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Sense of Balance in Children from Traditional and Forest Kindergartens

Zmysł równowagi u dzieci z przedszkoli tradycyjnych i leśnych

KEYWORDS

balance, sense of balance, sensory integration, vestibular system, forest kindergartens, traditional kindergartens

ABSTRACT

The area of interest in this article is the sense of balance in preschool children and the aim is to present a study comparing the balance abilities of children attending traditional and forest kindergartens in static and dynamic tests. The article was inspired by my own observations that children from forest kindergartens (aged 3 years and up) perform significantly better than children from other kindergartens when overcoming natural obstacles and solving difficult coordination tasks that require balance. The introductory section of this article outlines the importance of the vestibular system in anatomical and pedagogical terms. The research consisted of two static balance tests – standing on one leg with eyes open and closed – and two dynamic balance tests: walking freely on a beam and walking with a heel-toe step. In the research, the children from forest kindergartens obtained better results in all attempts than children from traditional kindergartens. Statistical inference using the "z" (normal) distribution was carried out using the Mann–Whitney U test, which showed that these differences were statistically significant. The article concludes with general pedagogical and practical educational recommendations.

SŁOWA KLUCZE

równowaga, zmysł równowagi, integracja sensoryczna, układ przedsionkowy, przedszkola leśne, przedszkola tradycyjne

ABSTRAKT

Obszarem zainteresowania w tym artykule jest zmysł równowagi u dzieci w wieku przedszkolnym, jego celem przedstawienie badań dotyczących porównania zdolności utrzymania równowagi w próbach statycznych i dynamicznych dzieci uczęszczających do przedszkoli tradycyjnych i do przedszkoli leśnych. Inspiracją do napisania były obserwacje własne wskazujące, że dzieci z przedszkoli leśnych (od 3. roku życia) znacznie lepiej radzą sobie z pokonywaniem naturalnych przeszkód i z wykonywaniem trudnych zadań koordynacyjnych wymagających utrzymania równowagi niż dzieci z innych placówek przedszkolnych. W części wstępnej artykułu przedstawiono znaczenie układu przedsionkowego w aspekcie anatomicznym i pedagogicznym. Badania polegały na przeprowadzeniu 2 prób sprawdzających równowagę statyczną – stanie jednonóż z oczami otwartymi i zamkniętymi oraz 2 prób sprawdzających równowagę dynamiczną – swobodne przejście po belce i przejście krokiem mierniczym. Z badań własnych autorki wynika, że we wszystkich próbach dzieci z przedszkoli leśnych uzyskały lepsze rezultaty niż dzieci z przedszkoli tradycyjnych. Wnioskowanie statystyczne z wykorzystaniem rozkładu z (normalnego) przeprowadzono na podstawie testu U Manna Whitneya. Test ten wykazał, że wspomniane różnice były istotne statystycznie. Artykuł kończą rekomendacje ogólnopedagogiczne i praktycznoedukacyjne.

Introduction

In the social sense, when thinking about the sensory organs, we refer to Aristotle's classical typology (n.d., Book 2, 5–15), which distinguishes five senses: sight, hearing, taste, smell, and touch. We forget about the vestibular system and proprioception,[1] which provide information about gravity and movement, as well as the muscular movements of the body and its position in space. It is through the senses that all stimuli from the internal and external environment reach the various parts of the central nervous system (spinal cord and brain). Sensory perception is the basis for forming an image of reality, so the synergy of all the sensory systems is essential for proper human development. In this article, I pay special attention to the vestibular system and the sense of balance, the efficiency of which can affect children's future school careers.

[1] Proprioception: kinesthesia, kinesthetic sense or deep sensation

The vestibular system – anatomical and physiological aspects

Equilibrium is the ability to maintain the projection of the body's center of mass, which is located in the lower abdominal region, within a small area of support determined by the outline of the feet (Held-Ziolkowska, 2006). The area of the foot base marks the anatomical area of stability. At equilibrium, the vertical projection of the body's center of mass cannot move beyond these limits. Balance can also be defined as the ability to independently maintain an upright position, as well as the ability to regain balance during or after movement.

Our sense of balance (the organ of equilibrium) allows us to sense the position of our body in space. It is located within the inner ear, or more precisely, in the membranous falx, which is formed by two otolithic structures: the saccule and the ganglion (responsible for spatial orientation) and three arch-shaped semicircular canals set at near-right angles to each other. Thanks to the movement of the endolymph inside the canals, we can register the movement of the body in three-dimensional space as well as rotational motion. Balance reactions appear after the age of 5–6 months due to the interaction of the cerebral cortex, subcortical nuclei, and cerebellum. When they develop correctly, a person achieve a bipedal position and adapt their body alignment to the changing position of their center of gravity (Borkowska, 2018, p. 137).

The vestibular system, thanks to its receptors, reports linear motion (forward-backward and up-down), vibration, and rotational movement. It is very sensitive to even the slightest changes in position and movement (it registers a change in movement by even one degree). Thanks to its efficient functioning, a person has awareness and directional orientation, as well as information about the spatial relationship between themselves and their environment, which provides them with a sense of gravitational security and, consequently, a sense of emotional security. Misinterpreted stimuli result in an irrational fear of movement, staying in higher positions, or pulling one's legs off the ground.

The maintenance of body balance is dynamic, systemic, and dependent on muscle and joint control. This is referred to as unconscious involuntary and automatic control (Goddard, 2004, p. 83), which is regulated largely below the level of the cerebral cortex. In order to not fall, it is necessary to constantly maintain adequate muscle tension, which in turn is controlled by responses from the central nervous system. The smooth functioning of the entire system depends on information from many sources: from sensory receptors located in the skin and joints (the position of the body in space and the location of all parts of the body in relation to each other), vision (the position of the body in relation to the environment), and from the vestibular system (the position and movements of the head) (Cassan, 2008, pp. 126–127). The main tasks of the balance system are as follows:

- providing data on the position of the body in space and the direction and speed of its movement,
- a quick, fall-preventing response that corrects any deviation of the body's center of gravity from its equilibrium position within the basal area, and
- control of eye movement to maintain a correct image of the environment while a person and/or their surroundings is moving (Paszko-Patej et al., 2011, p. 121).

To sum up, the maintenance of body balance in humans, both at rest and during motor activity (static and dynamic balance), as well as the subjective sensation of spatial orientation, is possible thanks to the cooperation of the vestibular organ of the inner ear, the ocular organ, the cerebellum, numerous deep sensory receptors located in the muscles, joints, and connective tissues, and the organs of hearing and touch.

The importance of the vestibular system in child development – pedagogical aspects

The tactile, vestibular, and proprioceptive systems are assumed to be of fundamental importance in a child's development. They begin to function very early on in a child's life, even during the prenatal period, and it is these structures that provide stimuli for the higher-order senses (Maas, 1998, p. 21), such as vision and hearing. After a baby is born, there is an intensive stage of the vestibular system integrating with other sensory systems. A child's physical activity plays a significant role in this process. It should be noted that even during intrauterine life, the vestibular system is constantly stimulated by the movements of the fetus, as well as the mother's daily physical activity. This stimulation should be continued in the early stages of a child's development, for example, through passive and active motor play with the child.

The connections between the vestibular system, the cerebral cortex, and the eyes and trunk muscles are believed to be extremely important for a child's learning processes. Coordination of the sense of sight and hearing with movement, balance, locomotion, and related emotions (such as the gravitational security mentioned above), proper reception of stimuli coming from the environment, and adequate feedback all rely on a properly functioning vestibular system. The entire learning process of the child in the first 15 months of life focuses on the development of the vestibular system (Hannaford, 1995, p. 156), which is crucial for the child's learning of new experiences and development of the gross motor skills, and is responsible for keeping the eyeballs in the optimal position for reading.

Dysfunctions of the vestibular system have been found to cause learning difficulties and can result in hyperactivity, developmental delay, autism and schizophrenia. A study by John Frank and Harold Levinson (as cited by Hannaford, 1995, p. 156) found that 94%–97% of children with dyslexia and learning difficulties had a medical problem with the cerebellar-vestibular system. Some disorders related to the child's physical behavior (problems with locomotion and motor coordination, such as motor awkwardness or clumsiness in performing basic daily activities of self-care, shoe-tying, and button-fastening), to their cognitive development (difficulties concentrating and paying attention, which can result in problems with writing, reading, and drawing) or their emotional development (an inability to cope with stressful situations or emotional lability), are difficult to diagnose and are often not associated with vestibular dysfunction in the first assessment. However, in such cases, there is most likely a problem with sensory integration. The vestibular system is considered by many neurophysiologists to be the coordinator of all sensory systems (Maas, 1998, p. 88).

The day-to-day behavior of children with vestibular disorders seems relevant tor school experience. When there is reduced or no motor stimulation, these children can quickly move from a state of consciousness to a state of unconsciousness, as a result of which they relatively often lose their balance and get into accidents (bumping into other people, falling, tripping, etc.). In addition, they are unable to sit still in a chair, so they fidget and rock in order to constantly stimulate the reticular activating system – and thus become a nuisance for teachers. Herein lies a paradox, namely, that children who clearly need movement (when immobile, when their body and head do not move, their brain activation decreases) are disciplined by teachers with comments such as "stop fidgeting," "sit still," or "sit up straight and pay attention." From the child's point of view, this is a contradiction in terms. Studies show that stimulation of movement and balance significantly help with concentration disorders and improve reading skills (Mosse, 1982).

Other serious disorders associated with dysfunction of the vestibular system include developmental dyspraxia, which refers to an inability to perform simple and complex motor tasks despite understanding instructions and having no neurological disorders (the so-called clumsy child syndrome). A child with dyspraxia performs movements inefficiently and slowly, while putting a lot of effort into the steps of the activity. Other symptoms are articulatory, linguistic, or graphomotor disorders, as well as problems mastering the basics of reading and writing (Szafron, 2022).

In summary, the vestibular system, together with the tactile and proprioceptive systems are of fundamental importance in child development. Dysfunctions of the vestibular system can result in learning disorders (reading and writing), dyspraxia, behavioral problems (failure to stay disciplined during lessons, inability to concentrate), inadequate responses to stress, and problems dealing with emotions.

Forest kindergartens

Forest kindergartens are atypical institutions, considered to be alternative forms of preschool education in Poland. Their history can be traced back to England (early 20th century) and Denmark (1950s), though it is believed that they originated in Scandinavian countries, who were their main propagators. The premise of forest kindergartens is that, regardless of the weather, the children spend most of their time outdoors in a designated natural area: a forest, meadow, clearing, etc. The proportion of time spent outdoors to time spent indoors is 80% to 20%. Children have the opportunity to realize their basic developmental biological need: the need for free, unhindered movement. During free play, they run, climb trees, navigate natural obstacles (fallen trees, streams, steep slopes, and hills), jump, crawl, swing on branches, and creep on the ground. They also experience "failures": they fall down and tumble. Forest kindergartens provide an excellent opportunity for them to hone their sense of balance. Free exploration of the diverse natural environment promotes the proper development of the vestibular and proprioceptive systems, which in turn enables the acquisition of motor coordination, the ability to plan movement in space, confidence, and fluidity of movement which is correlated with appropriate muscle tone and the maintenance of proper sensory integration (Nitecka-Walerych, 2019).

It would also be appropriate to note that, in general, a child's development, including physical development, is influenced by their predispositions and environmental conditions, related to the lifestyle of the entire family. Most "forest children" come from families with pro-environmental attitudes that implement multifaceted health-promoting measures in their daily lives. Consequently, it would be reasonable to assume that these children spend less time in the overstimulated virtual world and more time in the real world, where they have the opportunity for independent experience, both physical and sensory. Modern children are essentially sedated by the one-sided sensory stimuli offered by mass media: the distance senses (sight and hearing) are overexploited, while the near senses (smell, taste, touch, and balance) are blunted. As a human species, we are well on the way to losing our true relationship with the natural world.

Research

The aim of the study was to compare the ability of healthy children aged 5–6 years to maintain balance (and, indirectly, the efficiency of the vestibular system) during static and dynamic tests.

Study group. The research group was purposively selected among children attending traditional and forest kindergartens[2] in the Tri-City area. The criteria for selection were age (5–6 years), type of kindergarten (traditional and forest kindergartens), and accessibility (permission to participate in the study from parents and management). The study included 15 children from forest kindergartens (8 girls and 7 boys) and 27 children from traditional kindergartens (13 girls and 14 boys).

The selected forest kindergartens are located in forested areas, where the children stay in non-standard wooden facilities and in tents (Baza Marzeń [Dream Base], n.d.). In a typical daily schedule (7:45 a.m. to 5 p.m.), about eight hours are devoted to field activities. The main point of the day is expeditions to a forest, meadow, pond, or river, during which, in a playful atmosphere, the core curriculum of preschool education is taught (Minister of National Education, 2017). The length of the expeditions depends on the weather and the needs of the children. In the winter, they usually last up to 2 hours and are longer in the summer.

The selected traditional kindergartens are located in brick buildings in two districts of Gdańsk. They have gardens equipped with typical sports and recreational equipment (ladders, slides, sandboxes, and swings). The daily schedule for older children does not deviate from the standard one, in which it is recommended that at least 1/5 of the time at the kindergarten each week should be spent outside the facility: in a garden, park, or playground. In practice, this equates to 2 hours (on average on a weekly basis).

Methods. The children were tested for static and dynamic balance (Wytregovich, 2016). The tests for *static equilibrium* involved two similar trials. First, the children stood on their dominant leg, with their eyes open, then with their eyes closed. They stood shoeless, with their hands extended in front or to the side. In both trials, the time of maintaining balance in these positions was measured from the time the leg was pulled off the ground until balance was lost or until 30 seconds had elapsed.

Two trials were also used to study *dynamic equilibrium*. First, the child's task was to walk with their eyes open in any way they chose to along a wooden beam measuring 7 cm wide, 250 cm long, and 4 cm high. The arrangement of hands during this task was left up to the child. The time needed to walk the entire distance or the time after which the child touched a foot on the ground (which clearly indicated that the test was interrupted) was measured. At the beginning of the test, the child placed one foot on the beam (heel on the edge) and the other on the ground. On command, they would start walking and the measurement of their time (with a stopwatch) would

[2] For those who do not deal with the issues of alternative preschool education on a daily basis, I recommend the website of the Polish Forest Preschool Institute: https://lesneprzedszkola.pl/o-instytucie/.

begin. The second test was similar, though the variable was the technique of crossing the beam. This time the child was asked to walk over the same beam "toe to heel."

Before both trials, the children had time to familiarize themselves with the beam; they could touch it, stand on it, or walk around for practice. If a child wanted to improve their score, they were given a second opportunity. Caregivers were present during all tests.

In the statistical analysis of the data, the Mann–Whitney U test was used to examine the differences between the medians in the two groups. This test is the non-parametric equivalent of Student's *t* test for comparing two independent groups.

Results. I did not distinguish the subjects by gender in the statistical calculations, because there were no significant differences along gender lines in the children's ability to maintain balance. Table 1 shows the values of Mann–Whitney's U, on the basis of which I made statistical inference using the *z* (normal) distribution. In order to present the results of the study as clearly as possible (omitting further in-depth statistical calculations), I give the values of the two-tailed *p*-level corresponding to the calculated value of *z*, which indicates whether the two groups were statistically significantly different in terms of medians.

Table 1. Results of Mann–Whitney U test conducted on two independent groups: children from forest kindergartens and children from traditional kindergartens

			Standing on one leg, eyes open	**Standing on one leg, eyes closed**	**Free passage along the beam**	**Passage with a heel-toe step**
1	**Forest kinder-garten (n=15)**	Successful attempt	15	15	15	15
		Unsuccessful attempt	0	0	0	0
	Average		21,1000	12,7580	6,0640	10,9660
	Median (Mdn)		**19,1000**	**13,1000**	**5,8600**	**10,2000**
	Standard deviation		7,81610	6,31405	1,88354	3,39451
	Minimum		6,20	3,50	3,30	4,30
	Maximum		30,00	30,00	10,80	18,76

2	**Traditional kindergarten (n=27)**	Successful attempt	27	26	20	15
		Unsuccessful attempt	0	1	7	12
	Average		12,9889	5,4038	9,6550	16,0667
	Median		**10,2000**	**4,4500**	**8,2500**	**16,4000**
	Standard deviation		9,68994	4,02557	3,65535	2,98033
	Minimum		2,40	1,00	4,80	9,40
	Maximum		30,00	15,90	16,90	21,80

The results for standing on one leg with eyes open among the children from forest kindergartens (PL) ($Mdn = 19.10$) were better than those of the children from traditional kindergartens (PT) ($Mdn = 10.20$). The difference was statistically significant ($U = 98.50$, $z = -2.75$, $p = 0.006$). The results for standing on one leg with eyes closed among the PL group ($Mdn = 13.10$) were better than those of the PT group ($Mdn = 4.45$). The difference was statistically significant ($U = 53.50$, $z = -3.83$, $p < 0.001$).

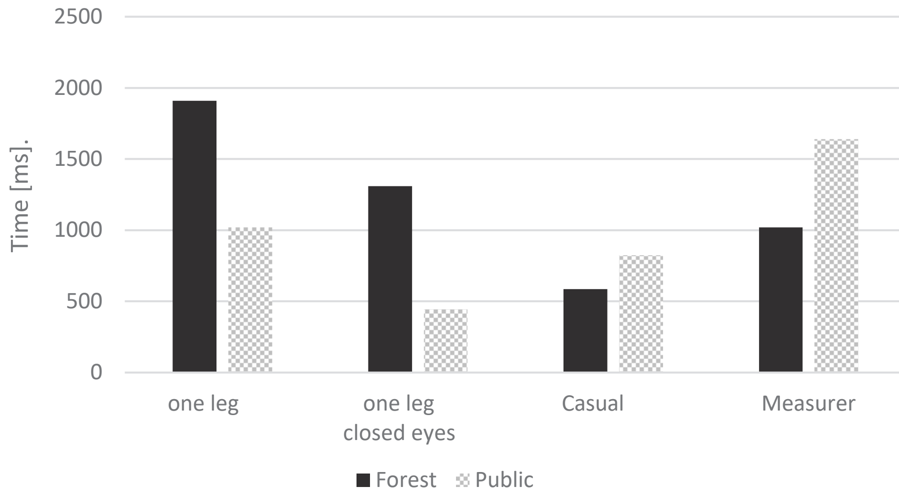
The free-pass test scores of the PL group ($Mdn = 5.86$) were better than those of the PT group ($Mdn = 8.25$). The difference was statistically significant ($U = 49.00$, $z = -3.37$, $p = 0.001$). The performance on the toe-to-heel step test in the PL group ($Mdn = 10.20$) was better than that of the PT group ($Mdn = 6.40$). The difference was statistically significant ($U = 26.00$, $z = -3.59$, $p < 0.001$).

The results clearly indicate that in all tests, for both static and dynamic balance, the children from forest kindergartens obtained better results than the children from traditional kindergartens. Also, all the differences in performance turned out to be statistically significant. According to the median scores, the children from forest kindergartens maintained their balance almost 9 seconds longer while standing on one leg with their eyes open and 8.6 seconds longer while standing on one leg with their eyes closed. In addition, the “forest children” crossed the beam 2.4 seconds faster freely and 6.2 seconds faster with the “heel-toe” step.

It is noteworthy that even when only those children who successfully completed the test of walking with a “heel-toe” pattern (without falling off the beam [PL = 15, PT = 15]) were included in the statistical calculations, the children from forest kindergartens obtained statistically significantly better results in three tests: standing one-legged with eyes closed, walking freely on the beam, and walking on the beam with a "heel-toe" step.

The results of the study are presented in a graph in Figure 1.

Figure 1. Static and dynamic test results based on median values [ms]



Discussion of results. When analyzing the results of the study, one may note that the children from forest kindergartens obtained better results in all trials than those from traditional kindergartens, and that the results were statistically significant in all trials. In addition, 12 (44%) children from traditional kindergartens failed in their attempt to walk across the entire beam with a measuring step, as did 7 (26%) with a free step. All children from forest kindergartens (N = 15) succeeded in both attempts. These differences can be explained by considering at least two aspects:

1. An important factor is the type of facility the children attended. Forest kindergartens are more conducive to developing the sense of balance than traditional kindergartens.
2. It is reasonable to assume that the lifestyle of the families of "forest children" was also a differentiating variable.[3]

When testing balance, attention should be paid to the development of the child's postural control ("egocentric" strategy for 2–6-year-olds and "exocentric" for 7–10-year-olds), as well as the repetition of trials (Sobera, 2010, p. 17). Three trials are recommended, one after another without long breaks (Hertel et al., 2006).

[3] While this is something I have not directly researched, I have obtained information about families when collecting data from educators in forest kindergartens.

Some reference for assessing static balance (standing one-legged with eyes open and closed) can be found in a study conducted by Cillin Condon and Kate Cremin in 2014 on 534 children aged 4–15 years.[4] The findings of this study have been taken as standards (Condon & Cremin, 2014).

Children with learning and behavioral problems should be looked at in terms of vestibular system disorders, such as dyspraxia.

Summary and Conclusions

General pedagogical conclusions: The proper psychophysical development of a child requires a multifaceted, harmonious influence on all spheres of development and the synergy among all perception channels. The postmodern world is not conducive to nurturing biologically construed physical fitness,[5] which is dramatically declining among Polish children, as evidenced vividly by the results of a study conducted on a population of 50,000 children and adolescents by Janusz Dobosz of the Academy of Physical Education in Warsaw (Nauka w Polsce, 2016). The physical competencies related to fitness motor skills are considerably declining in favor of the mental competencies related to information acquisition. Inconsistencies and imbalances in individual development, as well as SI disorders, could lead to the situation that Margaret Chan warned against in 2004: "the current generation of children may be the first in a long time for which life expectancy will be shorter than that of their parents" (Nauka w Polsce, 2010).

Practical and educational conclusions: Intentional human movements are the most complex form of motor activities. They require integration of all the senses, in which the vestibular system plays a coordinating role. Some specific recommendations can be made based on the findings of this study:

1. Children should spend as much time as possible outdoors as often as possible.
2. Outdoor active leisure activities (variable ground) are preferred.
3. Exercises/play that require relatively difficult coordination should not be avoided. On the playground, ladders, swings, merry-go-rounds, etc. should be used – in general, equipment that allows changing body positions.
4. In working with preschool children, conventional and unconventional equipment should be used. For balance exercises, balancing platforms, sensory cushions, balance training equipment, balance pads, etc. are recommended.

[4] The study involved children aged 4–15 years and included seven tests, including three one-legged trials: on a hard surface with eyes open and closed, and on a foam surface with eyes open.

[5] The fitness of the postmodern body can be interpreted as the ability to receive sensations and consume experiences.

5. During movement classes, exercises in isolated positions (sit-ups and core exercises) and unstable positions (standing on one leg), on stable (floor) and unstable (sponge) surfaces, and with eyes open and closed should be used.

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