ORIGINAL ARTICLE

Motor skill development in schoolchildren with hearing impairments during physical education in general secondary schools

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Abstract

Background and Study Aim: Hearing impairment is a common childhood disorder that influences communication, learning and physical development. It is often associated with delays in motor skills and reduced functional capacity. Although physical education is widely applied in schools, its role in supporting children with hearing impairments remains a practical concern. The purpose of this study was to compare motor and functional indicators between schoolchildren with hearing impairments and their typically developing peers.

Material and Methods: A comparative cross-sectional study was conducted with 36 schoolchildren with hearing impairments (7–8 years old) and 50 typically developing peers. Functional development was assessed using anthropometric measurements, spirometry, the Ruffier test, the Stange test, and the Genchi test. Statistical analysis included descriptive statistics, tests of normality (Shapiro–Wilk), Student's *t*-test, and calculation of effect sizes (Cohen's *d*). Results are presented as mean ± standard error (SE), with significance set at $p < 0.05$.

Results: Children with hearing impairments demonstrated significantly lower lung vital capacity (1100–1250 ml vs. 1200–1300 ml in peers, $p < 0.05$) and a reduced vital index (approximately 41–43 ml/kg vs. 44 ml/kg, $p > 0.05$). The Ruffier test showed consistently higher scores (17–19 vs. 10–11, $p < 0.01$), reflecting poorer cardiovascular adaptation. The Stange test revealed markedly shorter breath-holding times (18–20 s vs. 34–40 s, $p < 0.001$), while the Genchi test confirmed limited hypoxic reserves (13–14 s vs. 16–18 s, $p < 0.01$). These patterns were consistent across both age groups and sexes.

Conclusions: Schoolchildren with hearing impairments exhibit marked functional limitations compared to their typically developing peers. These results underline the need for differentiated approaches in physical education and provide a scientific basis for the development of adapted programs focused on improving cardiorespiratory endurance, motor coordination, and overall physical fitness in this group.

Keywords: motor development, hearing impairment, schoolchildren, physical education, Ruffier test, respiratory endurance

Introduction

The health and development of children with special educational needs represent a complex issue that extends beyond medical care and requires coordinated attention from educators, psychologists, and specialists in physical culture. Hearing impairment is one of the most widespread sensory disorders in childhood, influencing not only communication but also motor development, emotional well-being, and social integration. The multifactorial nature of this condition means that its impact is reflected in reduced physical activity, limitations in motor skills, and challenges in adapting to the demands of the school environment. The scale of the problem is illustrated by global and national statistics, which underline the significance of hearing impairment as a widespread health and educational challenge.

According to the World Health Organization (WHO), about 540 million people worldwide have hearing problems, including approximately 32 million children. In Ukraine, more than 1.5 million people live with hearing impairments, among them over 300,000 children. Around 100,000 adults and 11,000 children suffer from complete deafness. Moreover, the prevalence of hearing impairment continues to rise, reflecting a concerning trend in modern society

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[1]. In this context, recent reviews provide valuable insights into how hearing loss influences motor development and highlights the importance of adapted approaches within physical education.

Vestibular dysfunction is strongly linked with delays in gross motor milestones among children with hearing loss, which has direct implications for physical education and motor training [2, 3, 4]. Systematic reviews further show that structured balance interventions of 8–16 weeks can significantly improve motor outcomes, reinforcing the feasibility of implementing such programs in PE curricula [5, 6, 7]. Together, these findings highlight the relevance of focusing on balance, coordination, and functional fitness in adapted PE. Building on this evidence, diagnostic and applied studies have explored specific manifestations of motor deficits and provided tools for assessing postural control in children with hearing impairments.

Observational evidence indicates that children with hearing impairments often demonstrate postural instability and higher sway during balance tasks [8, 9, 10]. The Geneva Balance Test provides a child-friendly instrument for identifying vestibular deficits in school settings [11, 12]. Additional research shows that BOT-2 balance tasks can reveal vestibular loss in students with sensorineural hearing loss, highlighting their potential use for screening within PE and school health programs [13, 14]. Long-term follow-ups also confirm persistent differences in vestibular and motor performance, which are relevant for monitoring progression across school years [15, 16]. Complementing these international findings, national studies provide region-specific evidence that reflects the educational and cultural context of Ukraine.

Regional investigations add further detail to the specific challenges of motor development in schoolchildren with hearing impairments. Research points to difficulties in balance and coordination during PE classes [17], the importance of activating sports and recreational activities for students with disabilities [18], and ongoing debates around the terminological framework of motor qualities [19]. Other studies emphasize the need for modern technologies of inclusive physical education [20] and the positive role of physical activity in supporting students' academic performance [21]. Collectively, these findings justify adapted PE strategies in Ukraine that align with global evidence. At the policy level, broader monitoring initiatives and population-based analyses further illustrate the significance of physical activity and health surveillance for children with hearing loss.

Large-scale analyses highlight associations between adherence to 24-hour movement guidelines and improved emotional, social, and academic functioning in children with hearing loss [22, 23]. School-based enhanced hearing screening combined with telehealth demonstrates scalable approaches that can be integrated with educational monitoring and PE observations [24]. In parallel with these organizational efforts, intervention studies focused on physical activity, recreation, and sport provide practical evidence of how targeted exercise programs can enhance balance, coordination, and overall motor performance in children with hearing impairments.

Exercise-based interventions show direct benefits for balance and motor performance. A randomized trial demonstrated that dance-sport activity improved vestibular function and balance in children with hearing impairments [5, 25]. Additional studies confirm that postural stability is influenced by physical activation and that exercise programs can be integrated into sport and recreation modules [26, 27]. Comparable findings were also reported for adolescents with intellectual disabilities, who show lower levels of cardiorespiratory fitness but maintain similar physical activity compared to typically developing peers [28]. These findings support embedding progressive balance and coordination exercises into PE curricula, recreational sport, and fitness programs.

The analysis of research results has shown that children with hearing impairments face consistent challenges in motor development, balance, and overall functional fitness. Authors emphasize the importance of integrating differentiated approaches into physical education and highlight the potential of targeted exercise programs to improve motor coordination, cardiorespiratory endurance, and postural stability. Researchers also underline that adapted educational strategies and the inclusion of recreational and sport activities can significantly enhance social participation and quality of life in this population. At the same time, there remains a need for continued investigation, as gaps in knowledge about the long-term effects of adapted physical education and the optimization of intervention models still hinder the full development of evidence-based practices.

The hypothesis of the study is that assessing the level of motor development in schoolchildren with hearing impairments is a necessary condition for designing modern programs and recommendations in physical education. Such an approach can significantly enhance motor activity and facilitate students' adaptation to the external environment.

The purpose of this study was to compare motor and functional indicators between schoolchildren with hearing impairments and their typically developing peers.

Materials and Methods

Participants

The study included 36 students with hearing impairments (HI) aged 7–8 years (17 aged 7 and 19

aged 8) and 50 typically developing peers without impairments (Control) (25 aged 7 and 25 aged 8). Participants with HI were recruited from specialized schools, while the Control group consisted of students from general education schools. Inclusion criteria were: an officially confirmed diagnosis of hearing impairment (for the HI group), regular attendance of physical education classes, and absence of severe comorbidities. Written informed consent was obtained from parents/guardians of all participants. Age, level of motor development, and general health of both groups were considered to ensure sample comparability. The study was conducted in accordance with the Declaration of Helsinki. Ethical approval was granted by the Ethics Committee of T.H. Shevchenko National University "Chernihiv Collegium."

Study Design

The applied approach allowed the formation of two representative and relatively homogeneous groups, ensuring the correct comparison of results and increasing the reliability of the research conclusions. This study was designed as a comparative cross-sectional investigation aimed at evaluating motor and functional development indicators in schoolchildren with hearing impairments compared to students without impairments.

Motor development was assessed using the Ruffier test [28], lung vital capacity, the vital index, and the Stange and Genchi tests [29, 30]. Data collection was carried out at Chernihiv Secondary School No. 1 and the Sosnytsky Educational and Rehabilitation Center. Students with hearing impairments were examined in the laboratory "Problems of the Formation of Motor Function of Persons Engaged in Physical Education and Sports" at the National University "Chernihiv Collegium" named after T. H. Shevchenko, while students without impairments were assessed in the general school setting.

The Ruffier test [28, 31] is a simple physiological assessment used to evaluate cardiac response to muscular exertion. It provides information about the functional capacity of the cardiovascular system under physical load. Detailed procedures and scoring criteria are presented in Table 1.

Table 1. Ruffier test scoring scale in conventional units

Result	7–8 years old
Poor	⩾ 21
Weak	17–21
Satisfactory	12–16
Good	6.5–11
Excellent	⩽ 6

The Ruffier test is a standardized medical procedure used in Ukrainian schools to evaluate the functional state of the cardiovascular system. The results are applied to determine the physical education group to which a child can be assigned, taking into account their motor capacity and health status. On the basis of the Ruffier test score, students receive an official certificate indicating the appropriate physical education group.

The Ruffier test is performed after five minutes of rest in a sitting position. The pulse is first recorded for 15 seconds (P1). The participant then performs 30 squats within 45 seconds. Immediately after completing the squats, the pulse is measured twice: during the first 15 seconds (P2) and during the last 15 seconds (P3) of the first minute of recovery.

The Ruffier index is calculated according to the following formula:

$$RI = \frac{(P1 + P2 + P3) - 200}{10}$$

where P1 = resting heart rate, P2 = post-exercise heart rate, P3 = recovery heart rate.

Vital capacity of the lungs is a key indicator of the functional state of the respiratory system. It depends on body size and age and correlates with both physical fitness and overall functional status [32]. To further characterize the development of the respiratory muscles and the efficiency of the respiratory organs, the vital index (ratio of vital capacity to body weight) was calculated according to established spirometry guidelines [33].

In addition, standardized hypoxic tests were applied to assess the body's oxygen supply during breath-holding. The Stange test (breath-holding after a deep inhalation) and the Genchi test (breath-holding after a deep exhalation) were performed using a stopwatch to record the duration [34].

Testing procedure

All participants were tested under similar environmental conditions (quiet indoor setting, temperature 20–22 °C). Each test was conducted in the morning, at least two hours after the last meal. Standardized instructions were provided, and each measurement was performed twice; the best result was recorded.

Measurements and instruments

1. Anthropometry: body height was measured using a stadiometer (accuracy ±0.1 cm), and body weight with mechanical scales (accuracy ±0.1 kg).
2. Spirometry: lung vital capacity was assessed using a portable spirometer. Calibration was performed before each testing session [35].
3. Vital index: calculated as lung vital capacity (ml) divided by body weight (kg), according to established spirometry guidelines [33].
4. Stange test: breath-holding duration after maximal inhalation, recorded with a stopwatch.
5. Genchi test: breath-holding duration after

maximal exhalation, recorded with a stopwatch.

Statistical analysis

Data were processed using Microsoft Excel 2010. Results are presented as mean ± standard error (SE). Between-group comparisons (children with and without hearing impairments) were performed using Student's t-test. Statistical significance was accepted at $p < 0.05$.

Results

The analysis of anthropometric indicators showed no statistically significant differences in height between students with and without hearing impairments at either age group ($p > 0.05$). However, 8-year-old boys with hearing impairments had significantly higher body weight compared to their peers without impairments ($p < 0.01$).

Regarding functional tests, Ruffier index scores were significantly higher, indicating poorer cardiovascular adaptation, in children with hearing impairments. Among 7-year-old girls, the difference reached statistical significance ($p < 0.05$). Similarly, 7-year-old boys with hearing impairments scored significantly higher than their peers ($p < 0.01$). At the age of 8, this trend persisted, with both girls ($p < 0.01$) and boys ($p < 0.01$) showing less favorable results. The findings are summarized in Table 2.

Analysis of the results presented in Table 2 revealed a consistent tendency toward lower lung vital capacity in girls with hearing impairments compared to their peers without impairments. This difference was evident in both age groups and reached statistical significance. By contrast, the vital index showed only minor variations between groups and was not statistically significant. The breath-holding tests demonstrated clear differences: in both the Stange and Genchi tests, girls with hearing impairments achieved substantially shorter times, indicating reduced hypoxic tolerance and lower respiratory endurance.

The vital index (ml/kg) was consistently lower in children with hearing impairments, although the differences did not always reach statistical significance ($p > 0.05$). The results are summarized in Table 3.

Analysis of the results presented in Table 3 showed that boys with hearing impairments demonstrated a consistent disadvantage in breath-holding performance. In the Stange test, they had markedly shorter times compared to their peers without impairments, and the differences were highly significant across both age groups ($p < 0.001$). A similar pattern was observed in the Genchi test, where boys with hearing impairments consistently achieved lower values, with differences reaching statistical significance ($p < 0.01$). These findings indicate reduced hypoxic tolerance and lower respiratory endurance among children with hearing impairments.

The comparative results of the Ruffier, Stange,

Table 2. Results of motor skills indicators for girls aged 7–8 years (Mean ± SE)

Test name	7 years (HI, n=8)	7 years (Control, n=12)	8 years (HI, n=9)	8 years (Control, n=11)
Body weight (kg)	26.36 ± 2.45	26.65 ± 2.38	27.50 ± 2.56	28.32 ± 3.72
Body height (cm)	128.16 ± 2.89	129.78 ± 2.29	133.67 ± 3.18	134.39 ± 4.36
Ruffier test (index)	18.78 ± 3.61	11.87 ± 2.43	18.52 ± 2.04	10.67 ± 1.82
Lung vital capacity (ml)	1100.42 ± 139.78	1200.06 ± 169.21	1200.00 ± 122.12	1300.00 ± 149.31
Vital index (ml/kg)	41.9 ± 6.38	43.8 ± 7.05	42.8 ± 7.10	44.7 ± 7.40
Stange test (s)	18.5 ± 3.3	34.3 ± 4.6	19.3 ± 3.9	36.9 ± 4.9
Genchi test (s)	12.2 ± 2.18	14.6 ± 3.6	13.1 ± 3.8	15.7 ± 3.5

Note: HI = hearing impairments; Control = peers without impairments.

Table 3. Results of motor skills indicators for boys aged 7–8 years (Mean ± SE)

Test name	7 years (HI, n=8)	7 years (Control, n=12)	8 years (HI, n=9)	8 years (Control, n=11)
Body weight (kg)	33.9 ± 3.5	27.1 ± 2.96	36.1 ± 3.9	29.3 ± 2.7
Body height (cm)	131.57 ± 2.2	132.65 ± 3.1	134.6 ± 2.8	135.2 ± 3.3
Ruffier test (index)	18.06 ± 2.5	10.68 ± 2.4	17.1 ± 2.7	9.7 ± 2.9
Lung vital capacity (ml)	1200.0 ± 122	1250.1 ± 188	1250.0 ± 168	1300.0 ± 133.2
Vital index (ml/kg)	42.7 ± 7.4	43.5 ± 8.0	40.8 ± 7.6	41.3 ± 7.0
Stange test (s)	19.1 ± 3.7	36.8 ± 4.8	20.4 ± 5.3	39.7 ± 5.6
Genchi test (s)	13.9 ± 2.3	16.2 ± 2.6	14.3 ± 3.5	18.0 ± 4.2

Note: HI = hearing impairments; Control = peers without impairments.

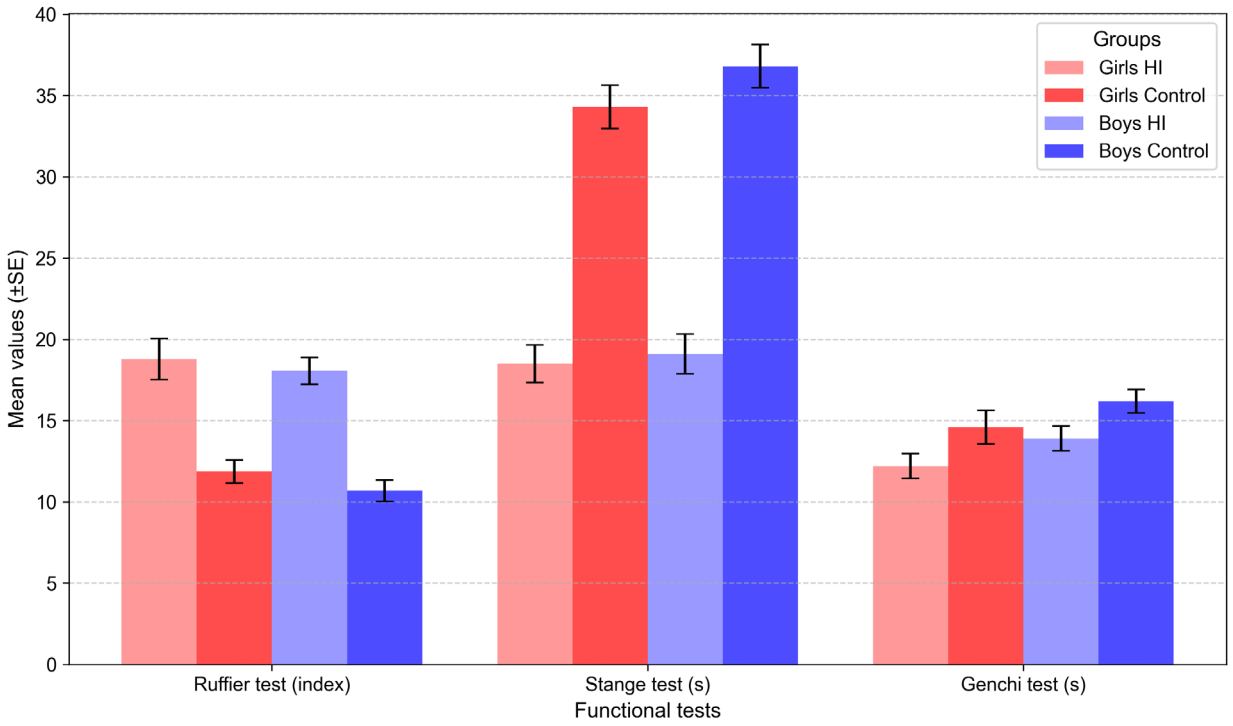

Figure 1. Comparison of Ruffier, Stange, and Genchi test results in 7-year-old students with and without hearing impairments. Values are shown as Mean ± SE. HI = hearing impairments; Control = typically developing peers.

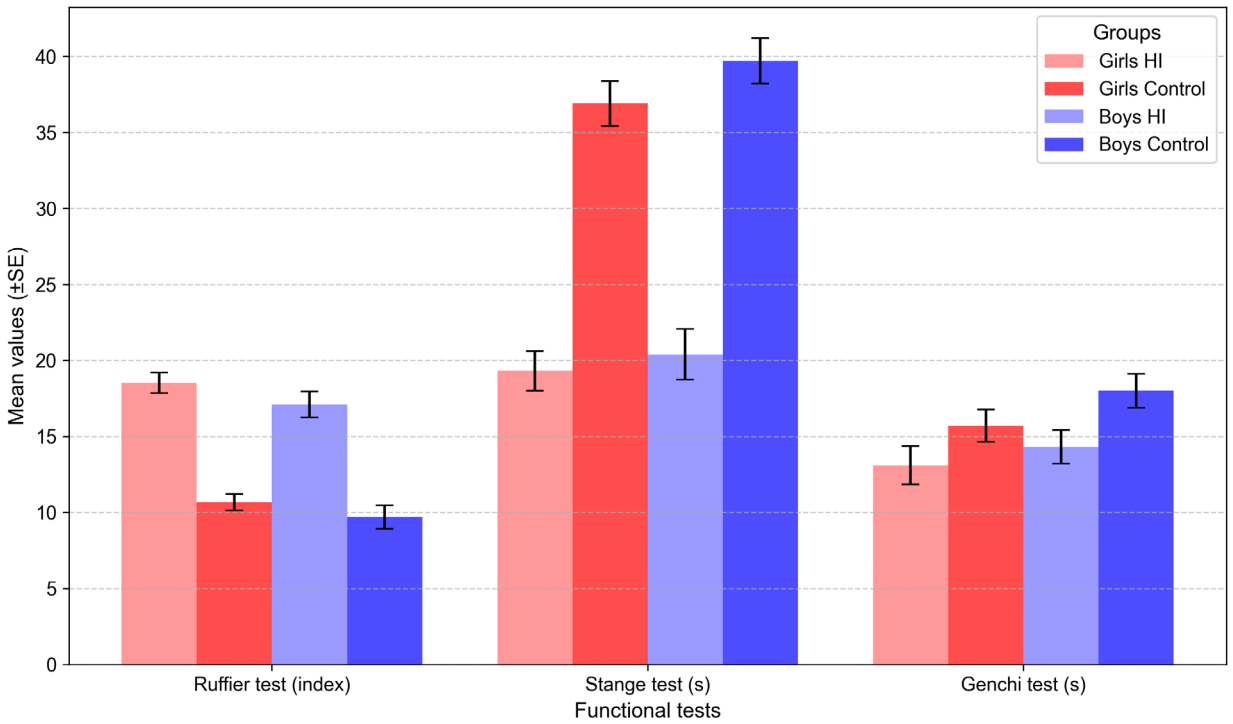

Figure 2. Comparison of Ruffier, Stange, and Genchi test results in 8-year-old students with and without hearing impairments. Values are shown as Mean ± SE. HI = hearing impairments; Control = typically developing peers.

and Genchi tests are presented in Figure 1 (7-year-olds) and Figure 2 (8-year-olds). These tests reflect cardiovascular adaptation and respiratory endurance, which were consistently reduced in the groups with hearing impairments.

In both age groups, girls with hearing impairments (Girls HI) and boys with hearing impairments (Boys HI) demonstrated significantly higher Ruffier index values and shorter Stange and Genchi test times compared to girls without impairments (Girls Control) and boys without impairments (Boys Control). These consistent patterns across sex and age indicate reduced cardiovascular adaptation and lower respiratory endurance in children with hearing impairments.

Discussion

The purpose of this study was to compare motor and functional indicators between schoolchildren with hearing impairments and their typically developing peers. The results demonstrated reduced lung vital capacity, lower respiratory endurance in the Stange and Genchi tests, and higher Ruffier index values in the hearing-impaired group, indicating poorer cardiorespiratory adaptation. Height did not differ significantly between groups, although boys with hearing impairments showed higher body weight.

A comparative analysis with international research supports these findings. Children with hearing impairments are consistently reported to demonstrate lower levels of coordination, endurance, and speed–strength abilities than their peers [2, 36, 37]. Similar to our results, D'Anna et al. [37] described a decline in physical activity and motor development among youth in recent years, which corresponds to the lower motor test scores observed in this study. Singh et al. [2] and Zhou et al. [5] also confirmed that vestibular dysfunction and impaired balance are strongly associated with delayed motor milestones in children with hearing loss. Moreover, the strong relationship between auditory and motor systems, highlighted by Bernstein [36], may explain the observed limitations in motor development when auditory input is impaired. Comparable conclusions have been drawn in broader physical education contexts, where insufficient coordination and endurance were found to negatively affect respiratory and cardiovascular function [7, 28, 38, 39].

National studies further support these tendencies. Ukrainian researchers emphasize that reduced motor activity and coordination difficulties negatively influence functional health indicators in students with hearing impairments [17, 18, 40]. Other works have drawn attention to the terminological and methodological aspects of assessing motor qualities, highlighting the need for unified diagnostic criteria [19]. Studies in the field of adaptive and inclusive physical education also underline the importance of technological and methodological innovations in promoting motor development among students with disabilities [20]. Furthermore, recent findings demonstrate the broader value of physical activity as a factor in supporting not only physical fitness but also academic performance and psycho-emotional well-being of Ukrainian students [21, 41]. Collectively, these results align with our data, confirming the need for early diagnostics and targeted interventions. At the same time, the literature indicates that these functional limitations are not solely biological but are also shaped by social and educational conditions, including reduced opportunities for active participation in physical education.

These national findings complement international evidence by demonstrating that functional and motor limitations in children with hearing impairments are consistently observed across diverse contexts. While global studies emphasize vestibular dysfunction, balance, and cardiorespiratory outcomes, Ukrainian research highlights pedagogical and educational dimensions, particularly the role of adapted teaching methods and activity promotion. Taken together, these perspectives reinforce the need for comprehensive assessment and form the basis for the novelty of the present study.

The novelty of this study lies in its integrated evaluation of motor and functional indicators in schoolchildren with hearing impairments at the early school age of 7–8 years. Unlike most international studies, which have focused primarily on vestibular dysfunction and balance [2, 3, 4], or national research, which has emphasized pedagogical and methodological aspects [17, 18, 19], the present work provides a comprehensive comparison with typically developing peers. Standardized functional tests (Ruffier, Stange, and Genchi), spirometry, and anthropometry were combined to assess both motor and cardiorespiratory performance. This multidimensional approach makes it possible to identify not only deficits in motor coordination and balance but also specific limitations of the cardiovascular and respiratory systems. The results extend current knowledge by demonstrating that functional impairments are evident at the onset of school education, thereby providing a timely rationale for the development of targeted adaptive physical education programs.

The reduced vital capacity and vital index found in this study suggest insufficient development of respiratory muscles and limited cardiorespiratory endurance. Lower Ruffier, Stange, and Genchi test results demonstrate decreased adaptability of the cardiovascular and respiratory systems to motor loads and hypoxic stress. These outcomes may be linked to reduced daily physical activity, impaired speech breathing, and limited practice of deep

breathing in communication. Similar associations between auditory deficits, vestibular dysfunction, and impaired postural or respiratory function have been described in international research [3, 8, 10]. Structural differences in motor control caused by auditory deficits may therefore explain not only slower motor reactions and poor balance but also the reduced hypoxic tolerance observed in this group.

The findings highlight the necessity of differentiated approaches in physical education for children with hearing impairments. Teachers should adapt lesson structures to provide clear instructions, integrate breathing and endurance exercises, and regularly monitor motor development using standardized tools. Evidence also suggests that targeted physical activity programs can improve functional outcomes in this population. For example, exercise interventions such as dance sports have been shown to enhance vestibular function and balance in children with sensorineural hearing loss [25], while research on cochlear implant users indicates measurable improvements in postural stability [26]. At the educational level, the integration of school-based screening and telehealth follow-up offers scalable approaches that can complement physical education monitoring [24]. Implementing adaptive physical education programs can therefore improve coordination, spatial orientation, and overall physical readiness. These recommendations are consistent with contemporary approaches to inclusive education and support both physical and social integration of students with hearing impairments [21, 42, 43].

The study demonstrated that schoolchildren with hearing impairments experience significant limitations in respiratory and cardiovascular adaptation, as well as in motor coordination and endurance, compared to their typically developing peers. These findings are consistent with both international and national evidence, reinforcing the understanding that motor and functional deficits in this group have multifactorial origins. The outcomes strengthen the evidence base for the importance of implementing adapted physical education programs in schools and highlight their role in supporting not only physical performance but also social integration of children with hearing impairments. At the same time, the present results provide a practical foundation for teachers and policymakers to design effective interventions and monitoring strategies, while also pointing to the need for continued research on long-term outcomes and innovative pedagogical approaches.

Limitations

This study has several limitations. First, the sample size was relatively small, which reduces the generalizability of the findings. Second, participants were recruited from specific educational institutions, limiting the applicability of the results to inclusive settings. Third, differences in the severity of hearing impairment and individual factors such as speech development and motivation could have influenced the outcomes. Fourth, the cross-sectional design of the study does not allow the tracking of long-term changes in motor or functional development. Fifth, while standardized tools such as the Ruffier, Stange, and Genchi tests are widely used, their interpretation in children with sensory impairments may have methodological constraints. Finally, although Student's t-test was applied, more advanced statistical methods (e.g., multivariate models) could provide deeper insights.

Future studies should address these limitations by expanding the sample to include students from different regions and educational settings (including inclusive schools) and by considering various levels of auditory impairment. It is also appropriate to investigate the long-term effects of motor development programs and their integration with other components, such as psycho-emotional support and speech therapy. A promising direction for further research is the study of individual trajectories of motor development and the use of digital technologies (virtual reality, interactive simulators) to enhance motor activity. Moreover, the relationship between motor development and social adaptation in schoolchildren with hearing impairments should be explored, as it may form the basis for comprehensive educational strategies.

Recommendations

Based on the results of the study, the following recommendations are proposed for physical education teachers working with schoolchildren with hearing impairments:

1. Adaptation to the educational process. Lessons should be clearly structured to facilitate comprehension of instructions and to reduce anxiety. The use of visual aids and non-verbal cues may enhance understanding.
2. Individual approach. Prior assessment of motor fitness is recommended to avoid excessive workloads. Individual capabilities should be taken into account, and breathing exercises may be incorporated to compensate for the reduced vital capacity observed in this group.
3. Enhancing motor activity. Programs should include targeted breathing, coordination, balance, and spatial orientation exercises to address the functional limitations revealed in Ruffier, Stange, and Genchi tests.
4. Psychological and social support. A supportive classroom atmosphere should be maintained, with an emphasis on activities that promote peer interaction and social integration.
5. Systematic observation and control. Regular monitoring of motor activity is recommended,

including the use of standardized functional tests, with progress recorded in individual reports to guide load adjustment.
6. Use of modern technologies. Where feasible, digital tools such as interactive simulators, virtual reality, or mobile applications should be employed to enhance motivation and engagement.
7. Interdisciplinary cooperation. Collaboration with speech therapists, psychologists, and medical professionals is advisable in order to design comprehensive strategies that integrate physical, communicative, and psycho-emotional development.

These recommendations are relevant for teachers working with students with special educational needs, both in specialized institutions and in inclusive classrooms. They provide practical guidance for improving motor skills, facilitating adaptation to physical activity, and supporting broader educational and social integration of children with hearing impairments.

Conclusions

A comparative analysis of physical and functional indicators in 7–8-year-old students with and without hearing impairments revealed consistent differences between groups. Children with hearing impairments showed lower lung vital capacity and vital index, suggesting insufficient development of respiratory muscles; higher Ruffier index values, indicating weaker cardiovascular adaptation to physical load; and poorer Stange and Genchi test results, reflecting reduced hypoxic resistance and respiratory endurance. These findings emphasize the need for individualized approaches in physical education, with training programs tailored to the functional characteristics of students with hearing impairments. The study provides a foundation for improving the effectiveness of adaptive physical education and for designing targeted measures to support motor and functional development in this population.

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Conflict of Interest

The authors declare no conflict of interest.

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