Journal of Sports Research
2015 Vol.2, No.2, pp. 52-61
ISSN(e): 2410-6534
ISSN(p): 2413-8436
DOI: 10.18488/journal.90/2015.2.2/90.2.52.61

THE ABILITY TO MAINTAIN STATIC BALANCE IN YOUNGER SCHOOL CHILDREN AND ITS RELATION TO THE STABILITY OF A POSTUROGRAPHIC SURFACE

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ABSTRACT

Introduction: The ability to maintain one's balance plays vital role during the activities of daily living. Efficient maintenance of body balance is determined by the number and type of stimuli providing information on a body position. The aim of this study was to analyze the ability to maintain balance in 7- to 12-year-old children. We analyzed the extent and direction of changes in balancing skills related to subject's age and stability of a posturographic surface. Material and methods: The study included 266 children aged between 7 and 12 years. The level of static balance was determined with a posturographic method, with a child standing with the eyes open, first on a stable, and then on an unstable position. Results: The children aged between 7 and 8 years presented lower levels of static balance. The level of balancing skills turned out to be higher in the case of 9- to 12-year-old children. Reduced stability of a posturographic surface resulted in greater difficulties in maintaining balance. This change was observed regardless of a subject's age and manifested as an increase in the area developed by the center of pressure and greater variability of both the velocity and number of sways in the sagittal and frontal plane. The change of the posturographic surface into an unstable one resulted in greater instability in both the frontal and sagittal plane. The increase in the area developed by the center of pressure reflected higher velocity and greater number of sways.

Keywords: Postural balance, Children, Motor skills, Ability, Surface, Sways.

Received: 15 December 2014/ **Revised:** 5 January 2015/ **Accepted:** 28 January 2015/ **Published:** 6 February 2015

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Contribution/ Originality

This study contributes in the existing literature to increased knowledge of the ability to body balance. This study uses new estimation methodology a posturographic method. This study originates new formula periodic testing more children from primary schools. This study is one of very few studies which have investigated children on a stable and on unstable surface. The paper contributes the first logical analysis between age of children and ability of balance. The paper's primary contribution is finding that posturographic method is objective diagnostic instrument. This study documents relationships between the ability to maintain static balance, age and stability of a posturographic surface.

1. INTRODUCTION

The ability to maintain one's balance belongs to leading coordination skills, along with spatial orientation, kinesthesis and reaction time. It is crucial during both everyday functioning and physical exercise. Due to balancing ability one can maintain his/her body's center of gravity in a stable position, both standing and during movements. This requires development of specific responses, being vital for the control of body posture. The level of balancing skills is determined by the capacity of the nervous system. Therefore, one objective of physical exercise is to develop neuromuscular coordination, as it is crucial for improvement of one's balancing skills. Due to the important role of body balance, numerous studies have been undertaken to analyze associations between its level, age, sex and physical activity (Allum and Shepard, 1999; Held-Ziółkowska, 2006; Lin *et al.*, 2006; Błaszczyk *et al.*, 2008; Starosta and Rynkiewicz, 2008; Rynkiewicz *et al.*, 2010; Żurek *et al.*, 2010).

Keeping a stable body posture requires coordination between the activity of the visual organ as well as the vestibular and proprioceptive systems. The effectors are all muscles of the body. Efficient maintenance of body balance is determined by the number and type of stimuli providing information on a body position. The latter, as well as the data on the level of muscle tone and joint angles are necessary for the nervous system to activate the muscles responsible for performing a given task, e.g. limiting body sway (Winter *et al.*, 1990; Sherington, 1994; Golema, 2002; Kuczyński, 2003; Trew and Everett, 2005; Hrysomallis, 2011). Inappropriate response of the nervous system may cause disturbances in body balance, thus leading to falls with resultant injuries and contusions.

Due to the important role of body balance in everyday functioning and physical activity, we have undertaken a study analyzing the ability to maintain balance in 7- to 12-year-old children. The aim of the study was to determine the ability to maintain static balance and age-related changes in this parameter. Moreover, we analyzed the level of balancing skills presented during examination on a surface with limited stability. Prior to the study we hypothesized that: 1. The ability to maintain static balance increases with age; 2. The change of surface to less stable one results in reduced ability to maintain static balance, but the degree of the reduction decreases with age.

2. MATERIAL AND METHODS

The study included 266 children aged between 7 and 12 years, among them 118 girls and 148 boys, attending primary school (Table 1). The protocol of the study was approved by the Local Bioethics Committee, and the participants' parents gave their written consent to take the measurements.

Table-1. Biometric characteristics of children participating in the study (n=266)

	Data	M	SD	Min.	Max
1.	Age [years]	9.2	1.7	7.0	12.0
2.	Weight [kg]	35.6	11.4	19.5	98.5
3.	Height [cm]	140.4	12.3	115.0	174.0
4.	BMI [kg/m^2]	17.7	3.3	12.6	32.5

The level of static balance was determined with a posturographic method, with a child standing on a force plate with the eyes open (Maurer and Peterka, 2005; Held-Ziółkowska, 2006). The measurements were taken twice: first on a stable and then on an unstable surface. In order to determine the level of static balance on an unstable surface, each child was examined standing on a standard cushion of a Balance Master training device (NeuroCom, United States). A posturograph (Olton, Poland) was comprised of a 400 x 400 x 55 mm force plate with tensometric converters enabling to determine the distribution of center of pressure (COP) amongst all posturograph sectors (Fig. 1 a, b).

a) stable surface b) unstable surface

Figure-1 a, b. Determination of the ability to maintain static balance on a stable (a) and unstable (b) surface

The following parameters were subjected to further analyses: the area developed by COP (COPA, in mm^2), number of COP sways in the frontal plane (NIFP), number of COP sways in the sagittal plane (NISP), sway velocity in the frontal plane (VIFP), and sway velocity in the sagittal plane (VISP). Statistical analysis of the results was conducted with Statistica 10.0 software package (StatSoft, Inc., United States; license no. AXAP012D837210AR-7). The results are presented as arithmetic means ± standard deviations. The normality of distribution was verified with the Kolmogorov-Smirnov test. The relationships between pairs of variables were analyzed on the basis of Pearson's and Spearman's coefficients of correlation. Statistical significance of all the tests was set at $p < 0.05$.

3. RESULTS

Mean COPA determined on a stable surface amounted to M=1232.1±994.5 mm^2, but the individual values of this parameter varied considerably (min=168 mm^2; max=6097 mm^2). The values of COPA determined on an unstable surface were less favorable and also showed significant variability (min=193 mm^2; max=5063 mm^2). Mean COPA on an unstable surface was M=3673.8±2703.9 mm^2 (Table 2). The number of sways in the frontal plane (NIFP) documented on a stable and unstable surface amounted to M=32.5±8.2 and M=37.7±7.2, respectively. The number of sways in the sagittal plane (NISP) equaled M=28.0±8.4 while measured on a stable surface, and the change of the surface to an unstable one resulted in significant increase in this parameter, to M=40.1±8.4.The change of the surface from a stable to an unstable one was also reflected by a significant increase in the sway velocity in the frontal plan (VIFP), from M=10.3±4.2 mm/s to M=18.0±5.8 mm/s. The mean velocity of sway in the sagittal plane (VISP) was M=6.9±3.7 mm/s while determined on a stable surface, and increased to M=17.9±7.2 mm/s when examined on an unstable surface (Table 2).

Table-2. Parameters characterizing balancing skills of the studied children (n=266)

Data	Stable surface				Unstable surface				p
	M	SD	min	max	M	SD	min	max	
COPA [mm^2]	1232.1	994.5	168	6097	3673.8	2703.9	193	5063	p≤0,005
NIFP [n]	32.5	8.2	13	66	37.7	7.2	19	61	p≤0,005
NISP [n]	28.0	8.4	4	50	40.1	8.4	21	81	p≤0,005
VIFP [mm/s]	10.3	4.2	3	34	18.0	5.8	7	40	p≤0,005
VISP [mm/s]	6.9	3.7	1	32	17.9	7.2	7	50	p≤0,005

As COPA is considered a crucial marker of one's balancing skills, we analyzed a relationship between this parameter and age of examined children. The values of COPA turned out to be the highest among 7- to 8-year-old children; the remaining, 9- to 12-year-old children did not differ markedly in terms of their COPA levels.

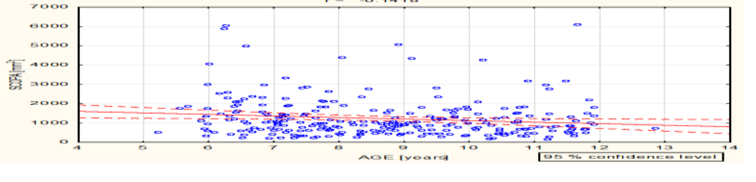

Figure-2. Relationship between the age of the study participants and the area developed by COP (COPA) during examination of balancing skills on a stable surface (n=266)

Legend: S PP (area developed by COP – stable surface)

The change of the surface from a stable to an unstable one resulted in an increase in COPA. The degree of this change was not associated with the participants' age (Fig. 2, 3).

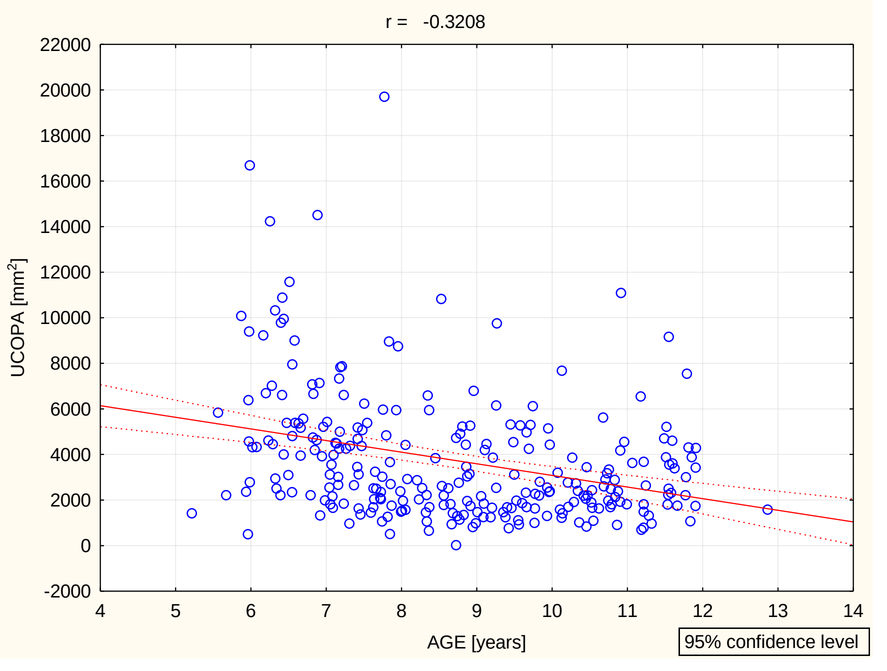

Figure-3. Relationship between the age of the study participants and the area developed by COP (COPA) during examination of balancing skills on an unstable surface (n=266)

Legend: N PP (area developed by COP – unstable surface)

A tendency to higher number of sways in the frontal plane than in the sagittal plane was observed during the testing on a stable surface. In turn, the numbers of sways in the frontal and sagittal plane, recorded during examination on an unstable surface, turned out to be similar. Regardless of the surface type, the number of sways in the frontal plane was the highest among the youngest, 7-year-old subjects.

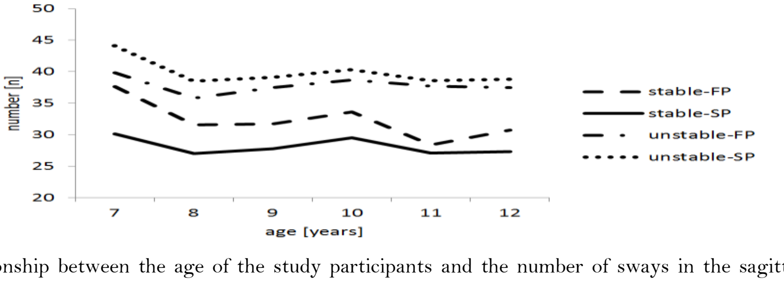

Figure-4. Relationship between the age of the study participants and the number of sways in the sagittal and frontal plane, determined on a stable and unstable surface (n=266)

Legend: stabilne-PC: stable surface, frontal plane; stabilne-PS: stable surface, sagittal plane; niestabilne-PC: unstable surface, frontal plane; niestabilne-PS: unstable surface, sagittal plane

We did not find any significant age-related differences in the number of sways in the sagittal plane determined on a stable surface. However, the number of sways increased markedly when examined on an unstable surface, especially in the case of 7-year-old children (Fig. 4).

The velocity of sway in the frontal plane determined on a stable surface turned out to be higher than the sway velocity in the sagittal plane. After changing the surface to an unstable one, we did not find a significant difference between the sway velocities in the frontal and sagittal planes. Irrespective of the type of the surface, 7-year-old children showed significantly higher sway velocities in either the plane when compared to the older subjects (Fig. 5).

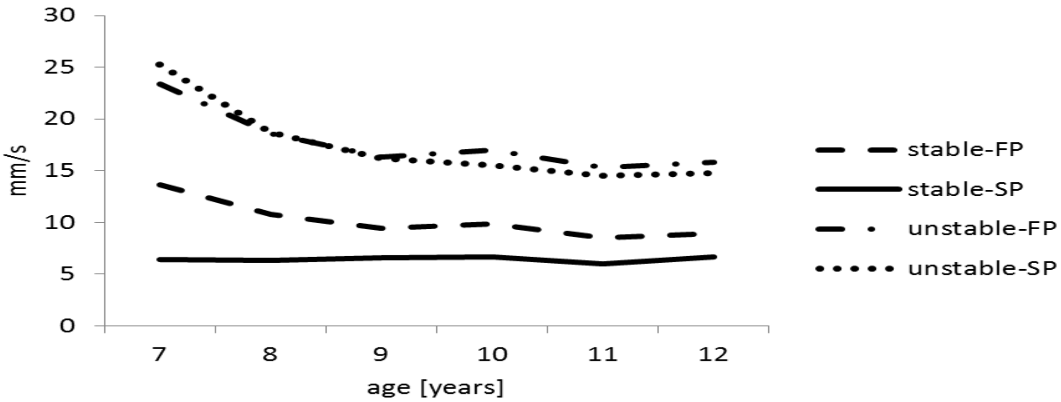

Figure-5. Relationship between the age of the study participants and the sway velocities in the frontal and sagittal plane, determined on a stable and unstable surface (n=266)

4. DISCUSSION

The posturographic method used in this study of 7- to 12-year-old children is considered an objective diagnostic instrument (Kostiukow *et al.*, 2009). We used this method to analyze relationships between the ability to maintain static balance, age and stability of a posturographic surface. The possibility of recording the force plate's reactions to changes in COP position allows to determine the so-called balancing strategies. The main of them are tarsal joint, hip joint and step strategies, preventing falling due to increase in the support area. These strategies constitute a basis for the mechanisms that enable one to maintain a stable body posture (Nashner, 1993; Held-Ziółkowska, 2006).

We determined the values of basic parameters of static balance. The values of COPA (considered a marker of stability) measured on a stable surface turned out to be higher than the respective values documented previously in subjects of similar age and older (Rynkiewicz *et al.*, 2010; Starosta and Żurek, 2012). The change of the posturographic surface to an unstable one resulted in greater difficulties in maintaining a stable posture. This was reflected by an increase in COPA and greater individual variability of this parameter. While the youngest (7- to 8-year-old) children presented with the highest COPA values, the remaining, 9- to 12-year-old participants did not differ significantly with regards to this parameter.

The change of the posturographic surface from a stable to an unstable one was reflected by an increase in COPA; the degree of this change was not associated with the age of the study participants. Regardless of the surface type, the highest COPA values were observed in the case of 7-year-old children. Probably, lesser ability to use an efficient balancing strategy might contribute to worse balancing skills presented by children from this age group. According to literature, the period between 7 and 9 years of age is critical for the development of an intrinsic movement pattern and control of vertical body position. This period is characterized by switching from the trunk strategy to the head stabilization strategy, both in a standing position and during locomotor movements. Development of balancing skills in children was shown to be comprised of the two principal stages: acquiring a set of various postural strategies, and subsequent learning of optimal strategy selection (Assaiante, 1998; Roncesvalles *et al*., 2005; Sobera, 2010).

Control of body balance is based on the sensory signaling from the organ of vision, labyrinth and proprioceptors. Therefore, the disturbances in body balance may result from impairment of any of these components. However, disturbed body balance does not necessarily reflect functioning of the balancing system, but may be also associated with growth-related changes, side effects of taken medicines, or disorders of spatial orientation (Cho and Kamen, 1998; Waśkiewicz, 2002; Kostiukow *et al*., 2009). According to literature, stabilization of body posture in children being under intensive biological development should be reflected by a decrease in the number body sways and degree of COP displacement (Hay and Redon, 1999).

During examination of our participants on the stable surface, the number of sways in the frontal plane turned out to be lower than the number of sways in the sagittal plane. After changing the surface from a stable to an unstable one, we did not find significant differences between the number of sways in either the plane. Regardless of the type of the surface, 7-year-old children presented the greatest variability with regards to the number of sways in the frontal plane. Examination on an unstable surface resulted in an increase in the number of sways in the two planes. Higher number of sways recorded in the sagittal plane suggests that maintenance of body balance, especially under atypical conditions, is associated with more frequent anteroposterior sways. Therefore, a displacement of COP in the sagittal plane and availability of an optimal balancing strategy seem to play a leading role in the control of body balance. The choice of a given balancing strategy is determined by an accurate analysis of information on a body position; resultant correction of the latter results in an improvement of symmetrization and simultaneous anterior body sway (Slobounov and Newell, 1994; Held-Ziółkowska, 2006; Slobounov *et al*., 2008).

We also analyzed the velocity of sway in the two planes. The velocity of the sway in the frontal plane was shown to be higher than in the sagittal plane. After changing the posturographic surface to an unstable one we did not find significant differences in the velocity of sway in the two planes. The velocity of the sways in children is postulated to decrease with age, as the changes in the distribution of COP reflect repositioning of the whole body (Sobera, 2010). The change of the surface from a stable to an unstable one resulted in an increase in the sway velocity in both the frontal and sagittal plane. Maintenance of balance on unstable surface is postulated to be more challenging for postural control mechanisms than balancing on a stable surface. Under such circumstances, the adjustment of body position to changeable conditions requires prompt and adequate control of limited afferent information from all sensory gateways (Ivanenko *et al.*, 1999). Therefore, the level of balancing skills on an unstable surface may serve as a criterion for coordination skills in humans (Rougier *et al.*, 2011; Tchórzewski, 2013).

According to literature, 11- to 13-year-old children show temporary stagnation in their level of balancing skills. Many activities of daily living are performed under disturbed stability, and as such require greater level of balancing skills (Szot, 2004; Kostiukow *et al.*, 2009; Hrysomallis, 2011). Everyday activities require a voluntary, repeated transient loss of balance and subsequent return to a stable position (Alpini *et al.*, 2008; Tchórzewski, 2013). Therefore, implementation of exercises aimed at the development of this skill to physical education classes curricula is crucial from the very beginning of school education.

5. CONCLUSIONS

The hereby reported study of balancing skills enabled us to formulate the following conclusions:

1. Higher values of a stability marker, the area developed by COP, documented in the case of the youngest children (7-8 years of age) pointed to their greater instability, especially in the sagittal plane. The values of COPA normalized in older subjects (9-12 years of age). Stabilization of body in children being under intensive biological development should be reflected by a lower extent of COP oscillation.
2. Reduced stability of a posturographic surface resulted in greater difficulties in maintaining balance. This change was observed regardless of a subject's age and manifested as an increase in COPA value and greater variability of both the velocity and number of sways in either the plane. Moreover, individual values of these parameters varied considerably. This likely reflected greater difficulties in maintaining balance on an unstable surface than on a standard stable posturographic force plate.

Funding: The study was supported from statutory funds of the Ministry of Science and Higher Education

Competing Interests: The authors declare that they have no competing interests.

Contributors/Acknowledgement: All authors contributed equally to the conception and design of the study. The authors would like to thank the administrators of Primary School no. 5 in Gorzow Wielkopolski for their assistance in conducting the study.

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