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Investigation of the Effects of Posture and Proprioception Sense on Balance and Gait

Postür ve Propriosepsiyon Duyusunun Denge ve Yürüyüş Üzerine Etkilerinin İncelenmesi

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Abstract

The aim of this study is to assess the effects of variations in head posture, proprioception sense, and balance metrics on the balance and gait of asymptomatic participants. One hundred ten individuals were included in the study. The assessment protocol contained multiple parameters: cervical spine range of motion, body posture, proprioception sense, static balance, dynamic balance, and gait. The study investigated the correlation between the Timed Up and Go Test and several independent variables such as head tilt, proprioceptive error, Flamingo Test score, Functional Reaching Test score, and Y Balance Test score. Statistical significance was accepted as $p<0.05$. The researchers employed multiple regression analysis to ascertain the characteristics that can predict balance and gait performance. The findings indicate that there is no statistically significant correlation between the Timed Up and Go Test score and any of the predicted variables. The results suggest that there may be a correlation between longer durations of the Timed Up and Go Test and limitations in upper extremity reaching capacity and specific components of dynamic balance. The aforementioned findings are important for evaluating and improving the physical abilities of individuals with mobility disabilities.

Keywords: Gait, head, postural balance, posture, proprioception

Özet

Bu çalışmanın amacı, asemptomatik bireylerde baş pozisyonu, denge ölçümleri ve propriyosepsiyon duyusundaki değişikliklerin denge ve yürüyüş üzerindeki etkisini değerlendirmektir. Çalışmaya yüz on kişi dahil edilmiştir. Değerlendirme protokolü birçok parametreyi içermektedir: Servikal omurganın hareket aralığı, vücut duruşu, propriyosepsiyon duyusu, statik denge, dinamik denge ve yürüyüş. Bu çalışma, Zamanlı Kalk ve Yürü Testi ile baş tilti, propriyoseptif hata, Flamingo Testi puanı, Fonksiyonel Uzanma Testi puanı ve Y Denge Testi puanı arasındaki ilişkiyi araştırdı. İstatistiksel anlamlılık değeri $p<0.05$ olarak kabul edildi. Araştırmacılar, denge ve yürüyüş performansını tahmin edebilecek özellikleri belirlemek için çoklu regresyon analizini kullandılar. Bulgular, Zamanlı Kalk ve Yürü Testi puanı ile yordanan değişkenlerden herhangi biri arasında istatistiksel olarak anlamlı bir ilişki olmadığını göstermektedir. Sonuçlar, Zamanlı Kalk ve Yürü Testinin daha uzun sürede tamamlanması ile üst ekstremite uzanma kapasitesindeki azalmalar ve dinamik dengenin belirli bileşenlerinin bozulması arasında bir korelasyon olabileceğini öne sürmektedir. Yukarıda belirtilen bulgular, engelli bireylerin fiziksel yeteneklerinin değerlendirilmesi ve restorasyonu açısından önem taşımaktadır.

Anahtar Kelimeler: Baş, postür, postüral denge, propriyosepsiyon, yürüyüş

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1. Introduction

Postural balance and gait control are important for individuals to carry out daily life activities effectively and participate in physically-based social activities (Onofrei & Amaricai, 2022). While the postural balance relates to the body's capacity to maintain its center of gravity within its base of support, gait refers to the style of movement exhibited by the individual. Impairment in balance and gait can lead to increased fall susceptibility, physical harm, and functional limitations, especially in the elderly population (Osoba et al., 2019). There are many elements that play a role in the regulation of balance and gait, such as sensory input (MacKinnon, 2018), musculoskeletal function (Mohd Said et al., 2015), and central nervous system processes (Yiou et al., 2017). The interaction between various factors is worth investigating, especially in terms of the role played by the cervical spine, posture, and proprioception sense (Peng et al., 2021).

The cervical spine plays a crucial role in the maintenance of postural stability and head control. The range of motion exhibited by a joint possesses the capacity to impact the alignment of the entire body, along with sensory perception, muscular coordination, and overall equilibrium (Ha & Sung, 2020). Research has indicated that limitations in the cervical joint's range of motion can disrupt the coordination among the visual, vestibular, and somatosensory systems, resulting in compromised balance and gait. The alignment and positioning of body parts relative to the gravitational axis is referred to as posture, which is critical in the regulation of balance and gait. This information is emphasized in the cited source (Carini et al., 2017). Ensuring proper postural alignment is fundamental for optimizing weight distribution and muscle activation, thereby enhancing stability in both stationary and moving states. Previous research have revealed that deviations from ideal posture are linked to the emergence of postural sway, decreased stability, and changed gait patterns (Paillard & Noé, 2015; Zago et al., 2020).

The proprioception sense is vital in the maintenance of balance and the coordination of intricate movements by enabling the detection of body part location and movement (Tsay et al., 2016). The central nervous system (CNS) is responsible for receiving proprioceptive data from the joints and muscles, which has an important role in enabling accurate motor control and facilitating the required adjustments in posture and gait. Previous studies have demonstrated a correlation between deficiencies in proprioceptive perception and discrepancies in balance, including modified ambulatory patterns (Allum et al., 1998).

While several studies have investigated the influence of cervical joint range of motion, posture, and proprioception sense on balance and gait, a dearth of comprehensive research incorporating all these variables exists. The primary objective of the present study was to investigate the effects of cervical joint range of motion, posture, and proprioception sense on balance and gait in a cohort of individuals without any known health conditions. By conducting a thorough assessment of these variables, our objective is to ascertain potential correlations and elucidate their significance in the maintenance of optimal equilibrium and locomotor regulation. The acquisition of this knowledge has the potential to enhance the

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development of targeted interventions designed to decrease the probability of falls and functional limitations, while simultaneously enhancing balance and gait.

2. Method

2.1. Objective of the Research

This study was carried out to evaluate the effects of individual differences in head posture, balance parameters, and proprioception sense on balance and gait in asymptomatic individuals.

2.2. Research Questions

- What are the effects of head posture on balance and gait in asymptomatic individuals?

- What are the effects of cervical joint range of motion on balance and gait in asymptomatic individuals?

- What are the effects of cervical proprioception sense on balance and gait in asymptomatic individuals?

- Is there a relationship between static and dynamic balance parameters and between these parameters and gait parameters in asymptomatic individuals?

2.3. Population and Sample of the Research

A total of 110 healthy adults aged 18-65 years were recruited for this study. Furthermore, it was a requirement for the participants to exhibit asymptomatic characteristics, indicating the absence of any symptoms or clinical problems that could potentially impact their balance or gait (Dynamic Gait Index Score<19). Participants who had a prior medical history of neurological or musculoskeletal conditions that could potentially impact their balance or gait ability were not included in the research study. Individuals who were currently undergoing pharmacological treatment that could potentially impact their balance or gait abilities were also excluded from the study. The study also excluded participants who exhibited abnormal range of motion in the cervical joint.

G*Power version 3.1.9.2 (Heinrich-Heine-Universität Düsseldorf) was used for calculating the sample size. A total of 102 participants (effect size: 0.20; alpha error of probability: 0.05; power: 0.80; and number of predictors: 10) were required for the regression analysis.

2.4. Data Collection and Data Tools

The study was conducted at the Çankırı Karatekin University Faculty of Health Sciences Research Laboratories between December 2022 and April 2023. The following assessments were performed on all participants:

Balance and Gait Assessment: The Timed Up and Go Test was used to assess participants' balance and gait (Shumway-Cook et al., 2000). The Timed Up and Go Test, which measured the duration required for a participant to ascend from a seated to a standing position, walk a three-meter distance, return to the start point, and then sit down constituted the dependent variable for the study. The study exclusion group was determined based on the use of the Dynamic Gait Index outcome measure (Dynamic Gait Index score<19). The Dynamic Gait Index covers many walking-related activities, such as walking in a straight line, turning, and maneuvering around obstacles (Herman et al., 2009).

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Cervical Spine Range of Motion Assessment: The participants' joint range of motion was assessed with a goniometer (Asha & Pryor, 2013). Individuals exhibiting an atypical range of motion were excluded from participation in the study.

Posture Assessment: Using the PostureScreen app (PostureCo, Inc., San Diego, CA, USA), the participants' posture was evaluated. The program utilizes the camera of a tablet or smartphone to capture images of users from diverse angles, subsequently computing a range of metrics associated with posture, including shoulder positioning and alignment of the spine (Boland et al., 2016).

Proprioception Sense Assessment: The study employed Head-to-Target (HtT) tests to assess proprioceptive sensory function. The participants were situated in ergonomically designed seating arrangements at a distance of one meter from the whiteboard. The individual's lumbar region and pelvic area were in close contact with the chair, exerting firm pressure. Additionally, their hands were positioned on their knees, forming a right angle of 90°. The experiments were conducted within a meticulously maintained physiotherapy laboratory, characterized by minimal external auditory disturbances and a consistent ambient temperature of 23 °C. The participants' eyesight was obstructed by the application of a blindfold, while laser beam equipment was affixed to their foreheads. During the Head-to-Target (HtT) tests, the participants were required to rotate their heads toward the designated target point, which was indicated at a 45° angle on the whiteboard. Following the memorization of the ideal posture, participants proceeded to rotate their heads back to the neutral position. Subsequently, the revised position of the laser beam was visually displayed on the board, prompting participants to subsequently align their visual focus towards the designated target area. The objective of this study was to test the participants' proprioceptive capacity and get a deeper understanding of proprioceptive sensory function through the evaluation of their accuracy in replicating the goal head position (Ntenezakos et al., 2021).

Static and Dynamic Balance Parameters: The study assessed the static and dynamic balance parameters of the individuals using three distinct tests: the Flamingo Test (Çakır & Özbar, 2019), the Functional Reaching Test (Bennie et al., 2003), and the Y Balance Test (Coughlan et al., 2012). The Flamingo Test is a standardized method for evaluating balance, wherein participants are instructed to maintain a unipedal stance while keeping their eyes both open and closed for a duration of 30 seconds. The Functional Reach Test is a clinical evaluation instrument utilized to quantify the maximum distance an individual may extend their reach in the forward direction while maintaining an upright stance on two feet. The Y Balance Test is a clinical evaluation instrument utilized to evaluate the maximum reach distance in three distinct directions: anterior, posteromedial, and posterolateral, all while maintaining a unilateral posture.

2.5. Ethical Aspect of the Research

All participants provided written informed consent before they participated in the study. The present study was approved by the Scientific Research and Publication Ethics Committee of Çankırı Karatekin University (decision date 06.28.2022 and code ae7cdbc412234fed). The study was carried out in line with the Declaration of Helsinki. Consent forms were obtained from all the participants in the study.

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2.6. Limitations of the Research

One of the limitations of the present study is the absence of an evaluation regarding the influence of cervical joint range of motion on both balance and posture. The evaluation methodology employed in the study solely identified the existence or non-existence of prevalent limitations, without yielding dependable quantitative data. The aforementioned limitation imposes a constraint on comprehending the potential influence of cervical joint range of motion on the variables under investigation. The study may have certain drawbacks, such as a very small sample size, which may restrict the generalizability of the findings. Additionally, the utilization of certain evaluation methods may not fully capture the intricacies of the variables under investigation. Additionally, the study primarily examined a cohort that was relatively youthful and influential, which may have restricted the applicability of the results to other population groups, such as elderly individuals or those with specific medical issues. It is advisable for future studies to employ more comprehensive measuring procedures and include bigger and more diverse participant cohorts in order to enhance the present comprehension of the associations between physical attributes and functional evaluations using the Timed Up and Go Test. This will address the current constraints and promote a more thorough comprehension of the topic.

2.7. Data Analysis

The utilization of descriptive statistics facilitated the provision of a thorough portrayal of the demographic features of the participants. The examination of categorical variables involved the examination of their frequencies and proportions. The determination of data normality was based on the outcomes derived from the Shapiro-Wilk test. Pearson Correlation Analysis was employed in the study to assess the association between the dependent variable, namely the Timed Up and Go Test, and several independent variables, encompassing balance, gait, posture, and proprioceptive sensory capacities.

A research study was undertaken to perform multiple regression analysis in order to ascertain the variables that exhibit predictability with respect to balance and gait performance. The statistical study was conducted using SPSS Inc., located in Chicago, IL. The analysis was conducted utilizing the SPSS version 28.0 software program, which was built by [IBM Company, Chicago, IL]. A statistical threshold was established with a significance level of $p < 0.05$. The statistical methods employed encompassed effect sizes, confidence intervals, and p values.

3. Results

The study encompassed a cohort including 110 participants, with 62 individuals (56.4%) self-identifying as female and 48 individuals (43.6%) self-identifying as male. Table 1 displays the demographic characteristics of the participants.

With respect to functional tests, participants showed competence in their ability to execute motions and sustain equilibrium. Based on the findings, the individuals exhibited notable dynamic balance when walking, as indicated by an average score of 23.02 out of 24 on the Dynamic Gait Index. The findings derived from the Time Up and Go Test reveal that the mean score obtained is 7.67 seconds. This outcome suggests that there exists an acceptable degree of mobility when doing a task under time

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constraints. The mean score obtained from the Flamingo Test was 1.5. The findings of the study demonstrate that the mean score obtained from the Functional Reach Test was 36.73 cm. This value signifies the average distance reached during a task that involves forward reaching, as presented in Table 1.

The Y Balance Test was employed to assess the participants' balance across multiple dimensions. The study's results indicate that the mean measurements for the anterior part of the right leg are 73.59 cm, while the right posterolateral region has an average measurement of 67.99 cm, and the left posterolateral region has an average measurement of 64.44 cm. The recorded measurements for the left leg were as follows: anterior, measuring 75.24 cm; right posterolateral, measuring 64.62 cm; and left posterolateral, measuring 66.33 cm (Table 1).

Table 1. Demographic Characteristics and Clinical Test Scores of Participants

VARIABLES	**x̄±SD**	**n (%)**
Gender		
Female		62 (%56.4)
Male		48 (%43.6)
Age (year)	35.8±11.4	
Weight (kg)	72.8±14.7	
Height (cm)	168.9±9.6	
Body mass index (kg/m²)	25.6±4.8	
Head anterior tilt (degree)	12.3±5.4	
Proprioceptive error (cm)	12.45±5.94	
Dynamic Gait Index score (0-24)	23.02±1.27	
Time Up and Go Test score (sec)	7.67±1.77	
Flamingo Test score (repeat)	1.5±2.6	
Functional Reach Test score (cm)	36.73±8.58	
Y Balance Test score (cm)		
Right-anterior	73.59±19.43	
Right-right posterolateral	67.99±16.05	
Right-left posterolateral	64.44±14.78	
Left-anterior	75.24±20.61	
Left-right posterolateral	64.62±15.45	
Left-left posterolateral	66.33±15.94	

x̄±S:=Mean± Standart deviation, n=Number, %=Percentage

Table 2 displays the correlation analysis conducted to examine the relationship between the Timed Up and Go Test and many factors. The study found a weak negative link between forward head tilt and the Timed Up and Go Test score. However, it is important to note that this correlation did not approach statistical significance (r = -0.119, p = 0.261). The findings indicated a favorable association between proprioceptive error and the score derived from the Timed Up and Go Test (r = 0.173, p = 0.100); however, the connection did not achieve statistical significance. In a similar vein, it was noted that there existed a little positive association between the Flamingo Test score and the Timed Up and Go Test score (r = 0.154, p = 0.145); however, this relationship did not reach statistical significance. The findings indicated a statistically significant moderate negative correlation (r = -0.265, p = 0.019*) between the

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performance on the Functional Reaching Test and the Timed Up and Go Test. The findings suggest a notable correlation between worse functional reaching skills and longer completion times on the Timed Up and Go Test, as presented in Table 2.

Furthermore, there were notable inverse associations observed between the scores of the Y Balance Test, a measure assessing balance across several orientations, and the score of the Timed Up and Go Test. The study revealed a modernately negative connection between the score of the Timed Up and Go Test and the scores of the right frontal, right posterolateral, and left frontal Y Balance Tests. The correlation coefficients observed in the study were -0.217, -0.228, -0.229, -0.247, -0.246, and -0.212, while the corresponding p-values were 0.039, 0.031, 0.029, 0.018, 0.019, and 0.042, respectively. The aforementioned associations indicate that participants who exhibited lower balance skills, as assessed by the Y Balance Test, required more time to complete the Timed Up and Go Test (Table 2).

Table 2. Correlation Analysis Between Timed Up and Go Test and Other Variables

VARIABLES	Time Up and Go Test (r)	Time Up and Go Test (p)
Head anterior tilt	-0.119	0.261
Proprioceptive error	0.173	0.100
Flamingo Test score	0.154	0.145
Functional Reach Test score (cm)	-0.265	**0.019***
Y Balance Test score		
Right- anterior	-0.217	**0.039***
Right- right posterolateral	-0.228	**0.031***
Right- left posterolateral	-0.229	**0.029***
Left- anterior	-0.247	**0.018***
Left- right posterolateral	-0.246	**0.019***
Left- left posterolateral	-0.212	**0.042***

Abbreviations= p Pearson Correlation Analysis*

A multiple regression analysis was conducted to examine the relationship between the score on the Timed Up and Go Test and other predictor factors. The model's adjusted R^2 value was determined to be 0.018. There was no statistically significant association found between any of the individual predictor variables and the Timed Up and Go Test results ($p>0.05$). The provided information is displayed in Table 3.

Table 3. Multiple Regression Analysis for Timed Up and Go Test

VARIABLES	β	95% CI	p value
Head anterior tilt	-0.082	-0.106 to 0.051	0.485
Proprioceptive error	0.127	-0.034 to 0.108	0.305
Flamingo Test score	0.148	-0.064 to 0.260	0.232
Functional Reach Test score (cm)	-0.171	-0.093 to 0.022	0.218
Y Balance Test score			
Right- anterior	0.399	-0.032 to 0.126	0.237
Right- right posterolateral	-0.361	-0.123 to 0.041	0.321
Right- left posterolateral	-0.036	-0.071 to 0.049	0.716
Left- anterior	-0.536	-0.137 to 0.015	0.115
Left- right posterolateral	-0.091	-0.071 to 0.049	0.716

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Table 3. Multiple Regression Analysis for Timed Up and Go Test (continued)

Left- left posterolateral	0.317	-0.051 to 0.126	0.396

*Abbreviations: Adjusted R^2 = 0.018, β: standardized regression coefficients, CI: confidence interval, p*multiple lineer regression*

4. Discussion

The primary objective of the present study was to investigate the association between several physical attributes and functional evaluations and the score obtained in the Timed Up and Go Test, among a group of participants. The study findings indicate a positive correlation between the Timed Up and Go Test score, a metric assessing gait and balance performance, and both Y Balance scores and functional reaching levels. However, no statistically significant correlation was observed between specific predictive variables, such as head tilt, proprioceptive error, and Flamingo Test score.

The absence of substantial correlations between the score obtained in the Timed Up and Go Test and the individual predictor variables indicates that these variables may not possess substantial predictive capacity for performance on the Timed Up and Go Test (Barry et al., 2014; Zarzeczny et al., 2017). The aforementioned findings align with prior studies that have demonstrated a limited association between specific physical attributes and performance on the Timed Up and Go Test. Nevertheless, prior studies have also observed notable associations between physical attributes and performance in the Timed Up and Go Test (Gomes et al., 2023; Uesugi et al., 2021). The presence of discrepancies in findings among different research might be ascribed to variations in sample characteristics, evaluation methodologies, and statistical approaches employed.

The results suggest a little inverse relationship between forward head tilt and performance on the Timed Up and Go Test. This suggests that persons with greater degrees of head tilt may demonstrate a slight decline in their Timed Up and Go Test scores. Nevertheless, the aforementioned association failed to achieve statistical significance. A study investigating the correlation between a posture defined by forward head tilt and probable irregularities in balance and gait has indicated that forward head tilt does not provide a substantial hindrance to postural control and stride (Silva & Johnson, 2013). Despite the lack of statistical significance in the present investigation, it is plausible that a bigger sample size or more refined measuring techniques could potentially unveil a more robust association between head tilt and performance on the Timed Up and Go Test.

The study conducted revealed a positive link, albeit of a weak nature, between the score obtained from the Timed Up and Go Test and proprioceptive error. Proprioceptive error refers to the discrepancy between the perceived position of a limb and its real position. While the observed results did not reach statistical significance, the findings indicate that persons with higher levels of proprioceptive errors may demonstrate a modest decline in their performance on the Timed Up and Go Test. Proprioception has been identified as a critical factor in the maintenance of balance and coordination of movement, as indicated by prior scholarly investigations (Ferlinc et al., 2019). The absence of a statistically significant association between the Timed Up and Go Test and the proprioceptive sense in this study may be attributed to the influence of several confounding factors on proprioception. To enhance the clarity of this finding, a greater quantity of samples is required.

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The Flamingo Test, a measure of an individual's capacity to maintain balance on a single leg, exhibited a modest positive correlation with the Timed Up and Go Test result. However, this correlation did not reach statistical significance. The maintenance of balance during unipedal stance is widely recognized as a critical component of functional mobility, particularly in the context of elderly individuals. The available research has demonstrated a significant association between subpar performance on this particular task and an elevated susceptibility to falls within this specific demographic (McLay et al., 2020; Omaña et al., 2021). The absence of statistical significance in the present study can potentially be ascribed to the relatively youthful and healthy nature of the subjects, as well as the limited sensitivity of the Flamingo Test in identifying subtle imbalances.

The findings of the study indicate a statistically significant moderate negative correlation between the functional reach test and the Timed Up and Go Test score. This finding indicates that people who had inferior functional reaching performance took longer to accomplish the task of the Timed Up and Go Test. The aforementioned discovery suggests that the decline in reaching ability in the upper limbs could contribute to the reduction in functional mobility speed. The evaluation referred to as functional reach testing assesses an individual's ability to extend their reach forward while concurrently maintaining balance, and is regarded as a metric of dynamic stability (Scena et al., 2016). The link shown between functional reach and performance on the Timed Up and Go Test aligns with prior research that emphasizes the significance of upper extremity functionality in both mobility and susceptibility to falls (Arnold et al., 2022; Ashburn et al., 2008; Dastan et al., 2021).

Y Balance Test scores, which assess dynamic balance in various aspects, exhibited significant negative correlations with the Timed Up and Go Test score. The findings mentioned above underline the importance of regulating dynamic balance in ensuring functional mobility. It also means that deficits in certain aspects of balance may have an impact on performance on the Timed Up and Go Test. Previous research has also shown correlations between performance on the Y Balance Test and mobility-related outcomes (Bauer et al., 2023; Kim et al., 2022). The study's findings documented that dynamic balance assessments are a strong indicator for predicting balance and gait-related functional mobility.

The absence of significant associations between the score of the Timed Up and Go Test and other predictor variables in a multiple regression analysis can be attributed to the intricate interplay of several factors that influence performance on the Timed Up and Go Test. The Timed Up and Go Test is a widely utilized evaluation instrument that encompasses various aspects like balance, gait, coordination, and cognitive processing, as indicated in the existing literature (Klotzbier et al., 2021). Hence, it is plausible that other nonquantitative characteristics, such as muscle strength, articulation flexibility, cognitive capacity, and psychological factors, may exert a more substantial influence on the outcomes of the Timed Up and Go Test. When formulating future research endeavors, it is advisable to choose an expanded sample size in order to attain a more comprehensive comprehension of the factors that influence scores on the Timed Up and Go Test.

5. Conclusion

In conclusion, this study offers significant contributions to the understanding of the complex associations

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between physical attributes and functional mobility, as evaluated by the Timed Up and Go Test. The existing literature has established relationships between the Timed Up and Go Test, Y Balance scores, and the Functional Reach Test. However, it is important to acknowledge that this study highlights the intricate nature of the several elements that influence balance and gait. Subsequent investigations employing a more extensive and heterogeneous cohort of subjects hold promise for yielding a more exhaustive comprehension of these associations, thus facilitating the formulation of focused therapies aimed at enhancing balance, gait, and mobility across varied demographic groups.

Authors Contributions

Issue selection: AÖ, CT, ZK; Design: AÖ, CT, ET, SK, ZK; Plan: AÖ, CT, ET, SK, ZK; Data selection: ET, SK; Data analysis: CT, SYE; Writing: CT; Critical review: AÖ, CT, ZK.

Conflict of Interest

There is no conflict of interest between the authors and other establishments in the planning, execution, and writing of the article.

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