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ORIGINAL ARTICLE

The relationship between primitive reflex profile and development of vestibular maturity in early school years

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Abstract

Previous research indicates that vestibular perception is related to muscle tone regulation. Muscle tone influences auditory and visual perception. Research findings suggest that the functioning of primitive reflexes affects the maturation and condition of the vestibular organ. The goal of the study is to examine whether the primitive reflex profile can be influenced by appropriate exercises and whether inhibition of persistent primitive reflexes affects vestibular functions. The sample consisted of 506 children aged 5–8 years (237 boys and 269 girls). In kindergartens and schools, 443 participants performed reflex inhibition exercises 3–5 times a week for 7 months. A control group of 63 individuals attended only regular PE lessons. Input and output results were compared using the Mann-Whitney test, and effect sizes were calculated. Input primitive reflex profile and vestibular maturity: not significant. Effect size: primitive reflex profile: 0.109; vestibular maturity: 0.052. Output: primitive reflex profile: $p < 0.001$; vestibular maturity: $p < 0.001$. Effect size: primitive reflex profile: 0.572; vestibular maturity: 0.306. The results obtained with appropriate non-parametric measurements show that children participating in the intervention achieved statistically significantly higher scores in all tested variables of primitive reflex profile and vestibular maturity compared to the control group. The children in the intervention group showed significant improvement in both primitive reflex profile and vestibular maturity: $p < 0.001$; effect size: primitive reflex profile: 0.714; effect size: vestibular maturity: 0.664; while there was no significant improvement in the control group: effect size primitive reflex profile: 0.01; vestibular maturity: 0.06. We found a strong, significant correlation between the inhibition of primitive reflexes and vestibular maturity: r=0.000; rho (ϱ)=0.000. Based on this study we recommend incorporating these exercises into physical education for 5–8-year-old children.

Keywords: sensorimotor development · vestibular perception · primitive reflexes · motor control · motor coordination

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Introduction

Previous research indicates that vestibular perception is related to muscle tone regulation (Markham, 1987). Muscle tone affects auditory and visual perception, which has a significant impact on basic learning skills (Stephens-Sarlós & Stephens, 2024). Research findings suggest that functioning of primitive reflexes affects the maturation and condition of the vestibular organ (Niklasson, 2012). The goal of the study is to examine whether the primitive reflex profile can be influenced by appropriate exercises and whether inhibition of persistent primitive reflexes affects vestibular functions.

The vestibular system is a phylogenetically ancient sensorimotor system whose function is to detect and compensate for movement. Special hair cells convert mechanical forces of angular and linear accelerations into neural discharges. These motion signals operate the vestibulocular and vestibulospinal reflexes, which stabilize vision, control head position and body posture, and maintain balance (Smith et al., 2023). In addition, it is essential for the functioning of cognitive functions (Angelaki & Cullen, 2008).

The vestibular organ in the inner ear reaches structural maturity at birth, but its central connections continue to be refined until adolescence. This development is dependent on vestibular stimulation, or vestibular experience. Research shows that vestibular function, influenced by experience and epigenetic factors, goes beyond mere control of body position, navigation, and stabilization of the head and vision. It also affects cognition, emotions, the autonomic nervous system, and hormonal balance. To emphasize the importance of appropriate vestibular stimulation, Božanić Urbančič et al. performed a comprehensive literature review of the effects of vestibular function on body homeostasis, cognition, and emotions (Božanić Urbančič et al., 2023).

Research suggests that vestibular information also has an impact on emotions (Bigelow et al., 2020). A link between the function of the vestibular system and cognitive function has also been demonstrated (Wiener-Vacher et al., 2013). El Khiati et al. elucidated the correlation between vestibular function and hormonal regulation (El Khiati at al., 2023) as well as the connection between vestibular function and memory (Mukkadan, 2017). In earlier research we found that children should have an appropriate level of vestibular maturity when they start school because of the impact it has on their visual and auditory perception, which affects their learning abilities (Sarlós, 2021).

For the reasons outlined above, it is very important that children enter primary school with an appropriate level of neurobiological maturity. It is essential because the functioning of the vestibular organ affects not only the performance of fine and gross motor movements, but also auditory and visual perception. As the presence of certain residual primitive reflexes may be related to vestibular function, it is legitimate to ask whether age-appropriate vestibular function can be achieved by exercises that inhibit reflexes. We wished to study this question using group-based development in an institutional setting.

This experimental study aimed to analyze the relationship between the presence of primitive reflexes (symmetrical neck tonic reflex, asymmetrical neck tonic reflex, Galant reflex, Moro reflex, tonic labyrinth reflexes, and grasping, sucking and rooting reflexes) and vestibular function using a school-based sensorimotor training program developed by the researchers. It also sought to answer the question: does inhibition of primitive reflexes improve vestibular function? The study also compared the results of the test group with those of a control group that did not receive any specific training.

In line with the objectives of this work, it was hypothesized that the primitive reflex profile could be developed through specific primitive reflex inhibitory exercises, resulting in significant improvements in vestibular function in children aged 5-8 years who participate in the program for at least six months. These differences will be reflected in improved primitive reflex and vestibular indices compared to the untreated control group.

Method

The study sample consisted of children enrolled in kindergarten and elementary school within Hungary. In the initial phase of recruitment, institutions were selected systematically from the database of the Educational Office, with every tenth institution chosen via random selection and subsequently invited to participate via email. Subsequently, from the pool of 98 institutions expressing willingness to participate, 36 were randomly selected, ensuring equitable territorial distribution and representation of various institution types (e.g., Budapest, county seat, city, village, state, municipal, ecclesiastical, and foundation). Rigorous attention was devoted to maintaining the sample's representativeness.

Regarding institutional location, 21% were situated in villages, 34% in cities, 28% in county seats, and 16% in the capital. In terms of ownership, most children (72%) attended state/municipal institutions, while 25% attended ecclesiastical institutions and 3% attended foundation institutions. Ethnographic data were not collected during the study.

The total participant pool comprised 506 Hungarian children aged 5–8 years, consisting of 237 boys and 269 girls, with 443 assigned to the intervention group and 63 to the control group. Given inherent complexities in sampling, achieving perfect representativeness proved unattainable. Nevertheless, the study aimed to mitigate this limitation by employing random selection techniques and ensuring inclusion of participants representing diverse demographic groups within the 5–8-year-old population. Notably, careful consideration was given during sampling to involve schools with varied characteristics, thereby affording each institution an equitable opportunity for study inclusion.

The study included groups from both kindergarten and school settings. Since perfect representativeness was challenging, we first employed random selection from all relevant institutions within the country and then ensured that the selected institutions represented a wide variety of geographic locations and types of institutions (state, municipal, ecclesiastical, and foundation).

In kindergartens and schools, 443 participants performed reflex inhibition exercises 3–5 times a week for 6–8 months. The 63 participants in the control group engaged in standard kindergarten physical education sessions and developmental activities. The inclusion of the control group was based on voluntary participation. Regrettably, engagement in the control group lacked appeal among teachers, parents, and children within the institutions, whereas enthusiasm for participation in the training program was notably higher.

The children of in the control group attended four or five physical education classes per week, according to the institution's implementation of the National Curriculum. Some children also participated in extracurricular sports training. It is important to note that the control group did not partake in targeted exercises aimed at sensorimotor or primitive reflex inhibition.

Ethical consideration

All parents and children provided their informed consent by signing the respective consent forms. Additionally, consent forms were signed by all teachers and school leaders from the participating institutions. Given that the sensorimotor development program was integrated into the physical activity curriculum of the involved schools and the data collected could not be linked to individual children, the university's ethics committee deemed additional ethical clearance unnecessary. Nevertheless, the research protocol adhered strictly to the ethical guidelines outlined in the British Psychological Society Code of Human Research Ethics (British Psychological Society, 2021) and the research principles involving human participants as per the Helsinki Declaration (World Medical Association, 2013).

Conceptualizations of the training program

The training program is specifically designed for children aged 5–8 years. It comprises 120 sensorimotor training sessions, encompassing three primary categories of exercises: inhibitory activities targeting primitive reflexes, sensorimotor tasks, and children's structured games. Each session typically lasts between 15 to 20 minutes. The training regimen incorporates both recurrent components, such as reflex integration exercises, and dynamically evolving elements, including sensorimotor movement coordination enhancement activities. We recommended conducting 3–5 sessions per week, with the overall duration of the program spanning 6–8 months depending on the number of sessions per week.

Detailed guidelines outlining the content of the group exercise sessions were provided to the supervising teachers in advance. These exercises predominantly focus on inhibiting primitive reflexes and were to be administered daily.

Calculation

Test tools

The reflex profile assessment utilized methodologies delineated in existing literature (Brandes, 2015; Fiorentino, 1981; Melillo, 2018; The Unlock Brilliance Way, 2016). In the evaluation of vestibular function, six distinct tests were employed, including static balance assessments encompassing closed and open-eye "flamingo tests" on both left and right feet (a total of four tests), a dynamic balance examination referred to as the "Tightrope walker test", and an assessment of left-rotated post-rotation nystagmus.

The investigation examined the impact of a training program (intervention) on children in comparison to their hypothetical outcomes had they not engaged in the program (control). In achieving this objective, various preparatory steps were undertaken, as outlined by Sági and Széll (2015). These steps involved the development of training materials, selection of measurement instruments, identification of the target groups (both experimental and control), and determination of the program's duration. To ensure the effective implementation of the program, efforts were made to adequately train the participating teachers for executing the training regimen and conducting baseline and post-intervention measurements. It is noteworthy that the involvement of teachers in the study was not voluntary but rather mandated by the administrative heads of their respective institutions. Furthermore, meticulous measures were taken to conduct the measurements under controlled conditions to mitigate any potential external factors.

Results

Given the ordinal nature of the data, non-parametric methods were employed for statistical analysis, including the Mann-Whitney U test, the Wilcoxon test, the Kruskal-Wallis statistics, and Spearman's rank correlations. In each instance, both effect sizes and significance levels were computed. Additionally, appropriate effect sizes were identified for all analyses concerning differences and relationships. Due to the ordinal nature of the variables, the Cliff's Delta effect size was determined, a measure commonly utilized in non-parametric analyses (Macbeth et al., 2011). Statistical analyses were conducted using SPSS and Excel.

Due to the smaller sample size of the control group in comparison to the experimental cohort, it became imperative to conduct an effect size analysis to facilitate the interpretation of the findings. Regarding sensorimotor development, the effect size yielded a value of 0.012. This outcome suggests that the disparity between the experimental and control groups was minimal.

Table 1. Average of percentages expressing reflex profile and vestibular development and its components in input and post-development output measurements for children in the experimental groups

Variable	Input measurement average (%)	Output measurement average (%)	Z value of the Wilcoxon test	Significance level of the Wilcoxon test	Effect size
Reflex profile	53.4	75.9	-15.024	$p < 0.001$	0.714
Vestibular development	40.1	56.7	-13.984	$p < 0.001$	0.664

The data in Table 1 show that the post-development measures of the components of sensorimotor development and the sensorimotor development indicator itself are significantly higher than the input measures. All comparisons show a significant difference at the $p < 0.001$ level. The effect sizes for the Wilcoxon test are explicitly large from 0.7 for three variables and, importantly, for the aggregate sensorimotor development variable, but the two effect sizes smaller than 0.7 are also close to this cut-off. This is one of the most important findings of the empirical research. Already these data show that the development was successful, with substantial increases in primitive integration and vestibular functioning.

To exclude the possibility that the development could have been caused by spontaneous maturation alone, we compared the results of the children in the experimental and control groups, as shown in Table 2. After 6-8 months the children in the control groups showed no change in reflex profile or vestibular maturity between the input and output measurements. None of the differences are significant, and the effect sizes do not reach 0.1. This result shows that without development, the spontaneous maturation of the children over about half a year was negligible. In comparison, the strong significance of the changes in the experimental groups, and in particular the significantly higher values of the effect sizes in the experimental groups, is quite convincing. It should be noted, however, that since the descriptive statistical test on the larger sample found that there is maturation from one year to the next without developmental intervention, we have to assume that the children in the control group also made progress during the six months, but the extent of this progress did not reach the level of statistical significance and the effect sizes are very small.

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Table 2. Average of percentages expressing reflex profile and vestibular development and its components in input and post-intervention output measurements of children in the control group

Variable	Input measurement average (%)	Output measurement average (%)	Z value of the Wilcoxon test	Significance level of the Wilcoxon test	Effect size
Reflex profile	48.3	49.4	-0.228	n.s.	0.01
Vestibular development	40.4	43.4	-1.460	n.s.	0.06

We now show the results of comparing the two groups separately for the input and output measures, comparing the two independent samples using the Mann-Whitney test, and calculating the effect sizes. These are presented in Table 3.

Table 3. Comparison of sensorimotor development and component scores of children in the experimental and control groups for the input and output measures, Mann-Whitney test, and effect size values (443 children in the experimental groups, 63 in the control groups)

Variable	Input measurement		Output measurement	
	Z-value and significance level	Effect size	Z-value and significance level	Effect size
Reflex profile	$Z = -1.420$; n.s.	0.109	$Z = -7.447$; $p < 0.001$	0.572
Vestibular development	$Z = -0.956$; n.s.	0.052	$Z = -3.960$; $p < 0.001$	0.306

Discussion

Our study revealed a statistically significant correlation between the inhibition of primitive reflexes and vestibular maturation (r=0.000; ρ=0.000). Building upon previous research indicating the relationship between vestibular perception and muscle tone regulation (Markham, 1987), as well as the influence of muscle tone on auditory and visual perception and its consequent impact on fundamental learning skills (Stephens-Sarlós & Stephens, 2024), this investigation sought to explore the potential influence of primitive reflex inhibition exercises on both primitive reflex function and vestibular organ condition.

The findings suggest that appropriate exercises targeting the inhibition of primitive reflexes may positively influence the primitive reflex profile and vestibular function in children aged 5–8 years. Therefore, it is advisable to consider incorporating such exercises into the physical education curriculum for this age group. Not only could this contribute to academic progress, but it may also enhance performance in sports activities. Further research is warranted to explore the long-term effects of these exercises and their broader implications for child development and well-being.

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