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The Relationship Between Physical Fitness, Urine Iodine Status, and Body-Mass Index in 6- to 7-year-old Polish Children

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The aim of this study was to assess physical fitness in 6- to 7-yr-old children and determine if there is any relationship between children's physical fitness, their urine iodine status, and their body-mass index (BMI). The studied population included 121 children from southern Poland. Physical fitness was measured using a physical fitness test for children age 3–7 yr. Urinary iodine concentrations were measured in the children's first urine output on waking using the modified PAMM (Program Against Micronutrient Malnutrition) method. Body height and weight were measured and BMI was calculated. The subjects were characterized by low physical fitness. Boys obtained better results in agility, power, and strength exercises ($p \leq .05$). In girls, 11 correlation coefficients between the scores obtained in the physical fitness test, urinary iodine, and anthropometric measures were statistically significant, and in boys, only 2. BMI correlated positively with agility in girls and with strength in girls and boys. Our study revealed low physical fitness in Polish 6- to 7-yr-old children, which shows the need to implement programs aimed at increasing their physical activity. The relationship found between physical fitness and urine iodine status in girls indicates that future research in this area is needed.

***Keywords**:* power, strength, agility, speed, anthropometric measures

Physical fitness is of vital importance to children's development, for both physical and psychological reasons. It may be related to health status and is the consequence of an individual's specific physical and physiological state. In addition, physical fitness plays an essential role in motor development because it enhances children's physical activity, kindles the imagination, and stimulates cognitive processes (e.g., Etnier, Nowell, Landers, & Sibley, 2006; Hillman, Buck, Themanson, Pontifex, & Castelli, 2009; Nielsen & Andersen, 2003).

Studies on young children's physical fitness are sparse (Annesi, Westcott, Faigenbaum, & Unruh, 2005; Chrzanowska & Golab, 2003; Graf et al., 2004; Makris, 2004; Makris & Zalewska, 2001; McKenzie et al., 2002; Momola, 2005; Sekita, 1988), mainly because of the difficulties in motivating such young children to perform their best. Among the methods of measuring physical fitness, most were developed for children age 7 years or older. The issue of physical fitness in younger children is often neglected, and that is why monitoring children's physical fitness has an important practical aspect.

Because iodine has an influence on both physical and mental development in children, we hypothesized that iodine status would be related to physical fitness. To our knowledge, there has been no study that aimed to find such relationship.

Because of the increasing prevalence of obesity among young children (Apfelbacher et al., 2008; Dieu, Dibley, Sibbritt, & Tran, 2009; Júlíusson et al., 2007; Kosti & Panagiotakos, 2006; van den Hurk, van Dommelen, van Buuren, Verkerk, & Hirasing, 2007; Vaska & Volkmer, 2004; Yanping et al., 2008) and observed low levels of children's physical fitness (Chrzanowska & Golab, 2003; Makris, 2004; Makris & Zalewska, 2001; Momola, 2005; Sekita, 1988), we also hypothesized that body-mass index (BMI) would be related to physical fitness. Because the increasing prevalence of obesity not only poses a major threat to both present and future health conditions of societies worldwide but also increases the burden of health care costs to society, numerous studies on children's obesity have been published (e.g., Apfelbacher et al. 2008, Júlíusson et al. 2007). To our knowledge, only two (Graf et al., 2004; McKenzie et al., 2002) investigated the relationship between children's physical fitness and anthropometric measures, and it was not the main purpose of those studies.

The aim of this study was to assess physical fitness in 6- to 7-year-old children and to determine whether there is any relationship between their physical fitness, urine iodine status, and BMI.

Methods

Subjects

The studied population included 121 children, 64 girls and 57 boys, who attended preschools associated with the

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Nowy Sacz League of Preschools and Schools Promoting Health. These preschools aim to incorporate the health-promotion program for preschool children recommended by the Polish Ministry of Education. We found only eight such preschools in Nowy Sacz and the vicinity, a mountainous region in southern Poland. Parents of all children who attended the last grade in those preschools, a total of 253, were asked if their children would take part in the study. Written consent was provided by parents of 149 children. We excluded 28 children from the study who suffered from diabetes, followed special diets because of food allergies, or were handicapped. Thus, 121 children who were eligible and whose parents gave consent participated in the study.

Each child's precise calendar age on the day of the physical fitness test was calculated. On this basis the children were classified into age categories. Children between the ages of 5 years 6 months and 6 years 5 months were classified as 6-year-olds, and children age 6 years 6 months and older on the day of the test were classified as 7-year-olds (Sekita, 1988).

Parents answered questions about their age and education and their opinions of their children's physical fitness.

This research was approved by the Bioethics Committee of the Poznan University of Medical Sciences, Poland.

Anthropometric Measures

Weight and height were measured using standard techniques (Lohman, Roche, & Martorell, 1988). BMI was calculated according to the following formula: weight (kg)/height (m^2). BMI *z* scores were calculated using the LMS method (see Cole, Bellizzi, Flegal, & Dietz, 2000; Kuczmarski et al., 2002) and the tables provided by Kuczmarski et al. BMI was classified to percentile ranges on the basis of those tables (Kuczmarski et al., 2002). The percentile ranges were classified using the terminology recommended by the International Obesity Task Force (Barlow & the Expert Committee, 2007): below the 5th percentile, underweight; from the 5th to the 84th percentile, healthy weight; from the 85th to the 94th percentile, overweight; and the 95th percentile or above, obese.

Physical Fitness Test

Physical fitness was measured using a physical fitness test for children age 3–7 years developed by Sekita (1988). This test comprises four exercises: 4 × 5-m shuttle run while carrying a 150-g building block (to measure agility, expressed in seconds), standing broad jump (to measure power, expressed in centimeters), 1-kg medicine-ball throw for distance (to measure strength, expressed in centimeters), and a 20-m run (to measure speed, expressed in seconds). The results of each exercise expressed in absolute measures were given with respect to both gender and age.

The next step was to transform the results into scores using reference tables provided by the author of the test (Sekita, 1988). We used reference tables with an erratum received from Sekita (unpublished data). The erratum contained lines in the reference tables that were omitted in the original publication (Sekita, 1988). The reference tables take into account the children's gender and age, so the same result expressed in absolute measure was scored differently for a 6-year-old girl, a 7-year-old girl, a 6-year-old boy, and a 7-year-old boy. Thus, the results of each exercise expressed in points were presented according to gender.

Then the scores obtained in the four exercises were used to assess the levels of all measured motor skills as follows: less than 40 points, insufficient; 40–49 points, sufficient; 50–59 points, good; 60 points or more, very good (Sekita, 1988). Finally, all points scored by a child were added up to determine the total score for the test. The scores on the whole test were used to assess physical fitness level as follows: less than 160 points, insufficient; 160–199 points, sufficient; 200–239 points, good; 240 points or more, very good (Sekita, 1988).

Urine Iodine Measures

Urinary iodine concentrations were measured in the children's first urine output on waking using the modified PAMM (Program Against Micronutrient Malnutrition) method (Kurzeja & Kochanska-Dziurowicz, 2002) and were expressed in µg/L. This method was used because it is recommended by the World Health Organization (WHO, UNICEF, & International Council for the Control of Iodine Deficiency Disorders [ICCIDD], 2007) as a good marker of recent dietary iodine intake that provides an adequate assessment of a population's iodine status (WHO et al., 2007). Twenty-four-hour urine samples were assessed as unnecessary and urinary iodine:creatinine ratios as unreliable and dependent on protein intake (WHO et al., 2007). Urinary iodine concentration expressed in µg/L, µg/dl, or µmol/L is used worldwide (Andersson, Takkouche, Egli, Allen, & De Benoist, 2005) and was also used in studies in populations of various ages, for example, by Jooste, Weight, and Lombard (2000); Kochanska-Dziurowicz, Stanjek, Kozielec, and Bijak (2005); Sebotsa, Dannhauser, Jooste, and Joubert (2005); and Valentino et al. (2004). To assess iodine status, five urinary iodine-concentration ranges were applied: severe deficiency (<20 µg/L), moderate deficiency (20–49 µg/L), mild deficiency (50–99 µg/L), normal (100–199 µg/L), and above requirements (200–299 µg/L). These ranges have also been used by other authors (e.g., Castañeda et al., 2002; Kochanska-Dziurowicz et al., 2005).

Statistics

Statistical analysis was carried out with the SPSS 12.0 PL for Windows computer program. For quantitative variables, means and standard deviations were calculated. The level of significance was set at $p \le .05$. The Shapiro–Wilk statistic was used to test normality of the quantitative variables. In case of two subgroups, the unpaired Student's *t* test for normally distributed variables and the nonparametric Mann–Whitney *U* test for skewed variables were used to investigate statistically significant differences. In case of four subgroups, Tukey's honestly significant difference test for normally distributed variables and the Kruskal–Wallis test for skewed variables were used to investigate statistically significant differences. Categorical variables were presented in contingency tables. A χ^2 test was used to compare these variables. Spearman's correlation coefficients between the scores of the participants on the physical fitness test and anthropometric and urinary iodine measures were calculated. Figures 1 and 2 were prepared using the SPSS 12.0 PL computer program, and Figures 3 and 4 were prepared using the Statistica 8 computer program.

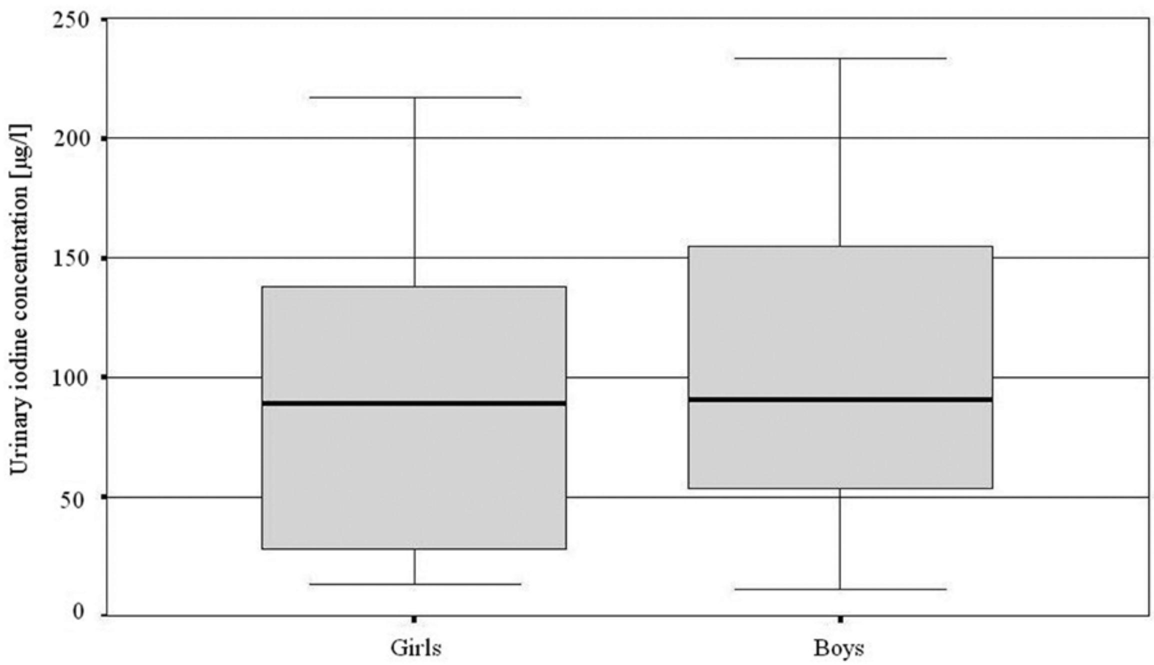

Figure 1 — Urinary iodine concentration in the studied girls and boys.

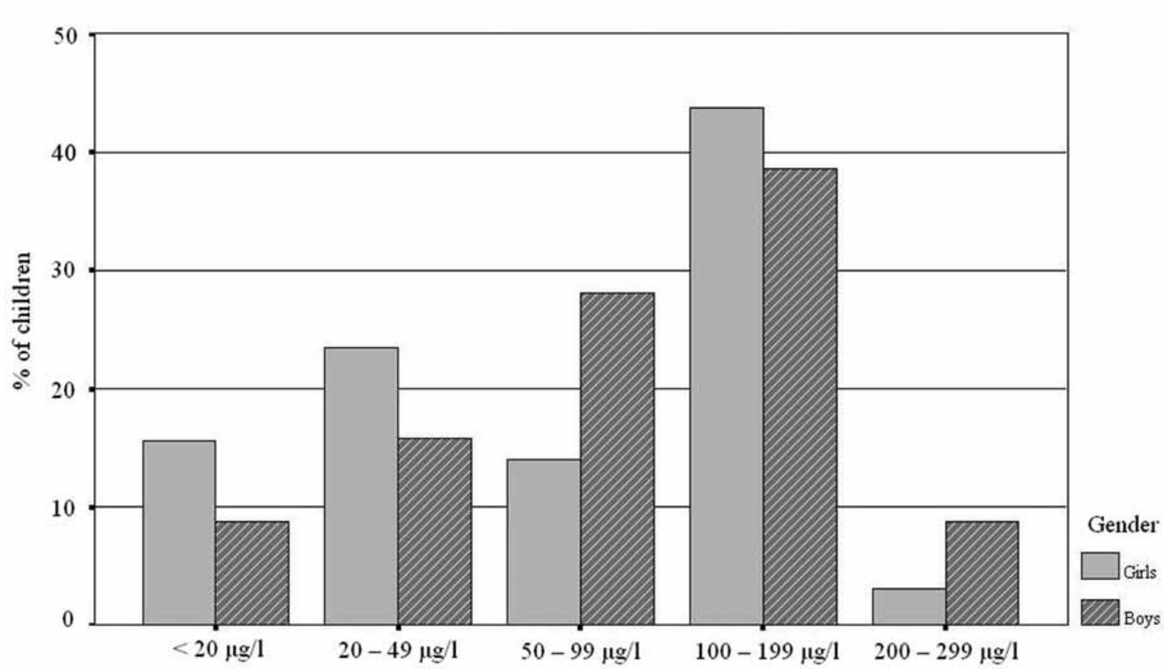

Figure 2 — Percentages of the studied girls and boys in the urinary iodine ranges.

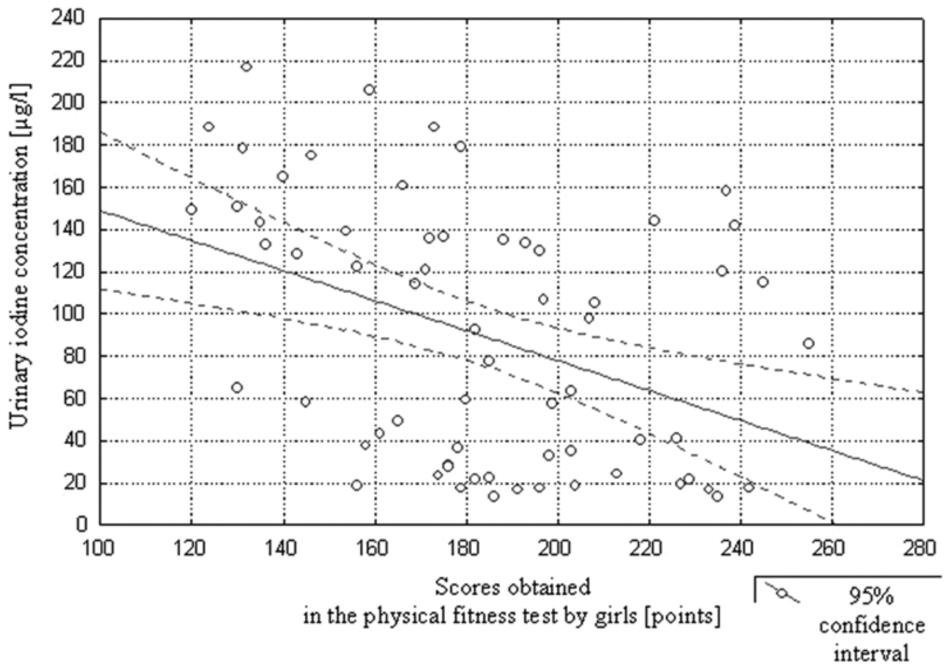

Figure 3 — Spearman's correlations between scores obtained in the physical fitness test and urinary iodine concentration in the studied girls.

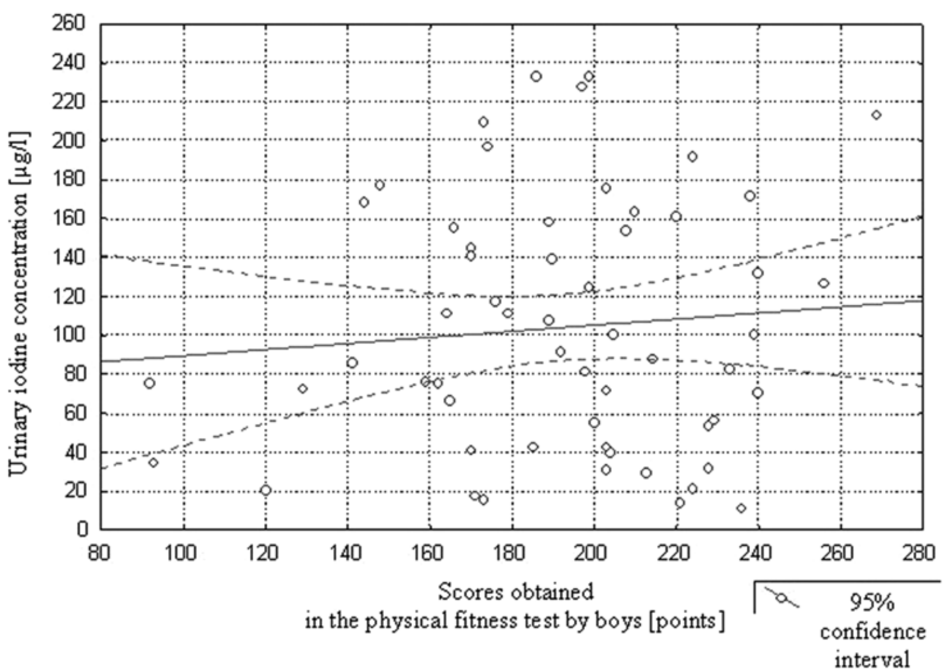

Figure 4 — Spearman's correlations between scores obtained in the physical fitness test and urinary iodine concentration in the studied boys.

Results

No statistically significant differences were observed between girls and boys in anthropometric measures (Table 1). The results of agility, power, and strength exercises were significantly different (Table 2). Better results were obtained by boys than girls and by older children than younger. No significant differences were found between the scores of the four exercises and the whole test (Table 3). However, agility levels were significantly different (Table 4). A higher percentage of girls had insufficient and sufficient levels of agility, and a higher percentage of boys had a good level.

Median urinary iodine concentrations were 89 µg/L in girls and 90 µg/L in boys (Figure 1). No statistically significant differences were observed in the percentages of the studied girls and boys in the analyzed ranges of urinary iodine concentration (Figure 2). The highest percentage of children had urinary iodine concentration in the normal range, and the lowest percentage, above requirements.

In girls, 11 correlation coefficients between the scores obtained on the physical fitness test and urinary iodine and anthropometric measures were statistically significant (Table 5). Urinary iodine concentration was negatively correlated with power, strength, speed, and physical fitness; body height correlated positively with strength and physical fitness; body weight was positively correlated with agility, strength, and physical fitness; and BMI correlated positively with agility and strength. In boys, only body weight and BMI were positively correlated with strength (Table 5). Figures 3 and 4 show Spearman's correlations between scores obtained in the physical fitness test and urinary iodine concentration, respectively, in girls and boys. No statistically significant differences were observed in sociodemographic characteristics of the studied girls and boys (Table 6).

Table 1 Anthropometric Measures

Variable	Girls (*n* = 64)	Boys (*n* = 57)
Height (cm)	119.5 ± 5.0	120.3 ± 5.6
Weight (kg)	23.0 ± 4.1	23.8 ± 3.8
Body-mass index (kg/m^2)	16.0 ± 1.8	16.4 ± 1.9
Body-mass index *z* score	0.206 ± 0.925	0.354 ± 1.181
Weight category (%)		
underweight	1.6	5.3
healthy weight	78.1	57.9
overweight	17.2	28.1
obesity	3.1	8.8

Table 2 Results of the Physical Fitness Test

	Girls		Boys	
Variable	6-year-olds (*n* = 42)	7-year-olds (*n* = 22)	6-year-olds (*n* = 42)	7-year-olds (*n* = 15)
Agility (s)	11.5 ± 1.3^{ab}	11.0 ± 1.1	10.7 ± 1.2^{a}	10.7 ± 1.3^{b}
Power (cm)	104.0 ± 13.5^{a}	106.5 ± 16.3^{b}	112.9 ± 13.9	118.7 ± 16.0^{ab}
Strength (cm)	271.7 ± 50.2^{ab}	296.8 ± 50.7^{c}	320.0 ± 62.8^{a}	327.3 ± 50.9^{bc}
Speed (s)	5.3 ± 0.5	5.0 ± 0.5	5.2 ± 0.6	5.0 ± 0.5

Note. Figures with the same superscript letters are significantly different ($p \le .05$).

Table 3 Scores on the Physical Fitness Test

Variable	Girls (*n* = 64)	Boys (*n* = 57)
4 × 5-m shuttle run	32 ± 12	39 ± 14
Standing broad jump	50 ± 10	52 ± 9
Medicine-ball throw for distance	53 ± 11	55 ± 12
20-m run	49 ± 11	47 ± 12
Total test score	183 ± 34	192 ± 37

Table 4 Level of Physical Fitness, %

Variable	Girls (*n* = 64)	Boys (*n* = 57)	*p*
Agility			
insufficient	64.1	45.6	.009
sufficient	29.6	26.3	
good	4.7	26.3	
very good	1.6	1.8	
Power			
insufficient	10.9	12.3	ns
sufficient	34.4	28.1	
good	35.9	49.1	
very good	18.8	10.5	
Strength			
insufficient	10.9	7.0	ns
sufficient	34.4	28.1	
good	28.1	35.1	
very good	26.6	29.8	
Speed			
insufficient	18.8	19.3	ns
sufficient	37.5	36.8	
good	23.4	35.1	
very good	20.3	8.8	
Physical fitness			
insufficient	26.6	14.0	ns
sufficient	43.7	40.4	
good	25.0	38.6	
very good	4.7	7.0	

Table 5A Spearman's Correlation Coefficients Between the Scores of the Girls and Boys on the Physical Fitness Test and Anthropometric and Urinary Iodine Measures

	Agility				Power				Strength			
	Girls		Boys		Girls		Boys		Girls		Boys	
Variable	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Urinary iodine concentration, µg/L	–.24	ns	.13	ns	–.37	.002	–.03	ns	–.42	.001	–.03	ns
Height, cm	.24	ns	.16	ns	.11	ns	.11	ns	.41	.001	.16	ns
Weight, kg	.31	.012	.12	ns	.16	ns	.03	ns	.41	.001	.31	.021
Body-mass index, kg/m^2	.27	.032	–.06	ns	.14	ns	–.13	ns	.28	.028	.31	.019

Note. Girls *n* = 64, boys *n* = 57.

Table 5B Spearman's Correlation Coefficients Between the Scores of the Girls and Boys on the Physical Fitness Test and Anthropometric and Urinary Iodine Measures

	Speed				Physical fitness			
	Girls		Boys		Girls		Boys	
Variable	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Urinary iodine concentration, µg/L	–.29	.020	–.03	ns	–.44	.000	–.00	ns
Height, cm	.18	ns	.11	ns	.30	.016	.17	ns
Weight, kg	.06	ns	.14	ns	.31	.013	.18	ns
Body-mass index, kg/m^2	–.07	ns	.13	ns	.20	ns	.04	ns

Note. Girls *n* = 64, boys *n* = 57.

Table 6 Sociodemographic Characteristics

Variable	Girls (n = 64)	Boys (n = 57)
Mother's age, years, $M \pm SD$	33.0 ± 5.3	33.7 ± 5.5
Father's age, years, $M \pm SD$	36.0 ± 6.5	35.7 ± 6.4
Mother's education, %		
vocational	9.5	13.0
secondary	54.0	42.6
higher	36.5	44.4
Father's education, %		
vocational	31.7	32.7
secondary	39.7	38.5
higher	28.6	28.8
Parents' opinion of their children's physical fitness, %		
sufficient	19.0	20.0
good	50.8	45.5
very good	30.2	34.5

Discussion

The cohort was characterized by low physical fitness. This is because the mean score of the whole test, for both girls and boys, was equivalent to only a sufficient level. In addition, the highest percentage of subjects had insufficient agility, and the highest percentage had only sufficient speed and physical fitness. Only good and very good results would be satisfying because they are equivalent to A and B school grades. The low physical fitness of our subjects is probably the result of their sedentary lifestyle, which we reported in a previous article (Chalcarz & Merkiel, 2005). To improve their physical fitness, it is essential to implement programs that encourage children to spend less time in front of a television and more time playing actively with their peers (Cody & Lee, 1999; Kain et al., 2004; Nielsen & Andersen, 2003; Ozdzinski & Chalcarz, 1994; Sääkslahti et al., 2004).

The results of the physical fitness test are even more disconcerting when taking into account parents' opinions on their children's physical fitness. The vast majority of them—more than 80%—considered their children's physical fitness to be either good or very good, which shows parents' unawareness of their offspring's real abilities and suggests unreal perception of their own children. To our knowledge, no study has compared parents' opinions of their children's physical fitness with measures of physical fitness, but similar parental misperceptions have been observed in relation to their offspring's anthropometric indices (Baughcum, Chamberlin, Deeks, Powers, & Whitaker, 2000; Fisher, Fraser, & Alexander, 2006). Baughcum et al. showed that most mothers did not perceive their overweight children as overweight, and Fisher et al. revealed caregivers' underestimation of their children's weight, especially if a child was overweight. In our cohort, 27 children were overweight and 7 were obese. Seven parents of those children assessed their physical fitness as very good, and 19 parents, as good, even though only 1 of those children had very good physical fitness and 7 had good physical fitness. Therefore, parents should be taught how to assess their children's BMI and physical fitness.

We found only eight articles on physical fitness in children of similar age as our cohort (Annesi, et al. 2005; Chrzanowska & Golab, 2003; Graf et al., 2004; Makris, 2004; Makris & Zalewska 2001; McKenzie et al., 2002; Momola, 2005; Sekita, 1988). In five of them the same physical fitness test was used as in our study (Chrzanowska & Golab, 2003; Makris, 2004; Makris & Zalewska, 2001; Momola, 2005; Sekita, 1988). It is noteworthy that the studied girls and boys scored lower—with only few exceptions—in shuttle run, standing broad jump, and 20-m run than their peers from other regions of Poland (Chrzanowska & Golab, 2003; Makris, 2004; Makris & Zalewska, 2001; Momola, 2005; Sekita, 1988). However, the studied girls and boys scored higher—also with few exceptions—in medicine-ball throw for distance (Chrzanowska & Golab, 2003; Makris, 2004; Momola, 2005; Sekita, 1988). Physical fitness of our cohort could not be compared with their foreign peers' physical fitness because Annesi et al., Graf et al., and McKenzie et al. used different tests.

The results of our study showed that BMI may play an important role in children's physical fitness, as implied by significant correlation coefficients between BMI and agility in girls and between BMI and strength in both girls and boys. However, it is surprising that in girls, despite statistically significant correlation between physical fitness and both body weight and height, the correlation with BMI did not reach statistical significance.

In addition, Graf et al. (2004) found statistically significant correlation between BMI and results of motor tests, as well as between BMI and the result of a 6-m run, in a group of German girls and boys age 5.7–8.1 years. McKenzie et al. (2002) showed statistically significant correlation between the sum of skinfolds and the result of a balancing test in American 4- to 6-year-old girls and boys, as well as between the sum of skinfolds and the result of a jumping test in girls. Despite the fact that McKenzie et al. used the sum of skinfolds, not BMI, and despite different measures of physical fitness in our study and the two cited studies (Graf et al., 2004; McKenzie et al., 2002), it is noteworthy that all these studies showed statistically significant correlations. However, in our study, correlation coefficients were positive, whereas in the studies by Graf et al. and McKenzie et al. the coefficients were negative. This may result from different percentages of children in BMI ranges in those three populations of children.

Iodine status in the studied girls and boys was inadequate, as implied by the median urinary iodine concentration, which indicates mild iodine deficiency (WHO et al., 2007). We consider this population ideal for investigating the relationship between physical fitness and urine iodine status because it was distributed across various ranges of urinary iodine concentration.

Our attempt to find a relationship between physical fitness and iodine status is based on two rationales. First, this trace element is known to influence both physical and mental development of children (WHO et al., 2007). Second, the mountainous region in southern Poland where the cohort lived is an iodine-deficient area, in which, for example, iodine content in drinking water is near 0 μg/L (Dluzniewska et al., 1991). Therefore, the studied population is at high risk of having iodine deficiencies, which may have a considerable influence on children's growth and development. We chose urinary iodine concentration as a biomarker of iodine status because it is considered the best tool to assess the content of this trace element in populations of more than 30 subjects (WHO et al., 2007).

The results of our study showed that there is a relationship between physical fitness and iodine status in girls; we found statistically significant correlations between urinary iodine concentration and power, strength, speed, and physical fitness. We suggest that the observed relationship in girls and no relationship in boys may be explained by a different effect of thyroid hormones on female children and male children that is not taken into account at this stage of life (Gardner & Shoback, 2007). It is known that thyroid hormones, which depend on the iodine content in the human body, up-regulate more than 380 genes critical for skeletal-muscle function (Clément et al., 2002). That is why the little differences in hormone effects on a girl and a boy may have contributed to statistically significant correlation between urinary iodine and physical fitness only in girls. In addition, it is known that there are gender differences in iodine metabolism that result in a higher prevalence of goiter in females (Korman, 1980).

At first, it may seem surprising that the coefficients were negative. One would rather expect the opposite relationship, which would mean that the higher the urinary iodine concentration, the higher the physical fitness. However, we have found in the literature evidence that may support our results. Antonio et al. (2008) reported that thyroid hormones influence athletes' performance, and McArdle, Katch, and Katch (2009) observed that very high intakes of iodine depress thyroid activity. Urinary iodine concentration is known to be a biomarker of iodine content in the human body. Based on these facts, we assume that the higher the iodine content in a girl's body, the lower her thyroid activity and the lower her performance. During the exercises of the physical fitness test, in those girls who had higher iodine content in the body, the thyroid activity was more depressed and, at the same time, their performance was worse. In the girls who had iodine deficiency, thyroid hormones improved their performance. This is in accordance with the idea of using thyroid hormone supplementation in sport because supplemental use of thyroid hormones decreases the proportion of iodine content in the human body to the sum of the thyroid hormone content, both secreted by the thyroid gland and ingested through supplements. Of course, using thyroid hormones as supplements may only be considered in professional athletes, but the suggested mechanism may explain the observed correlation. Obviously, we realize that it is difficult to make a direct link between athletes and children. However, we think that this hypothesis is worth future research.

In conclusion, our study revealed low physical fitness in 6- to 7-year-old Polish children, which shows the need to implement programs aimed at increasing their physical activity. Our study also revealed a positive relationship between physical fitness and BMI in the children. Finally, this is the first known study to investigate urinary iodine status and physical fitness in children, so the negative correlation found between physical fitness and urine iodine status in girls indicates that future research in this area is required.

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