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Article

Effect of suspension training intervention on the balance ability of juvenile deaf-mute patients

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Abstract: Maintaining balance is essential for daily activities; deficits in hearing-impaired adolescents can severely impact their academics and daily life. Suspension training is employed to enhance the coordination of multiple muscle groups within the body and ultimately to improve balance. A total of 105 students with non-genetic hearing impairments, comprising 65 boys and 40 girls, participated in the study. Balance training using the TRS suspension belt included exercises such as prone elbow brace, supine back brace, kneeling elbow brace, lateral elbow brace, prone hip flexion, and supine hip lift. Strength training using equipment involved exercises like single-leg suspension squat, flying bird brace, supine suspension arm flexion, seated static brace, and standing butterfly pinch chest. The main outcome measures included static balance tests (lambda footwork, Wolfson postural stress test), dynamic balance tests (functional forward reach test, balance beam walk test), and vestibule function tests (rotation-walk test). The results of the lambda footwork and Wolfson postural stress tests revealed highly significant differences between 8 weeks and 16 weeks of intervention ($p < 0.01$). The Functional Forward Stretch test demonstrated a significant difference between 8 weeks of intervention and 2 weeks of intervention at 16 weeks ($p < 0.05$). The balance beam walking test indicated a significant improvement at 8 weeks ($p < 0.05$) and a highly significant improvement at 16 weeks ($p < 0.01$). In the spin-walk test, no statistically significant differences were observed between the pre-experimental test, the 8-week intervention, and the 16-week intervention ($p > 0.05$). Leveraging the expropriation system to mediate skeletal muscle movement and muscle contraction coordination can improve balance. Suspension training significantly improved balance during activities requiring static non-interference maintenance. However, suspension training did not demonstrate a significant effect on improving vestibule function. Overall, suspension training was effective in enhancing balance in all patients with non-hereditary deafness.

Keywords: suspension training; static state; dynamic balance ability; vestibule function

1. Introduction

In daily life, balance ability is the foundation of all physical activities. Many movements require balance control to be maintained, making balance ability particularly critical. Deaf-mute patients, due to congenital functional deficiencies, exhibit significantly lower adaptive behaviors compared to the average person, especially in terms of balance ability (Liu, 2007). This deficiency not only brings long-term suffering to the individuals but also imposes a heavy emotional and financial burden on their families. It is well known that visual, proprioceptive, and vestibular system inputs, as well as the integration of the central nervous system, are key factors in maintaining human balance, with the vestibular sense acting as the receptor that governs balance and maintains body posture, playing an essential role in balance maintenance (Prokopy et al., 2008). Vestibular balance disorder is one of the most common issues in deaf-mute patients. Due to damage to the vestibular organs, their balance ability (especially the most important features), as well as the flexibility and coordination of their nerve and muscle activities, are significantly weaker than those of normal individuals. Based on this, balance deficiencies have become one of the most urgent problems to be addressed in related fields, requiring in-depth research and discussion. Therefore, actively seeking ways to improve their balance disorders is of great importance to enhancing the quality of life for deaf-mute patients.

Numerous studies have shown that when the central nervous system controls body posture and balance muscles, it does not govern a single muscle but all related muscle groups involved in the movement. Since different environments require specific coordination to activate muscles, leading to varied and complex movement patterns, multiple muscles must work in coordination in three-dimensional space to counteract gravity, support reaction forces, and respond to dynamic forces, ultimately improving balance ability (Zhao, 2009). Based on this conclusion, foreign scholars have attempted to use suspension training under unstable conditions to study its impact on athletes in ball sports such as golf, football, and handball. This research was later extended to cycling, volleyball, and other sports, further confirming the effectiveness of this intervention. Currently, Chinese scholars have also applied suspension training in experimental studies on the balance abilities of athletes in martial arts, diving, athletics, and windsurfing. The results show that suspension training can significantly improve athletes' body coordination and balance. Moreover, many studies on non-athletes have demonstrated that suspension training can enhance core muscle strength and stability in elderly individuals and stroke patients, effectively improving their balance abilities. Thus, by enhancing the coordination of multiple muscles through suspension training, balance ability can ultimately be improved. Clearly, the successful application of suspension training provides theoretical support and reference for the fields of sports and medicine. However, there has yet to be any literature or experimental research regarding the use of suspension training with deaf-mute patients, particularly in terms of improving their balance ability, which remains largely unexamined. Therefore, from the perspective of integrating theory and practice, in-depth exploration of the effects of suspension training on the balance ability of deaf-mute patients is needed to find more suitable developmental methods and provide valuable insights for their rehabilitation.

In conclusion, by combining domestic and international research results and conducting in-depth studies, the exploration of the impact of suspension training on the balance ability of deaf-mute patients holds significant research value and practical application. Not only does it enrich and refine training methods for this group, but it also offers a new research perspective for this field.

2. Literature review

Currently, the definition of suspension training varies across different interpretations. For instance, suspension exercise therapy refers to suspension training, also known as "suspension exercise therapy", as a therapeutic approach that integrates diagnostic and treatment systems, primarily utilized for musculoskeletal disorders, encompassing both active exercise and rehabilitation (Wei, 2006). Scholar Yu (2008) posits that suspension training utilizes non-static reactive forces to activate a large number of motor units, thereby serving as a method to enhance proprioceptive function (neuromuscular). Other researchers suggest that suspension training involves suspending a part of the body in an unstable state to facilitate adjustments that improve or enhance physical performance.

The term “balance” is extensively employed in both sports and medical fields, with its influencing factors including physical disabilities, cerebellar injuries, or limb impairments. Scholar Wang (2013) has emphasized that balance is fundamental to activities such as standing, running, and walking, serving as the foundation for all movements. Balance is influenced by visual, proprioceptive, and vestibular functions, and impairment in any of these systems can lead to a decline in balance capabilities. Within the domains of rehabilitation and training, scholars have investigated the factors influencing balance and developed assessment methods aimed at enhancing or restoring patients’ balance abilities. For instance, Gao (2000) and Chen’s (1996) balance beam experiments on mice revealed that long-term treadmill training could improve balance and coordination. Moreover, targeted core muscle training has been shown to promote daily functional abilities and limb recovery in stroke patients (Qiu, 2004). The introduction of balance training devices has also facilitated the rehabilitation of balance function (Wei, 2003), while gymnastics training has been demonstrated to significantly enhance balance abilities (Ren, 2005). In 2003, LanghaInI and colleagues compared motor relearning therapy and Bobath therapy for stroke patients, indicating that although early physical therapy supports brain recovery, its long-term efficacy is limited (Dong, 2004). In 2005, Zhai (2005) and colleagues utilized balance feedback training combined with Bobath therapy to investigate walking and balance functions in stroke patients, discovering that semi-squat balance training, when integrated with traditional Chinese medicine, contributed to functional recovery (Liu, 2005).

Research on balance function in individuals with hearing impairments has also made notable progress. In her article, strengthening exercise rehabilitation training to improve the physical fitness of deaf students, Xia (2020) noted that although deaf individuals are no different from ordinary people, hearing impairments lead to significant differences in sensitivity, orientation, self-control, reaction ability, and coordination, especially in balance ability. Lu (2003) observed that deaf individuals may occasionally experience issues with dynamic or static balance. The article “Fitness for people with disabilities” further highlighted that inner ear damage can affect the balance abilities and motor skill acquisition of deaf individuals (Yu, 1997). Consequently, hearing impairment is often associated with vestibular balance disorders or inner ear damage, with ototoxicity being a major cause of vestibular impairment, which is a critical factor affecting balance abilities.

Extensive research, both domestically and internationally, has demonstrated that the maintenance of balance relies on the coordination of the central nervous system, muscle tone, visual system, vestibular system, and proprioceptive system. The visual system conveys environmental information to the brain to aid in the regulation of body movement; the vestibular system perceives head position and provides information on acceleration and gravitational forces to the brain; while the proprioceptive system transmits data on muscle tension and spatial positioning. Balance is generally classified into static and dynamic types. Static balance refers to the control of a stationary posture, primarily achieved through isometric muscle contractions, whereas dynamic balance involves controlling the center of gravity during movement and continuously adjusting posture to maintain stability, primarily relying on isotonic muscle contractions. Suspension training has the potential to improve various aspects of muscular coordination and enhance balance function, particularly in enhancing balance capabilities among individuals with hearing impairments.

Therefore, balance refers to the body's ability to maintain stability and equilibrium while in motion or at rest. In recent years, research on human balance capabilities has become increasingly in-depth, focusing on areas such as the role of the vestibular organs, causes of balance disorders, and influencing factors. Most studies have primarily concentrated on balance training for healthy individuals and the assessment indicators of balance function. A review of numerous domestic and international studies indicates that suspension training can improve the coordination of multiple muscle groups, thereby enhancing balance ability. However, there has been relatively little research using deaf individuals as experimental subjects to study balance abilities, and even fewer studies focus on balance training for this group. suspension training is recognized for its therapeutic benefits in improving balance and proprioception, particularly for individuals with musculoskeletal issues and hearing impairments. Balance, essential for all movement, is influenced by visual, vestibular, and proprioceptive systems, with impairments in these areas leading to balance deficiencies. Research shows that training methods, including suspension training, core muscle exercises, and balance feedback therapy, can significantly improve balance and coordination. These approaches are particularly beneficial for stroke patients and those with vestibular issues, such as deaf individuals, whose inner ear damage often affects balance. Ultimately, suspension training offers promising potential for enhancing balance and muscular coordination across various populations.

3. Experimental subjects

Six special education schools in Shijiazhuang were selected as the study sites for recruiting student participants. Students were required to meet specific screening criteria, consent to participate in the study, and sign an informed consent form. A total of 105 students (65 boys and 40 girls) with non-genetic hearing impairments were selected for inclusion in the study. The inclusion criteria required that students be between 10 and 12 years old, have a binaural hearing range of less than 55 dB (including mutism patients), possess normal intelligence, be free from any diseases or functional disorders, and have sound limbs; have normal intelligence; have no diseases or other functional disorders; and have sound limbs. The exclusion criteria included deafness caused by chronic diseases, availability for less than two months, and any concurrent treatments other than suspension training at the time of the experiment. The 105 students who met the screening criteria were randomly assigned to either an exercise group or a control group using the random number table method.

4. Research methods

4.1. Experimental design

Exercise Group: balance training utilizing the TRX suspension training belt included exercises such as prone elbow support, supine back support, kneeling elbow support, side-lying elbow support, push-up hip flexion, and supine hip lift. Strength training exercises were performed using equipment and involved movements like single-leg suspension squats, bird support, supine suspension flexion, seated static support, and standing butterfly chest.

The control group did not receive any form of training.

4.2. Tests for indicating the balance ability

Multiple assessments were conducted to evaluate the students' balance abilities.

Static balance was assessed using two tests. The ability to maintain posture without external interference was measured by the word step test. The ability to control posture under disturbance was evaluated using the Wolfson postural stress test.

Dynamic balance was assessed using two tests. The ability to maintain balance during movement was measured by the functional forward reach test. The ability to control balance during stress-inducing activities was evaluated using the balance beam walk test.

The students' vestibule function was assessed using the rotation-walk test.

4.3. Experimental monitoring

Monitoring of students during suspension training was conducted throughout the study. Each week, 18 subjects were divided into 6 groups, with 3 subjects per group, for the experimental training. The training sessions took place at the respective schools where the subjects had been selected. Training times, intensity, and interval lengths between training sessions were consistent across all groups, and the experiment was conducted in a double-blind manner. If a student was unable to complete a required activity, the difficulty and load were adjusted to ensure completion. Subjects were instructed to cease all physical activities one week prior to the start of the experiment, and no additional experiments or related activities were permitted during their participation in the research. All subjects were assigned to a three-period testing regimen at each site. Test indicators were assessed in groups, and the rotation test was conducted simultaneously.

4.4. The mathematical and statistical analysis

Data were analyzed using SPSS 20.0 Statistics, employing repeated measures analysis of variance, multivariate analysis of variance, and independent sample t-tests.

5. Results and analysis

5.1. General comparisons

Of the 105 subjects, 98 successfully completed the trial, with 7 subjects withdrawing due to injury. The age of participants ranged from 10.2 to 11.9 years.

Post-testing analysis revealed no significant differences in basic physical attributes such as age, height, and weight between the groups ($p > 0.05$), indicating that the groups were comparable.

5.2. Test indexes in the exercise group and the control group before the training

A *t*-test was conducted on the variables of the exercise group and the control group. The experimental results indicated that all *P*-values were greater than 0.05, suggesting that the pre-experiment test indicators were not statistically significant, and the effects after the intervention were comparable across both groups (**Figure 1**).

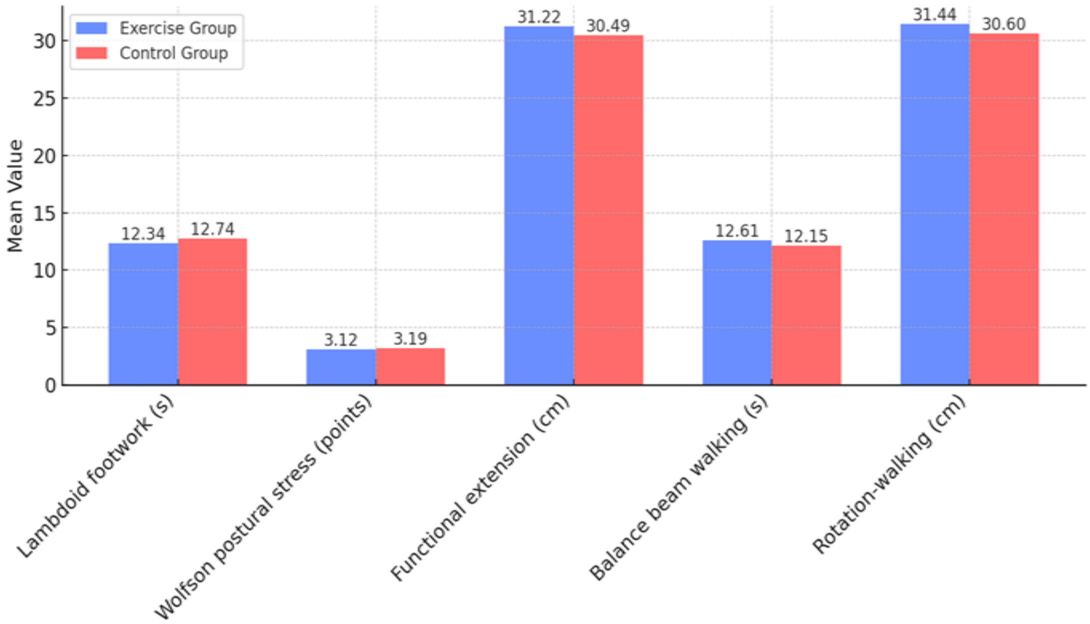

Figure 1. Comparison of groups across variable.

5.3. Test indexes in the exercise group and the control group after the training

The sphericity test revealed an approximate chi-squared value of 6554.9, with 275 degrees of freedom and a *P*-value of 0.000, indicating a high correlation among the three repeated measurements. According to Hotelling's trace, the *P*-value was 0.000, indicating that the interaction of the time factors was statistically significant.

5.4. Character step index

Compared to the control group, the exercise group exhibited no significant differences prior to the experiment ($p > 0.05$); however, significant differences emerged after 8 weeks and 16 weeks of training ($p < 0.05$). The time effect *F*-value and interaction effect *F*-value were highly significant ($p < 0.01$), and the grouping effect *F*-value also demonstrated significant differences ($p < 0.05$). When comparing the word step times between the two groups, no significant differences were found prior to the experiment ($p > 0.05$); however, highly significant differences were observed at 8 weeks and 16 weeks following the suspension training ($p < 0.01$) (**Figure 2**).

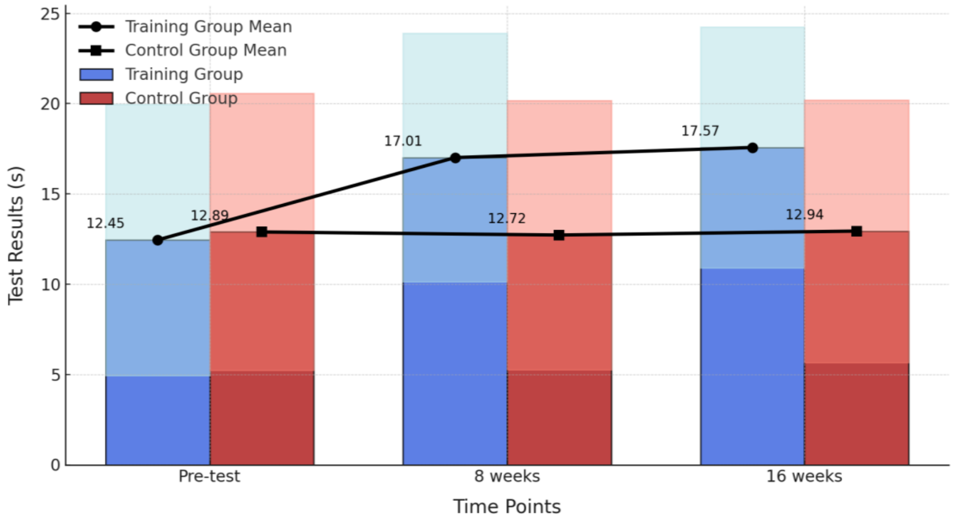

Figure 2. Effect of intervention on balance over time.

5.5. The changes of Wolfson postural stress index

Compared to the control group, the exercise group exhibited significant differences ($p < 0.05$) at 8 weeks and highly significant differences ($p < 0.01$) at 16 weeks following the experimental intervention, as illustrated in **Figure 3.** Notably, there were no significant differences ($p > 0.05$) between the groups before the experiment.

The time effect F-value, grouping effect F-value, and interaction effect F-value all showed high significance after the suspension training at 8 weeks and 16 weeks ($p < 0.01$), despite no significant differences before the experiment ($p > 0.05$).

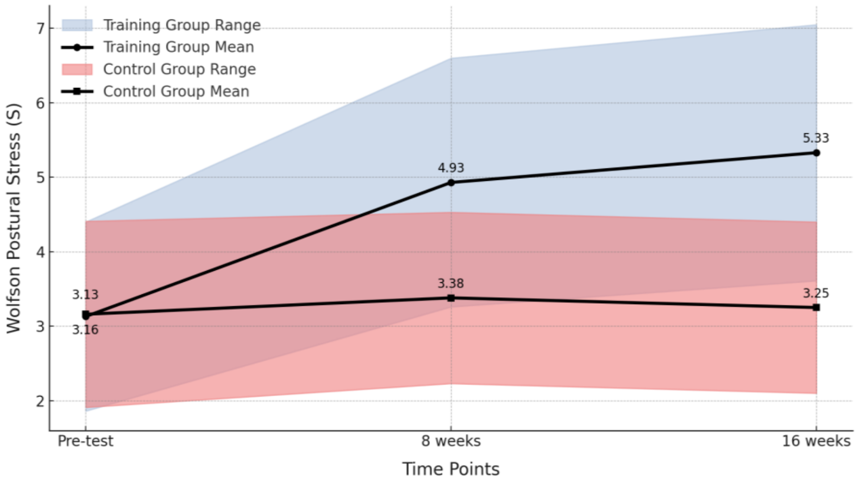

Figure 3. Wolfson postural stress index.

5.6. Changes in the functional extension index

Compared to the control group, the exercise groups exhibited significant differences ($p < 0.05$) at 8 weeks and highly significant differences ($p < 0.01$) at 16 weeks following suspension training; however, no significant differences ($p > 0.05$) were observed prior to the experiment. The time effect F-value and interaction effect F-value ($p < 0.01$) demonstrated highly significant differences, while the grouping effect *F*-value ($p < 0.05$) showed significant differences. In comparisons of functional extension between the two groups, significant differences were observed at 8 weeks and 16 weeks post-intervention ($p < 0.05$), whereas no significant differences were found in the pretest groups ($p > 0.05$) (**Figure 4**).

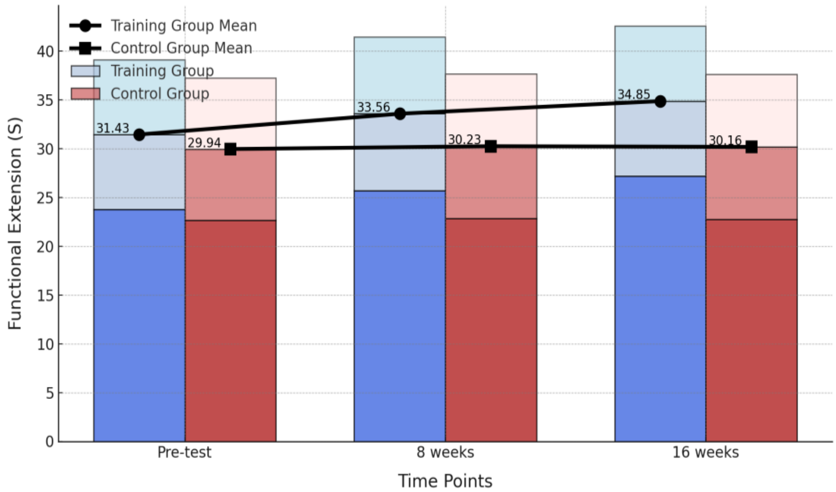

Figure 4. Functional extension over time.

5.7. Changes in the balance beam walking index

Pre-testing of the two groups revealed no significant differences ($p > 0.05$). However, after 8 weeks and 16 weeks of suspension training, significant differences emerged ($p < 0.05$). The time effect *F*-value and interaction effect *F*-value demonstrated highly significant differences ($p < 0.01$), while the grouping effect *F*-value exhibited significant differences ($p < 0.05$). Prior to the balance beam walking test, no significant differences were found between the two groups ($p > 0.05$). However, at 8 weeks ($p < 0.05$), the differences became significant, and by 16 weeks ($p < 0.01$), the differences were highly significant (**Figure 5**).

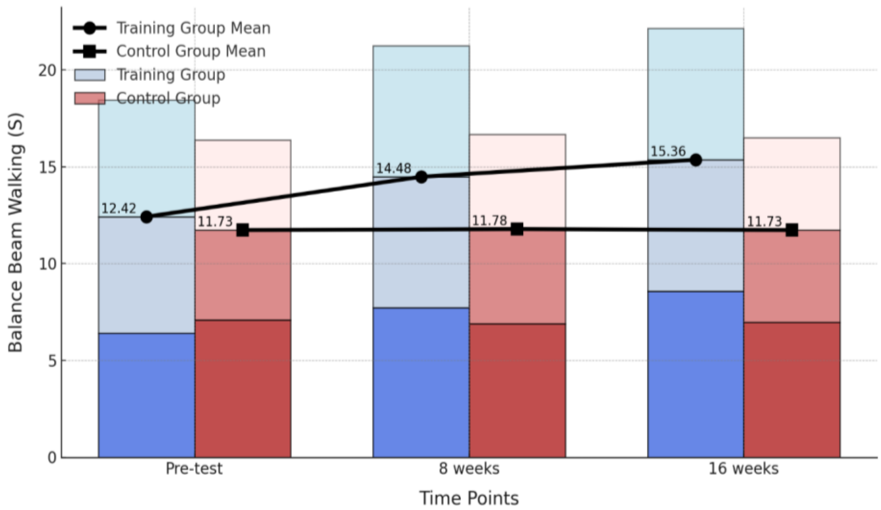

Figure 5. Balance beam walking over time.

5.8. The changes of rotation-walking index

No significant differences were observed within the groups before the test or after suspension training at 8 weeks and 16 weeks ($p > 0.05$), with the exception of the group effect F-value, which showed a significant difference ($p < 0.05$). The rotation-walking test indicated that there were no statistically significant differences between the two groups before the test or at 8 weeks and 16 weeks post-training ($p > 0.05$) (**Figure 6**).

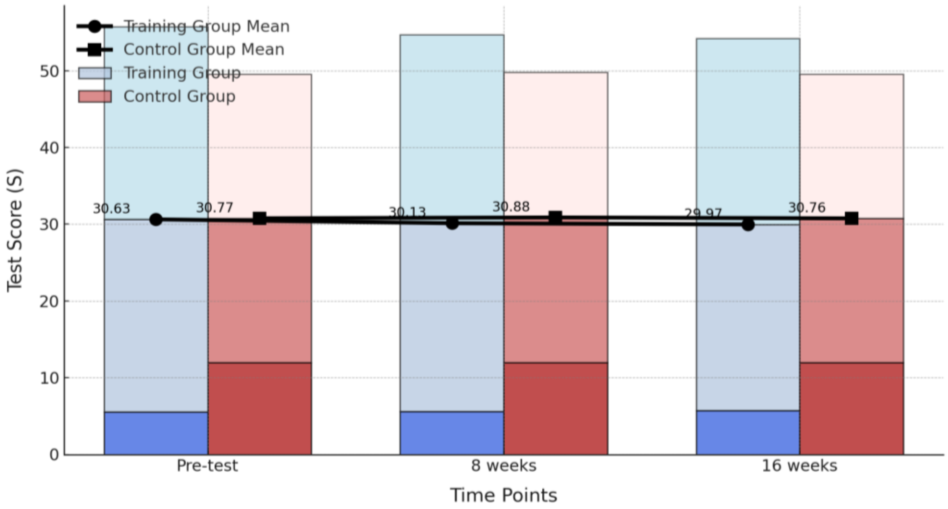

Figure 6. Rotating-walking test with repeated measures of analysis of variance.

6. Discussion

6.1. The effect of suspension training on static balance

The results of the character step test demonstrated that suspension training had a pronounced effect on improving balance during activities requiring static, non-interference maintenance. Suspension training effectively activated both the global motive muscles and the local stabilizer muscles. By improving muscle coordination, increasing the stability control of dorsal and abdominal muscles, and enhancing muscular synergy, the body's center of gravity is stabilized, thereby supporting the surface and achieving overall balance. The contraceptive system plays a critical role in receiving sensory input, which is essential for maintaining static balance. The results of the Wolfson postural stress test demonstrated that suspension training had a highly significant impact on improving balance when static posture control was disrupted. It is well known that balance is the ability to maintain proper body posture, particularly on small support surfaces, in order to control the body's center of gravity. Suspension training targets not only individual or multiple muscles but also the entire core muscle group. It effectively activates the muscular, filamentous, and facial systems, enhancing the efficiency and accuracy of sensory information processing, thereby improving the precision of intramuscular control (Walker et al., 2000). The axial load generated by suspension training maximizes the stimulation of receptors surrounding the joints, thereby enhancing afferent expropriation. During learning or training, the nervous system is activated, gradually replacing the subject's initial poorly coordinated muscle recruitment with coordinated muscle contractions. This transition enables conditioned reflexes and results in improved balance.

6.2. The effect of suspension training on dynamic balance ability

The functional forward test demonstrated that suspension training had a pronounced effect on dynamic balance. Suspension training employs low-load isometric contraction exercises targeting local stabilizer muscles, gradually activating the primary movers to achieve comprehensive support (Le, 2000). It emphasizes the mobilization of muscle fibers and the level of inter muscular coordination, thereby enhancing the body's ability to control muscles and maintain balance.

The balance beam walking test results indicated that suspension training also had a significant effect on dynamic balance, particularly during activities where muscle control was challenged. In humans, balance is not a fixed ability; it can adapt to various situations, including during responses to exercise-induced stress. Balance beam walking involves the legs swinging alternately in a circular motion, a process that disrupts and restores balance in a repetitive cycle. The specific sequence of actions begins with the knee joint acting as the axis for flexion and extension to adjust the body's center of gravity, thereby coordinating movement. Next, the ankle engages by rotating or swinging back and forth to maintain balance, with the ankle joint coordinating these actions. Finally, the stepping action takes over; when the center of gravity is disturbed, the feet remain stationary to maintain balance. These muscle groups work energetically across time, space, and intensity to maintain human balance.

6.3. Effect of suspension training on vestibule function

In the rotation-walking test, the test indices of the exercise group exhibited a gradual upward trend after 8 weeks of suspension training, followed by a downward trend after 16 weeks. The indices initially increased but then stabilized or even declined, which the author attributes to the phenomenon of vestibule adaptation. This occurs when regular or long-term stimulation of the vestibule system leads to a gradual weakening of the body's vestibule response. The control group exhibited a slow downward trend across all three testing periods. There were no significant differences in test data between the two groups ($p > 0.05$), indicating that suspension training had no significant effect on improving vestibule function.

In summary, suspension training had a significant impact on the balance abilities of juvenile deaf-mute patients, particularly with respect to static balance. However, this improvement was primarily achieved through the mediation of skeletal muscle movement, muscle contraction coordination, and other mechanisms, rather than through enhancement of the students' vestibule function. It can be concluded that suspension training had no significant effect on improving vestibule function in juvenile deaf-mute individuals. Furthermore, suspension training is universally beneficial for improving balance in deaf-mute individuals with non-genetic causes of deafness and is suitable for any age group. Due to limitations in funding and time, the experimental period of this study was relatively short, and the research was prematurely suspended. Future research will aim to build upon both domestic and international findings to conduct comprehensive investigations into the effects of suspension training on the balance abilities of individuals with hearing impairments. The goal is to provide novel insights into enhancing the balance capabilities of this population and to contribute valuable references for developing and refining training methodologies specifically designed for this group. Such efforts are expected to have significant implications for advancing research and practice in this area.

7. Conclusion

Leveraging the contraceptive system to mediate skeletal muscle movement and coordinate muscle contractions can enhance balance.

Suspension training had a pronounced effect on enhancing balance during static activities that require non-interference maintenance.

Suspension training did not produce significant improvements in vestibule function.

Suspension training is beneficial for improving balance in all patients with non-hereditary deafness.

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