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Correspondence
Aamir Latif, ch.aamir101@gmail.com

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Effects of Cawthorne–Cooksey Exercises on Balance and Quality of Life in Children with Hearing Deficits

Aamir Latif[1], Sara Khan[2], Shah Salman[3], Malik Muhammad Atif[4], Jaweria Shakeel[5], Iqra Zenub[6]

1 MS Pediatric Physical Therapy, Riphah International University, Lahore, Pakistan
2 Assistant Professor, Riphah International University, Lahore, Pakistan
3 Pediatric Physical Therapist at ORION ABA, Lahore, Pakistan
4 Lecturer, Department of Allied Health Sciences, University of Sargodha, Pakistan
5 MS Neuromuscular Physical Therapy, The University of Lahore, Lahore, Pakistan
6 MS Neuromuscular Physical Therapy, Riphah International University, Lahore, Pakistan

ABSTRACT

Background: *Balance deficits and impaired sensory organization are common in children with severe-to-profound sensorineural hearing loss (SNHL), frequently reflecting vestibular dysfunction that can limit functional participation and health-related quality of life (HRQOL).* ***Objective****: To determine the effects of adding Cawthorne–Cooksey vestibular rehabilitation exercises to Swiss ball training on balance and HRQOL in children with SNHL.* ***Methods****: A randomized controlled trial was conducted in a school for deaf children in Lahore. Thirty children aged 7–12 years with SNHL (PTA >90 dB) were randomized into Group A (Swiss ball exercises) or Group B (Cawthorne–Cooksey exercises plus Swiss ball exercises). Training was delivered for 45 minutes, three times weekly for eight weeks. Balance and HRQOL were assessed pre- and post-intervention using the Pediatric Balance Scale (PBS), Four Square Step Test (FSST), and a pediatric HRQOL questionnaire. Non-parametric analyses were applied.* ***Results****: Mean age was 9.20 ± 1.74 years in Group A and 9.80 ± 1.90 years in Group B. Shapiro–Wilk testing confirmed non-normality of outcomes ($p \leq 0.001$). Wilcoxon signed-rank testing showed significant improvement in FSST ($p < 0.001$) and HRQOL ($p = 0.005$), while PBS change was not significant ($p = 0.102$). Mann–Whitney U testing demonstrated significant post-intervention differences for PBS ($p = 0.035$) and HRQOL ($p = 0.002$).* ***Conclusion****: Vestibular rehabilitation incorporating Cawthorne–Cooksey exercises may improve dynamic balance performance and HRQOL in children with severe-to-profound SNHL.*

Keywords

Balance; Cawthorne–Cooksey; Hearing Loss; Sensorineural Hearing Loss; Vestibular Rehabilitation; Quality of Life.

INTRODUCTION

Sensorineural hearing loss (SNHL) is one of the most common congenital sensory impairments, with a substantial proportion of children affected from birth or early childhood, leading to long-term developmental, educational, and psychosocial consequences when not addressed with timely rehabilitation (1,4). Hearing loss severity is commonly classified as mild (21–40 dB HL), moderate (41–70 dB HL), severe (71–95 dB HL), and profound (>95 dB HL), with severe-to-profound loss often resulting in major functional communication limitations and restricted participation (2). While the clinical focus of pediatric hearing impairment traditionally emphasizes speech, language, and auditory rehabilitation, accumulating evidence indicates that SNHL frequently coexists with vestibular end-organ dysfunction because vestibular and cochlear structures share anatomical proximity and common neural pathways through the vestibulocochlear nerve (3). Consequently, a substantial proportion of children with severe-to-profound SNHL experience impaired sensory integration and deficient postural control, manifesting as delayed motor milestones, poor static and dynamic balance, reduced motor coordination, and increased functional limitations in school and community environments (3,7).

Vestibular dysfunction in children with SNHL is clinically important because balance and postural stability rely on the integration of vestibular, visual, and somatosensory inputs. When vestibular input is compromised, children may compensate by over-relying on vision and proprioception; however, this compensation is often incomplete and may be insufficient under challenging environmental conditions such as reduced visual cues, dynamic tasks, or uneven surfaces (6,7). Balance impairment has been documented in both unilateral and bilateral profound SNHL, and vestibular and balance abnormalities can occur even when auditory rehabilitation is initiated, thereby necessitating targeted physical therapy strategies to address postural control deficits and improve functional independence (3). Given that balance is closely linked to participation in play, physical activity, and school-based tasks, vestibular-related balance impairment may also contribute to diminished health-related quality of life (HRQOL) and psychosocial wellbeing for children and their families (17).

Vestibular rehabilitation programs are designed to enhance vestibular compensation through neuroplastic mechanisms including adaptation, habituation, and sensory substitution, ultimately improving vestibulo-ocular and vestibulo-spinal reflex function and optimizing postural control strategies (8,9). Cawthorne–Cooksey exercises represent a classical vestibular rehabilitation protocol consisting of graded eye, head, and body movements combined with progressive balance tasks in varied positions and environmental constraints (9).

Although these exercises have demonstrated benefits in balance outcomes across adult populations and various neurological conditions, evidence in pediatric populations with hearing deficits—particularly in structured school-based settings—remains limited and methodologically heterogeneous (6,10). Furthermore, conventional pediatric balance programs frequently emphasize general strengthening and core stability approaches such as Swiss ball-based training, yet it remains uncertain whether adding targeted vestibular habituation and adaptation exercises yields superior functional gains in balance and HRQOL among children with severe-to-profound SNHL (11).

Therefore, the present randomized controlled trial was conducted to determine whether an 8-week Cawthorne–Cooksey vestibular rehabilitation program combined with Swiss ball exercises leads to greater improvements in balance and health-related quality of life than Swiss ball exercises alone in children aged 7–12 years with severe-to-profound sensorineural hearing deficits.

The study hypothesized that children receiving combined vestibular rehabilitation and Swiss ball training would demonstrate significantly greater post-intervention improvements in Pediatric Balance Scale performance, Four Square Step Test performance, and HRQOL scores compared with the control intervention.

MATERIALS AND METHODS

A randomized controlled trial was conducted at the Government Secondary School of Special Education for Deaf Children, Main Gulberg, Lahore. Children were recruited from the school population and screened for eligibility based on predefined clinical criteria. Participants were eligible if they were aged 7–12 years, had a confirmed diagnosis of severe-to-profound sensorineural hearing loss defined as pure tone average (PTA) >90 dB, and had normal vision, as visual impairment may independently affect balance and confound intervention effects (13).

Children were excluded if they had any orthopedic or neurological impairments that could affect postural control, were taking medications known to influence the central nervous system or were unable to safely participate in balance exercises. Participants were also excluded from analysis if they missed more than two intervention sessions, experienced an orthopedic injury during the trial period, became medically unfit for training, or if caregivers declined continued participation.

After obtaining informed consent from parents/guardians and assent from children when appropriate, baseline assessment was performed for all enrolled participants. Participants were then allocated into two parallel groups: a control group (Group A) and an experimental group (Group B). Group A received Swiss ball-based exercise training, while Group B received a combined program consisting of Cawthorne–Cooksey vestibular rehabilitation exercises plus Swiss ball training. Both groups participated in supervised sessions of 45 minutes, three times per week for eight consecutive weeks. The Swiss ball program consisted of progressive balance and core stabilization activities designed to challenge postural control, including seated balance tasks, weight-shifting activities, and dynamic trunk control exercises.

The Cawthorne–Cooksey component consisted of graded vestibular rehabilitation tasks incorporating eye movements, head movements, transitions between postures, and progressively challenging balance tasks performed in sitting and standing, with systematic progression toward tasks requiring reduced visual dependence and increased sensory reweighting consistent with vestibular compensation principles (9).

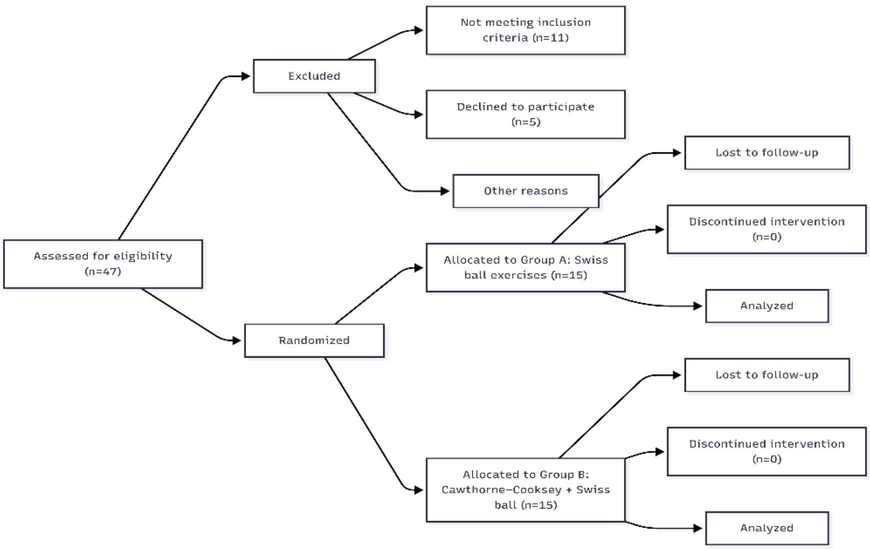

Figure 1 CONSORT Flowchart

Outcome assessment was performed at baseline (pre-intervention) and immediately after the 8-week intervention period (post-intervention). Balance was evaluated using the Pediatric Balance Scale (PBS), a pediatric adaptation of the Berg Balance Scale designed to assess functional balance tasks relevant to children, and the Four Square Step Test (FSST), which assesses dynamic balance, stepping speed, and multi-directional change-of-direction capability. Health-related quality of life was assessed using a pediatric quality of life questionnaire administered at the same time points.

All assessments were administered using standardized instructions and consistent testing conditions across time points. Where feasible, outcome assessment was performed by a trained assessor not involved in intervention delivery to reduce measurement bias.

The sample size was calculated using Win Pepi for estimation of a mean difference at a 95% confidence level, with an assumed standard deviation derived from prior evidence in children with hearing deficits (7).

A minimum sample size of 26 was obtained and inflated by 10% to account for attrition, resulting in a final target sample of 30 participants. Statistical analysis was performed using SPSS for Windows (version 25). Data distribution was assessed using the Shapiro–Wilk normality test. Because normality assumptions were not satisfied for the principal outcome variables, non-parametric tests were applied. Within-group pre–post comparisons were conducted using the Wilcoxon signed-rank test, and between-group comparisons were conducted using the Mann–Whitney U test. Statistical significance was set a priori at $p < 0.05$ for all analyses.

RESULTS

A total of 30 children with severe-to-profound sensorineural hearing loss (PTA >90 dB) were allocated equally into Group A (Swiss ball exercises) and Group B (Cawthorne–Cooksey exercises plus Swiss ball exercises), with 15 participants per group. The mean age of Group A was 9.20 ± 1.74 years and Group B was 9.80 ± 1.90 years (Table 1).

Shapiro–Wilk testing demonstrated statistically significant deviation from normality for baseline FSST, PBS, and HRQOL outcomes (all $p \leq 0.001$), therefore non-parametric tests were used for inferential analyses (Table 2).
Between-group comparisons using the Mann–Whitney U test demonstrated statistically significant differences for PBS at baseline ($Z = -3.247$, $p = 0.001$) and post-intervention ($Z = -2.112$, $p = 0.035$), and for HRQOL at baseline ($Z = -3.490$, $p < 0.001$) and post-intervention ($Z = -3.158$, $p = 0.002$). FSST did not demonstrate statistically significant between-group differences at baseline ($Z = -1.466$, $p = 0.143$) or post-intervention ($Z = -1.056$, $p = 0.291$) (Table 3).
Within-group pre–post comparisons using the Wilcoxon signed-rank test demonstrated statistically significant improvement in FSST ($Z = -3.742$, $p < 0.001$) and HRQOL ($Z = -2.696$, $p = 0.005$), whereas PBS change was not statistically significant ($Z = -1.633$, $p = 0.102$) (Table 4).

Table 1. Demographic Characteristics of Participants (n = 30)

Characteristic	Group A (Control) n=15	Group B (Experimental) n=15
Age (years), Mean ± SD	9.20 ± 1.74	9.80 ± 1.90

Table 2. Shapiro–Wilk Test of Normality for Baseline Outcome Measures

Outcome Variable (Pre)	Shapiro–Wilk W	df	p-value
FSST (Pre)	0.637	26	<0.001
PBS (Pre)	0.583	26	<0.001
HRQOL (Pre)	0.849	26	0.001

Table 3. Between-Group Comparisons (Mann–Whitney U Test)

Outcome Variable	Z-value	p-value
FSST (Pre)	−1.466	0.143
FSST (Post)	−1.056	0.291
PBS (Pre)	−3.247	0.001
PBS (Post)	−2.112	0.035
HRQOL (Pre)	−3.490	<0.001
HRQOL (Post)	−3.158	0.002

Table 4. Within-Group Comparisons (Wilcoxon Signed-Rank Test)

Outcome Comparison	Z-value	p-value
FSST (Post − Pre)	−3.742	<0.001
PBS (Post − Pre)	−1.633	0.102
HRQOL (Post − Pre)	−2.696	0.005

Table 5. Effect Sizes Derived from Z Statistics ($r = |Z| / \sqrt{N}$), N = 30

Outcome	Test Type	Z-value	p-value	Effect size r
FSST (Post − Pre)	Wilcoxon	−3.742	<0.001	0.68
PBS (Post − Pre)	Wilcoxon	−1.633	0.102	0.30
HRQOL (Post − Pre)	Wilcoxon	−2.696	0.005	0.49
FSST (Post)	Mann–Whitney	−1.056	0.291	0.19
PBS (Post)	Mann–Whitney	−2.112	0.035	0.39
HRQOL (Post)	Mann–Whitney	−3.158	0.002	0.58

Within-group comparisons demonstrated a large improvement in FSST ($r = 0.68$, $p < 0.001$) and a medium improvement in HRQOL ($r = 0.49$, $p = 0.005$), while PBS showed a small-to-medium effect and remained non-significant ($r = 0.30$, $p = 0.1$
Effect sizes were calculated from the reported Z statistics using $r = |Z|/\sqrt{N}$ with $N = 30$ to quantify the magnitude of effects. Within-group changes demonstrated a large effect for FSST ($r = 0.68$) and a medium effect for HRQOL ($r = 0.49$), while PBS showed a small-to-medium effect ($r = 0.30$). Post-intervention between-group contrasts demonstrated a medium effect for PBS ($r = 0.39$) and a large effect for HRQOL ($r = 0.58$), while FSST showed a small effect ($r = 0.19$), consistent with the non-significant between-group p-value (Table 5).
Collectively, inferential and effect size findings indicate substantial improvement over time in FSST performance and HRQOL, with clinically meaningful post-intervention differences between groups most evident for HRQOL and PBS.

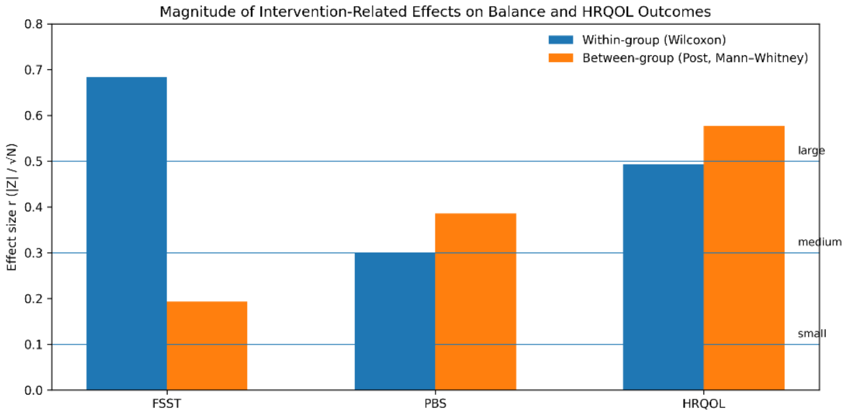

Figure 2 Effect size analysis showed a large within-group improvement for FSST (r = 0.68, p < 0.001) and a medium within-group improvement for HRQOL (r = 0.49, p = 0.005), while PBS within-group change remained non-significant with a small–medium effect (r = 0.30, p = 0.102). In contrast, post-intervention between-group differences were large for HRQOL (r = 0.58, p = 0.002) and medium for PBS (r = 0.39, p = 0.035), whereas FSST showed only a small between-group effect (r = 0.19, p = 0.291), indicating that clinically meaningful group separation was most evident for HRQOL and functional balance performance on PBS.

Post-intervention between-group comparisons demonstrated a large difference in HRQOL (r = 0.58, p = 0.002) and a medium difference in PBS (r = 0.39, p = 0.035), while FSST showed only a small between-group effect (r = 0.19, p = 0.291), indicating that the strongest group separation at the end of the intervention was observed in HRQOL and PBS outcomes.

DISCUSSION

This randomized controlled trial evaluated whether adding Cawthorne–Cooksey vestibular rehabilitation exercises to a Swiss ball-based program improved balance and health-related quality of life (HRQOL) in children with severe-to-profound sensorineural hearing loss (SNHL). The principal findings indicate statistically significant pre–post improvements in dynamic balance performance assessed by FSST and in HRQOL, while PBS did not demonstrate a statistically significant pre–post change in the reported within-group analysis. Post-intervention between-group comparisons demonstrated statistically significant differences for PBS and HRQOL, whereas FSST did not differ significantly between groups post-intervention. These findings suggest that vestibular-focused rehabilitation may support meaningful improvements in functional stepping performance and perceived wellbeing in children with SNHL, but the pattern of results also highlights the complexity of balance outcomes and the need to interpret changes across multiple instruments rather than relying on a single scale.

Balance impairment in children with hearing loss is increasingly recognized as a clinically relevant comorbidity rather than a secondary concern, reflecting the shared neuroanatomical substrate of auditory and vestibular pathways through the vestibulocochlear nerve and the high prevalence of vestibular end-organ dysfunction in this population (3). Prior studies have shown that children with profound unilateral SNHL frequently exhibit vestibular and balance deficits, supporting the plausibility of dynamic balance impairment even in the absence of overt neurological disease (3). Functional balance disturbances in children with hearing loss can manifest as difficulty maintaining postural stability during tasks requiring rapid stepping adjustments, directional changes, and sensory reweighting in the presence of reduced vestibular input, which aligns with observed improvements in FSST in the present trial (7). The significant gains in FSST performance may reflect enhanced neuromotor coordination, anticipatory postural adjustments, and improved sensory integration strategies over the 8-week training period, which are key targets of vestibular rehabilitation programs emphasizing adaptation, habituation, and substitution mechanisms (8,9).

The differential findings between FSST and PBS warrant consideration. PBS evaluates a broader range of functional balance tasks but may demonstrate ceiling effects or reduced responsiveness when baseline function is relatively preserved or when intervention primarily enhances dynamic stepping and rapid directional transitions rather than static control. Additionally, the reported within-group PBS change did not reach statistical significance, which may relate to limited power due to sample size, variability in task performance, or baseline imbalance across groups. In contrast, stepping-based measures such as FSST may be more sensitive to changes in dynamic balance and functional mobility in children with vestibular impairment, as supported by evidence that balance training improves motor coordination and attention-related balance performance in children with hearing deficits (7). The improvement in HRQOL observed in the current trial is clinically meaningful because balance confidence and functional participation may influence school engagement, peer interaction, and independence, and HRQOL is known to be substantially affected in families managing pediatric sensory impairments (17).

The present results are consistent with evidence supporting vestibular rehabilitation and balance-focused interventions across diverse populations. Trials in neurological conditions such as multiple sclerosis have demonstrated that vestibular-oriented exercises and balance training can improve postural control, supporting the conceptual transferability of these mechanisms to pediatric SNHL where vestibular dysfunction is prevalent (6). Similarly, studies in older adults have reported improvements in balance following Cawthorne–Cooksey training, reinforcing that structured vestibular exercises can produce measurable functional benefits through repeated sensorimotor exposure and neural compensation processes (10). In pediatric deaf populations, core stability programs have been shown to enhance trunk muscle endurance and may indirectly support postural control, but these approaches do not directly target vestibular reflex pathways, suggesting that combined vestibular and stability training may provide broader benefits than stability exercises alone (11). The current trial contributes to this evolving evidence base by focusing specifically on children with severe-to-profound SNHL in a school setting and by incorporating HRQOL as an outcome alongside balance measures.

Several methodological considerations should be acknowledged when interpreting these findings. First, baseline between-group differences in PBS and HRQOL were statistically significant, indicating imbalance that may have influenced post-intervention comparisons and underscoring the importance of analyzing change scores or adjusting for baseline values in future studies. Second, the current reporting does not include group-wise pre/post descriptive statistics for PBS, FSST, and HRQOL, limiting the ability to determine clinical magnitude, calculate confidence intervals, or compare observed changes against established thresholds of meaningful improvement. Third, the single-center setting and modest sample size may restrict generalizability. Future trials should incorporate stratified randomization, blinded assessment, standardized adherence reporting, and a prespecified primary endpoint with effect sizes and confidence intervals to strengthen causal inference and clinical translation.

Overall, the findings support the clinical rationale for integrating vestibular rehabilitation exercises into pediatric physical therapy programs for children with severe-to-profound SNHL, particularly where balance deficits limit functional participation. Larger multicenter trials with rigorous reporting standards are warranted to confirm effectiveness, clarify which balance domains respond most strongly, and establish optimized protocols for progression, adherence, and long-term maintenance of gains (3,7,9).

CONCLUSION

In children aged 7–12 years with severe-to-profound sensorineural hearing loss, an 8-week vestibular rehabilitation program incorporating Cawthorne–Cooksey exercises alongside Swiss ball training was associated with statistically significant improvements in dynamic balance performance (FSST) and health-related quality of life, while PBS did not demonstrate a statistically significant pre–post change in the reported within-group analysis; post-intervention comparisons indicated significant group differences in PBS and HRQOL, supporting the potential value of vestibular-focused rehabilitation within pediatric therapy programs, although future studies should report complete group-wise outcome data with effect sizes and confidence intervals and address baseline imbalance to strengthen clinical interpretability.

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