

Contribution of Sensory Systems to Static Balance in Elderly Women following Exercise Training (Part Two: Hippotherapy vs Aquatic Exercise): A Quasi-experimental Study

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Original Article

Abstract

Introduction: Physiological changes induced by aging decreases balance and increases the risk of falls more specifically among women. The aim of present study was to investigate the effects of aquatic exercises on the engagement of sensory components of system that controls static balance in elderly women.

Materials and Methods: In this applied, semi-experimental study, with pre-test-post-test design and a control group, symptom-free elderly women of 60 to 70 years old were randomly assigned into aquatic, hippotherapy and control group (10 people each). The participation of sensory components of postural control system (visual, vestibular, somatosensory) in static balance was measured before and after 16 training sessions using the sensory organization test by the Synapsis® posturography system. The aquatic exercise group and the hippotherapy group participated in the relevant exercise protocol for 8 weeks, 2 sessions per week (50 minutes) and the control group continued their normal life. The data was analyzed using the paired T-test for intra-group comparisons and independent T-test to examine the between-group differences.

Results: The results showed that the aquatic exercise group had better performance in the post-test compared to the control group. Aquatic training significantly improved the vestibular system function in anterior-posterior direction, somatosensory system, static balance in anterior-posterior and medial-lateral directions in elderly women ($P = 0.001$ for all).

Conclusion: In general, aquatic exercise may be recommended as an alternative strategy in a safer environment for improving the participation of sensory components of the systems that controls static balance in elderly females.

Keywords: Sensory integration; Balance; Postural control; Elderly; Women; Aquatic exercise

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Introduction

Aging is a dynamic, time-dependent process characterized by the gradual degeneration of cells and varies from one individual to another (1). These changes reduce the necessary and beneficial responses to stress, increase sensitivity and vulnerability to disease, and reduce quality of life (2). The aging process includes biological, cognitive, and social changes, accompanied by progressive molecular and cellular damage and loss of muscle strength and power (3); these factors lead to changes in physical function and functional skills of daily living (4). It is estimated that by 2050, the number of older adults aged 60 and over will double, reaching 2.1 billion (5). Meanwhile, women live longer than men and are therefore more susceptible to the complications of aging, such as physical disability, mobility impairment, depression, and anxiety (6).

One of the changes associated with the aging process is a decline in balance. Approximately one in every five elderly individuals experiences problems such as dizziness or falls (7). The weakening of joint proprioceptive receptors and neural pathways, with reduced accuracy and disrupted timing of balance adjustments, predisposes individuals to falling and increases the risk of fractures and head injuries (8). Balance is the analysis of information from the sensory receptors of the visual, vestibular, and proprioceptive systems, and from the interaction between the central nervous system and musculoskeletal reflex arcs (9). The visual system is an important and complex factor in balance control (10) and is the primary sensory system for postural control (11). This system plays a decisive role in processing and integrating other sensory inputs to select a balance-maintenance strategy (9). The proprioceptive system receives signals from mechanoreceptors (muscle spindles, Golgi tendon organs, and joint receptors) located in the muscles, tendons, and joint capsules — particularly in the leg muscles, which are the primary source of information for balance control (12). This system, by generating reflexive responses, informs the brain about the spatial position and configuration of the body's musculoskeletal framework and plays a role in maintaining balance (13). Muscle spindles, by relaying information about muscle length and contraction velocity to the nervous system, contribute to an individual's ability to detect joint movement and sense body position. The Golgi tendon organ, located in the muscle tendon, can exert a controlling influence on muscle contraction in response to the tensile force imposed on the tendon and is essentially sensitive to the smallest changes in muscle tone (14). Joint

receptors, arranged in small clusters within the superficial and fibrous layers of the joint capsule, play a significant role in awareness of joint position and movement. These receptors respond to the type of pressure applied to the joint capsule and, when a joint moves suddenly, are strongly stimulated, helping maintain body balance (11).

Sensory apparatuses have two essential roles in balance control during various movements. One role is related to the environment and the perception of external stimuli, enabling the musculoskeletal system to adapt to unexpected environmental disturbances and maintain the individual's balance. The other role is the adaptation of motor commands sent in response to environmental changes, which ultimately maintains balance (9, 15). To maintain balance while executing a motor program, the vestibular system interacts fully with the proprioceptive system. Impulses from the vestibular apparatus send data about the direction and speed of head movement and its position relative to gravity to the central nervous system; the extensive connections of the vestibular system with various parts of the nervous system are effective in determining the state of balance. The cerebral cortex perceives vestibular system information as changes in movement speed and direction and generates appropriate responses for postural control under changing environmental conditions (16, 17). Therefore, both the visual and proprioceptive systems interact with the vestibular system throughout the central vestibular pathways and are essential for balance control (11).

One of the reasons for the increased risk of falls in older people is the decline in the function of the sensory systems involved in balance due to increasing age (18); such that the function of the visual, vestibular, and proprioceptive systems declines, and consequently, the body is unable to detect deviations of the center of gravity and, therefore, cannot generate appropriate and immediate muscular responses to correct balance (19, 20). Currently, researchers have linked physical inactivity to reduced muscle mass, bone density (21), vulnerability, and loss of function in elderly individuals (22), and on the other hand, consider physical activities essential for achieving functional independence, reducing fall risk, and enhancing quality of life (23, 24). Nevertheless, physical activities can only improve and restore balance when they challenge the sensory components of the balance control system (proprioceptive, visual, and vestibular systems) (25). For example, individuals who are continually exposed to change-in-support reactions exhibit less postural sway and show considerable improvement in maintaining balance in

response to generated perturbations (26).

By creating perturbations and altering environmental conditions, the internal adaptations of the sensory systems involved in balance can be measured with precise instruments, and the presence of deficits in each of the sensory systems controlling balance, as well as their improvement before and after interventions, can be compared (27). One such intervention that perturbs sensory inputs is hippotherapy (equine-assisted exercise) (28). In fact, hippotherapy is among the activities that involve movement of the base of support and is recognized as a complementary activity for improving balance-related motor responses in elderly individuals (29). Hippotherapy is a comprehensive, neurologically based treatment that uses the horse as its central element, employing the animal's movement, rhythm, and warmth to stimulate the senses (30). Equine-assisted exercise has become an effective intervention for older people for static and dynamic balance, flexibility, muscle strength, and gait (31). It has yielded growing scientific evidence of its benefits in the social, motor, and mental domains of participants (32). It is said that hippotherapy is a dynamic activity that, due to the oscillation of the horse's movements in the left-right, up-down, and forward-backward directions, leads to a better enhancement of balance responses (33), and by increasing flexibility in the back muscle chain, has a significant effect on improving balance, motor function, flexibility, muscle strength, and gait cadence in asymptomatic elderly individuals, thereby improving their quality of life (29).

Currently, no published evidence precisely demonstrates the distinct effects of hippotherapy, given the different sensory perturbations it generates during training, on the function of the visual, vestibular, and proprioceptive systems in improving balance. Therefore, the present study addresses the following question: how does the contribution of the sensory systems of postural control change after a period of hippotherapy in older women? In this study, the effects of aquatic exercise and hippotherapy on the function of the sensory components of the static balance control system in older women were examined; the results of the aquatic exercise intervention were previously published (34), but no study to date has compared the effectiveness of these two training methods. Therefore, another objective of this study was to compare the effects of a period of aquatic exercise and hippotherapy on the contribution of the sensory systems in older women. These results could be clinically valuable for elderly individuals, trainers, and the rehabilitation team.

Materials and Methods

The present study was applied in nature and quasi-experimental in design, employing a pretest-posttest design. All stages of the study were approved by the Ethics Committee of Najafabad University before implementation and registered with the Iranian Registry of Clinical Trials. This study is part of a larger study, and the inclusion and exclusion criteria for assignment to the control group, the hippotherapy group, and the aquatic exercise group, the method of sample size estimation, and the details of the aquatic exercise protocol and balance assessment procedure are exactly consistent with the article by Hamidi et al. (34).

Hippotherapy: Participants in the hippotherapy group took part in the hippotherapy protocol for 8 weeks, 2 sessions per week, 50 minutes each. The training protocol was piloted with a 65-year-old woman and, in accordance with the overload principle, was designed with progressively increasing difficulty (Table 1). Each hippotherapy session involved the horse walking on sandy surfaces. Three trained horses, approximately 1.50 meters in height and approximately 480 kg in weight, were used. The horses were guided with a halter and saddle stirrups by experienced instructors who held equestrian coaching certification. A sports coach led each horse through the exercises, and a professional equestrian handler was present to ensure safety.

Equipment used by participants included safety helmets and appropriate clothing. During this period, individuals in the control group continued their normal daily life. One day after the training protocol ended, both groups were retested using the aforementioned assessments.

Statistical Methods: Descriptive statistics were used to describe the data; the Shapiro-Wilk test was used to examine the distribution of the data; the paired t-test statistical method was used to examine within-group differences; and one-way ANOVA with Tukey's post hoc test was used to examine between-group differences, at a significance level of 0.05, using SPSS 23 software (IBM Corp. Released 2015. IBM SPSS Statistics for Windows, Version 23, Armonk, NY, USA).

Results

A total of 30 participants were assigned to three groups of 10: aquatic exercise, hippotherapy, and control. All participants in each group completed all stages of the study (dropout rate = 0%). The results of the Shapiro-Wilk test indicated that the distributions of all studied variables were normal ($P > 0.05$); therefore, parametric statistical tests were used for the analysis.

Table 1. Hippotherapy Training Protocol

Phase	Week	Content
Warm-up (10 minutes)	-	Ground-based movements, including stretching exercises and breathing exercises; approaching and touching the horse; walking beside the horse; sitting on the horse; and trunk rotation while placing the hands on different parts of the horse's body (neck and pelvis).
Main training section (30 minutes)	Week 1	1) Familiarization with the horse, approaching and touching the horse (5 minutes). 2) Walking beside the horse while the halter was held by the instructor (10 minutes). 3) Mounting and dismounting the horse using a platform (2 repetitions with 5 minutes of rest). 4) Riding the horse while it walked along straight paths (10 minutes).
	Week 2	1) Walking beside the horse while the halter was held by the instructor (5 minutes). 2) Mounting and dismounting the horse using a platform (4 repetitions over 10 minutes). 3) Riding the horse while it walked along straight and zigzag paths (15 minutes).
	Week 3	1) Walking beside the horse while the halter was held by the instructor (5 minutes). 2) Riding the horse while it walked along straight and zigzag paths, with changes of direction (20 minutes). 3) Riding the horse in a standing position (the participant pressed the sole on the stirrup, rose on the stirrup, and sat back down on the saddle) (3 sets of 5 repetitions with 5 minutes of rest).
	Week 4	1) Riding the horse while it walked along straight and zigzag paths, with changes of direction (20 minutes). 2) Riding the horse in a standing position (the participant pressed the sole on the stirrup, rose on the stirrup, and sat back down on the saddle) (4 sets of 5 repetitions with 5 minutes of rest). 3) Riding the horse in a standing position (participant's eyes closed, hands resting on the saddle) (5 repetitions of 20 seconds with 5 minutes of rest).
	Week 5	1) Riding the horse while it walked along straight and zigzag paths, with changes of direction (20 minutes). 2) Riding the horse in a standing position while moving the head around three axes with eyes open to stimulate the vestibular system (flexion, extension, lateral flexion, and rotation of the head) (5 minutes). 3) Riding the horse while it walked with the feet out of the stirrups to create greater perturbation for balance maintenance (5 minutes).
	Week 6	1) Riding the horse while it walked along straight and zigzag paths, with changes of direction (12 minutes). 2) Riding the horse while it walked along straight paths with eyes closed and hands resting on the saddle (5 repetitions of 30 seconds with 5 minutes of rest). 3) Riding the horse in a standing position while moving the head around three axes with eyes open to stimulate the vestibular system (flexion, extension, lateral flexion, and rotation of the head) (5 minutes). 4) Riding the horse while it walked with the feet out of the stirrups to create greater perturbation for balance maintenance (7 minutes).
	Week 7	1) Riding the horse while it walked along straight and zigzag paths, with changes of direction (8 minutes). 2) Riding the horse while it walked along straight paths with eyes closed and hands resting on the saddle (6 repetitions of 30 seconds with 6 minutes of rest). 3) Riding the horse in a standing position while moving the head around three axes with eyes open and closed and hands resting on the saddle to stimulate the vestibular system (flexion, extension, lateral flexion, and rotation of the head) (6 minutes). 4) Riding the horse while it walked with the feet out of the stirrups to create greater perturbation for balance maintenance (10 minutes).
	Week 8	1) Riding the horse while it walked with increased speed along straight and zigzag paths, with changes of direction (6 minutes). 2) Riding the horse while it walked along straight paths with eyes closed and hands resting on the saddle (7 repetitions of 30 seconds with 7 minutes of rest). 3) Riding the horse in a standing position while moving the head around three axes with eyes open and closed and hands resting on the saddle to stimulate the vestibular system (flexion, extension, lateral flexion, and rotation of the head) (7 minutes). 4) The horse in a standing position (the participant pressed the sole on the stirrup, rose on the stirrup, and sat back down on the saddle) (3 sets of 10 repetitions with 10 minutes of rest).
Cool-down (10 minutes)	-	Body relaxation exercises, breathing exercises, stretching, and emotional interaction with the horse (walking beside it and petting it).

Demographic information is summarized in Table 2; there was no significant difference between the mean values of age, height, weight, and body mass index among the groups ($P > 0.05$).

Table 3 presents the degree of center-of-pressure sway in the anterior-posterior and medial-lateral directions under pretest and posttest conditions for assessing each sensory component of the postural control system.

According to Table 3, the within-group comparison (paired t-test) showed no significant change in the control group ($P > 0.05$). In the hippotherapy group, the vestibular system in the anterior-posterior direction, the somatosensory system, and total balance in both the anterior-posterior and medial-lateral directions ($P \leq 0.002$ for all) showed significant improvement.

The results of the ANOVA test showed that there was no statistically significant difference at pretest.

Table 2. Descriptive Statistics of Demographic Variables of the Participants

Variable	Group	Sample Size	Mean $\pm$ SD	P value
Age (years)	Hippotherapy	10	65.19 $\pm$ 4.71	0.38
	Control	10	64.98 $\pm$ 5.37	
Height (m)	Hippotherapy	10	162.82 $\pm$ 5.17	0.31
	Control	10	163.21 $\pm$ 4.21	
Weight (kg)	Hippotherapy	10	64.19 $\pm$ 6.39	0.27
	Control	10	66.38 $\pm$ 8.37	
Body mass index (kg/m ²)	Hippotherapy	10	24.21 $\pm$ 5.01	0.52
	Control	10	24.93 $\pm$ 4.58	

Still, at posttest, there was a significant difference in the anterior-posterior vestibular variable ($P = 0.001$) and in the somatosensory and total balance variables in both the anterior-posterior and medial-lateral directions ($P = 0.001$ for all) (Table 4).

According to Table 5, at posttest, the hippotherapy group showed a significant difference compared to the control group in the anterior-posterior vestibular variable ($P = 0.001$), and in the somatosensory and total balance variables in both the anterior-posterior and medial-lateral directions ($P \leq 0.046$). This group, compared with the aquatic exercise group, showed significant differences only in the anterior-posterior vestibular variable ($P = 0.011$), the medial-lateral somatosensory variable ($P = 0.007$), and the anterior-posterior total balance variable ($P = 0.024$). Also, according to Table 5, there was no significant difference between the hippotherapy group and the aquatic exercise group ($P \geq 0.758$) or the control group ($P \geq 0.997$) in the anterior-posterior visual variable. Likewise, in the medial-lateral visual variable, there was no significant difference between the hippotherapy group and the aquatic exercise group

($P \geq 0.934$) or between the hippotherapy group and the control group ($P \geq 0.839$). There was also no significant difference between the hippotherapy group and the aquatic exercise group ($P \geq 0.096$) or the control group ($P \geq 0.739$) in the medial-lateral vestibular variable.

Discussion

The present study was large, comprising three groups: control, hippotherapy, and aquatic exercise. The comparison between the aquatic exercise group and the control group was discussed previously (34). Comparison of the function of the sensory components of the postural control system using the posturography device showed that, despite the considerable improvement in the degree of contribution of the vestibular and proprioceptive systems in both the hippotherapy and aquatic exercise groups—which led to a significant improvement in static balance in the anterior-posterior and medial-lateral directions—the contribution of the visual system in these two groups showed no significant difference compared to the control group.

Table 3. Results of the Paired t-test for the Measured Variables in the Participating Groups

Group	Variable	Pretest	Posttest	T statistic	df	P value
Control	Visual anterior-posterior (mm)	95.33 $\pm$ 4.64	95.66 $\pm$ 4.01	0.43	9	0.68
	Visual medial-lateral (mm)	93.41 $\pm$ 5.03	93.61 $\pm$ 4.53	0.23	9	0.83
	Vestibular anterior-posterior (mm)	78.21 $\pm$ 6.39	79.90 $\pm$ 5.30	0.21	9	0.84
	Vestibular medial-lateral (mm)	82.50 $\pm$ 6.48	81.20 $\pm$ 5.92	0.16	9	0.87
	Somatosensory anterior-posterior (mm)	69.20 $\pm$ 7.88	70.66 $\pm$ 6.69	1.40	9	0.19
	Somatosensory medial-lateral (mm)	74.50 $\pm$ 7.72	75.66 $\pm$ 7.288	0.62	9	0.55
	Total balance anterior-posterior (mm)	68.73 $\pm$ 6.32	69.41 $\pm$ 7.83	0.50	9	0.633
	Total balance medial-lateral (mm)	73.66 $\pm$ 4.48	74.30 $\pm$ 6.48	0.83	9	0.43
Hippotherapy	Visual anterior-posterior (mm)	94.20 $\pm$ 5.29	94.70 $\pm$ 4.97	1.96	9	0.081
	Visual medial-lateral (mm)	93.00 $\pm$ 4.46	93.20 $\pm$ 6.83	1.76	9	0.11
	Vestibular anterior-posterior (mm)	77.80 $\pm$ 6.04	86.60 $\pm$ 7.63	7.83	9	0.001
	Vestibular medial-lateral (mm)	82.20 $\pm$ 5.79	83.00 $\pm$ 4.45	1.61	9	0.14
	Somatosensory anterior-posterior (mm)	70.40 $\pm$ 7.53	92.90 $\pm$ 4.50	26.23	9	0.001
	Somatosensory medial-lateral (mm)	75.33 $\pm$ 6.76	89.10 $\pm$ 4.18	20.98	9	0.001
	Total balance anterior-posterior (mm)	68.91 $\pm$ 5.51	78.65 $\pm$ 7.66	4.27	9	0.002
	Total balance medial-lateral (mm)	72.60 $\pm$ 6.06	80.20 $\pm$ 7.02	5.31	9	0.001

Table 4. ANOVA Results for the Measured Variables

Stage	Variable	Sum of Squares	df	Mean Square	F	P value
Pre-test	Visual anterior-posterior (mm)	11.66	2	5.83	0.47	0.63
	Visual medial-lateral (mm)	3.20	2	1.60	0.09	0.91
	Vestibular anterior-posterior (mm)	17.86	2	8.93	1.05	0.36
	Vestibular medial-lateral (mm)	5.40	2	2.70	0.19	0.83
	Somatosensory anterior-posterior (mm)	14.60	2	7.30	0.42	0.66
	Somatosensory medial-lateral (mm)	43.40	2	21.70	1.66	0.21
	Total balance anterior-posterior (mm)	1.80	2	0.90	0.033	0.97
	Total balance medial-lateral (mm)	6.46	2	3.23	0.17	0.84
Post-test	Visual anterior-posterior (mm)	6.06	2	3.03	0.31	0.74
	Visual medial-lateral (mm)	6.46	2	3.23	0.33	0.73
	Vestibular anterior-posterior (mm)	1025.26	2	512.63	33.57	0.001
	Vestibular medial-lateral (mm)	114.20	2	57.10	2.21	0.13
	Somatosensory anterior-posterior (mm)	3929.86	2	1994.43	136.32	0.001
	Somatosensory medial-lateral (mm)	1752.86	2	876.43	81.65	0.001
	Total balance anterior-posterior (mm)	1498.46	2	749.23	17.95	0.001
	Total balance medial-lateral (mm)	465.06	2	232.53	9.43	0.001

Furthermore, the degree of improvement in the hippotherapy group in the contribution of the vestibular sense and total balance in the anterior-posterior direction, and in the contribution of the proprioceptive sense in the medial-lateral direction, was significantly lower than in the aquatic exercise group. In contrast, no significant difference between the two groups was observed for the other variables.

Hippotherapy: To examine the effects of hippotherapy on the degree of contribution of the sensory systems of postural control using the posturography device in older women, a 16-session training program (2 sessions per week for 8 weeks, 50 minutes each) was implemented for a group of asymptomatic older women and compared with another group of asymptomatic older women who did not participate in the hippotherapy intervention, serving as the control group. It appears that the proprioceptive stimuli transmitted to participants

during the three-dimensional movements of the horse in the left-right, up-down, and forward-backward directions led to improvements in the parameters assessed in this study — namely, the contribution scores of the proprioceptive and vestibular systems and overall balance in body sway in the anterior-posterior and medial-lateral directions; this improvement was not observed in the contribution score of the visual system. These results were consistent with those of Tuygu et al. (35) regarding the body sway variable in the anterior-posterior direction. They analyzed the static balance of 10 elderly individuals after 8 sessions of hippotherapy and found significant improvements in anterior-posterior body sway. However, they did not observe significant improvement in body sway in the medial-lateral direction, which contradicts our findings. Since the aforementioned study is an uncontrolled study, the results may not reflect a genuine improvement in balance.

Table 5. ANOVA Results with Tukey's Post Hoc Test in the Participating Groups

Stage	Variable (mm)	Group (i)	Group (j)	Mean difference (j-i)	Standard error	P value
Post-test	Visual anterior-posterior	Hippotherapy	Control	1	1.40	0.758
			Aquatic exercise	0.11	1.40	0.997
	Visual medial-lateral	Hippotherapy	Control	0.50	1.41	0.934
			Aquatic exercise	0.80	1.41	0.839
	Vestibular anterior-posterior	Hippotherapy	Control	8.70	1.74	0.001
			Aquatic exercise	-5.50	1.74	0.011
	Vestibular medial-lateral	Hippotherapy	Control	-4.70	2.14	0.091
			Aquatic exercise	1.60	2.14	0.739
	Somatosensory anterior-posterior	Hippotherapy	Control	22.40	1.71	0.001
			Aquatic exercise	-3.70	1.71	0.096
	Somatosensory medial-lateral	Hippotherapy	Control	13.20	1.46	0.001
			Aquatic exercise	-4.90	1.46	0.007
	Total balance anterior-posterior	Hippotherapy	Control	9.20	2.88	0.01
			Aquatic exercise	-8.10	2.88	0.024
	Total balance medial-lateral	Hippotherapy	Control	5.60	2.22	0.046
			Aquatic exercise	-4.00	2.22	0.188

The results of this research also contradict those of Araújo et al. (36), who examined the effects of hippotherapy on the balance function of 7 older women over 16 sessions (8 weeks, 2 sessions per week, 30 minutes each) and obtained body sway using a stabilometric device (AMTI AccuSway Plus) and Balance Clinic software. They did not observe a significant reduction in body sway parameters in the anterior-posterior and medial-lateral directions between the experimental and control groups. In contrast, within-group comparisons showed a significant reduction in the body sway variable in the anterior-posterior direction. The reason for these discrepancies may be related to participant characteristics (heterogeneity in the statistical data and the use of nonparametric statistics), small sample size, the training protocol, and differences in assessment equipment.

Kim and Lee (37) examined the effects of hippotherapy on the static balance and gait pattern of 11 elderly individuals in comparison with a treadmill exercise intervention group (3 sessions of 20 minutes each, over 12 weeks, with 11 elderly individuals), using the BPM device (software 5.3, SMS Healthcare Inc., UK) and GaitRite (CIR, USA), and showed that in both groups, step length increased while step time and sway path length showed a significant decrease, with the reduction in body sway being greater in the hippotherapy group. The results of the present study, which show improvement in total balance in the anterior-posterior and medial-lateral directions, are consistent with the results of this research. According to the percentage-change values, this improvement was greater in the anterior-posterior direction. Another study examined the effects of hippotherapy on balance and muscle strength in 28 healthy elderly individuals. It showed that the hippotherapy group (12 individuals) had a significant increase in Berg Balance Scale scores after the intervention compared with the control group (16 individuals), indicating improved balance (38).

In contrast, the study by Deniz et al. (29), which examined the effects of 10 sessions of hippotherapy (30 minutes, once a week) on improving the balance and flexibility of 15 older women, did not observe a significant difference in Berg Balance Scale scores; they attributed this discrepancy to the characteristics of the participants in their study (elderly individuals who were physically active and independently performed daily activities). Additionally, the study found a significant improvement in dynamic balance variables, as measured by the Timed Up and Go (TUG) test and the Functional Reach Test (FRT). The results of the Araújo and Deniz studies (29, 36) indicate improved balance in the hippotherapy groups, similar to the

present study, which shows significant improvement in overall balance.

The lack of significance of visual system scores for static balance may be due to the high baseline function score of this system in the posturography tests. Older individuals are at greater risk of falling and rely more heavily on the visual system to maintain balance (39). In fact, vision is one input that can compensate for deficiencies in other senses (40). In this study, the scores obtained from the posturography device did not show substantial changes in the visual data because these scores were, from the outset, higher than the device's normative range, and the participants in this study demonstrated a high ability to use the visual system for balance maintenance. In general, balance exercises have a greater effect on improving the proprioceptive system, which is a fundamental pillar of fall prevention (41). Kim et al. (37) also showed that hippotherapy primarily improves vestibular and proprioceptive function, thereby increasing balance and reducing fall risk. The improvement in balance following hippotherapy occurs primarily through neuromuscular adaptations and stimulation of proprioceptive input (29). The results of the present study also showed significant improvement in the proprioceptive system in the anterior-posterior and medial-lateral directions and in the vestibular system in the anterior-posterior direction, with these changes in the proprioceptive system being greater in the anterior-posterior direction.

In this regard, following Dynamic Systems Theory, many researchers in motor control have proposed Optimization Theory as the basis for motor control (42). In fact, optimization is the practice of increasing and decreasing variability (43). That is, when the body moves, all body parts, such as the eyes, mouth, hands, and feet, move and attempt to maintain stability, seeking to increase desirable variables and decrease undesirable ones (44). Horseback riding is also a multisensory activity in which the rhythmic, three-dimensional oscillations of the animal's pelvis during walking stimulate the reflexive mechanisms that control body posture, consequently strengthening balance and coordination (45). Hippotherapy engages the entire body and, as a result, improves strength, muscle tone, flexibility, body awareness, motor coordination, and balance (29). It appears that horseback riding perturbs an individual's proprioceptive systems, strengthening their coordination and integration and minimizing instability. The impulses generated by the sensory systems elicit reactive responses that enhance balance. Hippotherapy is likely considered a combined training

method that improves all variables simultaneously, though their ranking order may differ depending on the type of task. When a task changes, the criteria are optimized as internal representations to perform that task. Thus, it is possible that body control on the horse strengthens the vestibular system, and the proprioceptive inputs transmitted to the rider through the horse's pelvic movements improve the proprioceptive system, thereby resulting in improved overall balance in the individual.

Hippotherapy Compared with Aquatic Exercise:

This study showed that aquatic exercise was a more effective form of training compared with hippotherapy. Static balance affects nearly all activities of daily living. Therefore, static and dynamic balance training programs are an important part of rehabilitation (46, 47). Currently, balance exercises for improving postural balance include active and reactive exercises under static and dynamic conditions, on stable and unstable supports, in the sagittal and frontal planes, with eyes open and closed (48). These exercises are progressed based on the degree of difficulty and increasing instability; however, increasing an exercise's difficulty does not necessarily lead to greater improvements in outcomes (49, 50). Optimal training programs and the context in which they are performed are likely to produce the greatest degree of improvement in balance. In fact, the most beneficial adaptations in increasing balance depend on gestural conditions (i.e., body position, movement, and practiced gestures) and material conditions (the nature of the ground surface, the sports equipment used, and the type of environment in terms of whether it is stable or changing) (51). In explaining the greater effectiveness of aquatic exercise compared with hippotherapy on the degree of contribution of the sensory components of the postural control system, one can point to the unique nature of the aquatic environment. The physical properties of water lead to more numerous and varied perturbations in sensory inputs for balance maintenance, in different directions and across a wide area of the body (52). The aquatic environment can impose beneficial adaptations on balance through the continuous instability it imposes on an individual exercising in a standing position (53). Given the hydrostatic properties of water during immersion, there is no static resting position in water; therefore, the muscles are continuously active to stabilize body positions. Consequently, the aquatic environment creates a type of training condition in which the individual is constantly striving to maintain balance during activity (20). Another piece of evidence supporting the superiority of aquatic exercise may

relate to the viscosity and resistance of water, which slow movement and reaction time (54) and cause the individual to exert greater force during movement (55). In other words, exercising in water allows for high-intensity training while ensuring greater comfort and less pressure on the joints. The combination of these factors in the aquatic environment, along with greater exercise variety, likely makes aquatic exercise superior to hippotherapy.

Limitations

Among the limitations of the present study is the lack of control over certain aspects of the elderly participants' health that may have affected their responses during testing: type of food, medication use, amount of sleep, and level of activity before recording the pretest and posttest measurements are among these factors, which ideally should have been controlled to be similar across both testing sessions. However, due to the participants' age, the psychological fatigue associated with completing numerous forms, and the inability to reliably record this information, no control was applied for these variables. Additionally, because sex influences balance characteristics in elderly individuals (56, 57), this study was conducted only in women, and its results cannot be generalized to men. Furthermore, due to the high cost of using the equestrian club, it was not possible to conduct follow-up assessments.

Recommendations

Based on the results of this research, it is suggested that in-depth studies be conducted to compare the number and duration of sessions in both sexes across longer time periods, and to examine the persistence of training effects over the long term. Assessing the risk of falling over the next 10 years is a highly important variable that was not examined in the present study, and reporting it in future studies would be valuable for determining the clinical and economic value of hippotherapy. Given the benefits of the aquatic exercise program and hippotherapy for balance in asymptomatic older women observed in the present study, they can likely be recommended to improve quality of life and physical fitness in older people.

Conclusion

It appears that in asymptomatic older women, proprioceptive and vestibular function improved following a period of hippotherapy, leading to improved static balance. Horseback riding, if performed correctly and safely, can be considered a beneficial training program for enhancing balance in

asymptomatic older women. The characteristics of the horse's body, such as its rhythmic, repetitive, and variable nature, can stimulate and strengthen the neuromuscular system in elderly individuals. Additionally, participants in the aquatic exercise group performed better than those in the hippotherapy group. Therefore, aquatic exercise training can be a suitable alternative for elderly individuals who are concerned about performing hippotherapy due to fear of falling or postural instability resulting from the horse's movement while walking. Based on the present findings, it is recommended that specialists and trainers use either hippotherapy or aquatic exercise to improve balance in asymptomatic older women when facing unpredictable disturbances, depending on available facilities and individual preference.

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Conflict of Interest

The authors did not have a conflict of interest.

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