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Does vestibular input affect body posture alterations?

Czy bodźce przedsionkowe wpływają na nieprawidłowości posturalne?

A – preparing concepts
B – formulating methods
C – conducting research
D – processing results
E – interpretation and conclusions
F – editing the final version

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Abstract

Introduction: The control of body posture is based on the integration of polisensoric stimuli and conscious body image. Previous studies on the influence of vestibular functioning on postural disturbances have been inconclusive. The purpose of this paper was to investigate the effect of vestibular input on the body posture.

Material and methods: We examined 65 healthy children (40 girls, 25 boys) at school age 7-12 years. Children were assessed using Kasperczyk Visual-point Method and Southern California Postrotary Nystagmus Test. Statistical analysis was carried out using Statistica software. Mann-Whitney U test and Spearman test were used to determine dependency between quantitative and qualitative characteristics. A $p<0.05$ was considered statistically significant.

Results: The greatest number of postural deviations was observed in the setting of the head (100%) and shoulders (72%). The median Southern California Postrotary Nystagmus Test score corresponded to the published standards. There was a significant association between lumbar hyperlordosis and the results of postrotatory nystagmus following rotation to the right ($p=0.033$).

Conclusions: The fact that there was a significant association between an increased lumbar lordosis and postrotary nystagmus might indicate that the assessment and treatment of postural abnormalities should consider vestibular system examination. This study confirmed that a slight imbalance in the activity of vestibular might lead to postural disturbances.

Key words: **children, posture, postrotary nystagmus, vestibular input**

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Streszczenie

Wstęp: Kontrola postawy ciała opiera się na integracji bodźców multisensorycznych oraz świadomym poczuciu obrazu własnego ciała. Poprzednie badania oceniające wpływ funkcjonowania układu przedsionkowego na zaburzenia postawy ciała nie były jednoznaczne. Celem naszego badania była ocena wpływu bodźców przedsionkowych na postawę ciała.

Materiał i metody: Przebadaliśmy 65 zdrowych dzieci (40 dziewcząt, 25 chłopców) w wieku szkolnym 7-12 lat. Dzieci oceniano za pomocą Metody Punktowania według Kasperczyka i Południowo–Kalifornijskiego Testu Oczopląsu Porotacyjnego. Analizę statystyczną przeprowadziliśmy za pomocą oprogramowania Statistica. Test U Manna -Whitneya i test Spearmana wykorzystaliśmy do określenia zależności między zmiennymi ilościowymi i jakościowymi. Wartość p <0,05 uznaliśmy za statystycznie istotną.

Wyniki: Największą liczbę nieprawidłowości zaobserwowaliśmy w ustawieniu głowy (100%) i barków (72%). Mediana dla Południowo–Kalifornijskiego Testu Oczopląsu Porotacyjnego odpowiadała opublikowanym standardom. Wykazaliśmy istotną zależność między hiperlordozą lędźwiową a wynikami Południowo–Kalifornijskiego Testu Oczopląsu Porotacyjnego dla pomiaru w prawo (p=0,033).

Wnioski: Obecność zależność pomiędzy zwiększoną lordozą lędźwiową a oczopląsem porotacyjnym, może wskazywać na potrzebę oceny układu przedsionkowego w przebiegu terapii nieprawidłowości posturalnych. Niewielka dysproporcja w aktywności układu przedsionkowego może prowadzić do zaburzeń posturalnych.

Słowa kluczowe: **dzieci, postawa, oczopląs porotacyjny, bodźce przedsionkowe**

Introduction

The proper spinal alignment and good body posture are defined by researchers in many ways. One's posture is a form of communication and a source of knowledge well-being about the individual's well-being. For example one's posture provides information such as: the wish of an individual to increasing or avoiding the interaction, the willingness of an individual to build a closer and more direct relationship with another person, the emotional reaction to another person, the individual's level of comfort with the interaction and their self-confidence, and the individual's status or dominance [1-3]. More and more frequently postural abnormalities affect children and youth and seem to contribute to the social problems of industrial civilizations [4]. Despite efficient adaptive antigravitational mechanisms, young organism cannot keep up with the progress of civilization. The increasingly rapid pace of life triggers the deviation of correct body posture [4]. Neglected and untreated postural habits lead to posture alterations, which influence the psyche and soma of a child. The presence of postural abnormalities can lead to pain complaints, which may restrict one's physical activity [5]. The sensory processes (vision, tactile, vestibular system), movement and body image are integrated for controlling overall body posture and spinal alignment The integration of external, proprioceptive and interoceptive stimuli generate in the central nervous system, a coherent picture of the various parts of the body, the body as a whole and the body's interaction to the environment [6-9]. In recent years, there has been an increasing interest in the role of vestibular system on controlling the body posture [7-9]. According to imaging studies by Pfeiffer et al., cortex activity during vestibular stimulation, identified in complex regions of cerebral cortex, coincides with cortical representation for vision, movement, somatosensation, and proprioception [8]. Vestibular signals are integrated with visual, motor, and sensory stimuli. Thus, multisensory processing of vestibular signals is essential for generating a coherent self-consciousness body image in the central nervous system. Furthermore, the otolith organs are especially engaged in spatial whole–body representation with respect to external environment [7,8]. The correlation between visual and motion perception is crucial element of effective activation of postural stability [7,8]. It should be emphasized that, the vestibular system supports balance, postural control, and mobility [6-9].

The purpose of this study was to investigate the effect of vestibular function on the body posture. On the basis of the literature and the knowledge based on the anatomy of the nervous system, we hypothesized that "under-responsiveness" or "over-responsiveness" of the postrotary nystagmus causes an asymmetry of body posture and a deterioration of the position of the head, shoulders, the extent of thoracic kyphosis and lumbar lordosis. Previously, few studies on the influence of vestibular functioning on body posture alterations have been inconclusive, therefore investigating this topic of the research seems to be justified [10,11].

Materials and Methods

The study was carried out between January and June 2015 and took place in the Mosina Community. The study group consisted of 65 consecutively selected healthy children (40 girls, 25 boys) aged 7 to 12 years. The average age was 9 years and 4 months (1 year and 7 months). Participants were divided into 3 groups according to age: 7-9 years old (33 children), 10-12 years old (32 children). Children with vestibular, neurological, orthopedic, or sensory disorders, medications affecting psychomotor activity, or reported dizziness were excluded from this study.

The examination of participants included the measurement of body posture and Postrotary nystagmus.

Kasperczyk Visual-point Method was used to evaluate the body posture of children. It is the visual–analytical assessment of individual parameters of body posture which is widely used in screening examination of school aged children. Each element of the child's body posture was measured in coronal, sagittal, and transvers planes while a child was in relaxed standing 1.5–2 meters distance from researcher. Visual assessment was supported by palpation. The following elements were assessed: the position of the head, shoulder girdle including scapula, abdomen, the shape of chest, thoracic kyphosis, lumbar lordosis, the angle of knee (genu valgum or genu varum) and foot arch (the Clarke's angle was also measured). Each parameter of body posture was scored on 5–point scale. The value of "0" indicated the correct state, 1- the slight deviation, 2 or 3- the significant deviation, 4 or 5–the structural deviation. The sum of the obtained points determined the quality of body posture.

Vestibular system parameter was tested objectively with Southern California Postrotary Nystagmus Test (SCPNT) [12, 13]. The SCPNT was performed by qualified Sensory Integration therapist who holds a required license to practice and analyze the SCPNT. For the examination a stopwatch and a rotating board (50cm) were used and they were placed in front of the white, plain wall to minimize distraction factors. Every child was instructed verbally about the proceeding and the possibility of its termination. The child was seated cross-legged on the rotating board with the head flexed forward 30° from the horizontal position which allowed to maximize stimulation of semicircular canal. The relevant part of the test was administered by first rotating the child 10 rotations to the left in 20 seconds at a constant swiftness 1 rotation in 2 seconds and then stopping the child [14,15].

According to the instruction, on the command "stop" child looked directly at the wall, which allowed the examiner a visual observation and the measurement of postrotatory nystagmus. After a 1-minute rest, the procedure was repeated again by rotating the child 10 times to the right in a similar manner. If the child demonstrated loss of the balance, nausea or other worrying signs of discomfort, the examination was stopped [14,15].

The resulting vestibular response was recorded as "normal" (duration of nystagmus 8-12s), "under-responsiveness (<8s)", or "over- responsiveness (>12s)" depending on the occurrence time of the observed postrotatory nystagmus [14,15].

While there are controversies in the literature about the SCPNT, it is a natural, cheap and noninvasive method of vestibular stimulation and a credible indicator of vestibular system functioning [12,13]. However, it should be noticed that SCPNT does not evaluate all aspects of the vestibular system [12,13].

Ethical Statement

The relatives of examined participants received in-depth information on the aim of the study and legal guardians gave informed consent for inclusion children in the study. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Local Ethics Committee for Poznan University of Medical Science.

Analysis of Data

All statistical analyses were performed with STATISTICA 8.1 (StatSoft). In respect to statistical quantitative features, we determined minimal and maximal values, median and range. Regarding the qualitative features, we gave the number of units that belong to described categories of a given feature respective percentages. The Spearman's rank correlation coefficient (rS) was applied to determine dependency between quantitative characteristics. Mann-Whitney U test was used to compare two independent samples with respect to quantitative variables. A $p<0.05$ was considered statistically significant.

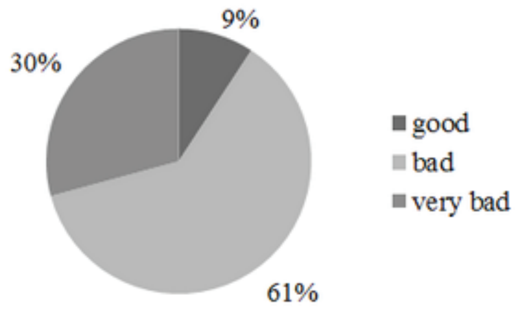

Fig. 1. Evaluation of body posture

Results

Body posture

The Kasperczyk's test demonstrated that only 9% of children had good body posture, 61% presented with bad body posture, and 29% had very bad posture (Figure 1).

The most common postural abnormalities detected were related to the position of the head. The percentage of lack of alignment in various posture parameters is presented in the Table 1.

Tab. 1. The frequency of incorrect elements of the body posture occurrence with the consideration of sex

Sex	Head	Shoulders	Scapula	Funnel chest	Pigeon chest	Abdomen	Increased kyphosis	Reduced kyphosis	Increased lordosis	Scoliosis	Genu varus	Flat foot
Girls	40 100%	37 93%	33 83%	27 68%	2 5%	32 80%	2 5%	21 53%	21 53%	9 23%	19 48%	25 63%
Boys	25 100%	10 40%	11 44%	20 80%	1 4%	20 80%	9 36%	10 40%	4 16%	10 40%	15 60%	21 84%
Total	65 100%	47 72%	44 68%	47 72%	3 5%	52 80%	11 17%	31 48%	25 39%	19 29%	34 52%	46 71%

Postrotatory nystagmus

The Boys in this study presented with vestibular under-responsiveness twice more often than girls. Girls presented with a tendency for vestibular over-responsiveness (Table 2).

Tab. 2. SCPNT results in relations to side of the following rotation and sex

	Duration of the nystagmus following left rotation			Duration of the nystagmus following right rotation		
	< 8s	> 12 s	8 – 12 s	< 8s	> 12s	8 – 12 s
Girls	10 25%	14 35%	16 40%	10 25%	12 30%	18 45%
Boys	15 60%	5 20%	5 20%	14 56%	5 20%	6 24%
Total	25 39%	19 29%	21 32%	24 37%	17 26%	24 37%

The postrotatory nystagmus scores after left rotation varied between 4.18s–26.69s and at right between 2.38s–31.41s.

The median SCPNT score corresponded to the published standards of SCPNT (Table 3).

Tab. 3. The obtained time of SCPNT in relations to side of following rotation and gender

	Girls		Boys	
	Rotation to the left (s)	Rotation to the right (s)	Rotation to the left (s)	Rotation to the right (s)
Median (min-max*)	10.75 (4.45-20)	11.394 (5.53-31.41)	8.749 (3.196-26.68)	8.289 (2.38-24.34)

Relationship between body posture and vestibular response

On the basis of the literature, we performed comparative analysis of body posture parameters: the position of the head, shoulders, the extent of thoracic kyphosis and lumbar lordosis with the results of SCPNT [16,17]. The obtained results are presented in Table 4.

Tab. 4. The correlation between SCPNT results and faulty body posture parameters

The duration of nystagmus following rotation side	Head protraction	Asymmetry or protraction of shoulders	Flattened thoracic kyphosis	Increased thoracic kyphosis	Increased lumbar lordosis
Left	rS=0.66 p=0.148	rS=0.85 p=0.604	rS=0.28 p=0.120	rS=1.00 p=0.664	rS=1.00 p=0.432
Right	rS=0.30 p=0.083	rS=0.46 p=0.804	rS=1.00 p=0.707	rS=1.00 p=0.515	rS=0.62 **p=0.033**

There was a statistically significant association between increased lumbar lordosis and the results of SCPNT following rotation to the right (p=0.033). However, there was no significant association between increased lumbar lordosis and duration of postrotatory nystagmus following left rotation (p=0.4327). It is probably because of differences in the number of children with over-responsiveness or under-responsiveness between the right and left measurements.

Discussion

Previous studies have reported alterations in children's' body posture and it appears that this is a very common problem. In our research, the majority of children in the study group had bad to very bad body posture (91%). This is consistent with previously screenings of school aged children [18,19]. Body posture disturbances, occurred in 90% of those assessed (children and adolescents) in the period from 2004 to 2006 among in one of the nationwide study [18,19].

The School environment plays an important role in forming postural habits such as correct sitting postures. Hours spent in forward flexed position at school desk, static loading of the spine, limitations in physical activities are common risk factors of developing postural abnormalities. Lack of prophylaxis and neglecting postural defects may lead to limitation of physical activity, back pain and malformation of posture [20].

Alterations in body posture such as abnormal cervical spine position (for example lack of cervical lordosis) lead to hyperactivity of deep cervical flexors which are related to not only deformities in neck but also in shoulder girdle, head (protraction of head), kyphosis [20-22]. We found that the deviation of head position affected almost all children and in the setting of shoulder girdle over it affected 70% of children. It should be noted that in the future such a posture as the forward-head and rounded-shoulder posture may play a role in the development of shoulder pain and pathologic conditions [21,22]. For this reason, improving children's body posture should be a prophylactic aim of school teachers [21,22].

Another parameter of body posture which was altered very often was foot arch (71%). The most frequently observed abnormality in this stud was the flat foot which occurred in the group of 7–9-year-olds. Literature suggests that the majority of preschool children commonly present abnormalities in foot arch [23]. The cause appears to be related to the occurrence of under layer fat masking foot arch which is physiological for this period of the ontogenesis and posturogenesis [24,25].

The developing foot arches are adaptable and change over time [24]. We noted a decrease in the incidence of flat foot in children over 10 years old. The age above 10 years refers to improvements in forming foot arch or development of increased foot arch during puberty. The foot spontaneously evolves to the proper physiological shape of the adult's foot at around 10 years of age [25]. Furthermore, we observed boys presented more often abnormal foot posture than girls. Similarly, Pfeiffer et al. in the sample group of 200 children and Pauk et al. who examined 80 children found that boys had a significant greater tendency for flat foot than girls [26,27]. It can result from the general process of foot morphology and development. Boys' development of feet occurs later than girls' [28]. Moreover, in the case of men, the period of the growth of their feet is longer [28,29].

Vestibular system is responsible for a wide range of postural and oculomotor functions, consciousness of body localization and head movement in space.

The disturbance of vestibular signals might lead to postural, motor, or oculomotor asymmetry [8]. Because of complexity of vestibular system organization and numerous levels of integration with the central nervous system and many connections with other sensory systems, the roll of vestibular system is also complex [30]. Additionally, this fact contributes to the limitation of clinical tests evaluating the assessment of pure vestibular system, especially its impact on body posture [31].

At least two types of examinations of peripheral vestibular system stimulation technique are described: natural and artificial. Linear and rotational acceleration which are obtained by passive body rotation or translation and using G–forces constantly impact on body are natural way to stimulate the vestibular system. In contrast, mono– or bipolar electrical stimulation (Galvanic Vestibular Stimulation), thermal irrigation of ear canals (Caloric Vestibular Stimulation), auditory stimulation by clicks and short–tone burst is classed as the artificial methods of vestibular system [8].

There were no differences in the results of SCPNT compared to the side of following rotation. We reported that median duration of postrotatory nystagmus differed form results in the Ayer‘s study [31, 32]. One of the reasons of difference is the fact that Ayres assessed the children with learning disabilities, whereas the presented study conducted among healthy children without any reported difficulties in learning. However, similar observations were made by Rendle-Short who assessed various techniques diagnosing the postrotatory nystagmus [31,32]. It is probably because Rendle-Short evaluated the postrotatory nystagmus among the population of healthy children as well.

We found that there was a significant correlation between an increased lumbar lordosis and the results of SCPNT at the measurement to the right side. This is consistent with other researchers’ studies and the knowledge based on the anatomy of the nervous system [8,33].

By regulating the skeletal muscle tone, the central vestibular system pathways, mainly the lateral vestibulospinal tract, play an important role in the correct postural muscle activity and maintaining correct body posture [6-9]. The vestibulospinal tract which is the neural tract starting primarily in lateral vestibular nucleus, partly in the inferior vestibular nucleus and the medial vestibular nucleus runs in front of and ends in the anterior part of the spinal cord where motor representation is located [7,33]. Moreover, the vestibulospinal tract together with the anterior cortico-core path and cortico-striatal path form the medially descending pathways that are responsible for alpha motor neurons stimulation which innervate spine extensor [6-9].

Ardic, Latt and Redfern found that there is a relationship between vestibular stimulation and paraspinal muscle stimulation [34]. They showed that surface electromyographic signals from paraspinal muscles were activated by galvanic vestibular stimulation [34]. A number of other studies have showed that there may be a correlation between vestibular system and erector spinae muscle which responses to electrical vestibular stimuli appear to be organized together with the lower limb muscle responses during maintaining balance in standing position [34-36]. The latencies associated with these responses are consistent with a progressively descending vestibular signal, occurring earlier in paraspinal muscles (~61 ms) [37,38].

Study limitations

The limitations of the present study include but are not limited to: the study group consisted of 65 participants and the group sample sizes were not equal. Unfortunately, the Kasperczyk Visual-point Method is a subjective tool that has not been assessed for validity and reliability. However, it is a cheap tool, easy and non-invasive tool that is used in the clinical setting and screening research. Southern California Postrotary Nystagmus Test is based on movement stimulation and only evaluates the vestibulo-ocular reflex. We are aware that those limitations might have influenced the study results. Therefore, further studies using objective tools and tools that evaluate more aspects of the vestibular system are needed to expand the results of our research.

Conclusions

There was a relationship between an increased lumbar lordosis and postrotary nystagmus. Our result shows that the effectiveness of physical therapy and assessment of children may require attention to postural alignment in general but it should also consider vestibular system examination. We pointed out that, a slight imbalance in the activity of vestibular might leads to postural disturbances.

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