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CHANGES IN SELECTED PARAMETERS OF POSTURAL STABILITY IN SCHOOL AGE CHILDREN

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SUMMARY

The aim of the study is to describe changes in selected parameters of postural stability while standing with eyes open and closed in boys and girls aged 7–11 years. Monitored parameters included center of pressure (COP) velocity and standard deviation (SD) of velocity. The sample consisted of 144 children from a primary school, i.e. 85 boys and 69 girls. Stability was measured on FootScane plate for 30 seconds at a frequency of 33 Hz. The results show a decrease of center of pressure (COP) velocity and SD of velocity with age while standing with eyes open and closed. In a standing position with eyes open, age changes of stability are more pronounced in the first half of the period, while in a standing position with eyes closed they are more remarkable in the second half of the period. In all age groups, COP velocity and SD of velocity were higher while standing with eyes closed when compared to the standing position with eyes open. On average, girls achieved lower values of COP velocity and SD of velocity than boys. Differences are disappearing after the ninth year of age. Postural stability of primary school children improves with age for both boys and girls. With the loss of visual information, postural stability declines. At the age of nine years, girls show a better postural stability than boys.

Key words: postural stability, center of pressure, primary school children

INTRODUCTION

Maintaining postural stability is an essential part of all movements (Westcott et al., 1997), and thus a prerequisite for the acquisition of motor skills. There are many discussions about the importance of acquiring a wide range of motor skills in school age, which may be beneficial for successful participation in physical activity.

School age is a period when postural stability achieves the level similar to the adults' one (Westcott et al., 1997, Shumway-Cook, Woollacott, 1985) and significant changes in postural stability in this period are pointed out by a number of authors (Riach, Starkes, 1994, Nolan et al., 2005, Kirchenbaum et al., 2001). For our study, we selected children

aged 7–11 years, who, according to the previously published results, are expected to manifest major changes in the parameters of postural stability.

The aim of the study is to describe changes in selected parameters of postural stability in different types of standing in school age children and to further describe the pattern of change with age and differences between boys and girls. Final orientation in space and a sense of balance are provided by interplay between the vestibular system and sensory systems, especially vision and proprioception (Nevšímalová et al., 2002). Central nervous system has to organize information from sensory receptors throughout the whole body and then it can determine the location of the body in space (Shumway-Cook, Woollacott, 1985). Ability to maintain balance is a result of the interplay between analyzers, by which people perceive their surroundings and body position in relation to the surroundings, and central nervous system that integrates and processes the information received and on that basis it allows to create an adequate muscle responses (Fetz, 1987, Hatzitaki et al., 2002). These muscle responses can be called balance movements; i.e. these are mainly movements in the joints of ankles, knees and hips, which control and coordinate the course of the kinematic chain of movements (Guskiewicz, Perrin, 1996).

Analysis of movement of the center of pressure by a foot in a standing position is one of the most commonly used methods for determination of balance (Doyle et al., 2007) and postural stability (Riach, Starkes, 1994). Equipment used for testing postural stability can record the movement of the point of application of the ground reaction force on the plate, the so called center of pressure (COP) (Kozáková et al., 2008). COP provides us with indirect information about stability in a quiet standing (Kirchenbaum et al., 2001), since its movement reflects the adaptation of the human body to control the balance. The data obtained in measuring COP can be used for determining differences between the balance in children and adolescents of different ages and also for determining the physical and functional abnormalities (Wolf et al., 1998). The most commonly used COP parameters in postural control studies are velocity and standard deviation (SD) of velocity (Hadian et al., 2008).

Starkes et al. (1992) state that the velocity parameter of COP is interesting from a functional point of view and its size reflects changes in strategies of balance control (Riach, Starkes, 1994). Decrease of COP velocity during childhood has been repeatedly proved (Hytönen et al., 1993, Riach, Starkes, 1994, Wolf et al., 1998, Nolan et al., 2005, Streepey, Angulo-Kinzler, 2002). Rapid changes occurred, according to Riach, Starkes (1994), between the 6th and 9th year. A similar trend was observed when comparing velocity of fluctuations in the age groups of children, when the velocity decreased more between 5–6 years than between 7–8 years and adulthood (Wolff et al., 1998, Streepey, Angulo-Kinzler, 2002). The decrease is more moderate after the ninth year (Nolan et al., 2005). Pronounced decrease in COP velocity between the fifth and eighth year may indicate a change in control strategy of regulation of balance from the ballistic one, based on the speed, towards the slower sensory-guided one, which is based on the accuracy (Kirchenbaum et al., 2001, Riach, Starkes, 1994). At the age between the seventh and tenth year, postural control and balance are becoming similar to that in adults (Westcott et al., 1997, Shumway-Cook, Woollacott, 1985).

While the development of postural responses of leg muscles has been completed during this period, the development of the upper body continues (Woollacott et al., 1987). Children in this period are gradually shifting to a more accurate balance control strategy,

so called dual strategy. It means that an individual is able to select an appropriate strategy according to what the situation requires. This is mirrored in the reduction of fluctuation velocity and decrease in the quantity of fluctuations. This decrease is more remarkable in the first half of the period. A response to changing sensory conditions is becoming similar to that in adults, as well (Shumway-Cook, Woollacott, 1985).

As Geurts et al. (1993) state, the parameter SD of velocity can be used as an indicator of variability of the extent of changes in COP. Similarly to Root Mean Square (RMS) of velocity, it may reflect the impaired ability to maintain an upright standing (Palmieri et al., 2002). The parameter SD of velocity shows a good intra-subject consistency and great sensitivity to visual deprivation (Geurts et al., 1993).

The results regarding the influence of gender on the fluctuations of the body vary. Some studies have shown that, in childhood, girls have less spontaneous fluctuations than boys (Usui et al., 1995, Nolan et al., 2005); in some works there is no convincing difference between the sexes (Figura et al., 1991). Significant differences between boys and girls may appear just due to differences in the maturation of CNS or different biological age. Odenrick, Sandstedt (1984) and Riach, Hays (1987) showed that the parameters of the fluctuations are stabilized earlier in girls than in boys. Unfortunately, mixed groups were used in most studies of postural control in children and only a small amount of studies have brought evidence of gender differences.

With regard to the published results so far, we may expect their decrease with age and with sex. According to these conditions the aim of this study is to describe how the pattern of changes varies with age in the standing position with open and closed eyes and to describe differences between boys and girls in age categories.

METHODS

The screened sample consisted of 154 children aged 7–11 years (average age 9.5 ± 1.5 years, average height 137.8 ± 14.9 cm, average weight 35 ± 8.9 kg). There were 85 boys (16 seven-year-old, 13 eight-year-old, 24 nine-year-old, 10 ten-year-old, 22 eleven-year-old) and 69 girls (10 seven-year-old, 12 eight-year-old, 22 nine-year-old, 12 ten-year-old and 13 eleven-year-old).

Data collection

Measurements took place over three days during the morning classes at a primary school. The study included only children with a written parental consent.

For measurement of postural stability we used FootScan device, which is a measuring plate of size 0.5 m × 0.4 m at which surface there are located approximately 4100 pressure sensors with sensitivities from decimals of N/cm^2 and a scanning frequency of 500 Hz. The plate measures and evaluates the pressure applied to each sensor and calculates the centers of pressure in contiguous areas under one and the other foot and then as a total center of pressure to the plate.

For measurements, we used standard tests (Kapteyn, 1983) of 30 s and with scanning frequency of 33 Hz. Evaluated parameters included values of absolute maximum

displacements in the sagital and right-left direction, fluctuation velocity calculated as the change in position of the center of pressure in regard to scanning frequency and the total trajectory during the measurement.

To assess changes in postural stability, we chose two COP parameters: mean velocity and SD of velocity.

Descriptive analysis of measured variables included arithmetic mean, standard deviation (SD), median, minimum and maximum. To compare paired samples in the standing position with open and closed eyes we used the Wilcoxon signed-rank test. Differences between age groups and groups of boys and girls were assessed by means of Mann-Whitney test. Statistical data processing was carried out in Statistica '98® program.

RESULTS

Mean values of COP velocity and SD of velocity while standing with eyes open and standing with eyes closed are shown in Table 1. The table also contains basic descriptive statistics.

The mean COP velocity is lower when standing with eyes open compared to standing with eyes closed. Differences in COP velocity while standing with eyes open and eyes closed were significant in all age categories. The biggest difference between the mean COP velocity while standing with eyes open (EO) and eyes closed (EC) is in eight-year-old children (velocity EO = 5.21 mm s^{-1}, velocity EC = 8.26 mm s^{-1}), the smallest difference was found in eleven-year-old children (velocity EO = 3.54 mm s^{-1}, velocity EC = 5.04 mm s^{-1}).

Table 1. Results of mean COP velocity and SD of velocity while standing with open (EO) and closed eyes (EC) (mm/s)

	N (mm s^{-1})	**Mean** (mm s^{-1})	**Median** (mm s^{-1})	**Minimum** (mm s^{-1})	**Maximum** (mm s^{-1})	**SD** (mm s^{-1})
COP velocity with EO	154	4.74	4.10	1.94	29.46	2.77
SD of velocity with EO	154	4.23	3.23	1.74	33.81	3.88
COP velocity with EC	154	6.90	6.03	2.58	21.38	3.47
SD of velocity with EC	154	6.14	5.16	1.99	31.83	4.06

Significant differences between the stability parameters measured while standing with eyes open (EO) and standing with eyes closed (EC) were found in girls and boys in all age categories irrespective of gender (Table 2).

While standing with eyes open and eyes closed, mean COP velocity and SD of velocity were higher in seven-year-old children than in those eleven-year-old. Statistical significance of differences in standing with eyes open is given in Table 3, while standing with eyes closed in Table 4.

Table 2. COP velocity differences between standing with eyes open and standing with eyes closed

	N	T	Z	p-level
All	154	319	**10.18904**	**.000000***
Boys	85	139	**7.398607**	**.000000***
Girls	69	43	**6.962483**	**.000000***
7 years	26	28	**3.746202**	**.000180***
8 years	25	21	**3.807328**	**.000141***
9 years	46	0	**5.905165**	**.000000***
10 years	22	2	**4.041974**	**.000053***
11 years	35	0	**4.372373**	**.000012***

Legend: N – sample size, T – the sum of ranks, Z – testing criterion of Wilcoxon test, p-level – the minimum level of significance from which we reject the null hypothesis; * significant at $p < 0.05$

Table 3. COP velocity (mm s^{-1}) while standing with eyes open: The differences between age groups

Age groups	X_1 (N)	X_2 (N)	Sum of ranks Group 1	Sum of ranks Group 2	U	Z	p
7 and 11 years	6.635 (26)	3.543 (25)	**896**	**430**	**105**	**4.145**	**.000034***
7 and 9 years	6.635 (26)	4.249 (46)	**1214**	**1414**	**333**	**3.107**	**.001893***
9 and 11 years	4.249 (46)	3.543 (35)	1802	754	429	1.758	.078819

Legend: X_1 – mean COP velocity in group 1, X_2 – mean COP velocity in group 2, U – Mann-Whitney statistics, Z – testing criterion of Mann-Whitney test, p – the minimum level of significance from which we reject the null hypothesis; * significant at $p < 0.05$

Table 4. COP velocity (mm s^{-1}) while standing with eyes closed: The differences between age groups

Age groups	X_1 (N)	X_2 (N)	Sum of ranks Group 1	Sum of ranks Group 2	U	Z	p
7 and 11 years	8.497 (26)	5.036 (25)	**857**	**469**	**144**	**3.410**	**.000649***
7 and 9 years	8.497 (26)	6.510 (46)	1108	1520	439	1.864	.062322
9 and 11 years	6.510 (46)	5.036 (25)	**1849**	**707**	**382**	**2.323**	**.020161***

Legend: X_1 – mean COP velocity in group 1, X_2 – mean COP velocity in group 2, U – Mann-Whitney statistics, Z – testing criterion of Mann-Whitney test, p – the minimum level of significance from which we reject the null hypothesis; * significant at $p < 0.05$

In a normal standing with eyes open and closed, most girls showed lower COP velocity and SD of velocity than boys. While standing with eyes open, COP velocity and SD of velocity are at the same level only for girls and boys aged 10 years (mean velocity boys = 4.03 ± 1.47 mm s^{-1}, mean velocity girls = 4.12 ± 1.25 mm s^{-1}).

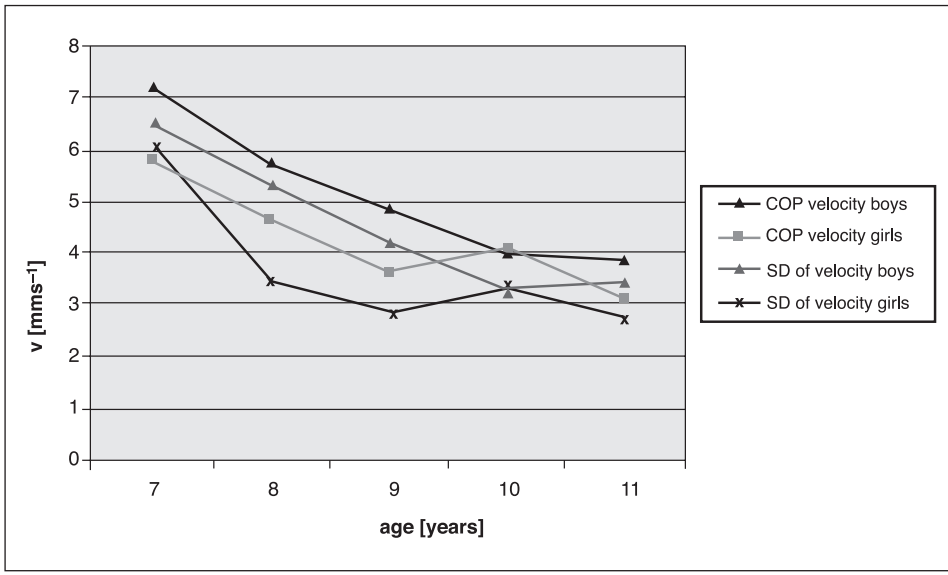

Figure 1. Differences in mean COP velocity and SD of velocity while standing with eyes open between boys and girls (mm s^{-1})

While standing with eyes closed, we observe a plateau of COP velocity between the 7th and 8th year for both boys and girls; it is followed by a significant decrease in girls under 9 years, which is, however, compensated by the slight increase of COP velocity between the 9th and 10th year (Figure 2).

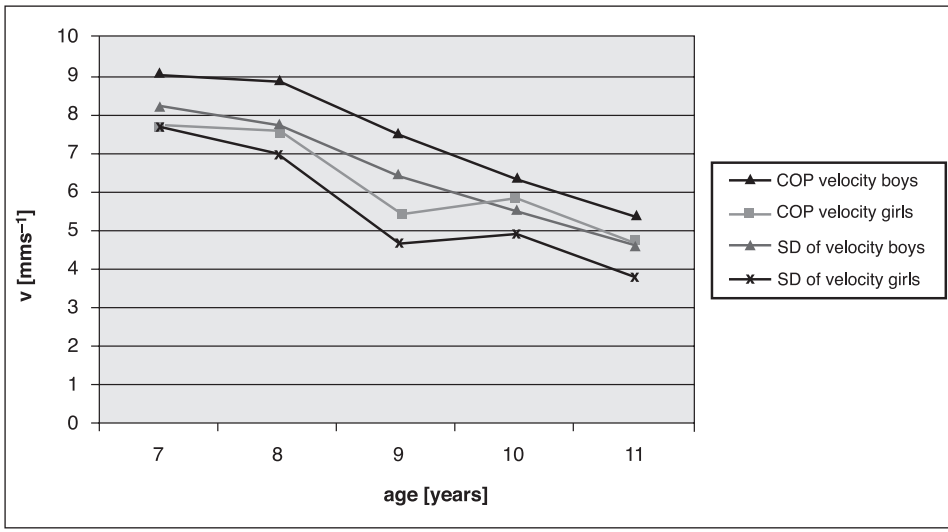

Figure 2. Differences in mean COP velocity while standing with eyes closed between boys and girls (mm s^{-1})

Girls showed significantly lower values of COP velocity and SD of velocity while standing with eyes open and closed than boys (Table 5 and 6).

In some age categories, there were significant differences in velocity or SD of velocity in eight and nine years. COP velocity and SD of velocity while standing with EO and COP velocity while standing with EC were significantly different for boys and girls aged nine years (Table 5 and 6). For girls aged eight, mean SD of velocity was significantly lower than for boys, while mean COP velocity was not significantly lower than for boys (Table 7). Mean COP velocity while standing with eyes open in nine-year-old boys was 4.84 ± 1.77 mm s^{-1}; in nine-year-old girls it was 3.61 ± 0.66 mm s^{-1}. While standing with eyes closed, mean COP velocity in nine-year-old boys was 7.48 ± 3.37 mm s^{-1} and in nine-year-old girls it was 5.45 ± 1.7 mm s^{-1} (Table 8).

Table 5. COP velocity (mm s^{-1}) while standing with eyes open: Differences between boys and girls

Age	X_{boys} (N)	X_{girls} (N)	Sum of ranks Group 1	Sum of ranks Group 2	U	Z	p
7–11 years	5.228 (85)	4.145 (69)	**7393**	**4542**	**2127**	**2.927**	**.003430***
7 years	7.184 (16)	5.757 (10)	228	123	68	.632	.527094
8 years	5.742 (13)	4.640 (12)	202	123	45	1.795	.072669
9 years	4.836 (24)	3.608 (22)	**670**	**411**	**158**	**2.330**	**.019763***
10 years	4.029 (10)	4.117 (12)	110	143	55	–.330	.741636
11 years	3.870 (22)	3.127 (13)	216	109	43	1.861	.062707

Legend: X_{boys} – mean COP velocity for the group of boys, Xgirls – mean COP velocity for the group of girls, U – Mann-Whitney statistics, Z – testing criterion of Mann-Whitney test, p – the minimum level of significance from which we reject the null hypothesis; * significant at $p < 0.05$

Table 6. COP velocity (mm s^{-1}) while standing with eyes closed: Differences between boys and girls

Age	X_{boys} (N)	X_{girls} (N)	Sum of ranks Group 1	Sum of ranks Group 2	U	Z	p
7–11 years	7.566 (85)	6.071 (69)	**7472**	**4463**	**2048**	**3.214**	**.001312***
7 years	9.029 (16)	7.646 (10)	243	108	53	1.423	.154739
8 years	8.893 (13)	7.583 (12)	182	143	65	.707	.479505
9 years	7.484 (24)	5.448 (22)	**655**	**426**	**173**	**2.001**	**.045391***
10 years	6.326 (10)	5.847 (12)	130	123	45	.989	.322636
11 years	5.362 (22)	4.619 (13)	200	125	59	.985	.324431

Legend: X_{boys} – mean of the group of boys, X_{girls} – mean of the group of girls, U – Mann-Whitney statistics, Z – testing criterion of Mann-Whitney test, p – the minimum level of significance from which reject the null hypothesis; * significant at $p < 0.05$

Table 7. SD of COP velocity (mm s^{-1}) while standing with eyes open: Differences between boys and girls

Age	X_{boys} (N)	X_{girls}(N)	Sum of ranks Group 1	Sum of ranks Group 2	U	Z	p
7–11 years	4.798 (85)	3.522 (69)	**7445**	**4490**	**2075**	**3.115**	**.001838***
7 years	6.512 (16)	6.038 (10)	230	121	66	.738	.460602
8 years	5.288 (13)	3.472 (12)	**207**	**118**	**40**	**2.067**	**.038749***
9 years	4.222 (24)	2.852 (22)	**697**	**384**	**131**	**2.925**	**.003451***
10 years	3.221 (10)	3.343 (12)	93	160	38	–1.451	.146891
11 years	3.447 (22)	2.749 (13)	217	108	42	1.916	.055365

Legend: X_{boys} – mean of the group of boys, X_{girls} – mean of the group of girls, U – Mann-Whitney statistics, Z – testing criterion of Mann-Whitney test, p – the minimum level of significance from which we reject the null hypothesis; * significant at $p < 0.05$

Table 8. SD of COP velocity (mm s^{-1}) while standing with eyes closed: Differences between boys and girls

Age	X_{boys} (N)	X_{girls} (N)	Sum of ranks Group 1	Sum of ranks Group 2	U	Z	p
7–11 years	6.739 (85)	5.399 (69)	**7441**	**4494**	**2079**	**3.101**	**0.001931***
7 years	8.233 (16)	7.701 (10)	242	109	54	1.370	0.170597
8 years	7.719 (13)	6.918 (12)	180	145	67	0.598	0.549630
9 years	6.433 (24)	4.682 (22)	653	428	175	1.957	0.050343
10 years	5.531 (10)	4.875 (12)	130	123	45	0.989	0.322636
11 years	4.634 (22)	3.802 (13)	200	125	59	0.985	0.324431

Legend: X_{boys} – mean of the group of boys, X_{girls} – mean of the group of girls, U – Mann-Whitney statistics, Z – testing criterion of Mann-Whitney test, p – the minimum level of significance from which we reject the null hypothesis; * significant at $p < 0.05$

DISCUSSION

COP velocity and SD of velocity while standing with eyes open decrease with age in the screened sample. The decrease of COP has been confirmed by other studies, as well (Hytönen et al., 1993, Riach, Starkes, 1994, Wolf et al., 1998, Kirschenbaum et al., 2001, Vařeka, 2002). Similar results in the development of COP velocity are presented by Figura et al. (1991), who monitored its faster decrease in children between the sixth and eighth year of age than between the eighth and tenth year of age. Uneven improvement of the balance control in this age is explained by two major developmental changes. Firstly, improvement of localization and the level of muscle activity, and secondly, improvement of control balance based on feedback (Rival et al., 2005).

COP velocity and SD of velocity while standing with eyes closed decrease throughout the whole monitored period. Based on the developmental curve of COP and SD of velocity

we may observe a faster decrease after the eighth year of age. This decrease can not be linked to a faster increase in body height or weight, as this has not shown up between the 8th and 9th year of age. Nonlinear development of COP is mentioned by Kirschenbaum et al. (2000). Also Riach, Starkes (1994) found out a steeper decrease in mean velocity of fluctuations between the 7th and 8th year of age; after the eighth year of age, the decrease was, according to their results, slight and in older age, mean velocity of COP fluctuations even temporarily increased.

The course of age changes in the parameter of COP velocity varies in the standing position with eyes open and closed. While standing with eyes open, significant differences between the groups of seven-year-old and nine-year-old children have been proved, but no significant differences have been found between nine-year-old and eleven-year-old children. This could suggest that stability in the standing position with eyes open significantly improves until the ninth year, while after the ninth year, this improvement is only slight. No significant difference in COP velocity while standing with eyes closed was proved between the groups of seven-year-old and nine-year-old children, while between the nine-year-old and eleven-year-old children the difference was significant. This indicates that the decrease in COP velocity in standing with eyes closed is shifted to a later age period. Explanation can be found in the fact that standing without visual control is more difficult. Stability in the standing position with eyes closed reaches the level similar to that of adults' probably later than in the standing position with eyes open. This may confirm the results of studies published previously. Figura et al. (1991) have not found any significant differences in bipedal standing with eyes open between ten-year-old children and adults. While standing with eyes closed, significant differences between ten-year-old children and adults have been found (Rival et al., 2005).

COP velocity and SD of velocity were lower in girls than in boys in our sample. Significant differences between the samples of girls and boys have been proved. This may indicate a better ability to maintain stability in girls. Another possible explanation may be girls' better ability to concentrate.

In the age groups, differences between nine-year-old boys and girls in the standing position with eyes open and closed have been confirmed; in younger eight-year-old children we have found a lower value of SD parameter in girls while standing with eyes open, which indicates smaller changes in COP velocity while standing with eyes open in girls. At nine years of age, girls showed significantly lower values of COP velocity while standing with eyes open and closed than boys. At a later period, no significant differences between boys and girls have been confirmed. The fact, that girls have lower values of COP velocity in the ninth year may support the hypothesis that fluctuation parameters are stabilized earlier in girls than in boys, as stated by Odenrick, Sandstedt (1984) and Riach, Hayes (1987).

CONCLUSIONS

- We confirm a decrease of monitored COP parameters while standing with eyes open among children aged seven to eleven years. The decrease is more pronounced in the first half of the monitored period. Postural stability of children while standing with eyes open is improving with age.

- We confirm a decrease of monitored COP parameters while standing with eyes closed among children aged seven to eleven years. The decrease is more pronounced in the second half of the monitored period. Postural stability of children while standing with eyes closed is improving with age.
- COP parameters are higher in a standing position with eyes closed. With the loss of visual information, postural stability of children aged seven to eleven years is getting worse.
- Girls reached, on average, lower values of COP velocity and SD of velocity than boys. In the age groups, we may confirm some significant differences in the eighth and ninth year of age. Differences are reduced after the ninth year. At the age of nine, girls have better postural stability than boys.

We are aware that the presented results can not be generalized to the whole population. Selection of children for this study was based on availability and it can not be regarded as random. The limiting factor for the usability of our study is the fact that this was a cross-sectional survey. In further studies it would be appropriate to carry out longitudinal measurements, which would be more suitable with respect to the large interindividual differences in children in age groups.

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REFERENCES

DOYLE, R. J., HSIAO-WECKLER, E. T., RAGAN, B. G., ROSENGREN, K. S. (2007). Generalizability of center of pressure measures of quiet standing. *Gait & Posture*, 25, 166–171.

FETZ, F. (1987). *Sensomotorisches gleichgewicht im Sport.* Wien: Östereichisches Bundesverlag.

FIGURA, F., CAMA, G., CAPRANICA, L., GUIDETTI, L., PULEJO, C. (1991). Assesment of static balance in children. *The Journal of Sports Medicines and Physical Fitness*, 31, 235–242.

GEURTS, A. C., NIENHUIS, B., MULDER, T. W. (1993). Intrasubjekt variability of selected force-platform parameters in quantification of postural control. *Arch Phys Med Rehabil,* 74, 11, 1144–1150.

GUSKIEWICZ, K. M., PERRIN, D. H. (1996). Research and Clinical Applications of Assessing Balance. *Journal of Sport Rehabilitation*, 5, 45–63.

HADIAN, M. R., NEGAHBAN, H., TALEBIAN, S., JAFAR, A. H., SANGARI, M. A., MAZANERI, M., PARNIANPOUR, M. (2008). Reliability of center of pressure measures of posture stability in patients with unilateral anterior cruciate ligament injury. *Journal of Applied Sciences,* 8, 17, 3019–3025.

HATZITAKI, V., ZISI, V., KOLLIAS, I., KIOUMOURTZOGLOU, E. (2002). Perceptual-Motor Contributions to Static and Dynamic Balance Control in Children. *Journal of Motor Behavior*, vol. 34, 2, 161–170.

HYTÖNEN, M., PYYKKÖ, I., AALTO, H., STARCK, J. (1993). Postural Control and age. *Acta Otolaryngol (Stockh)*, 113, 119–122.

KAPTEYN, T. S., BLES, W., NJIOKIKTJIEN, CH. J., KODDE, L., MASSEN, C. H., MOL, J. M. F. (1983). Standardization in Platform Stabilometry being a Part of Posturography. *Agressologie*, 24, 7, 321–326.

KIRSCHENBAUM, N., RIACH, C. L., STARKES, J. L. (2001). Non-linear development of postural control and strategy use in young children: a longitudinal study. *Exp Brain Res*, 140, 420–431.

KOZÁKOVÁ, D., SVOBODA, Z., JANURA, M., PARÁKOVÁ, B. (2008). Hodnocení posturální stability pacientů s transfemorální amputací s různou dobou používání protézy. *Česká kinantropologie*, vol. 12, 4, 77–86.

NEVŠÍMALOVÁ, S., RŮŽIČKA, E., TICHÝ, J. (2002). *Neurologie.* Praha: Galén a UK.

NOLAN, L., GRIGORENKO, A., THORSTENSSON, A. (2005). Balance control: sex and age differences in 9- to 16-year-olds. *Developmental Medicine & Child Neurology*, 47, 449–454.
ODENRICK, P., SANDTEDT, P., LENNERSTRAND, G. (1984). Postural sway and gait of children with convergent strabismus. *Dev Med Child Neurol*, 26, 495–499.
PALMIERI, R. M., INGERSOLL, C. D., STONE, M. B., KRAUSE, B. A. (2002). Center-of-presure Used in the Assessment of Postural Control. *J Sport Rehabil*, 11, 51–66.
RIACH, C. L., HAYES, K. C. (1987). Maturation of postural sway in young children. *Dev Med Child Neurol*, 29, 650–658
RIACH, C. L., STARKES, J. L. (1993). Stability limits of quiet standing postural control in children and adults. *Gait & Posture*, 1, 105–111.
RIACH, C. L., STARKES, J. L. (1994). Velocity of centre of pressure excursions as an indicator of postural control systems in children. *Gait & Posture*, 2, 167–172.
RIVAL, C., CEYTE, H., OLIVIER, I. (2005). Developmental changes of static standing balance in children. *Neuroscience Letters*, 376, 133–136.
SHUMWAY-COOK, M., WOOLLACOTT, M. H. (1985). The growth of stability: postural control from developmental perspective. *Journal of Motor Behavior*, 17, 131–147.
STARKES, J., RIACH, C., CLARKE, B. (1992). The effect of eye closure on postural sway: converging evidence from children and Parkinson patient. In: PROTEAU, L., ELLIOTT, D., ed. *Vision and Motor Control.* New York: Elsevier Science Publishers.
STREEPEY, J. W., ANGULO-KINZLER, R. M. (2002). The role of task difficulty in the control of dynamic balance in children and adults. *Human Movement Science*, 21, 423–438.
USUI, N., MAEKAWA, K., HIRASAWA, Y. (1995). Development of the upright postural sway of children. *Developmental Medicine and Child Neurology*, 37, 985–996.
VAŘEKA, I. (2002). Posturální stabilita (I. Část) Terminologie a biomechanické principy. *Rehabil. Fyz. lék.*, 9, 4, 115–121.
WESTCOTT, S. L., RICHARDSON, P. K., LOWES, L. P. (1997). Evaluation of postural stability in children: current theories an assesment tools. *Phys Ther,* 77, 629–645.
WINTER, D. A. (1995). Human balance and posture control during standing and walking. *Gait & Posture*, 3, 193–214.
WOLFF, D. R., ROSE, J., JONES, V. K., BLOCH, D. A, OEHLERT, J. W., GAMBLE, J. G. (1998). Postural balance Measurements for Children and Adolescents. *Journal of Orthopaedic Research*, 16, 271–275.
WOOLLACOTT, M., H., DEBŮ, B., SHUMWAY-COOK, A. (1987). Children's Development of Posture and Balance Control: Changes in Motor Coordination and Sensory Integration. In GOULD, P. *Advances in pediatric sport sciences. Behavioral issues.* Champaign: Human Kinetics Publ.

ZMĚNY VE VYBRANÝCH PARAMETRECH POSTURÁLNÍ STABILITY U DĚTÍ ŠKOLNÍHO VĚKU

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SOUHRN

Cílem studie je popsat změny vybraných parametrů posturální stability ve stoji s očima otevřenýma a zavřenýma u chlapců a dívek ve věku 7 až 11 let. Sledovanými parametry byly rychlost COP a SD rychlosti. Soubor tvořilo 144 dětí prvního stupně základní školy z toho 85 chlapců a 69 dívek. Stabilita byla měřena na zařízení FootScan po dobu 30 sekund s frekvencí 33 Hz. Výsledky ukazují na pokles rychlosti COP a SD rychlosti s věkem ve stoji s otevřenýma i zavřenýma očima. Ve stoji s otevřenýma očima jsou věkové změny stability výraznější v první polovině období, ve stoji se zavřenýma očima v druhé polovině období. Ve všech věkových skupinách byla rychlost COP i SD rychlosti ve stoji se zavřenýma očima vyšší oproti stoji s otevřenýma očima. V průměru dosáhly nižších hodnot rychlosti i SD rychlosti dívky oproti chlapcům. Rozdíly se ztrácejí po devátém roce věku. Posturální stabilita dětí mladšího školního věku se zlepšuje s věkem u chlapců i dívek. Se ztrátou zrakových informací se posturální stabilita zhoršuje. Dívky v devíti letech vykazují lepší posturální stabilitu než chlapci.

Klíčová slova: posturální stabilita, střed tlakového působení nohou, děti mladšího školního věku