Asian J Sports Med. 2024 December; 15(4): e148272 https://doi.org/10.5812/asjsm-148272

Published Online: 2024 December 14 **Research Article**

Eight-Week Pilates Program Effects on Balance, Fall Risk, and Proprioception in Visually Impaired Female Students

Akram Eskandari [1], Mostafa Zarei [2,*], Amirhossein Barati [2], Fariba Mohammadi [3]

[1] Shahid Beheshti University, Tehran, Iran
[2] Department of Sports Rehabilitation and Health, Faculty of Sports Sciences and Health, Shahid Beheshti University, Tehran, Iran
[3] Department of Sport Medicine, Sport Sciences Research Institute, Tehran, Iran

[*] ***Corresponding Author:*** Department of Sports Rehabilitation and Health, Faculty of SportsSciences and Health, Shahid Beheshti University, Tehran, Iran. Email: zareeimostafa@yahoo.com

Received: 4 May, 2024; **Revised:** 13 October, 2024; **Accepted:** 15 November, 2024

Abstract

Background: Vision plays a crucial role in human movement and posture control. Impaired vision can lead to significant challenges in maintaining balance and postural stability among visually impaired individuals. Various approaches have been explored to address these challenges.

Objectives: This study aimed to investigate the effects of an eight-week Pilates program on posture control, fall risk, and proprioception of the knee and ankle joints in non-athlete, visually impaired female students.

Methods: A total of 22 visually impaired, non-athlete female students from Tehran voluntarily participated in this study. Participants were randomly assigned to either an experimental group (n = 12) or a control group (n = 10). The experimental group completed an eight-week Pilates program (three one-hour sessions per week), while the control group maintained their regular daily activities. Pre- and post-intervention assessments included posture control and fall risk, measured using the Biodex Stability System, as well as proprioception (position sense and kinesthesia) of the knee and ankle joints, measured with a Biodex Dynamometer. Data were analyzed using two-way ANOVA.

Results: The Pilates intervention significantly improved knee position sense at 20° and 45° ($P \leq 0.05$), although no significant changes were observed at 60° ($P > 0.05$). A significant improvement was also noted in knee kinesthesia between the two groups ($P \leq 0.05$). However, no significant differences were found in the ankle position sense during dorsiflexion or plantarflexion ($P > 0.05$). Regarding posture control, significant improvements were observed in overall balance and anteroposterior balance in the Pilates group compared to the control group ($P \leq 0.05$), while no significant differences were noted in mediolateral balance ($P > 0.05$). The fall risk index also showed significant improvements in the Pilates group ($P \leq 0.05$).

Conclusions: The eight-week Pilates program positively affected posture control, reduced fall risk, and improved knee proprioception in visually impaired female students. These findings suggest that Pilates could be an effective addition to exercise programs aimed at enhancing functional performance and reducing injury risk in visually impaired individuals.

Keywords: Postural Balance, Proprioception, Falling Risk, Visually Impaired, Blindness

1. Background

Vision is essential for maintaining human balance. Impairment of this sense significantly reduces an individual's ability to sustain stability, thereby affecting daily activities and overall quality of life. Vision impairment also increases the risk of falling (1). Several factors influence balance, including postural changes, muscle weakness, and functional aspects such as walking speed (2). When the activity of a system involved in postural control is diminished or lost, the efficacy of postural control mechanisms decreases, leading to a heightened risk of falls (3).

Proprioception plays a crucial role in maintaining balance. Proprioceptive receptors convert tissue stimuli into neural signals, with the proprioceptors in the ankle being particularly vital for stability and fall prevention (4). Research indicates that dorsiflexion and plantarflexion movements in the ankle joint, as well as flexion in the knee joint, contribute to balance, reduce the risk of falls, and improve proprioception. Therefore, the sense of position and posture in the knee and ankle is essential for effective proprioceptive feedback. For instance, individuals with foot supination or pronation exhibit less postural control compared to those with neutral foot posture, while individuals with high arches experience greater postural fluctuations (5).

Knee proprioception is also critically important and is often referred to as a "fourth strategy" or a suspended/protective strategy. In this context, the individual engages in knee flexion to lower the center of gravity, thereby enhancing balance. Blind individuals often utilize this protective movement to maintain stability. Consequently, knee proprioception is essential for neuromuscular control, facilitating muscle activity, movement awareness, and joint position sense (6).

Visual impairment affects spatial orientation, balance, motor skill execution, cognition, and learning in visually impaired individuals (7). These individuals adapt their sensory information processing and vestibular system functions to support motor patterns and maintain their center of gravity. This adaptation often requires modifications or limitations in their movements, which can affect their ability to respond to environmental changes (8). Insufficient information from these systems can lead to postural sway; excessive sway may result in a loss of balance, even during simple walking tasks (9).

Additionally, visual impairments can lead to complications such as head contraction, increased pelvic rotation, excessive trunk flexion with thoracic kyphosis, compensatory forward head posture, abnormal trunk, and contralateral arm movements due to improper posture, weak leg muscles, flat feet, pelvic and knee flexion, dropped shoulders, and an abnormal widening of the base of support (10).

Given the importance of balance and proprioception in postural control, researchers have explored methods to improve these variables in visually impaired individuals. Mansori et al. investigated the effects of vestibular exercises on postural control, fall risk, and quality of life in visually impaired individuals, reporting positive effects on these variables in blind participants (11). Mavrovouniotis et al. studied the effects of Pilates and Greek dance exercises on balance and fall risk in blind individuals, also observing positive results (12). In 2023, Carretti et al. conducted a review examining the effects of exercise and physical activities on individuals with visual impairments, highlighting positive outcomes across various studies (13).

Additionally, Casonatto and Yamacita review and meta-analysis reported the positive effects of Pilates exercises on balance and postural control in the elderly (14). In 2021, Salar et al. evaluated the positive impact of balance and core stability exercises on posture in blind individuals (15). Shah and Wasnik investigated the effects of Pilates exercises on knee joint proprioception, cognition, and fatigue levels in elderly women, finding positive results in these indicators (16). Danshamdi et al. highlighted the benefits of training programs such as Pilates, SPARK exercises, and Frenkel exercises in promoting balance adaptation in blind individuals (17).

In 2022, Jiang et al. evaluated the effects of Pilates and balance exercises, demonstrating greater improvements in balance with Pilates exercises, particularly in the triple hop and Y Balance tests (18). Zarei et al. reported improvements in static and dynamic balance in deaf individuals through Pilates exercises, both with and without closed eyes on foam surfaces (19). A 2023 meta-analysis examined the effects of aerobic exercises on mobility and balance in blind individuals, revealing positive results for static and dynamic balance but no changes in mobility (20). Moghadas Tabrizi et al. explored the effects of perturbation and vestibular exercises on fall risk and static and dynamic balance in blind individuals, reporting significant improvements (21). Finally, Kaouri et al. evaluated the effects of Pilates exercises on aerobic capacity, endurance, and other physical fitness factors, also reporting positive outcomes (22).

2. Objectives

Given the limited studies evaluating the effects of Pilates exercises on balance, postural control, and joint proprioception of the ankle and knee, as well as fall risk, and the lack of research on Pilates interventions specifically for visually impaired individuals, this study aimed to determine the effects of an eight-week Pilates program on postural control, fall risk, and proprioception of the knee and ankle joints in blind and visually impaired female students.

3. Methods

All visually impaired female students in Tehran Province were invited to participate in this study with the cooperation of the Education Department of Tehran Province. A total of 48 individuals volunteered to take part in the research. After reviewing their medical records and confirming their health status, 22 students met the eligibility criteria for inclusion in the study. Using G*Power software, the sample size was calculated based on an effect size of 0.35, a power of 80%, and $\alpha = 0.05$, indicating that 20 participants were sufficient for the study. These participants were then randomly

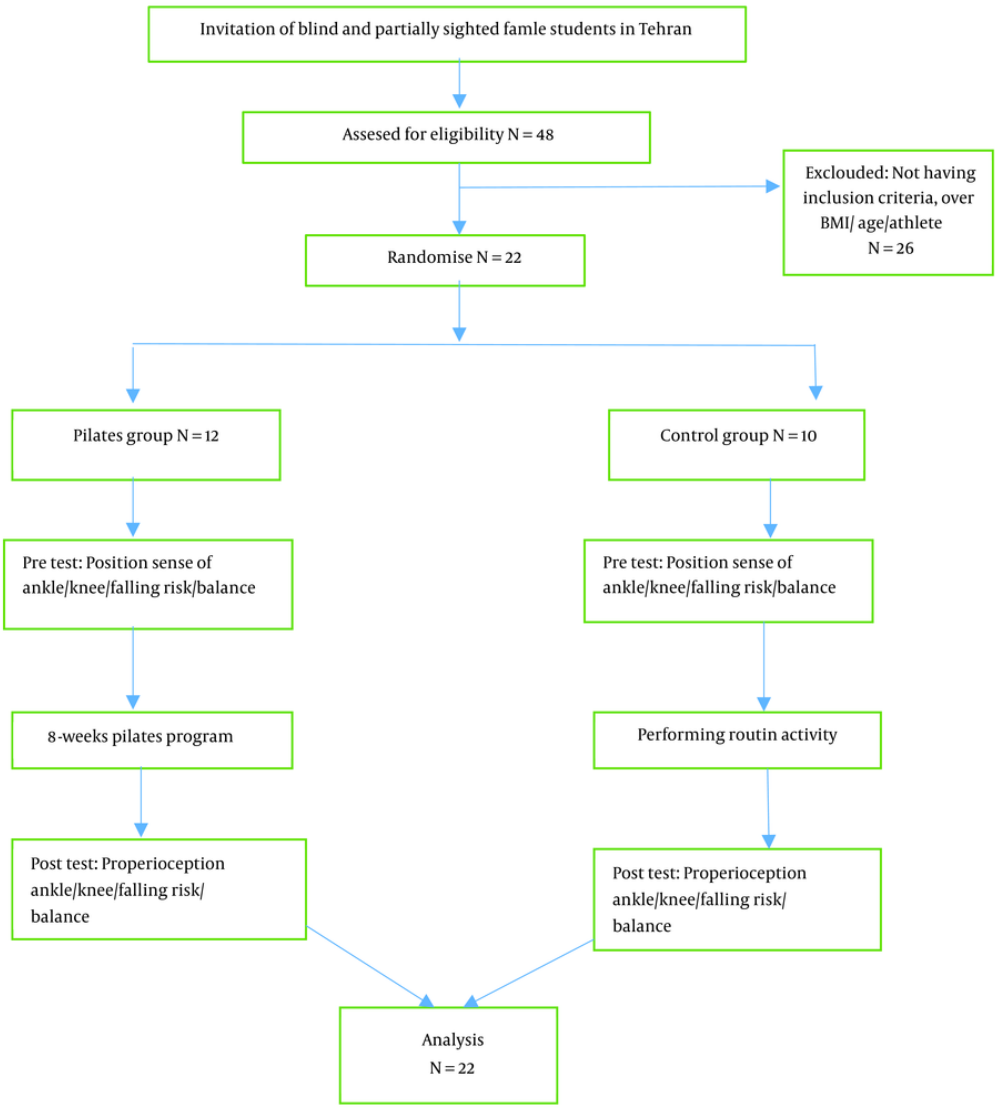

Figure 1. Participants' flow

assigned to either the control group (10 participants) or the experimental group (12 participants) (Figure 1).

The participants in this study were blind and visually impaired female students aged 14 - 16 years who were non-athletes. They had no history of serious injuries, vestibular diseases, bone or joint conditions, or balance issues, as confirmed by a physician's report in their medical records. Balance was assessed using the Tandem Gait Test and the Stork Test (10 seconds). All participants had not engaged in regular exercise prior to the study and continued with their daily activities throughout its duration.

Exclusion criteria included missing more than two sessions and unwillingness to continue with the study and exercises. The experimental group performed Pilates exercises three times per week for eight weeks, with each session lasting one hour. Meanwhile, the control group maintained their regular daily activities and refrained from participating in any structured exercise programs or physical training. This allowed

Table 1. Pilates Exercises

Explanation of Exercise	Set/Repetition
(1) Opposite hand, opposite shoulder, and arm in front and above the shoulder. Raising the right knee at a 90° angle and the right arm lowering the leg and hand slowly and repeating on the opposite side (along with a contracted abdomen).	One set/10 repetitions
(2) The right hand behind the head or the arm externally. The right leg is bent with a 90° knee and is elevated until the thigh is parallel to the ground level, abdominal contraction, the leg is moved towards the side and back, and repetition with opposite side.	One set/10 repetitions
(3) As in exercise number 2, instead of holding hands behind the head, we hold one ball in the hand. The arm moves forward, upward, and sideward with leg movement.	One set/5 repetitions
(4) We keep the balance on the right side for 30 s and extend the left leg in knee bent position from the thigh. We then repeat with the other side.	One set/30 seconds
(5) As with exercise 4, with the difference that the person is in a semi-sitting position and holds the ball with extended arm forwards.	One set/30 seconds
(6) Standing on one leg and with the other leg whose thigh is bent with a 90° knee angle. Rotating the ball around the body - Doing with the opposite side	One set/30 seconds
(7) As with exercise 6, with the difference that the ball is rotated around the thigh axis. Doing with the opposite side	One set/30 seconds
(8) Standing on one leg and holding the ball concurrently, the body weight is guided forward and downward, with the arm stretched forward and an attempt should be made to keep the balance. Doing with the opposite side.	One set/30 seconds
(9) Standing on one leg and with the other leg, whose thigh is bent with 90° knee; arm with 90° flexion, attempt to keep the balance for 30 seconds.	One set/30 seconds
(10) Imaginative sitting beside the wall, flexion of thigs things parallel to the ground and knee 90°, arms stretched, and Pilates ball in the hands	Hold for 30 seconds
(11) Hundred: In the supine position, knee extension and hip flexion, elevation of the head and chest, and hands parallel to the hip.	First week/5 repetitions
(12) Single-leg stretching: Positioning in supine position, with flexion of knee and hip and hands in front of the knee and double-leg stretching: Similar to the previous exercise for both legs concurrently in supine position with 90° knee flexion and hip flexion, the elevation of the head and chest and hands in parallel to the hip, verbal positioning in lying state on the side, abduction of the knees off each other and the inner ankle of both legs attached.	Two-first week + single leg stretch and pair of leg stretch/5repetitions + calam/5 repetitions
(13) Positioning in the supine state with 90° knee flexion and elevation of the trunk and thigh, while the legs are on an upper level and fixed. This exercise was based on Pilates reformer, but given the test subjects, it was done without stopping	Three-second week + shoulder bridge/7 repetitions
(14) Positioning in a sitting state with stretched legs keeping hands behind the bench for support and doing hip joint rotational movement; this exercise was done on a mat and ground.	Four-third week + hip rotation/7 repetitions
(15) Scissors: Positioning in a supine state and elevation of the head and chest, as well as moving both legs (alternately) upwards, in a prostrate state and reclining on forearms, knees should be bent and straightened	Five-4th week + scissors + single leg kicks/10 repetitions each
(16) Positioning in a lying state, hands behind the head, elevation of the leg from the side, and returning to the initial state	Six-5th week + kik side/10 repetitions
(17) Positioning in a supine state and direct elevation of the leg and its rotation plus full knee extension	Sixth week + single-leg circling/12 Reps
(18) Repetition of the 7th week exercises	Seventh week/5 Reps
(19) Ankle exercises: Point and flex	Thirty times sitting on the chair (point & flex)
(20) Rising on toes	Five reps and each time holding for 3 s
(21) Leg pull side	Two sets and 5 reps of both sides

them to continue with their usual routines, such as walking, household chores, and other non-exercise-related activities. By doing so, we ensured that the control group did not receive any additional physical training that could influence the study outcomes, thereby providing a clear contrast to the experimental group engaged in the Pilates program.

In this study, postural control was measured using a balance assessment device at difficulty level 8, and fall risk was assessed with the same device at difficulty level 6 (23). Knee joint movement proprioception was evaluated using an isokinetic dynamometer at an angular velocity of 0.5 meters per second, with a 15-degree knee flexion angle and a starting angle of 90 degrees (24). Ankle joint proprioception was assessed at 10-degree dorsiflexion and 25-degree plantar flexion, starting from an angle of 0 degrees (25), and knee position was assessed at angles of 20°, 45°, and 60°, also starting from 90°, using the same device (26, 27).

This study was approved by the Beheshti University Ethics Committee under the ethics code IR.SBU.REC.1402.043. In addition to obtaining ethical approval, all participants were fully informed about the study's purpose, procedures, and potential risks before providing written informed consent. Participants were also made aware of their right to withdraw from the study at any time without repercussions. Confidentiality was strictly maintained throughout the research process; all personal information was anonymized and securely stored. Participants were assured that their data would be used solely for research purposes and would not be disclosed to third parties.

The Pilates exercise program was conducted over eight weeks, with three one-hour sessions per week. Each training session included the following components:

(1) Warm-up (10 minutes): This phase focuses on preparing the body for exercise through gentle movements to increase blood flow and enhance flexibility.

(2) Main exercises (40 minutes): The core of each session involved a series of Pilates exercises designed to improve strength, flexibility, and balance. The program was developed based on protocols from similar studies, incorporating Pilates tools such as resistance bands and balls to enhance the practice (12, 27, 28) (Table 1).

Cool down (10 minutes): The final phase allowed participants to gradually lower their heart rate and stretch their muscles, promoting recovery and flexibility. This structured approach aimed to ensure a comprehensive and effective Pilates training experience.

3.1. Procedure

Upon arrival at the Faculty of Sport Sciences laboratory at Shahid Beheshti University, participants had their height measured using a Seca stadiometer (accuracy: 0.01 meters) and their weight measured with a BSM370 scale (accuracy: 0.1 kilograms), both manufactured in South Korea.

3.2. Knee Joint Position Sense Assessment

Knee joint position sense was evaluated using a Biodex isokinetic dynamometer (Pro 4 model, USA). After calibrating the device, participants were seated with belts securely fastened. The dynamometer arm's axis of rotation was aligned with the knee's axis of rotation, and the arm's pad was positioned on the lower third of the calf. Participants held their knee at three target angles—20°, 45°, and 60° of active knee flexion—for 5 seconds before returning to the starting position. They were then instructed to actively replicate each angle. Participants rested for 10 seconds between each 20-second attempt before starting the protocol for the next target angle, with the starting angle set at 90°.

3.3. Knee Kinesthesia Sense Assessment

Knee kinesthesia sense was assessed similarly using the isokinetic dynamometer. Participants' knees were passively positioned at a 90° anatomical angle. After a brief pause, the dynamometer arm moved passively to 15° of flexion at a speed of 0.5°/s. Participants were instructed to press a button as soon as they detected the start of the movement. Each participant practiced the test once to familiarize themselves with the procedure, and the average movement detection threshold was recorded after three attempts.

During both tests, headphones, and blindfolds were used to minimize visual and auditory feedback. Assessments were conducted only on the dominant leg, which was determined by the leg participants would use to kick a ball (as indicated by the Waterloo Questionnaire) (29).

3.4. Ankle Joint Position Sense Assessment

Ankle joint position sense was assessed using the same isokinetic dynamometer, equipped with the ankle attachment. Participants performed three active attempts, moving from 10° of dorsiflexion to 25° of plantar flexion, starting from a 0° angle. This test was conducted exclusively on the dominant leg.

3.5. Postural Control Assessment

Postural control was measured using the Biodex Stability System (Biodex Stability System SD, USA). This device features a movable, circular, graduated platform mounted on a large ball with multiple sensors, capable of tilting between 20° and 360°. The tilt is controlled by a resistance spring, with stability levels ranging from 12 (most stable) to 1 (least stable). Participants stood barefoot on the device in a natural posture, with their arms hanging by their sides and feet shoulder-width apart. Foot coordinates were recorded from the device at the heels and toes, and details of the exercise protocol were documented.

In this study, the postural control index was measured at difficulty level 8 over three 20-second trials, with 10 seconds of rest between each trial. Participants were instructed to cross their arms on their chest during the trials. Assessments were conducted in three sections: Overall control, anterior-posterior control, and medial-lateral control.

Fall risk was evaluated using the Biodex Stability System at difficulty level 6, with three 20-second attempts and 20 seconds of rest between each attempt. All tests were conducted in the morning between 8 AM and 11 AM to ensure consistency in timing. No discrepancies were observed in the test results.

3.6. Data Analysis

Data analysis was conducted using SPSS software (version 27). The normality of the data, categorized by groups, was assessed using the Shapiro-Wilk test, while the homogeneity of variances was evaluated with Levene's test. No significant differences were found in the demographic information between the two groups, indicating homogeneity. To examine group differences, a two-way ANOVA was performed. If significant results were observed, post-hoc Bonferroni tests were applied.

4. Results

Table 2 summarizes the demographic variables of the participants in both groups. The analysis showed no significant differences in age, height, weight, or Body Mass Index (BMI) between the groups, confirming homogeneity in these characteristics. This homogeneity is critical for ensuring that any observed effects can be attributed to the interventions rather than demographic variations.

Table 3 presents the results of the two-way ANOVA comparing test outcomes between the two groups. The analysis revealed a significant difference in the overall balance variable, with a 62% improvement attributed to Pilates exercises ($P \leq 0.05$). A significant improvement of 45% was also noted in the anterior-posterior balance variable ($P \leq 0.05$). However, no significant difference was observed in the medial-lateral balance variable, which demonstrated a 39% improvement ($P > 0.05$).

For the fall risk index, the ANOVA results indicated a significant difference between the two groups ($P \leq 0.05$), with a 44% improvement due to the Pilates exercises. Additionally, the kinesthetic sense showed a significant improvement of 39% ($P \leq 0.05$).

Regarding knee position sense, significant improvements were found at angles of 20° and 45%, with increases of 46% and 62%, respectively ($P \leq 0.05$). However, no significant effect was observed for knee position sense at 60° ($P > 0.05$).

In the ankle position sense index, no significant differences were observed for plantarflexion and dorsiflexion movements between 10° and 25°.

5. Discussion

The purpose of this study was to assess the effects of an eight-week Pilates exercise program on postural control, fall risk, and ankle joint position sense in visually impaired female students. The findings revealed significant improvements in overall balance, fall risk, and knee joint position sense at angles of 20° and 45°, as well as enhancements in kinesthetic sense. However, no significant improvements were observed in the knee joint position sense at 60° or in the ankle joint position sense during plantarflexion and dorsiflexion.

The notable improvements in specific outcomes can be attributed to several interrelated factors associated with the unique characteristics and benefits of Pilates exercises. Pilates emphasizes core stability, body alignment, and muscle control, all of which are essential for maintaining balance. The significant enhancements in overall balance and fall risk may result from the strengthening of core and stabilizing muscles, which play a critical role in postural control. The consistent engagement of the core during Pilates exercises likely enhanced participants' ability to stabilize their center of mass during both dynamic and static activities, contributing to improved overall balance (30, 31).

The improvement in knee joint position sense at 20° and 45° can be attributed to the focus on enhancing proprioception through controlled movements and body awareness techniques inherent in Pilates. The exercises often involve eccentric loading and stretching of the muscles surrounding the knee joint, which stimulates muscle spindle activity, a critical factor in proprioception (32). Such exercises likely activated the proprioceptors, enhancing the participants' ability to perceive joint positions at these angles. The lack of significant improvement at 60° may be explained by several factors:

(1) Fatigue: By the time participants reach the 60° measurement, they may have experienced fatigue, which could diminish proprioceptive feedback and joint awareness (32).

(2) Learning effect: Participants may have had difficulty with the higher angle due to a learning effect or unfamiliarity with the test, leading to inconsistent responses (32).

(3) Joint mechanics: The mechanics of the knee at higher angles might produce different proprioceptive feedback compared to lower angles, suggesting that the exercises may not have specifically targeted the muscle spindles at that angle.

In contrast, the lack of significant change in ankle joint position sense can be attributed to the depth of proprioceptive feedback and the specific nature of the Pilates exercises employed. While the ankle joint is critical for balance, it may have deeper proprioceptive pathways that were not sufficiently engaged by the open-chain exercises typically used in Pilates. Closed-chain exercises, which provide more comprehensive stimulation to mechanoreceptors, may have yielded better results for ankle proprioception. The limited focus on ankle-specific exercises during the intervention may not have provided enough stimulation to promote improvement in this area (32).

Table 2. Demographic Variables at the Baseline for the Groups

Variables	Experimental Group [a]	Control Group [a]	*t*	P-Value
Age (y)	15.4 ±1.2 (16.15 - 14.6)	15.6 ± 1.3 (16.52 - 14.68)	0.42	0.68
Height (cm)	159 ± 4 (160 -157)	158 ± 3 (160 - 156)	0.49	0.63
Weight (kg)	52.9 ± 8.1 (58.03 - 47.77)	48.7 ± 3	1.69	0.11
BMI (cm/m ^{2})	21.05 ± 3.14 (23.04 - 19.05)	19.21 ± 1.5 (20.28 - 18.15)	1.80	0.099

[a] Values are expressed as mean ± SD (95% CI).

Table 3. Results of Two-Way ANOVA for the Groups

Variables	Groups [a]				Interactive Effect		
	Experimental Group		Control Group		F	P-Value	Effect Size
	Pre-test	Post-test	Pre-test	Post-test			
Overall Balance	3.21 ± 1.10 (3.90 - 2.51)	1.98 ± 0.72 (2.43 - 1.51)	3.19 ± 0.93 (3.85 - 2.52)	3.01 ± 0.87 (3.63 - 2.38)	4.44	0.048 [b]	0.182
A-P Balance	2.76 ± 1.34 (3.61 - 1.90)	1.50 ± 0.85 (2.04-0.95)	1.89 ± 0.78 (2.43- 1.33)	3.11 ± 1.72 (4.34 - 1.87)	14.77	0.001 [b]	0.425
M-L Balance	1.62 ± 1.05 (2.28 - 0.95)	0.98 ± 0.65 (1.39-0.56)	0.99 ± 0.58 (1.4 - 0.57)	1.11 ± 0.61 (1.4 - 0.67)	2.50	0.130	0.111
Kinesthesia sense 15°	3.26 ± 1.38 (4.13 - 2.63)	1.97 ± 0.92 (4.13 - 2.38)	3.55 ± 1.52 (2.55 - 1.38)	3.54 ± 1.83 (4.84 - 2.33)	5.89	0.025 [b]	0.228
Position sense knee 20	3.2 ± 2.08 (4.5 - 1.9)	1.7 ± 1.28 (2.52 - 0.89)	2.31 ± 2.07 (3.79 - 0.82)	2.2 ± 1.87 (4.47 - 1.14)	7.66	0.012 [b]	0.227
Position sense knee 45	4.3 ± 3.42 (6.43 -2.08)	1.6 ± 1.43 (2.49 ± 0.68)	2.6 ± 1.66 (3.81 - 1.44)	2.3 ± 1.35(3.29 - 1.36)	4.33	0.178	0.05 [b]
Position sense knee 60	2.5±1.59 (3.01-1.48)	1.5 ± 1.09 (2.23 - 0.85)	1.3 ± 1.03 (2.06 - 0.57)	1.7 ± 1.22 (2.55 - 0.82)	3.74	0.067	0.158
Dorsiflexion ankle 10	1.1 ± 0.84 (1.6 - 0.53)	0.7 ± 0.61 (1.04 - 0.26)	1.5 ± 1.28 (2.36 - 0.53)	1.2 ± 0.88 (1.84 - 0.59)	0.157	0.69	0.008
Pelantarflexion ankle25	1.5 ± 0.95 (2.12 - 0.91)	1 ± 0.79 (1.5 ± 0.49)	1.9 ± 1.03 (2.1 - 6.13)	1.6 ± 1.39 (2.6 - 0.61)	0.226	0.64	0.011
Falling risk	2.97 ± 1.09 (3.67-2.28)	1.66 ± 0.52 (2.69 - 1.69)	2.19 ± 0.69 (1.33 - 1.99)	2.88 ± 1.3 (2.28 - 3.36)	19.26	< 0.001 [b]	0.491

[a] Values are expressed as mean ± SD (95% CI).
[b] P < 0.05 was considered statistically significant.

Moreover, the absence of significant differences in mediolateral balance may reflect the specificity of Pilates exercises, which tend to emphasize stability in the anteroposterior direction more than in the mediolateral plane. This finding aligns with previous research indicating that Pilates primarily activates muscles responsible for forward and backward stabilization, thus enhancing anteroposterior balance more than mediolateral balance (33, 34).

Additionally, other external factors, such as environmental conditions during testing and variations in individual engagement and compliance with the exercise program, may also contribute to variability in outcomes. Although participants attended the Pilates sessions consistently, factors like individual motivation, fatigue levels on test days, and mental focus could impact the measurement of proprioception and balance (30, 31).

In summary, while significant improvements were observed in overall balance, fall risk, and certain aspects of proprioception, the nuanced nature of joint mechanics, exercise specificity, and participant-related factors likely played a crucial role in determining the outcomes of this study. Future research should consider longer intervention durations, varied exercise modalities, and a more detailed analysis of individual responses to training to elucidate the complex relationship between exercise and proprioception, particularly in populations with visual impairments.

5.1. Limitations

This study faced several limitations, primarily due to the small population of visually impaired individuals available for research. This limitation may affect the generalizability of our findings; however, it is a common challenge in studies involving this population. Future research with larger sample sizes is recommended to validate and expand upon these results.

Additionally, the duration of the study was limited to eight weeks due to accessibility constraints with participants. Although this duration aligns with similar studies investigating the effects of exercise on balance and proprioception, it may not be sufficient to induce lasting changes from Pilates interventions. Future research could benefit from longer intervention periods to assess the long-term effects of Pilates on balance and proprioception.

Furthermore, due to time constraints during testing, we were unable to randomize the joint position sense tests at different angles for participants. As a result, the tests were conducted in the same order for all participants, which may have led to learning effects and fatigue, potentially influencing the results.

5.2. Recommendations

(1) Broaden the participant demographic: Considering the anatomical, gender, and balance differences between females and males, future studies should include male participants to provide a more comprehensive understanding of the effects of Pilates across genders.

(2) Explore additional physical fitness factors: Future research should also examine the effects of Pilates training programs on other dimensions of physical fitness in individuals with visual impairments, including strength, endurance, and flexibility, to further establish the benefits of such interventions.

Acknowledgements

I would like to express my sincere gratitude to the blind students of the Narjes School in Tehran for their invaluable cooperation throughout this study. Their participation made this research possible.

Footnotes

Authors' Contribution: Study concept and design: A. E. S., M. Z., A. H. B., and F. M.; Acquisition of data: A. E. S. and M. Z.; Analysis and interpretation of data: A. E. S. and M. Z.; Drafting of the manuscript: A. E. S., M. Z., A. H. B., and F. M.; Critical revision of the manuscript for important intellectual content: M. Z., A. H. B., and F. M.; Statistical analysis: A. E. S. and M. Z.; Administrative, technical, and material support: A. E. S., M. Z., A. H. B., and F. M.; Study supervision: M. Z. and A. H. B.

Conflict of Interests Statement: The authors declared that they have no conflicts of interest.

Data Availability: The dataset presented in this study is available upon request from the corresponding author, either during submission or after publication.

Ethical Approval: This research received ethical approval under the code IR.SBU.REC.1402.043 .

Funding/Support: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Informed Consent: Informed consent was obtained from all participant.

References

1. Gandawidura RGG, Ikeda Y. Correlation analysis of balance and postural stability as a risk for falls in individuals with visual impairment. *Brit J Visual Impair*. 2024. https://doi.org/10.1177/02646196241226836.
2. Omidi M, Shamsi Majalan A, Karimizadeh Ardakani M, Hani Mansoori M. The Effect of a 6-week Core Stability Exercises on the Risk of Falling and Quality of Life in Blind People. *Specific Physical Therapy J*. 2019:227-34. https://doi.org/10.32598/ptj.9.4.227.
3. Soares AV, Oliveira CS, Knabben RJ, Domenech SC, Borges Junior NG. Postural control in blind subjects. *Einstein (Sao Paulo)*. 2011;**9**(4):470-6. [PubMed ID: 26761248]. https://doi.org/10.1590/S1679-45082011AO2046.
4. Iordan AD, Cooke KA, Moored KD, Katz B, Buschkuehl M, Jaeggi SM, et al. Aging and Network Properties: Stability Over Time and Links with Learning during Working Memory Training. *Front Aging Neurosci*. 2017;**9**:419. [PubMed ID: 29354048]. [PubMed Central ID: PMC5758500]. https://doi.org/10.3389/fnagi.2017.00419.
5. Page P, Frank C, Lardner R. Gheitasi M, Hosseini SM, translators. *[Assessment and treatment of muscle imblance: The janda approach]*. Tabriz, Iran: Tanin Danesh, Tabriz; 2010. FA.
6. Subasi SS, Gelecek N, Aksakoglu G. Effects of different warm-up periods on knee proprioception and balance in healthy young individuals. *J Sport Rehabil*. 2008;**17**(2):186-205. [PubMed ID: 18515917]. https://doi.org/10.1123/jsr.17.2.186.
7. Ramke J, Zwi AB, Silva JC, Mwangi N, Rono H, Gichangi M, et al. Evidence for national universal eye health plans. *Bull World Health Organ*. 2018;**96**(10):695-704. [PubMed ID: 30455517]. [PubMed Central ID: PMC6238994]. https://doi.org/10.2471/BLT.18.213686.
8. Saleem SY, Al-Salahat MM. Evaluation of Sensory Skills among Students with Visual Impairment. *World J Edu*. 2016;**6**(3). https://doi.org/10.5430/wje.v6n3p66.
9. Theodorou P, Tsiligkos K, Meliones A, Filios C. An Extended Usability and UX Evaluation of a Mobile Application for the Navigation of Individuals with Blindness and Visual Impairments Outdoors-An Evaluation Framework Based on Training. *Sensors (Basel)*. 2022;**22**(12). [PubMed ID: 35746320]. [PubMed Central ID: PMC9227192]. https://doi.org/10.3390/s22124538.
10. Nakamura T. Quantitative analysis of gait in the visually impaired. *Disabil Rehabil*. 1997;**19**(5):194-7. [PubMed ID: 9184784]. https://doi.org/10.3109/09638289709166526.
11. Mansori MH, Moghadas Tabrizi Y, Karimizadeh Ardakani M. Effects of a Four-Week Vestibular Exercise Program on Postural Control, Risk of Falling, and Quality of Life in Visually-impaired Individuals. *Specific Physic Therapy*. 2020;**10**(1):23-32. https://doi.org/10.32598/ptj.10.1.429.1.
12. Mavrovouniotis FI, Papaioannou CS, Argiriadou EA, Mountakis CM, Konstantinakos PD, Pikoula IT, et al. The effect of a combined training program with Greek dances and Pilates on the balance of blind children. *J Physical Edu Sport*. 2013;**13**(1):91-100. https://doi.org/10.7752/jpes.2013.01016.

13. Carretti G, Manetti M, Marini M. Physical activity and sport practice to improve balance control of visually impaired individuals: a narrative review with future perspectives. *Front Sports Act Living*. 2023;**5**:1260942. [PubMed ID: 37780118]. [PubMed Central ID: PMC10534048]. https://doi.org/10.3389/fspor.2023.1260942.
14. Casonatto J, Yamacita CM. Pilates exercise and postural balance in older adults: A systematic review and meta-analysis of randomized controlled trials. *Complement Ther Med*. 2020;**48**:102232. [PubMed ID: 31987246]. https://doi.org/10.1016/j.ctim.2019.102232.
15. Salar S, Karimizadeh Ardakani M, Lieberman LJ, Beach PS, Perreault M. The effects of balance and core stability training on postural control in people with visual impairment: A systematic review. *Brit J Visual Impair*. 2022;**41**(3):528-41. https://doi.org/10.1177/02646196221077215.
16. Shah SS, Wasnik S. Effect of Pilates exercise on the level of fatigue, cognition and knee proprioception in the elderly population of 60-80 years. *Int J Physiotherapy Res*. 2021;**9**(2):3774-9. https://doi.org/10.16965/ijpr.2020.188.
17. Daneshmandi H, Norasteh AA, Zarei H. Balance in the Blind: A Systematic Review. *Specific Physical Therapy J*. 2021;**11**(1):1-12. https://doi.org/10.32598/ptj.11.1.430.2.
18. Jiang Q, Kim Y, Choi M. Kinetic Effects of 6 Weeks' Pilates or Balance Training in College Soccer Players with Chronic Ankle Instability. *Int J Environ Res Public Health*. 2022;**19**(19). [PubMed ID: 36232203]. [PubMed Central ID: PMC9566560]. https://doi.org/10.3390/ijerph191912903.
19. Zarei H, Norasteh AA, Rahmanpournashrudkoli A, Hajihoseini E. The effects of Pilates training on static and dynamic balance of female deaf students: A randomized controlled trial. *J Bodywork Move Therapies*. 2020;**24**(4):63-9. https://doi.org/10.1016/j.jbmt.2020.05.003.
20. Zhikai Q, Zizhao G, Junsheng W. Effects of aerobic exercise on balance and mobility in individuals with visual impairment: a systematic review. *Disabil Rehabil*. 2024;**46**(22):5134-43. [PubMed ID: 38059361]. https://doi.org/10.1080/09638288.2023.2288931.
21. Moghadas Tabrizi Y, Mansori MH, Karimizadeh Ardakani M. Postural control and risk of falling in people who are blind: The effect and durability of perturbation and vestibular exercises. *Brit J Visual Impair*. 2022;**41**(3):517-27. https://doi.org/10.1177/02646196211067355.
22. Kaouri I, Argiriadou E, Katartzi E, Praskidou A, Vrabas I, Mavrovouniotis F. Assessment of the Effectiveness of a Pilates Program on Physical Fitness Among Adolescent Students in School. *Alberta J Edu Res*. 2024;**70**(1):98-113. https://doi.org/10.55016/ojs/ajer.v70i1.77592.
23. Sarmadi A, DadashiArani L. [Learning effects of the biodex balance system during assessment of postural task with in test-retest measurements]. *J Koomesh*. 2012;**13**(3):354-63. FA.
24. Harriell K, Jacobs KA, Kaplan LD, Perry AC, Candela D, Signorile JF. The Influence of the Menstrual Cycle on Joint Position Sense, Joint Kinesthesia, and Dynamic Balance. *Med Sci Sports Exercise*. 2010;**42**(10). https://doi.org/10.1249/01.MSS.0000389565.34851.ef.
25. Ozdemir RA, Pourmoghaddam A, Paloski WH. Sensorimotor posture control in the blind: superior ankle proprioceptive acuity does not compensate for vision loss. *Gait Posture*. 2013;**38**(4):603-8. [PubMed ID: 23477840]. https://doi.org/10.1016/j.gaitpost.2013.02.003.
26. Piran HM, Jafarnezhadgero A. [The effect of 8 sessions of Thera-band exercises on the joint position sense of the knee and ankle in diabetic patients with osteoarthritis of the knee]. *J Anesthesiol Pain*. 2021;**12**(1):43-31. FA.
27. Özdemir N, Subaşı SS, Gelecek N, Sari Ş. [The Effects of Pilates Exercise Training on Knee Proprioception–A Randomized Controlled Trial]. *Dokuz Eylul Univ Med Faculty J*. 2009;**23**(2):71-9. TR.
28. Sakinepoor A, Letafatkar A, Naderi A, Hashemian AH, Nourozi Z, Alimoradi M. [Effect of postural control in individuals with mild cognitive impairment after Pilates training: A clinical trial study]. *J Gorgan Univ Med Sci*. 2021;**23**(2):8-15. FA.
29. Koreili Z, Fatahi A, Azarbaijany MA, Sharifnezhad A. [Comparison of Static Balance Performance and Plantar Selected Parameters of Dominant and Non-dominant Leg in Active Adolescent's Female With Ankle Pronation]. *The Sci J Rehabilitation Med*. 2023;**12**(2):290-303. FA. https://doi.org/10.32598/sjrm.12.2.7.
30. Patti A, Zangla D, Sahin FN, Cataldi S, Lavanco G, Palma A, et al. Physical exercise and prevention of falls. Effects of a Pilates training method compared with a general physical activity program: A randomized controlled trial. *Med (Baltimore)*. 2021;**100**(13). e25289. [PubMed ID: 33787615]. [PubMed Central ID: PMC8021317]. https://doi.org/10.1097/MD.0000000000025289.
31. Dlugosz-Bos M, Filar-Mierzwa K, Stawarz R, Scislowska-Czarnecka A, Jankowicz-Szymanska A, Bac A. Effect of Three Months Pilates Training on Balance and Fall Risk in Older Women. *Int J Environ Res Public Health*. 2021;**18**(7). [PubMed ID: 33915843]. [PubMed Central ID: PMC8037700]. https://doi.org/10.3390/ijerph18073663.
32. Segal NA, Hein J, Basford JR. The effects of Pilates training on flexibility and body composition: an observational study. *Arch Phys Med Rehabil*. 2004;**85**(12):1977-81. [PubMed ID: 15605336]. https://doi.org/10.1016/j.apmr.2004.01.036.
33. Quartarolo I, Yassunaga Jr L, Santinha JAA, Gabriel RE, Shamus E. Electromyographic analysis of the tibialis anterior and peroneus longus muscles in pilates proprioceptive exercises. *American J Sports Train*. 2016:1-7.
34. Karaman A, Yuksel I, Kinikli GI, Caglar O. Do Pilates-based exercises following total knee arthroplasty improve postural control and quality of life? *Physiother Theory Pract*. 2017;**33**(4):289-95. [PubMed ID: 28443790]. https://doi.org/10.1080/09593985.2017.1289578.