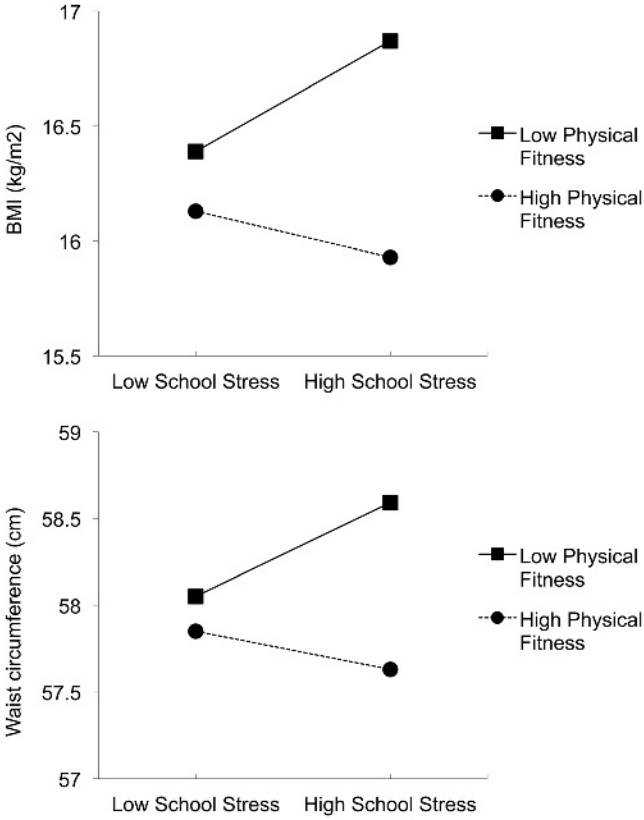

FIGURE 1—Two-way interaction between school-related stress and physical fitness on BMI and waist circumference, after controlling for sex, age, and parental education.

from childhood to adulthood, showing that more than 80% of overweight youth were also overweight as adults (13).

Although the underlying mechanisms by which stress may lead to childhood obesity are not fully understood, researchers have suggested that these relationships can be explained with behavioral and biological pathways (29). These theories include emotional (comfort) eating, lack of sleep, impulsive behaviors, and a preference for specific (high-caloric) foods among individuals exposed to high stress. In support of these hypothesized pathways, a recent experiment demonstrated that acute physical activity reduces urges for sugary snacks and attenuates those urges in response to psychological stress (22). In addition, researchers have pointed toward the role of dysregulation of the stress system through increased secretion of cortisol and catecholamines, in combination with concurrently elevated insulin concentrations in the development of central obesity, insulin resistance, and the metabolic syndrome (29). In line with this assumption, a study with Finish children supports the notion that physically active children show a less severe endocrine response to a psychological stressor (24).

The strengths of this study are that fitness was measured objectively with an established field-based test in a large sample of children of the same age. Moreover, several validated instruments and procedures were used to assess psychosocial stress and obesity-related measures, and all regression analyses were controlled for social and demographic background before testing the main and interaction effects.

Limitations were the cross-sectional study design, which does not permit conclusions about cause and effect. Because participation in the study was voluntary, a selection bias may have occurred. Moreover, sample size calculations were based on bivariate correlation analysis. However, because analyses examining moderating influences of physical activity are more power limited, it is possible that some significant two-way interactions remained undetected in the multiple regression analyses because of limited sample size. Furthermore, because of the low age of the children, psychosocial stress and physical activity were assessed by means of parental reports. Although no reliable methods currently exist to objectively assess children's stress levels, we acknowledge that the present findings should be replicated with objective accelerometry and fitness tests that provide a more precise estimate of children's physical activity and $\dot{V}O_{2max}$. Although researchers have questioned whether physical activity can be adequately assessed in younger children via self-report instruments (34), others have emphasized that physical activity and cardiorespiratory fitness can be independently associated with major cardiovascular risk markers (27). Given this background, we have decided to test two-way interactions with stress separately for fitness and physical activity. Because we used a proxy measure to assess vigorous physical activity, we acknowledge that the data related to physical activity should be interpreted with caution. However, it is noteworthy that for school-related stress, the interactions pointed into the same direction for both fitness and physical activity.

CONCLUSION

On the basis of our results, we conclude that school-related stress is associated with increased BMI, body fat, and waist circumference. Moreover, support for a classic stress-buffering effect was found in this sample of first-grade primary schoolchildren, showing that high levels of fitness and physical activity protect against increased obesity-related outcomes if children perceive elevated school-related stress.

These findings indicate that policies aimed at reducing overweight and obesity should include the promotion of physical activity both inside and outside the school context. Moreover, this study highlights the importance of strengthening children's capacities to cope successfully with school-related pressures.

The Department of Education of Basel-Stadt, Switzerland, financially supported this project.

None of the authors has any conflict of interest. The results of the present study do not constitute endorsement by the American College of Sports Medicine. The results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation.

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