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Motor Coordination and Body Mass Index in Primary School Children

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***Abstract*—**Obese children will probably become obese adults, consequently exposed to an increased risk of comorbidity and premature mortality. Body weight may be indirectly determined by continuous development of coordination and motor skills. The level of motor skills and abilities is an important factor that promotes physical activity since early childhood. The aim of the study is to thoroughly understand the internal relations between motor coordination abilities and the somatic development of prepubertal children and to determine the effect of excess body weight on motor coordination by comparing the motor ability levels of children with different body mass index (BMI) values. The data were collected from 436 children aged 7–10 years, without health limitations, fully participating in school physical education classes. Body height was measured with portable stadiometers (Harpenden, Holtain Ltd.), and body mass—with a digital scale (HN-286, Omron). Motor coordination was evaluated with the Kiphard-Schilling body coordination test, Körperkoordinationstest für Kinder. The normality test by Shapiro-Wilk was used to verify the data distribution. The correlation analysis revealed a statistically significant negative association between the dynamic balance and BMI, as well as between the motor quotient and BMI ($p<0.01$) for both boys and girls. The results showed no effect of gender on the difference in the observed trends. The analysis of variance proved statistically significant differences between normal weight children and their overweight or obese counterparts. Coordination abilities probably play an important role in preventing or moderating the negative trajectory leading to childhood overweight and obesity. At this age, the development of coordination abilities should become a key strategy, targeted at long-term prevention of obesity and the promotion of an active lifestyle in adulthood. Motor performance is essential for implementing a healthy lifestyle in childhood already. Physical inactivity apparently results in motor deficits and a sedentary lifestyle in children, which may be accompanied by excess energy intake and overweight.

***Keywords*—**Childhood, KTK test, Physical education, Psychomotor competence

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I. Introduction

In the long term, obese children are more likely to become obese adults. Longitudinal studies show a risk that obese children will become obese adults, who, as a consequence, are exposed to an increased risk of comorbidity and premature mortality [1], [2]. It has also been confirmed that obese children display lower fitness levels. However, it is difficult to specify a cause-and-effect relationship which would scientifically justify this phenomenon. The answer probably lies in a biocultural matrix of factors affecting the development of children and youth and resulting in a cycle that involves the interactions of fatness, physical inactivity, and fitness. Overweight or obese children are less fit and more likely to experience less positive experience and success when performing physical activities. Consequently, their motivation, participation, and preferences related to physical activity will be reduced, which may naturally lead to a decline in fitness and motor competences, as well as the formation of a sedentary and less active lifestyle [3].

The effects of excess body weight in children are well known and influence not only the domain of physical health. These effects are complex and they negatively modify the social and emotional aspects of a child's personality; they decrease self-assessment and self-concept, which during puberty may induce the risk of eating disorders, etc.

Overweight and obese children present lack of physical activity as a remarkable characteristic of their usual behavior; this lack may be also reflected in insufficient motor experience, which influences motor development. There seems to be a trend to underestimate motor abilities and skills of overweight and obese children. It is often visible in physical education classes when teachers consider these children unable to reach success in motor tasks. Such behaviors may lead to less motor experience, harming the children's motor development [4].

Stodden et al. [3] present a conceptual model hypothesizing that a low level of coordination results in limited opportunities for engagement in physical activities, poor health-related fitness, and overall low motor skill competence, leading to increased weight and obesity. Low motor skill competence may result in disengagement in games, as well as other physical and sports activities in middle and later childhood. Consequently, a negative spiral of disengagement arises, characterized by adopting a negative attitude towards pursuing a physically active lifestyle later in life. Also, the authors hypothesize that a continuous development of coordination and motor skills may indirectly determine body weight.

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Williams et al. [5] report that the level of motor skills and abilities considerably promotes physical activity since early childhood. Children with better-developed motor skills may find it easier to be active and engage in more physical activity than those with less-developed motor skills. The relationship between motor abilities and skills and physical activity may most probably be a crucial determinant of the complex mechanism of adopting a healthy lifestyle since childhood.

A study by Gentier et al. [6] provides evidence that lower motor competence in obese children is not limited to gross motor skills and physical fitness alone, but includes fine motor skills as well. According to the authors, obese children experience difficulties with the integration and processing of sensory information. However, the hypothesis needs to be investigated further by seeking possible underlying mechanisms.

II. Aim of the Paper

The aim of the research was to investigate the relationships between the indicators of motor coordination and those of somatic development in prepubertal children. The authors also intended to verify the effect of excess body weight on motor coordination; therefore, they compared motor ability levels of children with different BMI values.

III. Methods

The data were collected from 436 children (boys, n=214; girls, n=222) between 7 and 10 years of age. The research group included only individuals without health limitations, fully participating in school physical education classes, two lessons a week. Students involved in the system of sports preparation were excluded from the research. The statistical analysis took into consideration only the students who completed all the items related to a rather extensive diagnostic scope. All the children attended primary schools in the region of Eastern Slovakia. The parents and children were informed about the aims of the research project and provided their consent. The field research was carried out in cooperation with trained teachers of the involved primary schools in the March-June period from 2013 to 2014.

The children's body height was measured with the use of portable stadiometers (Harpenden, Holtain Ltd.), and their body mass—with a digital scale (HN-286, Omron). The values were rounded to the nearest 0.1 cm and 0.5 kg, respectively. Then, BMI was calculated by dividing the body weight (kg) by the square of the body height (m^2).

Within the scope of the research group, individuals with standard weight and with overweight or obesity were identified on the basis of the BMI value. The distribution of the research group required the application of international BMI standards for the population aged from 2 to 18 years corresponding with the standards intended for the adult population, over 18 years of age [7].

In the research group distributed on the basis of internationally accepted standards of BMI for the population from 12 years to 18 years, the level of motor performance was compared between the group of children with standard weight and the group of overweight or obese children—without the influence of gender, as well as independently among girls and boys.

To evaluate motor coordination, the Kiphard-Schilling body coordination test, Körperkoordinationstest für Kinder (KTK) was employed [8]. The test battery includes the following items:

1. Backward balance (BB). The child walks backward on three balance beams 3 m in length, of different widths: 6 cm, 4.5 cm, and 3 cm.
2. Hopping obstacles (HO). The child is instructed to hop on one foot at a time over a stack of foam square (50 cm × 20 cm × 5 cm). After a successful hop with each foot, the height is increased by adding another square.
3. Lateral jumping (LJ). The child makes consecutive jumps from side to side over a small beam as fast as possible for 15 s.
4. Sideways moving (SM). The child begins by standing with both feet on a platform (25 cm × 25 cm × 2 cm, supported on a 3.7 cm height). They place the second platform alongside the first one and step onto it. Then the first platform is placed alongside the second one and the child steps onto it. This sequence continues for 20 s.

The four items served to calculate the motor quotient (MQ) adjusted for age and gender. The MQ allows an assessment of the gross motor development in the following categories: not possible (MQ<56), severe motor disorder (MQ 56–70), moderate motor disorder (MQ 71–85), normal (MQ 86–115), good (MQ 116–130), and high (MQ 131–145). The test-retest reliability coefficient for the raw score on the total battery is 0.97. The coefficients for individual test items range from 0.80 to 0.96.

The data distribution was verified with the use of the normality test by Shapiro-Wilk. The relationships between the BMI and the motor coordination abilities and MQ were analyzed by the Pearson correlation (r_p). The significance level established was 5% ($p<0.05$) or 1% ($p<0.01$). One-way design analysis of variance (one-way ANOVA) allowed to determine the differences between the standard weight group and the overweight, plus obesity group. The data were processed with the IBM SPSS Statistics software, version 20.

IV. Results

Fig. 1 shows the distribution of the research group from the perspective of BMI. Out of the entire scope of the research group (n=436), 347 (79.6%) children represented standard weight, and 89 (20.4%) were overweight or obese. The percentage of children with obesity, identically with the separate assessment of girls and boys, equaled approximately 5%. Therefore, the group of obese children were not analyzed independently. Out of the total number of girls (n=222), 169 (76.1%) students could be assumed to have standard weight, and 53 (23.9%) were overweight or obese. In the group of boys (n=214), the respective numbers turned out to be 178 (83.2%) and 36 (16.8%). These findings point to a higher prevalence of overweight and obesity in girls by almost 7%

and thus they correspond to the current European trends of overweight and obesity occurrence in children aged 7–11 years, according to which overweight is observed in 21% of girls in Slovakia, and obesity in approximately 4%. The percentage of overweight or obese boys in the research group was slightly lower, contrary to the worldwide average, which remains on the level of almost 20% for overweight, and approximately 5% for obesity [9].



Fig. 1 The research group distribution on the basis of BMI standards

As revealed in the correlation analysis (r_p), there was a statistically significant negative association between the BB and BMI, as well as between the MQ and BMI ($p<0.01$) in the case of both boys and girls. Gender had no influence on the difference within the trends that were noted (Table I).

TABLE I
CORRELATIONS BETWEEN PHYSICAL AND MOTOR PARAMETERS

Motor parameters in the KTK test	Pearson's correlation (r_p) between the motor parameter and BMI	
	Girls	Boys
Backward balance (n)	–0.18[a]	–0.17[a]
Hopping obstacles (n)	–0.01	–0.01
Lateral jumping (n)	0.06	0.02
Sideways moving (n)	–0.02	–0.08
Motor quotient (MQ KTK)	–0.27[a]	–0.28[a]

[a]Correlation is significant at the 0.01 level (2-tailed); KTK = Körperkoordinationstest für Kinder.

The ANOVA analysis of variance showed statistically significant differences between normal weight children and those who were overweight or obese (Table II) in all studied coordination parameters except LJ, which may be considered a measure of lower body frequency speed. The estimated effect size (d) was at the small and moderate level for all significant parameters in all research groups (0.26–0.75).

The analysis of variance revealed statistically significant differences between normal-weight girls and their overweight and obese counterparts in several motor coordination parameters (Table III). Overweight or obese girls demonstrated a significantly lower level in the dynamic balance and the speed of locomotor coordination (BB, SM), and also in the overall coordination parameter—the MQ (MQ: F=19.61; p=0.000; d=0.70). An important finding is that the average MQ, which almost reached the boundary value (85.82) in overweight girls, represented the category of individuals with a moderate motor disorder. On the other hand, normal-weight girls showed an average value of MQ falling in the interval identifying individuals with a normal level of body coordination.

TABLE II
MOTOR PARAMETER COMPARISONS BETWEEN RESEARCH GROUPS

Indicator	Girls + boys n=436		$F_{(2.432)}$	Sign.	Cohen's (d)
	Standard weight n=347 x±s	Overweight + obesity n=89 x±s			
Backward balance (n)	46.30 ±14.25	38.02 ±14.93	23.42	0.000[a]	0.58
Hopping obstacles (n)	50.80 ±16.82	46.36 ±17.74	4.82	0.029[a]	0.26
Lateral jumping (n)	49.91 ±15.09	48.07 ±16.07	1.03	0.312	0.12
Sideways moving (n)	40.32 ±9.17	37.73 ±9.47	5.580	0.019[a]	0.28
Motor quotient (MQ KTK)	98.50 ±13.33	88.13 ±15.85	39.48	0.000[a]	0.75

[a]Statistically significant values; KTK = Körperkoordinationstest für Kinder, Sign. = significance.

TABLE III
MOTOR PARAMETERS FOR GIRLS ACCORDING TO BMI

Indicator	Girls n=222		$F_{(1.220)}$	Sign.	Cohen's (d)
	Standard weight n=169 x±s	Overweight + obesity n=53 x±s			
Backward balance (n)	47.20 ±13.39	38.11 ±13.60	18.43	0.000[a]	0.68
Hopping obstacles (n)	47.76 ±16.38	44.70 ±16.58	1.40	0.238	0.19
Lateral jumping (n)	50.22 ±15.13	46.92 ±16.27	1.85	0.176	0.21
Sideways moving (n)	39.54 ±8.68	36.70 ±9.20	4.20	0.042[a]	0.32
Motor quotient (MQ KTK)	95.37 ±12.34	85.82 ±14.85	19.61	0.000[a]	0.70

[a]Statistically significant values; KTK = Körperkoordinationstest für Kinder, Sign. = significance.

TABLE IV
MOTOR PARAMETERS FOR BOYS ACCORDING TO BMI

Indicator	Boys n=214		$F_{(1.212)}$	Sign.	Cohen's (d)
	Standard weight n=178 x±s	Overweight + obesity n=36 x±s			
Backward balance (n)	45.44 ±15.01	37.89 ±16.91	7.27	0.008[a]	0.49
Hopping obstacles (n)	53.69 ±16.77	48.81 ±19.30	2.41	0.122	0.28
Lateral jumping (n)	49.61 ±15.11	49.75 ±15.84	0.01	0.961	0.02
Sideways moving (n)	41.06 ±9.58	39.25 ±9.78	1.07	0.303	0.19
Motor quotient (MQ KTK)	101.47 ±13.59	90.81 ±17.09	16.82	0.000[a]	0.75

[a]Statistically significant values; KTK = Körperkoordinationstest für Kinder, Sign. = significance.

For boys (Table IV), overweight had both a practically and statistically negative effect on the dynamic balance (BB:

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F=7.27; p=0.008; d=0.49). The MQ value is most probably affected by an unfavorable ratio of body weight to body height. The average MQ found in normal-weight boys was both practically and statistically higher (MQ: F=16.82; p=0.000; d=0.75). Despite that, it may be concluded that the domain of coordination abilities is significantly affected by somatic dimensions, and excess body weight exerts a negative effect on the domain of these motor abilities as well.

V. Discussion

Dietz and Belizzi [10] assume that although a number of sophisticated methods of physical condition measurement exist, the identification of BMI or measuring the skinfolds thickness represent adequate and justified methods of somatic development diagnosis in the child population. Determining BMI represents a simple method recommended even for school practice, despite its application, is burdened with certain limitations. These are bound especially with the fact that the BMI value stems from the ratio of body weight and height, and does not discriminate between fat and muscle mass, and also does not indicate the fat distribution in the body. In a similar way, Krebs et al. [11] consider BMI to be a scientifically justified means of obesity determination in children and adolescents at the age from two years to 19 years.

As reported by Catenassi et al. [4], somatic parameters such as body height, body weight, and BMI do not have a significant effect on the domain of coordination abilities and basic motor skills. On the contrary, our findings suggest that somatic parameters (especially their unfavorable trend), probably affect coordination abilities (their lower level). Similarly, a cross-sectional study by Lopes et al. [12] based on the measurement of 7,175 children aged from six years to 14 years and a study by Cawley and Spiess [13] revealed a significantly lower level of motor abilities in overweight or obese boys and girls, as compared with normal-weight children.

Similarly to the results of our study, D'Hondt et al. [1], [2] reported that childhood overweight and obesity significantly contributed to a lower level of motor abilities as assessed by the KTK testing battery. Normal weight children demonstrated a similar level of MQ in particular age cohorts (5–7, 8–9, 10–12 years). The authors found that 10–12-year-old overweight and obese children represented a significantly lower level of motor competence than their overweight and obese counterparts aged 5–7 years. This confirms that the difference in the motor competence in relation to BMI increases with age. Therefore, early and sensitive education regarding physical activity and movement directed towards physical activity promotion in overweight and obese individuals seems to be beneficial.

As reported by Dumith et al. [14], prepubertal normal-weight children demonstrated significantly higher fitness levels than their overweight or obese counterparts in most motor tests except curl-ups. In addition, the authors hypothesize that obese children represent a low level of processing and integrating sensory information.

Despite the lack of evidence related to the association between coordination abilities and somatic development, Graf et al. [15], [16] confirm a moderate inverse correlation between coordination abilities (KTK test) and BMI. To be explained is the causal relationship and answer to the question whether overweight and obesity result in declined motor performance and motor deficits or not. The design of cross-sectional studies cannot provide the solution. However, research shows that physically active children, who participate in either organized or non-organized forms of physical activity in their leisure time, demonstrate a higher level of motor abilities, especially in the domain of motor coordination. Prepubertal children prefer especially naturally game-based, coordination demanding endurance activities, and strength exercises or activities. It is assumed that lower physical activity and motor performance levels, as well as limited development of coordination abilities co-interact with or probably represent independently acting key determinants of obesity in children.

In contrast with our study results, Psotta et al. [17], who studied 400 Czech children (mean age 9.4±1 years), found that 4.4% of them demonstrated motor dysfunctions. The incidence of motor disorders decreased twofold in pubertal children. Worldwide, the mean values range from 5% to 10%. The authors reported that neither boys nor girls who demonstrated motor dysfunctions differed significantly in the BMI from their age-matched healthy counterparts of the same sex. No significant differences were found between the genders for both different levels of motor functions.

A longitudinal study by Lopes et al. [12] regarding motor proficiency of children aged 6–10 years showed that the level of motor coordination constituted a significant predictor of physical activity. The trend related to the level of inverse correlation between BMI and coordination abilities increasing with age indicates that in the context of movement education, preschool and prepubertal children should be provided with adequate "room" for playing games, as well as direct teaching situations, necessary to develop their coordination abilities.

As observed by Haga [18], it is improbable to assume that children with motor problems are likely to grow out of them. A variety of motor deficits rather tend to persist into adulthood. Low motor competence has long-term unfavorable effects on other domains of personality development, influencing especially socio-affective and cognitive skills**.**

VI. Conclusion

Recording and explaining associations between motor abilities and motor skills in prepubertal children and their physical activity levels may to a large extent face the trend of increasing incidence of overweight and obesity since early childhood.

Our research findings support results reported by a variety of authors who emphasize the significance of early and sensitive education and support of physical activity, especially in overweight and obese individuals.

Coordination abilities are probably of considerable importance in preventing or shaping the negative trajectory leading to overweight and obesity in children. Therefore,

developing coordination abilities should become a key strategy at this age, aiming at long-term prevention of obesity and promotion of an active lifestyle in adulthood.

What remains crucial is the "role" of motor performance in the complex mechanism underlying the adoption of a healthy lifestyle as early as in childhood. Physical inactivity most probably leads to motor deficits and consequently supports a sedentary lifestyle in children; this is often further accompanied by excess energy intake and overweight.

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