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DIFFERENCES IN PHYSICAL FITNESS BETWEEN NORMAL-WEIGHT, OVERWEIGHT AND OBESE CHILDREN AND ADOLESCENTS

RAZLIKE V MOTORIČNIH SPOSOBNOSTIH MED NORMALNO TEŽKIMI, PRETEŽKIMI IN DEBELIMI OTROCI IN MLADOSTNIKI

Abstract

The aim of the study was to examine the relationship between obesity and the physical (motor) fitness of children and youth. In spring 2005, more than 80 % of the Slovenian schoolchild population from 7 to 18 years participated in a national fitness evaluation system (Sports Educational Chart), similar to *Eurofit*. The sample of subjects was divided into normal-weight, overweight and obese groups on the basis of their body mass index and according to internationally recognised IOTF norms. The groups were compared with a MANOVA analysis in eight physical fitness items. The biggest differences between the groups were found in items that required movement of the whole body mass. In items which involved only small body parts, the differences between the groups were small or even non-existent, suggesting that the motor abilities of obese children are not less than those of the normal population. At the end, suggestions for physical activity programmes for obese children are presented.

Key words: body mass index, obesity, fitness, children

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Izvleček

Namen raziskave je bil preučiti odnos med debelostjo in motoričnimi zmožnostmi otrok in mladostnikov. Spomladi 2005 je več kot 80 % populacije šoloobveznih otrok v starosti od 7 do 18 let sodelovalo v nacionalnem sistemu za preverjanje motoričnih sposobnosti *športno-vzgojni karton,* ki je podoben sistemu *Eurofit*. Vzorec je bil razdeljen na normalno težke, pretežke in debele otroke v skladu z mednarodno uveljavljenimi IOTF normami. Skupine so se primerjale po metodi MANOVA v 8 motoričnih testih. Največje razlike so bile v testih, ki zahtevajo gibanje celotnega telesa. V testih, pri katerih gre za premikanje manjših delov telesa, so bile razlike majhne ali pa jih sploh ni bilo. To je navedlo na zaključek, da (prirojene) motorične sposobnosti otrok s preveliko telesno težo v povprečju niso manjše od sposobnosti njihovih normalno težkih vrstnikov. Na koncu so podani še napotki glede vadbe predebelih otrok.

Ključne besede: indeks telesne mase, debelost, motorične sposobnosti, otroci

INTRODUCTION

Overweight and obesity are health-related problems which have taken on epidemic proportions in the last few decades. The WHO (2006) estimated that in 2005 approximately 1.6 billion adults (aged 15+) were overweight and at least 400 million adults were obese. Over 20 million children under the age of 5 are already overweight. In the last decade, the prevalence of obesity in Western and Westernising countries has more than doubled (James, 2004). About 70 % of obese adolescents grow up to become obese adults (Parsons, Power, Logan, & Summerbell, 1999).

There are various definitions of child obesity and no commonly accepted standard has yet emerged. The body mass index ('BMI'; weight/height^2) is widely used in adult populations, while a cut-off point of 25 kg/m^2 and 30 kg/m^2 is recognised internationally as a definition of adult overweight and obesity (Malina & Katzmarzyk, 1999). The International Obesity Task Force (IOTF) proposed age- and sex-specific cut-off points from 2-18 years, which are internationally based and should help to provide internationally comparable prevalence rates of overweight and obesity in children (Cole, Bellizzi, Flegal, & Dietz, 2000). The BMI has been found to be both a reliable and valid index of adiposity in children and adolescents (Pietrobelli et al., 1998; Dietz & Bellizzi, 1999).

There are several consequences of obesity. As well as increasing mortality, obesity is a risk factor in a range of chronic diseases such as Type 2 (adult-onset) diabetes, Coronary heart disease, some types of cancer, osteoarthritis and back pain (Pi-Sunyer, 1993). There are also social and psychological consequences – including stigmatisation, discrimination and prejudice (Cash, 2004; Goni & Zulaka, 2000; Lobstein, Baur, & Uauy, 2004). Some of the consequences of obesity – hyperinsulinaemia, poor glucose tolerance and a raised risk of Type 2 diabetes, hypertension, sleep apnoea, social exclusion and depression – onset already in childhood, while other obesity-related conditions onset mainly in adulthood (Lobstein, Baur, & Uauy, 2004).

The relationship between obesity and physical activity or physical fitness is less known. It seems that physical activity is the common denominator in the treatment of poor fitness and excess weight (Blair, 2004; Trost, Kerr, Ward, & Pate, 2001). Most studies have focused on the relationship between obesity and cardiovascular fitness, confirming that obese children are less fit than their normal weight peers, although most of the differences disappear after adjusting for body weight or fat-free mass (Treuth et al., 1998). Deforche et al. (2003) found obese Flemish youth also had poorer performances in weight-bearing tasks, however, they did not have lower scores in other fitness components *(Plate tapping* and *Sit and reach* tests), measured by the Eurofit physical fitness test battery (Eurofit Handbook, 1988). Inferior performances in tests requiring propulsion or lifting were found in other studies (Pate, Slentz, & Katz, 1989; Malina et al., 1995; Beunen et al., 1983; Minck et al., 2000). Similar results were found in Greek (Biskanaki et al., 2004) and German (Korsten-Reck et al., 2007) children with the exception of throwing of a heavy object (medicine ball) where obese children performed better than their normal weight peers if the weight of the object had not been adjusted for their body weight.

It is confirmed that obesity occurs when energy intake exceeds energy expenditure, suggesting a proper diet and physical activity are the key strategy for controlling the current epidemic of obesity (Dehghan, Akhtar-Danesh, & Merchant, 2005). When controlling for body mass, obese children were found less physically active than their non-obese peers (Huttunen, Knip, & Paavilainen, 1986; Raudsepp & Jurimae, 1998). When physical activity was measured as total energy expenditure, no significant differences were found between obese and normal-weight youth (Bandini, Schoeller, & Dietz, 1990; Grund et al., 2000).

The purpose of the present study was to ascertain the level and nature of differences between obese and normal-weight children and adolescents in different aspects of their physical fitness. The findings should serve as a basis for future actions when both tackling the obesity epidemic and constructing special programmes which would take into account the physical fitness level of obese youth.

METHODS

Sample

The cross-sectional sample (Table 1) consisted of all pupils from primary and secondary schools in Slovenia, who in 2005 participated in measurements for the fitness evaluation system *Sports Educational Chart* (Strel et al., 1997). 90 % of the population up to the age of 15 was included in the measurements, whereas the proportion of older pupils (16 to 18 years) was between 60-80 % depending on the type of high school involved (Strel, Kovač, & Rogelj, 2006). The measurements were undertaken in April during normal physical education lessons in all Slovenian schools. Only healthy children who were not exempt from physical education for health reasons and whose parents had given their written consent to participate were measured.

Table 1: Size of the subsamples in different age and sex groups

	age (years)											
Sex	7	8	9	10	11	12	13	14	15	16	17	18
Male	7668	8159	8235	8419	8375	8916	8557	9080	8392	6902	6735	5858
Female	7201	7617	7767	7828	7985	8181	7808	8170	7477	5865	5777	5414

Variables

Data from the *Sports Educational Chart* were used in the analysis. The test battery consisted of two anthropometrical measures and eight motor tests (Table 2). All the tests had suitable measuring characteristics. The body mass index (BMI) was calculated as the ratio of body weight (in kilograms) to the body height (in metres) squared. On the basis of the BMI, each subject was included in one of the three weight groups – normal (i.e. non-overweight), overweight and obese – according to the IOTF's (International Obesity Task Force) proposed age- and sex-specific cut-off points (Cole, Bellizzi, Flegal, & Dietz, 2000).

The selection of motor tests was based on the model created by Kurelić et al. (1975). The model is hierarchic and based on the functional mechanisms responsible for latent motor abilities. There are four dimensions at the lower level: the mechanism for movement structuring, the mechanism for synergy automation and regulation of the tonus, the mechanism for regulation of excitation intensity, and the mechanism for regulation of the duration of excitation. There are two dimensions at the higher level: the mechanism for the central regulation of movement and the mechanism for energy regulation. At the highest level the mechanism for the regulation of movement is called the general factor of motor behaviour.

Table 2: Sample of variables

Test	Measured capacity	Measuring unit
Body height	Longitudinal dimension of the body	mm
Body weight	Volume of the body	kg
Arm plate tapping – 20 seconds	Speed of alternate movement	no. of repetitions
Standing broad jump	Power of legs	cm
Obstacle course backwards	Co-ordination of the whole body movement	seconds
60-second sit-ups	Muscular endurance of the torso	no. of repetitions
Forward bench fold	Flexibility	cm
Bent arm hang	Muscular endurance of the shoulder girdle and arms	seconds
60-metre run	Sprint speed	seconds
600-metre run	General endurance	seconds

Data analysis

The data were analysed with the use of the SPSS 15.0 statistical package. Basic parameters of the distribution of variables were calculated (mean value standard deviation). A multivariate analysis of variance (MANOVA) was used to test the differences between the weight category (normal, overweight, obese), gender and the age of the pupils. The power of the concurrent influence of the BMI (weight category), sex and age on the dependent variables (fitness tests) was measured by Wilks' lambda; its statistical significance was tested by Bartlett's V transformation (Bray & Scott, 1985). The amount of explained variance for the entire system of dependent variables was estimated with a partial η^2 separately for all the main effects (weight category, sex, age) and all their two- and three-way interactions. Univariate tests were also carried out for each dependent variable separately: F-tests for the entire model, for all the main effects and all their interactions were used. The amount of explained variance was estimated with the adjusted R^2 for the entire system of predictors (all the main effects and all interactions) and with a partial η^2 for individual predictors.

RESULTS

The proportion of overweight (excluding obese) pupils (Figure 1) is rising up until early puberty, i.e. around 10 years for girls and 12 years for boys. Afterwards, the proportion of overweight pupils is constantly decreasing in girls, whereas in boys it increases slightly after the age of 15.

The proportion of obese boys and girls is almost constant at around 6 % for 7- to 10-year-old children and afterwards gradually decreases until the end of the observed period. Both the obese and overweight proportions are higher in boys than in girls, although the difference is small in early ages.

Differences between the different weight categories in the means of the physical fitness tests (Figure 2, Figure 3) depend greatly on the test observed; however, they are similar for both boys and girls. Except for *Hand-tapping* and *Bend forward on bench,* where the differences were small, normal-weight children achieved substantially better results than overweight children; in turn, the results of the latter group are substantially better compared to the obese children.

Figure 1: Proportion of overweight and obese pupils by age and sex

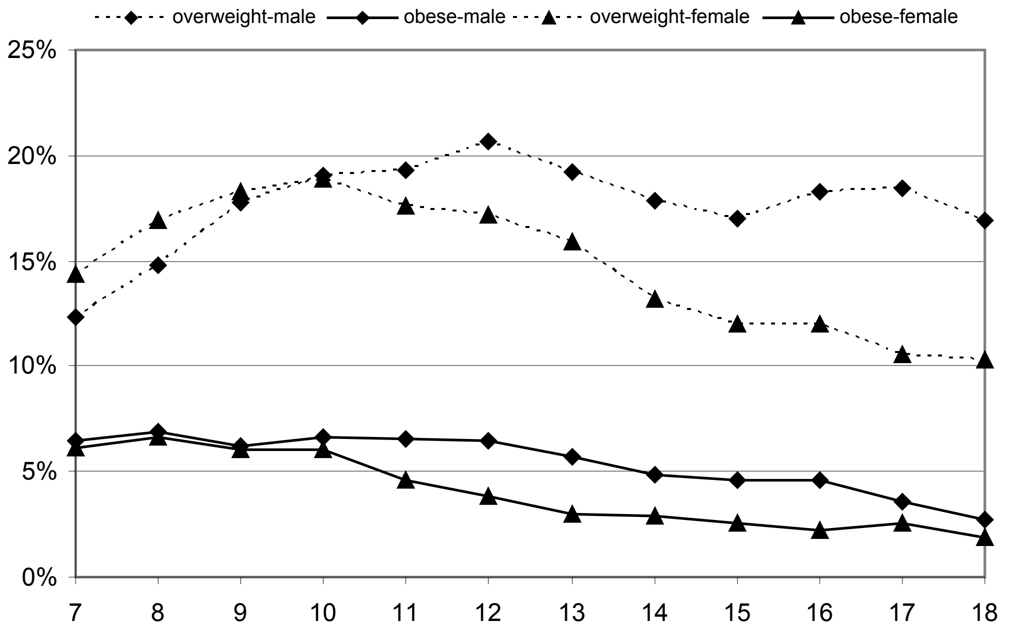


Figure 2: Means of the physical fitness tests for the different weight categories in boys

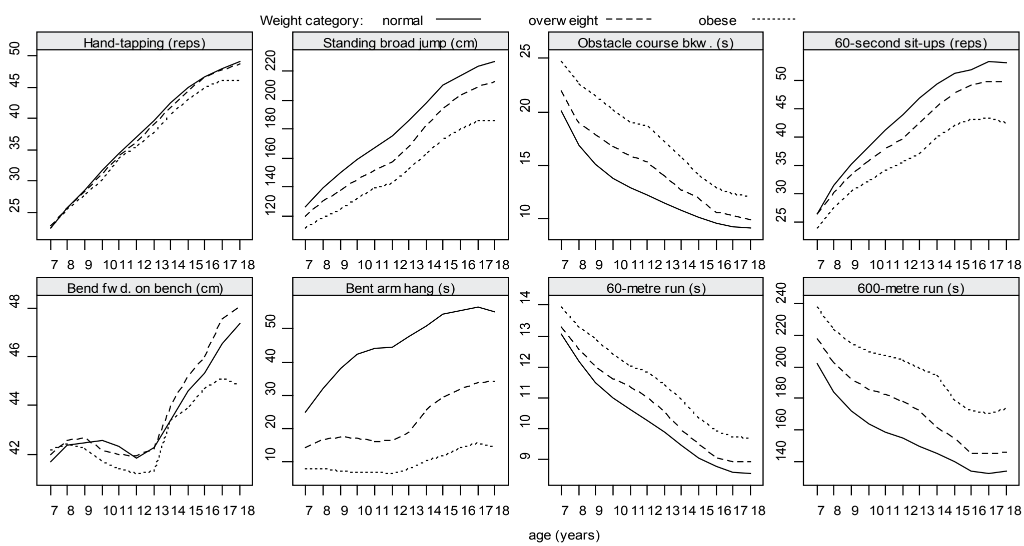
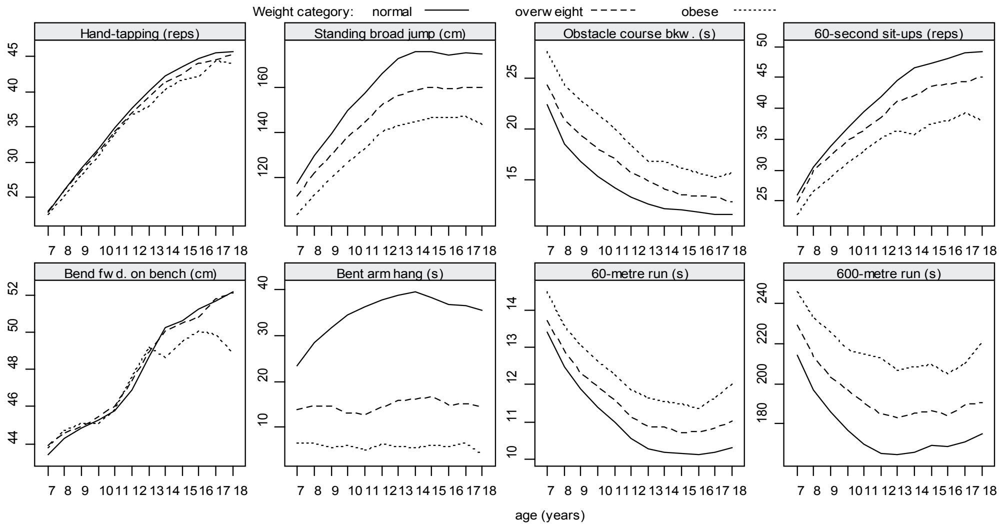


Figure 3: Means of the physical fitness tests for the different weight categories in girls



A multivariate analysis of variance (Table 3) shows that the weight category (BMI) has strong (partial eta squared η^2_{part}=12 %) and a statistically significant effect on the block of fitness test variables. This effect is similar to that of sex (η^2_{part}=12.2 %) and higher than the effect of age (η^2_{part}=8.2 %). Interaction effects are much smaller than the effects of the main factors. Most of the interaction between the BMI and age (η^2_{part}=0.34 %) is attributable to *Hand-tapping* and *Bent arm hang.* In *Hand tapping,* the means of the different weight categories are almost equal, whereas in the older age group the results of obese pupils of both sexes and overweight girls are substantially worse than those of the normal-weight group. In the *Bent arm hang* test, the results of the normal-weight group, especially for the girls, are improving at a much higher rate than those of the obese and overweight groups.

Table 3: Multivariate test (Wilk's λ) and explained variance for the model effects

	Effect size (partial eta squared)					
Effect	λ	F	df1	df2	p	Partial η^2
BMI	0.77	3115	16	364614	<0.001	12.0 %
age	0.51	1490	88	1195476	<0.001	8.2 %
sex	0.88	3170	8	182307	<0.001	12.2 %
age * BMI	0.97	29	176	1376869	<0.001	0.34 %
sex * BMI	1.00	28	16	364614	<0.001	0.12 %
age * sex	0.95	108	88	1195476	<0.001	0.65 %
age * sex * BMI	1.00	3	176	1376869	<0.001	0.04 %

Univariate tests of differences between the groups (Table 4) show that the fitness test items should be arranged in three groups depending on the effect of the BMI: a) *Bent arm hang* with the strongest effect of the BMI (η^2_{part}=14.6 %); b) *Standing broad jump, Obstacle course backwards, 60-metre run* and *600-metre run* with a medium effect of the BMI (η^2_{part} from 7.5 to 10.7 %);

and c) items with a small *(60-second sit-ups* with η^2_{part}=3.5 %) or neglecting *(Arm plate tapping, Forward bench fold)* the effect of the BMI.

Table 4: Effect sizes of main and interaction effects. All effects, except those marked with * are significant at the 5 % level.

	Effect size (partial eta squared)							
Effect	Arm plate tapping	Standing broad jump	Obstacle course backwards	60-second sit-ups	Forward bench fold	Bent arm hang	60-metre run	600-metre run
BMI	.003	.102	.078	.035	.000	.146	.075	.107
age	.400	.255	.186	.142	.021	.007	.259	.093
sex	.001	.062	.013	.005	.024	.007	.035	.033
age * BMI	.001	.007	.005	.005	.000	.008	.002	.002
sex * BMI	.000	.001	.000*	.000*	.000*	.001	.000	.000
age * sex	.003	.032	.003	.002	.004	.003	.018	.011
age * sex * BMI	.000*	.000	.001	.000	.000	.000	.001	.001

DISCUSSION

About one-fifth of the population of Slovenian schoolchildren is overweight (including obese children). The proportion of overweight children is higher in boys than in girls. The proportion of overweight girls tends to decrease with age, whereas the proportion of overweight boys remains high throughout the observed period from 7 to 18 years of age. The overall obesity prevalence and relationship of the overweight proportion between boys and girls in Slovenia coincides with its geographical position in Europe. A review by Lobstein, Baur, and Uauy (2004), which used the same IOTF cut-off points as the present study, found that the prevalence (percentage) of overweight (including obese) children aged 7 to 11 was higher in southern Europe (Italy 36 %, Spain 34 %, Greece 31 %) and lower in northern Europe (Holland 12 %, Denmark 15 %, Germany 16 %). Among adolescents aged 14 to 17, the prevalence ranged from below 10 % (Slovakia, Czech Republic, Russia) to above 20 % in some southern countries (Cyprus 23 %, Greece 22 %, Spain 21 %).

The performance in almost all the fitness tests measured in the present study was substantially hindered (or at least had a negative correlation) with obesity – regardless of the age or sex of the children. The greatest influence of obesity was found in tests requiring movement of the whole body *(Standing broad jump, Obstacle course backwards, 60-* and *600-metre run)* or holding the whole body in a position *(Bent arm hang).* A smaller influence was found in the test *60-second sit-ups,* which requires a movement only of the upper body. Almost no differences between body weight categories exist in *Hand-tapping,* which requires the moving of only one (dominant) hand. In a test measuring flexibility, *Forward bench fold,* differences between weight categories are also small except for older boys and girls where normal and overweight children performed substantially better than their obese peers.

These results are similar to other studies (Beunen et al., 1983; Malina et al., 1995; Minck et al., 2000; Deforche et al., 2003) which also found a negative relationship between body mass and performance in tests requiring the propulsion or lifting of that mass. Poor performances in these tests are a result of the extra load of body fat, which is especially obvious in the *Bent arm hang* test, but probably also due to the smaller amount of physical activity of obese children (Huttunen, Knip, & Paavilainen, 1986) especially with tasks which may represent an overloading of the joints of obese individuals (Hills, Hennig, Byrne, & Steele, 2002). In test requiring flexibility *(Forward bench fold)* and co-ordination with small body parts *(Arm plate tapping),* the small influence of obesity is also similar to the other studies mentioned above. In the *600-metre run* Strel (2006) found a relatively large multiple correlation (up to 0.5) with body height, body weight and upper-arm skin fold.

The poor fitness levels of obese children in those test items requiring the propulsion of lifting of the whole body on one side and the average fitness of these children for items that do not require propulsion and lifting may lead to the conclusion that worse results in some components of the physical fitness of obese children are *not* the consequence of their lower physical (motor) abilities, but merely the result of the direct influence of excessive body weight and the indirect influence of less physical activity. Therefore, it seems vital that obese children follow a proper diet and are motivated to participate in physical (sport) activities. Although some studies have shown that physical activity alone may reduce body fat in obese children, some other studies suggest that better results should be expected when physical activity is combined with a low-calorie diet (Goran, Reynolds, & Lindquist, 1999).

The type of physical activity should be carefully chosen so as to avoid a joint overload and to provide appropriate levels of energy expenditure. Among the traditional activities, hiking, swimming and cycling seem best for this purpose. Other activities suitable for obese children and especially adolescents are fitness activities, which may include exercising on cardio-respiratory machines (stationary cycling, elliptical motion trainers, stair-climbing and rowing machines, treadmills etc.) along with middle-intensity exercise on weight/resistance machines. Besides the high energy expenditure while exercising these activities may also contribute to the muscle body mass growing which, in turn, would also raise basal, sleeping and sedentary metabolic rates.

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