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Research Article

# Dynamic balance in people with and without visual impairment analyzed on an unstable platform

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**HIGHLIGHTS**
• Sighted individuals outperformed visually impaired participants in dynamic balance tasks when visual information was available.
• Under visual occlusion, individuals with visual impairment did not perform significantly better than sighted individuals.
• Unstable platform testing revealed the critical role of vision in dynamic balance assessment.

**ABBREVIATIONS**

| | |
|---|---|
| AP | Antero-posterior condition |
| BP | Blind people |
| $H_1$ | Hypothesis 1 |
| $H_2$ | Hypothesis 2 |
| IE | Imbalance events |
| MBT | Mean balance time |
| ML | Medio-lateral condition |
| NV | Condition with no vision |
| SP | Sighted people |
| SI | Sighted individuals |
| TBT | Total balance time |
| V | Condition with vision |
| α | Margin of error |

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**BACKGROUND:** The analysis of postural control in individuals with and without visual impairments under unstable conditions contributes to understanding the role of vision and other sensory systems in maintaining balance.
**AIM:** to compare dynamic balance between individuals with and without visual impairment.
**METHODS:** Seventeen participants (24-58 years) with visual impairment, including totally blind and partially sighted individuals (blind people, BP), and 16 sighted individuals (sighted people, SP; 18-55 years). Participants performed three 10-s trials of a balance task on an unstable platform, in both parallel and semi-tandem foot positions. The platform recorded total balance time, mean balance time, and the number of imbalance events, in both the medio-lateral and antero-posterior directions.
**RESULTS:** Under visual conditions, the sighted group demonstrated better balance performance than blind group. When visual input was removed, the performance of sighted individuals declined, reaching similar levels to the blind participants. Even though visually impaired individuals may develop compensatory strategies through long-term reliance on non-visual sensory inputs, suggesting that such adaptations may not fully compensate in unstable conditions. Sighted individuals outperformed the BP group when visual information was available, and performed similarly without vision. The presence of vision notably benefited the sighted group.
**INTERPRETATION:** The findings highlight that, under visual occlusion, the dynamic balance of sighted individuals deteriorates to a level similar to that of visually impaired individuals. This suggests that the absence of visual input places comparable demands on postural control. These results underscore the importance of non-visual sensory strategies for understanding balance in the visually impaired.

**KEYWORDS**: Postural Control | Balance | Blind People | Visual Impairment | Visual Information

## INTRODUCTION

Postural control acts through integration of the motor system, including muscle synergies and sensory systems, encompassing visual, vestibular, and somatosensory inputs. It plays a pivotal role in maintaining postural orientation, whether in static balance or in controlled movements for dynamic balance [1]. Among the sensory inputs, vision is acknowledged as dominant for balance maintenance [2]. A dynamic hierarchy exists, where supplementary sensory references may complement vision to enhance balance [3], while vision occlusion or its absence increases postural sway [4].

Visually impaired individuals (blind people) exhibit increased postural oscillation compared to sighted individuals [5,6]. Some studies propose incomplete replacement of visual information by other sensory sources in blind individuals, indicating compromised sensorimotor integration [7]. However, conflicting reports show similar postural control performance in blind and sighted individuals across different age groups, suggesting that other somatosensory information is able to maintain postural sway, despite the lack of visual information [8,9]. It remains unclear whether the sensorimotor adaptation strategies employed by blind individuals are sufficient to maintain postural control in dynamic conditions.

Several studies have investigated postural control in individuals with visual impairment, revealing diverse findings depending on

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the task type and sensory conditions [10, 11,12]. For instance, blind individuals exhibited greater postural sway in the Sensory Organization Test under proprioceptive or visual manipulation, suggesting limited sensory reweighting capacity [10,12]. In contrast, other studies reported that blind individuals achieved comparable performance to sighted controls during simple static standing, especially in younger subjects, potentially due to enhanced proprioception or haptic compensation [13]. Nonetheless, this equivalence does not extend to more complex motor tasks, as blind children show reduced improvement in dynamic multi-joint balance tests compared to sighted peers, indicating that maturation and experience alone may not fully compensate for the absence of vision [14]. In fact, evidence suggests that the long-term absence of visual input cannot be entirely substituted by other sensory modalities, reinforcing the idea that vision plays an essential and irreplaceable role in selecting balance strategies during postural control [12]. Although some studies have attempted to induce dynamic conditions using foam surfaces [15,16] or computerized systems such as the Neurocom® balance master[17], few studies have explored how visually impaired individuals respond to dynamic multidirectional balance tasks involving real mechanical instability, such as those produced by unstable platforms, for example, with a hemispherical base[18]. Moreover, only a limited number of studies have examined balance performance under instability in both the medio-lateral and antero-posterior directions. This gap is crucial, as real-life balance demands often exceed static postural adjustments.

Blind individuals exhibited greater postural sway than sighted individuals during dynamic balance tasks performed on unstable surfaces [19]. These tasks, which impose increased demands on postural control mechanisms, are particularly relevant for understanding how sensory inputs are integrated in the absence of vision. Considering falls are more frequent under these unstable conditions [20,10], we emphasize the importance of assessing postural control performance in contexts that challenge sensorimotor integration. Most balance research for blind populations uses static tasks, overlooking dynamic balance demands [21], and consequently, further investigations are warranted to examine the postural control of blind and sighted individuals in demanding dynamic balance situations.

Given the need for further investigation into postural control under unstable conditions, analyzing dynamic balance performance in blind and sighted individuals is crucial for understanding how sensory reweighting mechanisms adapt to the absence of vision. Visual deprivation induces neuroplasticity, enhancing the processing of non-visual sensory inputs, such as proprioception, vestibular function, and touch feedback [6,8, 22]. Although blind individuals may develop sharper ankle proprioception[23], their balance strategies favor hip movements over ankle adjustments [8]. In dynamic tasks—where vision normally supports proprioception —this reliance on proprioceptive and vestibular cues becomes critical. Some studies suggest that enhanced reliance on non-visual sensory cues may provide a compensatory advantage in certain contexts [24], while others argue that these adaptations may not be sufficient for blind individuals to achieve a balanced performance that is comparable to sighted individuals [5]. Thus, examining postural control mechanisms under conditions of unstable support and unreliable proprioception is crucial for understanding how blind individuals adapt to these challenges and whether sensory reweighting in these individuals facilitates or hinders dynamic balance performance.

Thus, the current study aimed to compare dynamic balance on an unstable platform of a group of blind participants – including those with total congenital blindness, defined as no light perception, and those with residual vision, including low vision and near-total blindness – against sighted controls. We hypothesized ($H_1$) that blind, compared to sighted individuals, exhibit worse balance performance under visual input, and ($H_2$) perform better when vision is occluded in the sighted people, based on the hypothesis that long-term sensory adaptation in blind individuals enhances their reliance on non-visual sensory inputs, such as proprioception and vestibular information.

## METHODS

### Participants

The sample size was pre-determined based on the t test through the G*Power program [25], considering an effect size of -0.63, margin of error of 5% (α), and power of 80% (1 - β), resulting in a target sample of 94 participants (47 for each group). However, due to recruitment limitations, the final sample consisted of 33 male participants: 17 participants with visual impairment, age range 24-58 years (referred to as blind people – BP) and 16 sighted participants, age range 18-55 years (SI). Invitations were made to individuals affiliated with the Instituto Roberto Miranda, which aids those with visual impairments (referred to as blind people), within the city where the study was carried out. Participants with visual impairment were classified as blind people (BP) according to the operational criteria of our partner institution, Instituto Roberto Miranda, encompassing both totally blind (total absence of light perception) and partial impairment (including low vision and near-total blindness). Although precise clinical stratification was unavailable, all diagnoses were medically confirmed via institutional records, ensuring the inclusion of participants with functionally impaired vision for at least one year. This time criterion ensured the inclusion of individuals with sufficient exposure to sensory adaptation processes.

No participants reported participation in regular structured physical training programs or balance-specific therapies during the recruitment phase. The control group (SP) consisted of 16 individuals without any reported visual, neurological, or musculoskeletal impairments that might interfere with postural control.

### Study procedures

Participants were briefed on the study's objectives and protocols and subsequently provided informed consent by signing the

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approved consent form. The study procedures received ethical approval from the local university's Ethics Committee (CAAE N. 19886713.0.0000.5231; Report N. 387.123).

Dynamic balance was assessed using a customized unstable platform supported on a semicircular base, designed to introduce instability, equipped with sensors capturing platform-edge contact with the ground [see Figure 1]. This platform was connected to a computer via an analog-to-digital adapter to interface with the Dynamic Balance Task software (v.1.0), and provide the analysis variables. Prior studies have demonstrated the reliability of these procedures [26] and their application in assessing the balance of various populations, including ballet dancers [27], young and older adults [28], and individuals with Down Syndrome [29]. Similar devices and unstable platforms have been employed in other studies for postural control analysis and balance training [30,31].

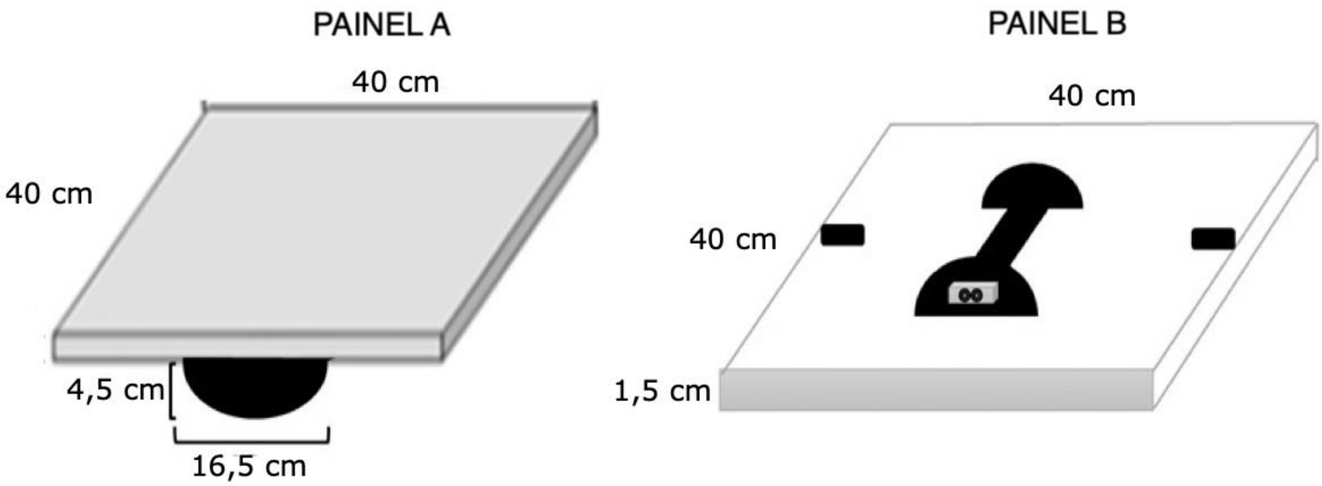


**Figure 1.** Unstable platform dimensions in superior (Panel A) and inferior (Panel B) views.

The task involved maintaining balance on an unstable platform for 10 seconds, with participants assessed under four conditions: (A) medio-lateral direction with vision, (B) medio-lateral direction without vision, (C) antero-posterior direction with vision, and (D) antero-posterior direction without vision. For the medio-lateral conditions, the semicircular base was positioned with its flat side aligned in the antero-posterior axis, allowing the platform to tilt from side-to-side. In these conditions, participants stood with feet shoulder-width apart. For the antero-posterior conditions, the base was rotated 90 degrees, aligning its flat side along the medio-lateral axis to enable forward-backward tilting. In these conditions, participants adopted a semi-tandem stance with the right foot positioned approximately 2.5 cm in front of the left foot [3]. In the vision conditions, sighted participants were instructed to keep their eyes open and focus on a fixed point on the wall at eye level. Blind participants, who are permanently deprived of vision, remained in their usual state, but wore opaque blindfolds to standardize tactile input around the eyes. In the no-vision conditions, sighted participants wore the same opaque blindfolds and were instructed to keep their eyes closed throughout the task. Blind participants remained with eyes closed and blindfolded, replicating the same sensory condition across all trials [3] [see Figure 2]. The experiment was conducted in a quiet, enclosed room (approximately 5 x 4 meters), with neutral-colored walls and uniform ambient lighting to minimize external visual distractions. For the vision condition, sighted participants gazed at a high-contrast visual mark—a black circular dot (10 cm diameter) printed on white paper—placed at eye level on the wall 2 m in front of the participant. The mark was positioned in the center of the wall, ensuring symmetrical visual input. In contrast, blind participants were instructed to maintain a neutral head position and keep their eyes closed, this was reinforced with a soft, opaque blindfold to ensure complete visual occlusion.

Participants received standardized instructions before the beginning of the task, including a familiarization trial, followed by three test trials in each of the four experimental conditions (medio-lateral and antero-posterior directions, in both visual conditions with eyes opened and closed). Participants were instructed to remain on the unstable platform for a fixed duration of 10 s, using any bodily strategy they deemed effective to maintain balance, with the practical goal of avoiding any contact between the platform's edges and the ground. If contact occurred, they were required to promptly regain control and continue balancing until the end of the trial. The number of these contacts was recorded and defined as the variable "imbalance", representing the total number of times the edges of the platform touched the ground during each trial. Participants were allowed to employ compensatory strategies, including ankle, hip, or full-body adjustments, provided that their initial foot positioning remained fixed throughout the task. No restrictions were imposed on the type of postural control used, allowing for natural, individualized responses aimed at stabilizing the platform during the entire 10-second period. Each test began with a specific starting procedure depending on the direction of instability. In the medio-lateral condition, participants stepped onto the platform with the right foot, pressing one of its edges to the ground to activate the sensors, and then positioned the left foot beside the right foot, adopting a stance with feet shoulder-width apart. In the antero-posterior condition, the participant first placed the posterior part of the platform in contact with the floor using the left foot, and then positioned the right foot forward in a semi-tandem stance, with approximately 2.5 cm between feet. The trial officially started when the sensor located at the bottom of the platform was no longer in contact with the ground, indicating full suspension of the platform. The order of conditions was randomized across participants, with a 1-minute rest between trials to avoid fatigue. Two trained evaluators remained nearby during the entire procedure to ensure participants' safety.

**Figure 2.** Illustration of platform medio-lateral instability (posterior view) and antero-posterior instability (lateral view).

### Study variables

The independent variables in this study were visual status (sighted vs. blind participants) and visual condition (eyes open vs. vision occluded). The dependent variables, recorded by the software during each 10-second trial, included: total balance time (TBT), defined as the total duration in seconds that the participant remained balanced on the platform without any edges touching the ground, reflecting the cumulative time of successful postural control within the trial—higher values indicating better performance; mean balance time (MBT), calculated as the average time interval in seconds between consecutive edge contacts, representing the typical duration of balance maintained between instability episodes—higher values also indicating better control; and imbalance events (IE), referring to the total number of times the edges of the platform contacted the ground during the trial, whether on the left or right edge in the medio-lateral condition, or the front or rear edge in the antero-posterior condition—where lower values reflect superior balance performance.

### Statistical analysis

The Shapiro-Wilk normality test indicated non-normality of data distribution for some variables ($p<0.05$), necessitating the use of non-parametric tests for both descriptive and inferential statistics. Descriptive analysis utilized median values and the 1st and 3rd quartiles. Inferential analysis employed the Mann-Whitney U test for comparing two independent samples (groups: BP and SP) and the Wilcoxon test for comparing conditions with and without vision. Statistical analyses were conducted using SPSS (v.28.0.1.1), with significance set at 5% ($p<0.05$).

Effect size was calculated using the formula $r = Z/(\sqrt{N})$ [32], and a post hoc power analysis was performed based on the t-test using G*Power software. Effect size calculations considered each variable and sample size, with a 5% (α) margin of error.

## RESULTS

Figure 3 presents the median values and 1st and 3rd quartiles of the variables total balance time (Panel A), mean balance time (Panel B), and imbalance events (Panel C), in the condition with vision (V) and no vision (NV), in the medio-lateral (ML) and antero-posterior (AP) conditions, for the blind (BP) and sighted (SP) groups.

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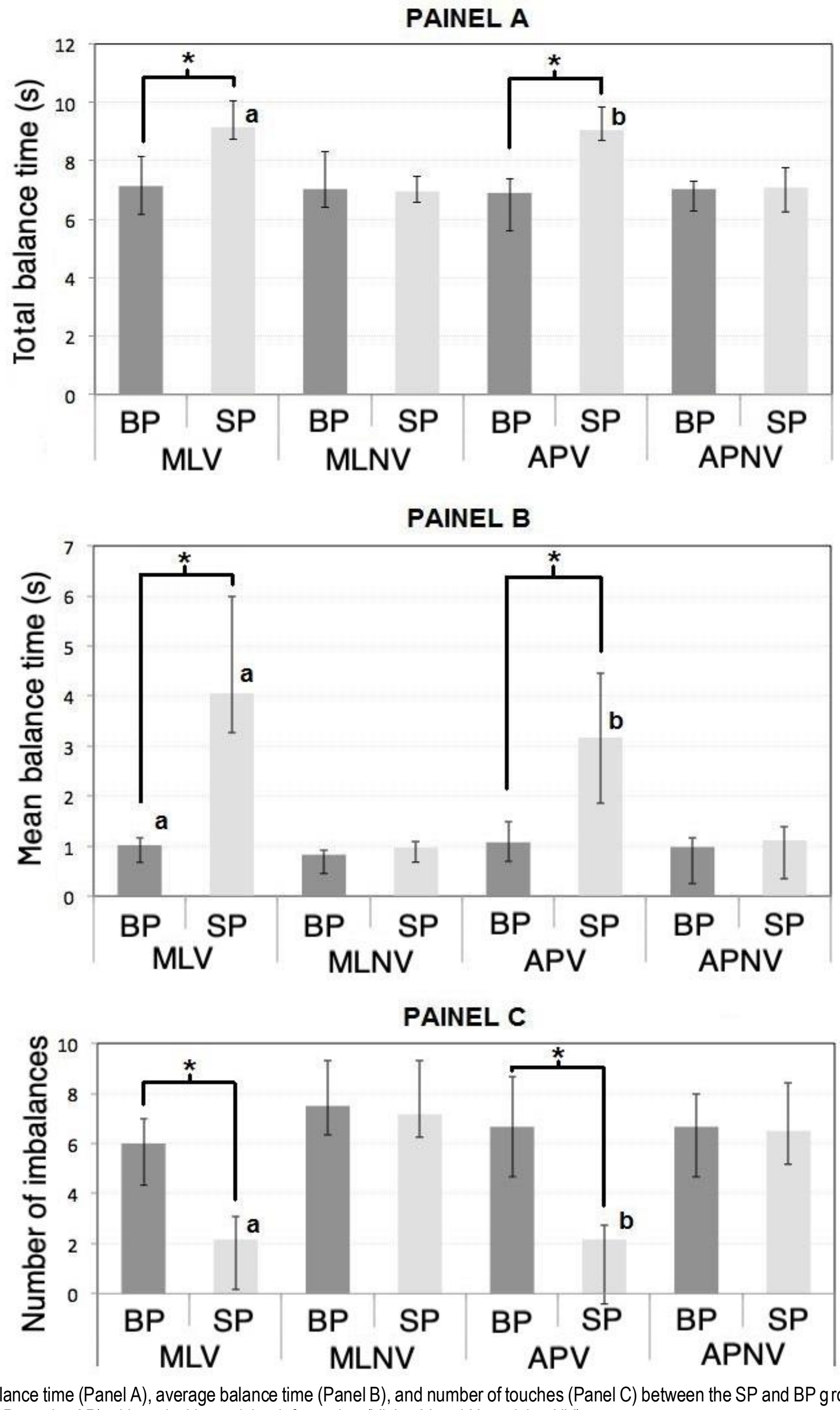


**Figure 3.** Comparison of balance time (Panel A), average balance time (Panel B), and number of touches (Panel C) between the SP and BP groups in two platform conditions (Medio-Lateral ML x Antero-Posterior AP) with and without vision information (Vision V and Non-vision NV).
Legend: Significant difference (P<0.05) between *SP and BP; aMLV and MLNV within the same group; and bAPV and APNV within the same group.

Analysis of the Medio-Lateral Oscillation Task (ML): The Mann-Whitney U test showed greater total balance time for the SP, in comparison with the BP, in the medio-lateral with vision condition ($U = 36.00$, $Z = -3.60$, $p < 0.001$, $r = -0.63$, $\eta 2 = 0.4$). The Wilcoxon test showed greater total balance time for the SP in the medio-lateral with vision condition, when compared to the medio-lateral without vision

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condition (T = 8.50, Z = -3.52, p < 0.001, r = -0.62, η2 = 0.6).

The Mann-Whitney U test also showed greater mean balance time for the SP, in comparison with the BP, in the medio-lateral with vision condition (U = 41.00, Z = -3.42, p < 0.001, r = -0.60, η2 = 0.4). The Wilcoxon test showed greater mean balance time for the SP in the medio-lateral with vision condition, when compared to the medio-lateral without vision condition (T = 9.0, Z = -3.47; p < 0.001, r = 0.61, η2 = 0.4). The BP showed greater mean balance time in the medio-lateral with vision condition, when compared to the medio-lateral without vision condition (T = 8.50, Z = -2.39, p = 0.02, r = -0.41, η2 = 0.3).

The Mann-Whitney U test demonstrated a greater number of imbalance events for the BP in the medio-lateral with vision condition, when compared to the SP (U = 55.0, Z = -2.92, p = 0.003, r = -0.51, η2 = 0.3). The Wilcoxon test showed a greater number of imbalance events for the SP in the medio-lateral without vision condition, in comparison to the medio-lateral with vision condition (T = 1.50, Z = -3.24, p < 0.001, r = -0.57, η2 = 0.6).

Analysis of the Antero-Posterior Oscillation Task (AP): The Mann-Whitney U test showed greater total balance time for the SP, in comparison with the BP, in the antero-posterior with vision condition (U = 52.00, Z = -3.03, p = 0.002, r = -0.53, η2 = 0.3). The Wilcoxon test showed greater total balance time for the SP in the antero-posterior with vision condition, when compared to the antero-posterior without vision condition (T = 8.73, Z = -3.26, p < 0.001, r = -0.58, η2 = 0.6).

The Mann-Whitney U test also showed greater mean balance time for the SP, in comparison with the BP, in the antero-posterior with vision condition (U = 49.50, Z = -3.12, p = 0.001, r = -0.54, η2 = 0.3). The Wilcoxon test showed greater mean balance time for the SP in the antero-posterior with vision condition, when compared to the antero-posterior without vision condition (T = 8.93 Z = -2.95; p = 0.002, r = -0.52, η2 = 0.3).

The Mann-Whitney U test showed a greater number of imbalance events for the BP, in the antero-posterior with vision condition, when compared to the SP (U = 61.0, Z = -2.71, p = 0.006, r = -0.47, η2 = 0.3). The Wilcoxon test showed a greater number of imbalance events for the SP in the antero-posterior without vision condition, in comparison to the antero-posterior with vision condition (T = 2.0, Z = -3.21, p < 0.001, r = -0.57, η2 = 0.6).

## DISCUSSION

The current study aimed to compare dynamic balance between visually impaired (BP) and sighted (SP) individuals using a platform with an unstable support base in both the ML and AP directions, with and without visual occlusion. Confirming the first hypothesis ($H_1$), the results showed that the SP group exhibited better balance in the vision condition compared to the BP (Figure 3, Panels A, B, and C). Our second hypothesis ($H_2$) was rejected, as the BP group showed equivalent performance to the SP in conditions of visual occlusion for the sighted participants (Figure 3; Panels A, B, and C).

Sighted individuals exhibited better dynamic balance (greater total balance time, higher mean balance time, and fewer imbalance events in both ML and AP conditions) when visual information was available, compared to blind individuals under the same conditions. Their performance worsened with visual occlusion, reinforcing the important role of vision in postural control. Comparative studies have shown that individuals with visual impairments, including blindness, tend to exhibit greater postural sway and reduced balance stability compared to sighted peers [6,7]. Visual input plays a particularly relevant role in postural control for sighted individuals. Sighted participants demonstrated better balance control than blind individuals across tasks of increasing difficulty, and postural sway of these individuals increased when vision was occluded, indicating strong reliance on visual input [21]. Sighted individuals rely on visual information to complement other sensory inputs in postural control [33]. Although blind individuals develop cortical reorganization through cross-modal plasticity to compensate for vision loss, this neural adaptation does not translate into improved postural control, despite enhanced integration of proprioceptive and vestibular inputs [5]. Visual occlusion in sighted individuals acutely disrupts balance and increases sway [7,20], whereas long-term visual deprivation may lead to neuroplastic adaptations that support postural control [22]. Loss or impairment of vision has been associated with poorer balance and an increased risk of falls, and may negatively affect daily activities [34,35]. These findings are consistent with previous literature that used compliant surfaces to simulate instability (e.g., foam platforms), where blind individuals also exhibited inferior performance compared to sighted controls [15,16]. However, the current study adds novel evidence by using a dual-axis unstable platform with real mechanical perturbations in both medio-lateral and antero-posterior directions.

The findings of the current investigation are consistent with prior research that indicates better balance among individuals without visual impairment when their eyes are open, as opposed to their visually impaired counterparts, in both children/teenagers [36,37] and in adults and older individuals [17,38]. This observation underscores the inability of individuals with visual loss to fully compensate for the integral role played by vision in sustaining postural control [10]. The process involves a recalibration of sensory information weighting [39]. Essentially, individuals with sight can dynamically redistribute emphasis from one sensory modality to another, thereby enhancing performance through visual input. Blind individuals demonstrate postural control deficits, which they compensate for through enhanced weighting of remaining sensory systems (proprioceptive, vestibular, and haptic inputs) [5]. Blind individuals compensate for the lack of visual postural control through enhanced sensorimotor cortex activity and distinct cortical oxygenation patterns, although these neural adaptations seem to be insufficient to achieve balance performance comparable to sighted individuals [19].

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Existing evidence suggests that congenitally blind individuals develop heightened sensitivity to feedback from these alternative sensory sources, as a compensatory mechanism for vision loss [9]. Nevertheless, certain studies posit that the spatial orientation of blind individuals may be less effective, possibly attributed to a lack of experience rather than the condition of blindness per se, or due to dependence on haptic and auditory cues, which could constrain their performance in balancing tasks [40].

When comparing the groups in the non-vision conditions, both the blind and sighted groups showed similar results (total balance time, mean balance time, and imbalance events; ML and AP conditions). These results are consistent with other studies reporting comparable balance performance between sighted individuals with closed eyes and blind individuals [17]. This verified similarity may be explained by the fact that automatic postural responses and postural sway control during perturbations appear to be relatively unaffected by the absence of vision from birth, indicating that the vestibular and somatosensory systems function in a comparable manner in both blind and sighted individuals [9]. Unlike studies that observed better dynamic balance performance in blind individuals compared to sighted blindfolded individuals [9,37], our findings indicate that this advantage is not consistent across all conditions [37]. Moreover, sports training improves dynamic postural stability [7], our results emphasize that even without formal training, chronic adaptation to blindness may not be sufficient to overcome the absence of vision in dynamic balance regulation.

Blind individuals exhibit a reduced reliance on visual information, in contrast to their sighted counterparts [9,37]. This diminished dependency is attributed to a chronic adaptation, characterized by the reevaluation of sensory input weightings, particularly from somatosensory and vestibular sources, compensating for the diminished reliance on visual information [9]. An alternative hypothesis posits that both muscle activities and movement coordination are centrally preprogrammed and initiated solely by sensory input [9]. However, despite these adaptive mechanisms, the performance of blind individuals across all conditions resembled the poorer performance observed in sighted individuals under conditions without vision - characterized by lower total balance time and mean balance time, and higher imbalance events. This discrepancy may be elucidated by the lower motor stimulation experienced by blind individuals [41], directly impacting dynamic balance performance. Indeed, individuals with visual impairments tend to have limited access or invest less time in physical activities compared to their visually unimpaired peers [42]. Various environmental factors, such as transportation, and personal barriers, including dependency on others, constrain the engagement of individuals with visual impairments in physical activities [43]. This movement deprivation could explain the persistence of performance deficits despite neural adaptations, suggesting that both biological and socio-environmental factors must be addressed to optimize postural control in blindness.

Despite neuroplastic adaptations to congenital blindness (including cortical changes and neuronal reorganization), these modifications do not yield relevant improvements in postural control [5]. This results in blind individuals employing distinct postural control strategies where the predictive capacity of vision is replaced by reweighted somatosensory and vestibular inputs [6,8,22]. Therefore, physical activity programs targeting this population should give special attention to balance training, considering these specific sensory adaptations.

The current study employed the institutional classification 'Blind People (BP)' for cohort definition, encompassing varying degrees of vision loss. While this approach enhances ecological validity for rehabilitation settings, it limits granular analysis of how specific acuity levels influence balance performance due to population heterogeneity (e.g., age range, physical activity levels, motor experiences, and blindness severity). From a methodological perspective, the inclusion of both totally blind (no light perception) and partially sighted participants requires careful interpretation. This heterogeneity in the visually impaired group represents a methodological limitation of the study, as it may have masked specific effects of blindness severity on balance performance.

## CONCLUSION

Sighted individuals in the condition of full vision showed better dynamic balance on the unstable platform when compared to individuals with visual impairment. The dynamic balance of blind people was found to be similar to that of sighted people when their vision was occluded. Therefore, even though there is a chronic adaptation in people with visual impairment, their sensorimotor reorganization for movement regulation did not lead to better performance on the unstable platform in comparison to the sighted people. These results reinforce the significant contribution of visual information to postural control for sighted individuals to maintain balance, as vision loss acutely disrupts balance performance.

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