T.C.

YEDİTEPE UNIVERSITY

INSTITUTE OF HEALTH SCIENCES

DEPARTMENT OF PHYSIOTHERAPY AND REHABILITATION

THE EFFECT OF DIFFERENT VISUAL STIMULI PROVIDED BY VIRTUAL REALITY ON POSTURAL CONTROL IN HEALTHY SUBJECT

MASTER THESIS

SAHRA ŞİRVAN CAN, PT.

İSTANBUL-2021

T.C.

YEDİTEPE UNIVERSITY

INSTITUTE OF HEALTH SCIENCES

DEPARTMENT OF PHYSIOTHERAPY AND REHABILITATION

THE EFFECT OF DIFFERENT VISUAL STIMULI PROVIDED BY VIRTUAL REALITY ON POSTURAL CONTROL IN HEALTHY SUBJECT

MASTER THESIS

SAHRA ŞİRVAN CAN, PT.

ADVISOR

Assist. Prof. ÇİĞDEM YAZICI MUTLU

İSTANBUL-2021

THESIS APPROVAL FORM

Institute : Yeditepe University Institute of Health Sciences

Programme : Phsiyotherapy and Rehabilitation

Title of the Thesis : The Effect of Different Visual Stimuli Provided by Virtual Reality on Postural Control in Healthy Subject

Owner of the Thesis : Sahra Şirvan Can

Examination Date : 06.10.2021

This study have approved as a Master Thesis in regard to content and quality by the Jury.

	Title, Name-Surname (Institution)
Chair of the Jury:	Prof Dr Feryal SUBAŞI Yeditepe University
Supervisor:	Assist. Prof. Çiğdem YAZICI MUTLU Yeditepe University
Member/Examiner:	Prof Dr Feryal SUBAŞI Yeditepe University
Member/Examiner:	Assist. Prof. Çiğdem YAZICI MUTLU Yeditepe University
Member/Examiner:	Assist. Prof. Anıl TOSUN Fenerbahçe University

APPROVAL

This thesis has been deemed by the jury in accordance with the relevant articles of Yeditepe University Graduate Education and Examinations Regulation and has been approved by Administrative Board of Institute with decision dated 06.10.2021 and numbered 2021/10.06

Prof. Dr. Bayram YILMAZ

Director of Institute of Health Sciences

DECLARATION

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree except where due acknowledgment has been made in the text.

06.10.2021

Sahra Şirvan CAN

DEDICATION

I would like to dedicate my thesis to my family and friends who are too many to write their names, and to my the one and only advisor Assist. Prof. Çiğdem YAZICI MUTLU.

ACKNOWLEDGEMENTS

First of all, I would like to express my respects and gratitude to my thesis advisor Assist Prof Çiğdem Yazıcı Mutlu, who is more than just an advisor and helps me in every stage of my thesis.

I would like to thank our head of department Prof Dr Feryal Subaşı and all my lecturers who have supported us in all matters and contributed to my development since my undergraduate period.

I am grateful to Ömer Faruk Başargan and Özgün Eşim for their support in software.

I would also like to extend my endless thanks to Doğukan Tongar who we have progressed together in every stage of life. I extend my best wishes to all my friends for believing and encouring me.

I offer my love to my whole family, especially to my grandmother Gönül Demirsu, who is with me in all my material and spiritual imrovement.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

2D:	Two–Dimentional
3B:	3 Boyutlu
3D:	Three-Dimentional
A-P:	Anterior-Posterior
ANOVA:	Analysis of Variance
BM:	Basınç Merkezi
BMI:	Body Mass Index
BoS:	Base of Support
CoG:	Center of Gravity
CoM:	Center of Mass
CoP:	Center of Pressure
CP:	Cerebral Palsy
EC:	Eyes Closed
EO:	Eyes Open
GA:	Gözler Açık
GK:	Gözler Kapalı
HMD:	Head Mounted Display
LSSD:	Large-Screen Stationary Displays
LVR-:	Virtual Reality with Negative Feedback
LVR+:	Virtual Reality with Positive Feedback

M-L:	Medial-Lateral
MS:	Multiple Sclerosis
PD:	Parkinson’s Disease
SA:	Sway Area
SD:	Standart Deviation
SG:	Sanal Gerçeklik
SGL:	Sanal Gerçeklik – Laboratuvar
SGLN:	Sanal Gerçeklik – Laboratuvar (Negatif Geribildirim ile)
SGLP:	Sanal Gerçeklik – Laboratuvar (Pozitif Geribildirim ile)
SPSS:	Statistical Package for Social Sciences
TBI:	Traumatic Brain Injury
VR :	Virtual Reality
VRL:	Virtual Reality Image of Laboratory
VRLN:	Virtual Reality Image of Laboratoy with Negative Feedback
VRLP:	Virtual Reality Image of Laboratoy with Positive Feedback

ABSTRACT

Can, Şirvan, S. (2021). The effect of different visual stimuli provided by virtual reality on postural control in healthy subject. Yeditepe University, Institute of Health Sciences, Department of Physiotherapy and Rehabilitation, MSc Thesis, İstanbul.

The aim of this study is to investigate the effect of the real environment image reflected in the virtual reality environment and the positive and negative feedbacks added to it on postural control. 20 healthy young people (F/M 10/10) aged between 18-30 years were included in the study. The visual stimuli in the virtual reality (VR) environment used in the study were created after modeling the laboratory environment where the study would take place and transforming this model three-dimensional (3D) with the Unity program. Participants were evaluated in a state of static balance in terms of the svay velocity, sway area and perimeter variables of the center of pressure (CoP) using Prokin PK 252 balance device under 5 different conditions: eyes open (EO), eyes closed (EC) and three VR images: laboratory environment image (VRL), positive (VRLP) and negative (VRLN) visual feedback added to this image. Statistical analysis of the data was performed using the SPSS analysis program using arithmetic mean, standard deviation, repeated ANOVA and Bonferroni method in multiple comparisons. CoP, Sway velocity, Sway area and Perimeter obtained as a result of five different visual stimuli (EO, EC, VRL, VRLP, VRLN) were compared. There was no significant difference between conditions in terms of the distance of the participants' average CoP values to the center ($p>0.05$). Although the Sway velocity was significantly lower in the EO condition ($p<0.05$), there was no significant difference between all other conditions in terms of sway velocity ($p>0.05$). The sway area and perimeter obtained at the EO were significantly decreased ($p <0.05$) and also the perimeter ah the EC were significantly increase ($p<0.05$). Although it was observed that the sway area in the EC was increased than the LVR, there was no significant difference ($p> 0.05$). It was found that the sway velocity, sway area and perimeter variables increased significantly in the VR compared to the EO, however this increase was less than the EC. In addition, it was observed that there was no significant difference between the visual feedback added to the VR environment.

Key words: Postural Control, Static Balance, Virtual Reality, Visual Stimulus, CoP

ÖZET (Turkish)

Can, Şirvan, S. (2021). Sanal Gerçeklik Aracılığı ile Sağlanan Farklı Görsel Uyaranların Sağlıklı Kişilerde Postural Kontrol Üzerine Etkisi. Yeditepe Üniversitesi, Sağlık Bilimleri Enstitüsü, Fizyoterapi ve Rehabilitasyon Bölümü, Yüksek Lisans Tezi, İstanbul.

Bu çalışmanın amacı, gerçek ortam, sanal gerçeklik ortamına yansıtılmış olan gerçek ortam görüntüsü ve buna eklenen pozitif ve negatif geri bildirimlerin postural kontrole olan etkisini araştırmaktır. Çalışmaya 18-30 yaş arasındaki 20 sağlıklı genç (yaş: 22.68 ± 1.79, K/E 10/10) dahil edilmiştir. Çalışmada kullanılan sanal gerçeklik (SG) ortamındaki görsel uyaranlar, çalışmanın gerçekleşeceği laboratuvar ortamının modellenmesi ve bu modelin Unity programı ile üç boyutlu (3B) hale getirilmesi sonrasında oluşturulmuştur. Katılımcılar statik denge durumunda; gözler açık (GA), gözler kapalı (GK), üç SG görüntü: laboratuvar ortamı görüntüsü (SGL), bu görüntüye eklenen pozitif (SGLP) ve negatif (SGLN) görsel geri bildirimler olmak üzere 5 farklı koşulda Prokin PK 252 denge cihazı kullanılarak, basınç merkezinin (BM) oluşturduğu salınım hızı, alanı ve çevre değişkenleri açısından değerlendirilmiştir. Verilerin istatistiksel analizi SPSS analiz programı aracılığı ile aritmetik ortalama, standart sapma, tekrarlı ANOVA ve çoklu karşılaştırmalarda Bonferroni yöntemi ile gerçekleştirilmiştir. Çalışmada beş farklı görsel uyaran (GA, GK, SGL, SGLP, SGLN) sonucunda elde edilen CoP salınım hızı, alanı ve çevresi karşılaştırıldığında; GA pozisyonunda elde edilen salınım hızı, alanı ve çevresinin diğer görsel uyaranlara göre istatistiksel olarak anlamlı düşük olduğu ($p<0.05$) ve ayrıca GK pozisyonunda elde edilen salınım çevresinin SG görsel uyaranlarına göre anlamlı bir şekilde yüksek olduğu bulunmuştur ($p<0.05$). GK pozisyonunda salınım alanının SG pozisyonlarına göre yüksek olduğu görülmekle birlikte anlamlı bir fark oluşturmamıştır ($p>0.05$).Postural kontrol değişkenleri incelendiğinde, gerçek ortam ile kıyaslandığında SG ortamında salınım hızı, alanı ve çevre ölçümünün anlamlı olarak arttığı fakat bu artışın GK durumundan daha az olduğu bulunmuştur. Ayrıca SG ortamına eklenen görsel geri bildirimler arasında postural kontrol değişkenleri yönünden anlamlı bir fark olmadığı görülmüştür ($p>0.05$).

Anahtar Kelimeler: Postural Kontrol, Statik Denge, Sanal Gerçeklik, Görsel Uyaran

1. INTRODUCTION AND PURPOSE

Newton's 1st law states that unless a net force acts on a stationary object, the object remains fixed and in balance (1). In addition, when the object's center of gravity (CoG) falls on its base of support (BoS), this is referred to as a state of balance (2). If the CoG of the object moves out of the BoS, the balance is disturbed and the object falls (1,2).

The existence of gravity made it necessary throughout life to maintain the position and to ensure the alignment of the body parts during possible position changes (3). As with objects, the CoG must be within the BoS in order to achieve balance in humans.

Humans have a relatively high CoG and a relatively small BoS, which makes it difficult to maintain balance (4). However, unlike objects, humans have the ability to control their balance by using their muscles in case of any change of position or threat of stability. This is referred to as postural control (5).

The terms balance and postural control are often used synonymously. While the term balance is used more in the clinic, the term postural control is preferred for quantitative data (6). Postural control; is a process in which the relationship between the center of mass (CoM) of the body and the center of pressure (CoP) is regulated by using different strategies thanks to the organization of the central nervous system, sensory system and musculoskeletal system (7).

Postural control is needed in situations such as maintaining a position, performing voluntary movements, or responding to any external force that might disturb balance (5). It is provided in four different forms such as static, reactive, anticipatory and adaptable. Static postural control maintains the CoM within the BoS in the static position, whereas reactive postural control manages the unexpected movement of the CoM within the BoS. While the necessary postural adjustments made before movement express anticipatory postural control, the change in motor response as a result of environmental variation is defined as adaptive postural control (7).

Postural control should be maintained under both traditional and different challenging conditions for a good balance. For this purpose; it can be evaluated under different environmental conditions by using different support surfaces such as static or dynamic and applying mechanical perturbation or sensory manipulations at different durations (8).

Oscillation variables of the CoP are frequently used in studies investigating postural control (9). These oscillation variables are calculated from ground reaction forces through a force platform. Variables such as mean, velocity, perimeter and area of the CoP oscillation are obtained. However, there is no consensus on which variable reflects the changes of postural control better (10).

Postural control requires the integration of the motor and multi-sensory functions of the brain. The integration of visual, vestibular and proprioceptive information obtained through the sensory system plays a key role in ensuring precise postural control (11).

There are studies in the literature investigating the superiority of sensory stimuli over postural control (8). In this context, mostly visual, auditory, proprioceptive and haptic stimuli were used (11, 12). As a result of the studies, it has been shown that visual information has a leading position on postural control compared to other senses (12, 13, 14).

In previous studies, the effect of visual information on postural control was examined both by removing visual stimuli and by using different visual perturbations. In a study conducted by Chander et al., an increase in postural oscillation was observed as a result of a visual illusion applied by creating the perception that the room is moving (14). In another study in which the effects of these stimuli on balance training were investigated by creating central and peripheral vision fields, it was concluded that the peripheral vision field was a more effective visual stimulus for postural control and balance training (15).

Thanks to the development of technology in recent years, virtual reality applications have started to be included in physiotherapy. Virtual reality is used in both clinical and academic studies for the purpose of training rather than evaluation. In the literature, it has been emphasized that traditional balance training does not have any superiority over virtual reality and virtual reality training can be used as a practical alternative in the long term (16,17). Furthermore, the feedback provided by virtual reality games is effective in the patient's participation in the treatment.

Different visual stimuli created using virtual reality can affect postural control in different ways (18). In addition, there is no study comparing the effect of real image and virtual reality image on postural control by transferring the current environment to virtual reality. The study aimed to investigate the effect of the real environment image reflected in the virtual reality environment and the positive and negative feedbacks added to it on postural control.

Two hypotheses were determined in this study.

H0: There is no significant difference between the real environment and three virtual reality environment on postural control in healhthy subject.

H1: There is a significant difference between the real environment and three virtual reality environment on postural control in healthy subject.

2. GENERAL INFORMATION AND THEORETICAL FRAMEWORK

2.1. Balance

Balance refers to the situation where the net force on an object is zero. The CoG line of an object must be within the support surface in order to maintain balance (Figure 2.1). If the CoG line of an object moves outside the BoS, the balance is disturbed and the object falls (5).

Balance can be divided into two categories as static and dynamic. Static balance refers to keeping the CoG line within the BoS while the body parts are fixed. Although dynamic balance is the ability to maintain postural stability while body parts are in motion (19).

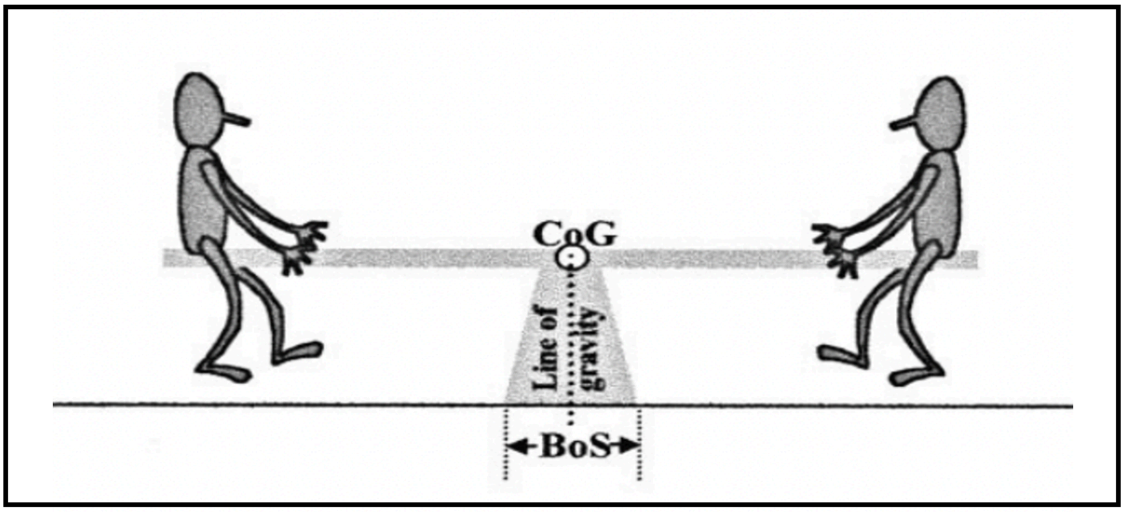


Figure 2.1 Balance illustration with CoG in BoS (5).

2.2. Postural Control

Unlike objects, humans have the ability to control their balances using musculoskeletal and sensory systems when the CoG line is out of the BoS. The ability of humans to control their balance is called postural control.

Balance and postural control are often used synonymously. While balance is a clinically observable term, the term postural control is preferred when it comes to investigating the balance in a measurable and objective manner (6).

2.2.1. Types of Postural Control

Postural control includes four types such as static, reactive, anticipatory and adaptive. Static postural control refers to maintaining stability by keeping the CoM in the BoS. In this case, the net force affecting the body is zero. Although in this case the balance is assumed to be static, CoP shows oscillations during this time.

Reactive postural control is activated by the unexpected displacement of the CoM. Different postural strategies can be observed depending on the displacement speed of the CoM and whether it exceeds the BoS limits.

Postural adjustments made before performing any voluntary movement are referred to as anticipatory postural control. Meanwhile, the central nervous system stimulates the relevant postural muscles and preparation for movement takes place. Before the actions such as stepping, reaching or lifting a load, the person plans these movements and adjusts the posture accordingly. Experience is crucial for anticipatory postural control.

Finally, adaptive postural control occurs in response to unexpected external changes. It is produced in response to conditions such as external perturbations, ground changes, environmental changes or reduction of visual stimulus (19).

2.2.2. Postural Strategies

In order to maintain the standing position, the relationship between CoG and BoS must be constantly and actively regulated. As a result of any possible perturbation, it is aimed to balance the CoG by taking the CoG back into the BoS and prevent falling, thanks to postural strategies. These postural strategies occur involuntarily and automatically.

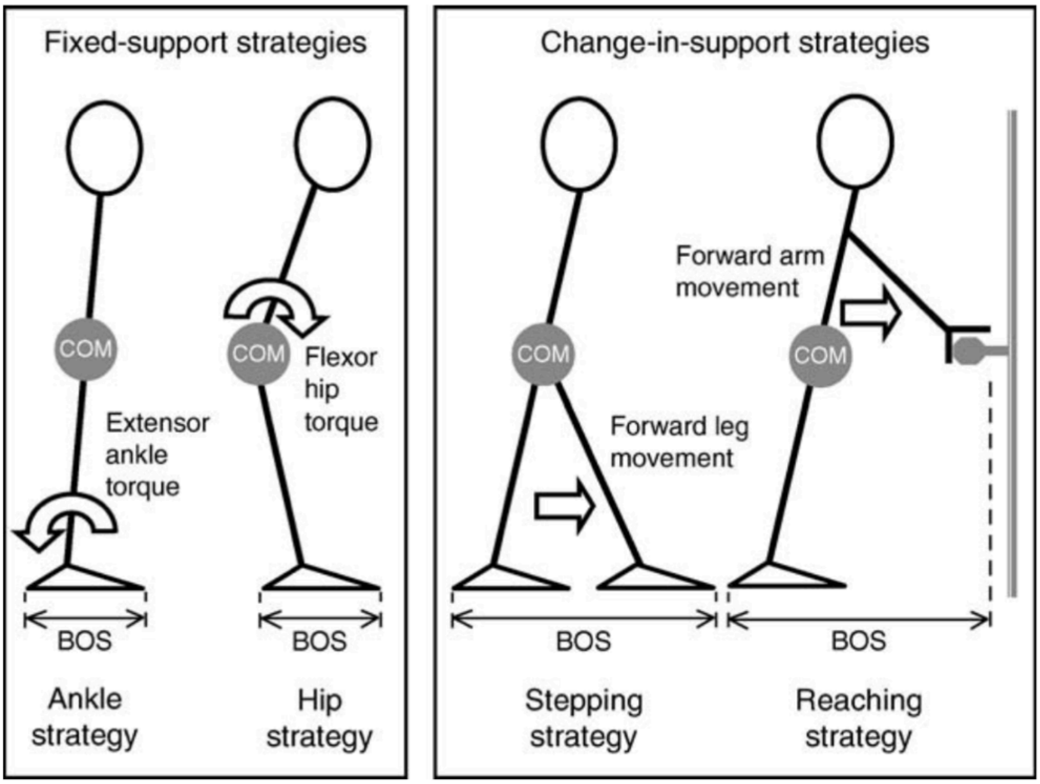


Figure 2.2 Postural strategies (20).

Postural control, which is threatened as a result of perturbation, can be provided in two different ways as slowing the CoM while the BoS does not change (fixed support) or positioning the BoS according to the CoM (change in support) (Figure 2.2.) (20).

Fixed Support Strategies: In strategies with fixed support, CoM movement caused by postural perturbation is decelerated with the contraction of the upper extremity and trunk muscles instead of the lower extremity. It can be expressed as the first defense against postural perturbation and it have to occur quickly (20). According to the studies, there are two strategies in which BoS is fixed: ankle strategy and hip strategy (21).

1. Ankle Strategy***:*** The postural strategy provided by the rotation of the ankle as a result of perturbation is called the ankle strategy. In cases where the CoG shifts forward, contraction occurs in the posterior compartment muscles of the ankle, whereas when the CoG shifts backward, contraction occurs in anterior compartment musles of the ankle. While the name of this strategy is the ankle strategy, the knee and hip joints are also involved (20).

2. Hip Strategy*:* In the hip strategy, the dominant muscle contraction is on the hip muscles. When the CoG shifts forward, the posterior compartment muscles of the thigh and trunk and when the CoG shifts to the backward, contraction occurs in the anterior compartment muscles of the tight and trunk. The stabilization force is much greater compared to the ankle strategy. Therefore, if the level of perturbation is low, the ankle strategy is dominant. However as the perturbation level increases, the hip strategy is essential (20).

Change in Support Strategies: Strategies in which the BoS increase in response to perturbation is accomplished by stepping or reaching using extremities are included in change in support strategies. The increase in BoS results in a better tolerance of CoM motion caused by perturbation. It is often used even in situations where postural control can be achieved without the need to change the BoS (20).

1. Stepping Strategy: is used in larger perturbations where ankle or hip strategy is not sufficient. In other words, the correction effect of the stepping strategy is greater than the ankle and hip strategy (22). It is aimed to provide the postural control by expanding the BoS width with stepping.

2. Reaching Strategy: refers to reaching and holding on to any object near the person in order to prevent falling after perturbation. It is the last line of defense that the body creates against a fall. It is observed when the level of perturbation is highest and other strategies are inadequate and initiated much faster than step-taking strategies. (20).

2.2.3 Variables of Postural Control

People have some oscillation even in a standing position. The reason for this is gravity and small movements such as breathing and looking. Quantitative data such as CoG, CoP, BoS, sway area (SA), perimeter, sway velocity are used to evaluate postural control objectively. However, there is no consensus in the literature about which variable expresses the postural control change more accurately (10).

CoG which can also be defined as the balance point, is the point where all forces on the body are equal to zero. It is a passive variable that can also be expressed as the point where the body's weight concentrates (23). In the anatomical position, the center of gravity is in the anterior part of the sacral spine (Figure 2.3.a). However, because humans are constantly in motion, CoG also moves and does not remain stationary. In addition, the proportion of body parts is among the factors affecting the location of CoG.

However, CoP is the center of the total force applied to the support surface (Figure 2.3.b). CoP is a variable dependent on CoG. Depending on the CoG movement, changes are seen in CoP in order to maintain balance (10).

Although people do not know the location of CoG and CoP, they are unconsciously aware of their limits. There is a change in the support surface in order to compensate for any changes in CoG. In such cases, people use strategies such as taking steps to position the support surfaces according to the CoG. (23, 24). Although both CoG and CoP are important in evaluating postural control, CoP changes are used more frequently in studies (10).

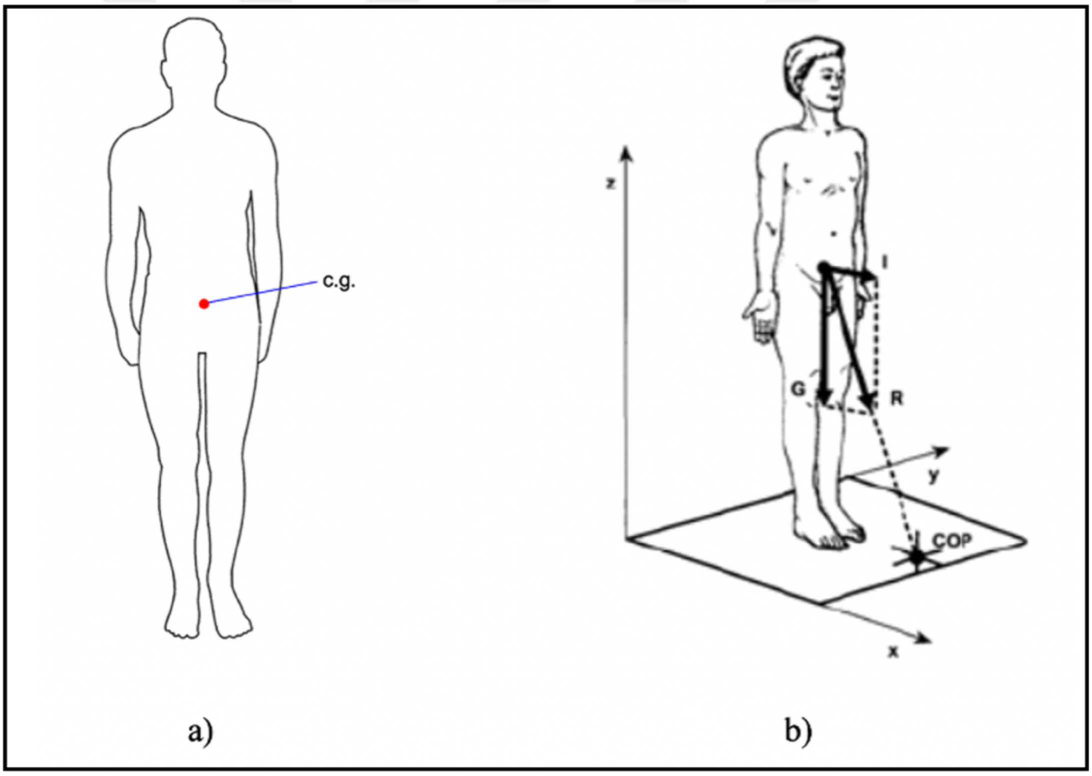


Figure 2.3 Representation on the human body a) CoG (25). b) CoP (26).

BoS is defined as the horizontal step width in case of both feet come into contact with the ground (27). The CoG line must be located within the BoS in order to maintain balance (28).

BoS width can affect postural stability in different ways. In other words, a larger BoS means a better postural stability (28, 29). BoS has constantly changed in positions such as lying down, crawling, sitting and standing up in the developmental process. However, in the upright position the human body has a relatively small BoS width compared to CoG (5). At the same time, the BoS is different from each other in double-legged stance, single-legged stance and tandem stance as it is presented in Figure 2.4. (10). During normal walking, the BoS is approximately in the range of 50-100 m. Decrease in BoS width is among the factors that make it difficult to maintain balance.

In cases where the BoS remains constant despite the displacement in CoG, the balance is disturbed. Postural control strategies emerge with the movement of the BoS for compensation when the CoG is displaced (5).

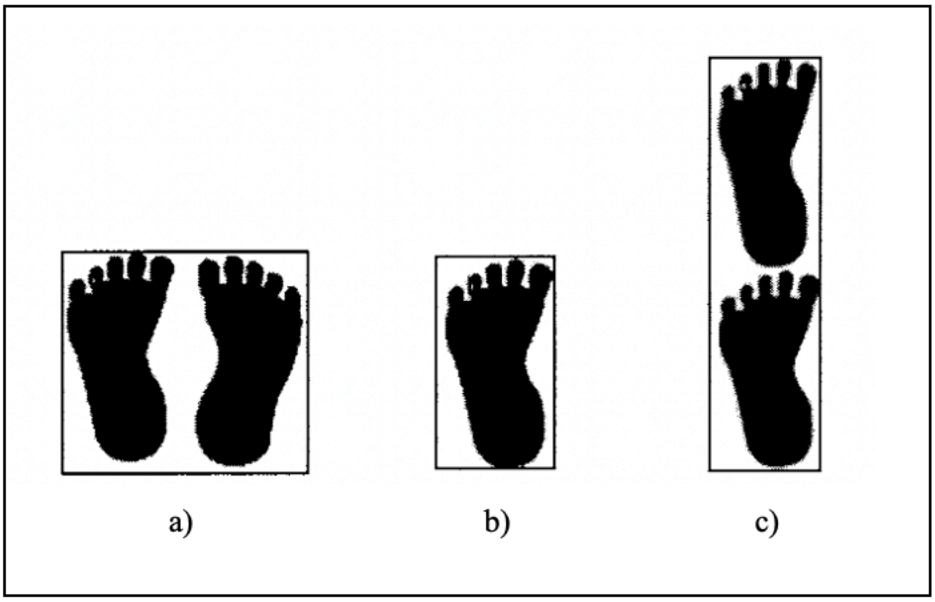


Figure 2.4 Change of BoS in different stance positions (10). a) Double legged stance b) Single legged stance c) Tandem stance

Body sway can be evaluated by measuring CoP displacement using a force platform. Factors such as disorders of central nervous system, musculoskeletal system and sensory system, neurological problems and aging can cause an increase in body sway (30).

The SA refers to the total area obtained by the displacement of the COP and is expressed of mm ² (Figure 2.5.) while perimeter is the total displacement of CoP (Figure 2.5.). The smaller the sway area and the perimeter means better postural control (8).

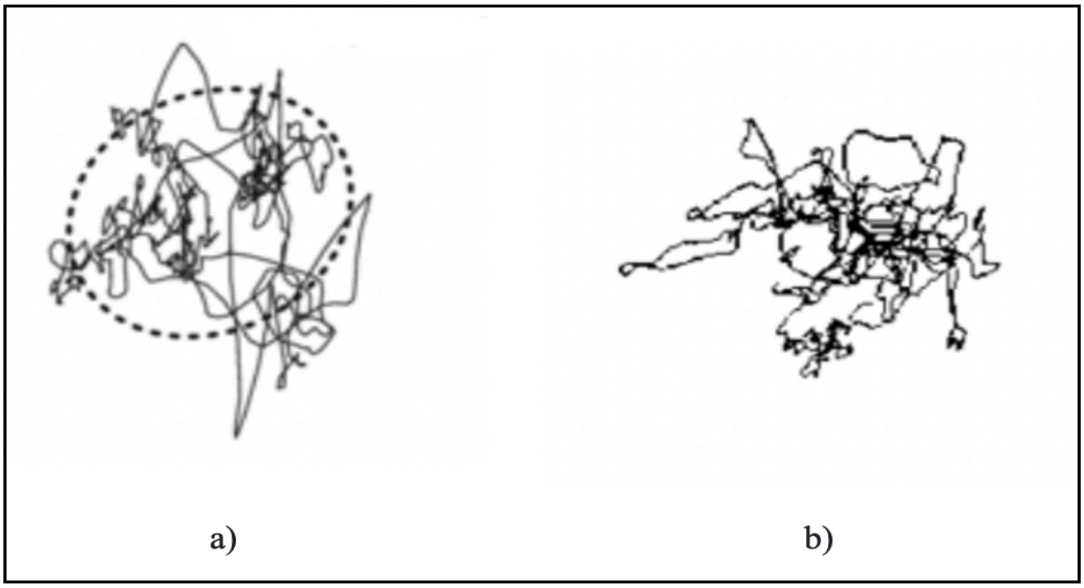


Figure 2.5 Sample representation pictures a) SA (31) b) Perimeter (32).

Postural Sway Velocity is an objective data which refers to the average displacement of CoP per second expressed in mm / sec (Figure 2.6.). It can be evaluated separately as anterior-posterior (AP) and medial-lateral (ML), and is measured with a force platform (33). Faster sway velocity indicates that CoG can be controlled faster. Studies have shown that sway velocity is the most reliable parameter in evaluating postural control (34).

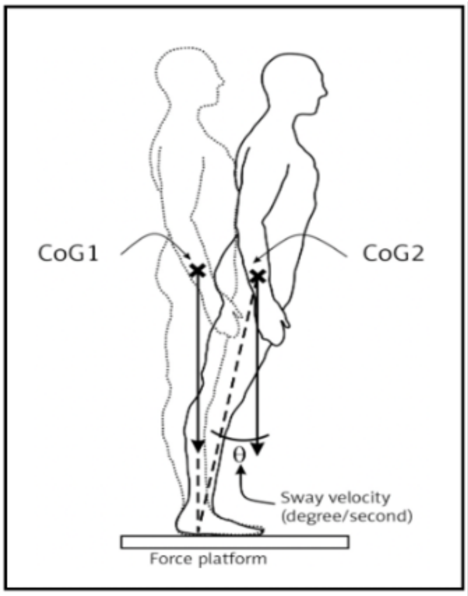


Figure 2.6 Sway velocity. Changing degrees per second during CoG's movement from the starting position to the end position (35).

2.2.4. Assessment of Postural Control

Postural control assessment provide more objective results compared to evaluation of balance used without equipments. In postural control evaluation, CoP displacement is usually analyzed under an uncomfortable condition such as external perturbation (6). Standard deviation (SD), sway area, perimeter and velocity of CoP are among the objective variables investigated in the postural control assessment.

Instrumental tests that allow kinetic, kinematic and electrophysiological analysis should be used for detailed analyses. Force platforms that examine the CoP variables are most common device to assess the postural control (Figure 2.7.) (36). It provides quantitative data on the different parameters of whole body CoP (37). There are load sensors under the force platforms and the platform can be used with or without motion (8).

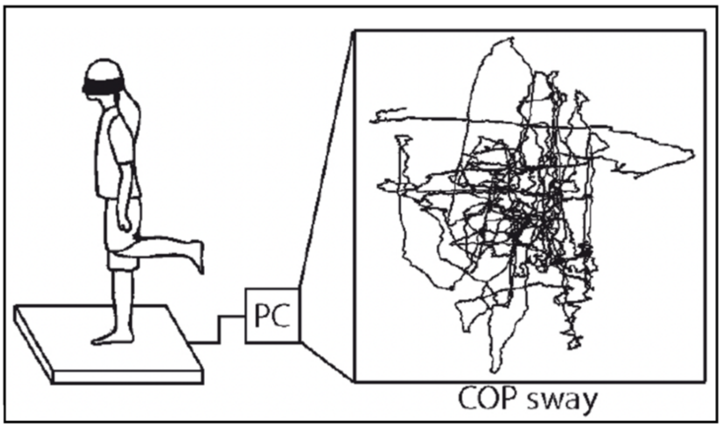


Figure 2.7 Example of force platform diagram used for postural control assessment in static position (37).

2.2.5. Systems Responsible for Postural Control

Postural control is a complex process that requires the organization of the central nervous system, musculoskeletal system and sensory systems. Complex neuromuscular mechanisms are necessary to maintain the upright position and maintain balance during movements.

2.2.5.1. Nervous System

Postural control is a complex motor system that requires the integrated operation of the nervous system including the forebrain, brainstem, cerebellum and spinal cord. Injury in any part of the nervous system causes many problems during upright posture and walking. There are studies showing that the tone of the antigravity muscles increases as a result of electrical stimulation of the dorsal and ventral tegmental areas in the brain stem and certain parts of the cerebellum (38). The reticular formation, which has many neurons on the brainstem, helps to form postural strategies as well as regulate muscle tone.

There are two closed loop neural mechanisms that act on postural control as it is shown in Figure 2.8. The first loop is located in the spinal cord and provides corrective motor responses and spinal reflexes, thanks to the information it receives through mechanoreceptors. The other mechanism is located in the brainstem and motor cortex and provides information about head position from the visual and vestibular system in addition to the information it receives from mechanoreceptors. Vestibulospinal and reticulospinal pathways contribute to postural control through this mechanism (39). According to studies conducted on cats, an increase in the activation of these pathways mediated by the brainstem was observed with the change in the angle of inclination of the BoS (40).

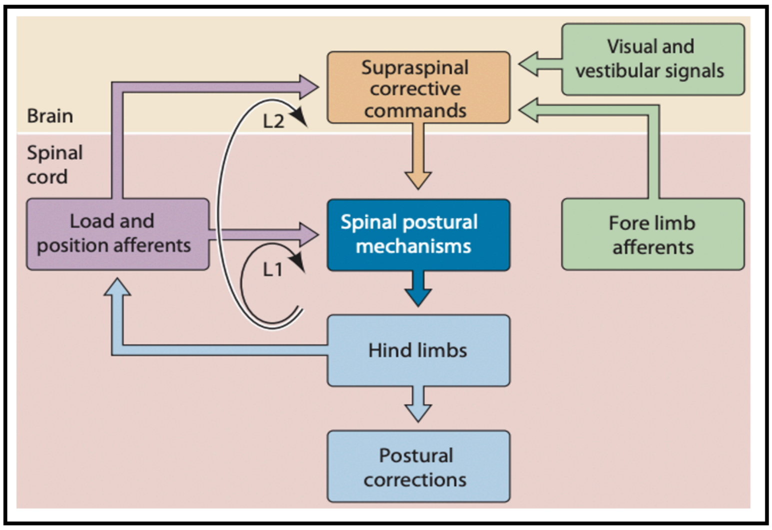


Figure 2.8 Two loop mechanisms that contribute to postural control (41).

2.2.5.2. Musculoskeletal System

Muscles, bones, joints and ligaments are very important to maintain the postural control. Antigravity muscles are required to maintain the upright position of the body against gravity. These muscles usually involve the extensor muscles and play a primary role in maintaining balance. Lower extansor muscles (muscles of the foot, ankle plantar flexors, tibialis anterior, knee flexors, gluteal muscles), upper extremity muscles (shoulder flexors) and body and neck muscles are important muscles contribute to postural control (19). In addition, normal muscle tone, muscle strength and muscle coordination are required to maintain a posture and support movement (42).

2.2.5.3. Sensory System

Integration of sensory systems such as visual, vestibular and somatosensory systems is essential for maintaining postural control. The nervous system obtains information about CoM through the organization of sensory systems. In healthy adults, these sensory systems are well organized and other systems compensate for the absence of any system (43).

Gravity is perceived with vestibular sensory cues and the postural contol is maintained accordingly. Visual cues provide visual orientation of the environment and the head. Finally, the support surface, which is significant for postural control, is perceived through proprioceptive information (7).

Vestibular System; Postural control is carried out by the organization of many systems. However the vestibular system has more specific tasks among these systems. Vestibular system affects postural control at all levels such as cortical, midbrain, medulla oblongata and spinal cord (44). Movement perception and spatial orientation are provided through the vestibular input. The vestibular receptors, which can also be expressed as the balance organ in the inner ear, are specialized for the sense of the position of the head in space. Through vestibular labyrinths, the position of the head against gravity is detected and its orientation is provided (45). In addition, postural control difficulties are generally observed in patients with vestibular system damage (46).

The vestibulospinal path activates the trunk and lower extremity antigravity muscles and contributes to an upright posture by regulating muscle tone. In both static and dynamic situations, vestibulospinal reflexes are essential in maintaining the position of the head and maintaining an upright posture against gravity. Stimulation of the vestibular organs causes activity in many muscle groups, especially the neck and spine muscles. In addition, thanks to the vestibuloocular reflex, the eye can be fixed when the head position changes. This provides an opportunity to receive visual stimuli (44).

As a result, while the vestibular system is important in providing postural control even alone, it works in an organized manner with many other systems in central nervous system, leading to an effective postural control (47).

The somatosensory system is essential for postural control, with the contribution of the visual and vestibular systems. It transmits the information received from inside and outside the body to the upper centers through neurons and pathways. It contributes to the postural control by allowing the motor response to occur as a result of the processing of the information about the body position transmitted to the upper centers (48).

Humans primarily need proprioceptive and cutaneous input to maintain upright posture and maintain postural control in daily living activities. Mechanoreceptors located in muscle spindles, which provide information to the nervous system about the length of the muscle and the rate of contraction, have the ability to perceive the joint motion and position sense. Afferent feedback received through the muscle spindles enables the necessary voluntary movements and reflexes to be revealed (48).

Golgi tendon organ, which is located at the muscle tendon interface and is sensitive to small changes about tensile forces, is another organ that contributes to the proprioceptive system (47,48).

The visual system plays a key role in postural control relative to other sensory systems by providing synchronized information about body position and environment. Postural sway increases by approximately %36 under any visual perturbation compared to normal vision (49, 50). As a result of the researches, it has been observed that visual impairment is a risk factor for falling (51). In addition, effective postural control is achieved by increasing the visual stimulus and improving the visual environment.

The contribution of the visual system to postural control has been studied either by removing visual stimuli or by using different visual perturbations such as moving room or virtual reality (7, 52). In a study conducted by Chander et al., an increase in postural sway was observed as a result of a visual illusion applied by creating the perception that the room is moving According to studies, it has been shown that eye movements increase postural sway in healthy (53). In another study in which the effects of visual stimuli on balance training were investigated by creating central and peripheral vision fields, it was concluded that the peripheral vision field was a more effective visual stimulus for postural control and balance training (15).

Visual information helps other systems contributing postural control to function properly as well. Despite any incorrect or insufficient information coming from the visual system negatively affects the function of other systems, as a result of the failure of any sensory system, other systems can compensate for this.

2.2.6. Disturbing Postural Conditions

Postural control can be evaluated under many uncomfortable conditions. For this, usually motor, sensory, and cognitive manipulations are used (8).

External Mechanical Disturbance: The condition that aims to disrupt postural control and displace CoM through external factors is defined as external mechanical disturbance. Postural reactions that help maintain body balance are revealed by using mechanical disturbances such as perturbations or pushing of body segments. In addition, mechanical disturbance can be caused by external factors that cause changes in the BoS, such as using a moving platform (8).

Sensory Disturbance: Postural control was evaluated using many sensory manipulations in order to examine the effects of different sensory systems on postural control. However, manipulation created for one sensory system also alters the contribution of other sensory systems to postural control (8).

Since the visual stimulus plays a key role in balance and postural control, disturbing of the visual stimulus is often used in studies. Examples of disturbances in the visual system can be given by reducing the field or brightness of vision. Mostly, the visual stimulus is removed completely by closing the eyes. (8).

Disruption of proprioceptive information is usually accomplished by vibration applied to the muscle tendon. Usually the applied vibration frequency is between 30-100 Hz and the higher the frequency increases the postural reaction that occurs (8,54). In addition, the proprioceptive system can be disrupted by the application of neuromuscular electrical stimulation to the muscle or nerve (55,56).

Postural control can also be disrupted by creating anesthesia through hypothermia using ice water, using a foam surface or reducing plantar cutaneous sensitivity by provoking ischemia. Among these methods, it seems that the most effective and safe is the use of a foam surface (57, 58, 59).

Cognitive Disturbance: Postural control is not a completely automatic process and requires the use of cognitive functions (60). For this reason, the decrease in cognitive functions such as attention with increasing age is one of the factors that cause falls (61, 62).

Dual tasks are often used during postural control assessments. Tasks such as attention, calculation, memory, visual search, and verbal fluency are used simultaneously during the evaluation of postural control (63). In addition, the reaction time given to visual auditory sensory stimuli is among the secondary tasks used simultaneously during maintaining postural control (8).

2.3. Virtual Reality (VR)

According to Sherman and Craig's definition, VR can be defined as computer stimulation that provides synthetic stimulation of one or more senses by getting information about the direction and position of the user. While more visual and auditory stimuli are used in virtual reality, it includes the sense of touch, vestibular, taste and smell rarely (64). VR is used in many areas such as architecture, natural experiences, medical, social sciences, psychology, digital marketing, learning, flight, space and art. However, especially since the early 1990s, it has been used rapidly in the field of physiotherapy and rehabilitation (65).

2.3.1. Visual Displays

Sensory images can be presented to the user through different devices. Although the most familiar are Head Mounted Displays (HMD), there are display tools such as Large-Screen Stationary Displays (LSSD) that cover the vast majority of the user's view, Destkop VR Displays delivered via the computer monitor, and Hand Based VR Displays, which are not used much and provide limited field of view. The cost, field of view, portability, usage and immersion of all these devices are different from each other (64).

2.3.1.1. Head Mounted Displays (HMD)

HMD, the most familiar display device, is placed on the user's head and offers VR to the user through the screen positioned in front of the eyes (Figure 2.9.). Because the motion of the image transferred with HMD is created according to the user's movements, the screen does not need to be moved. It is enough for the user to move his head for the movement of the image. The most important advantage of HMD is that it can provide 100% viewing angle with the user's head movements. Additionally, it is less expensive, takes up much less space, and is portable than large screens. However, its weight is a disadvantage considering it is placed on the user's head. Finally, it is limited to a single user and does not allow sharing of experience (64)

Figure 2.9 Application of virtual reality to the participant with HMD (64).

2.3.2. Use of VR in Rehabilitation

Since traditional treatment is expensive and time consuming, alternative rehabilitation methods have been needed over time. In this context, VR is used not only by medicine and surgery, but also by physiotherapists for the rehabilitation of disabled individuals since 1990s (65). Due to the fact that VR is flexible, programmable and controllable, it has been used in physiotherapy sessions recently. Thanks to VR, patients perceive themselves in an artificial environment and different sensory inputs and enriched experience is provided to the patient. In addition, different environments that cannot be provided to the patient in the hospital can be reached through VR (66).

Gamification of exercises is effective in keeping patients' attention focused and motivated. Among the important benefits of VR for rehabilitation are that the difficulty level of the exercise can be adjusted and that it increases the motivation by offering environments according to the special interests of the person (67).

In addition to the advantages of virtual reality, there are also some limitations. The time it takes for the sensory stimulus to be provided and the motor response to be perceived by the system is expressed as the latency of system. This situation causes a sensory conflict that may impair postural control. In addition, the distance achieved with virtual reality is perceived less than the real environment. This can be considered as a limitation for balance assessment (68).

Studies have shown that VR is promising in motor learning after stroke (69, 70). In addition, many benefits of Kinect-based systems have been observed for muscle atrophy in children with cerebral palsy and neuromuscular disease (71). Studies conducted on patients with diseases such as Parkinson's Disease (PD), Multiple Sclerosis (MS), Traumatic Brain Injury (TBI) have shown many benefits on balance and gait in these diseases (72).

Many positive effects of VR on walking, balance, upper extremity and cognitive rehabilitation have been demonstrated (66). Some studies have even suggested that VR may be more effective in rehabilitation than conventional therapy (72,73). However, VR's superiority over traditional therapy in rehabilitation remains questionable. It is not known how much the skill acquired in virtual reality is transferred to the real environment and how effective it is in daily life (66).

2.3.3. VR and Motor Learning

Rehabilitation means re-teaching movement in congenital or acquired disabilities. The aim of physiotherapy and rehabilitation is to make the individual independent in daily life activities by compensating for a lost motor skill and gaining a new motor skill (74). Motor learning is a process that causes relatively permanent changes in motor skills depending on practice and experience. Experience, augmented feedback, non-repetitive repetition, imagination, observational learning, motivation, and the use of different environments are important components for motor learning. The application of these components to rehabilitation supports motor learning by increasing neuroplasticity (75).

These motor learning components required for rehabilitation are inherent in VR applications. The number and intensity of practice are among the factors that improve motor learning. Compared to traditional treatment, it is possible to practice much more and involving different environments with virtual reality (65).

In order to increase the effectiveness of motor learning, the training environment and task should be as close as possible to the environment and tasks that will be used in daily life (76). Through VR, different degrees of specification of the task and the environment can be achieved (65).

Augmented feedback is one of the most important factors supporting motor learning. The frequency, duration, timing and type of feedback for effective rehabilitation has been studied for many years (77). As a result of the study by Molier et al., it has been shown that increased feedback supports stroke rehabilitation (78). VR applications provide more consistent and simultaneous visual, auditory, or tactile feedback compared to the real environment. Thanks to virtual reality, an objective and numerical summary is provided through game scores. With the additional tactile feedback provided, a realistic environment can be presented to the user (65).

Observational learning contributes to motor learning as a result of imitating targeted movement patterns by means of mirror neurons. With virtual reality, the user receives visual feedback about his body position and perceives the correctness of his movements. This allows movement errors to be detected faster learning becomes easier (65).

Finally, motivation is important to increase the number of repetitions. The fact that it is a new application, that the games are goal-oriented and includes feedback and rewards, unexpected variations and advances in difficulty, can be customized are among the features that make VR motivating (65).

2.3.4. Use of VR in Balance Rehabilitation

Virtual reality applications are frequently used in rehabilitation because they allow to adjust the number of repetitions, intensity and difficulty level by providing visual, auditory and tactile feedback (79). Especially in balance training, feedback on the correctness of movement is essential (80). Supporting neuroplasticity in neurological patients and being effective in overcoming fear of falling are among the advantages of balance training given by virtual reality application (17). According to the researches, although using virtual reality applications in rehabilitation provides benefits in terms of motivation, this benefit is difficult to quantify (81).

Balance problems, especially encountered in neurological diseases, seriously affect daily living activities. For this, effective techniques to be used in rehabilitation are needed. VR-based balance rehabilitation is frequently used in neurological diseases such as stroke, PD, TBI, and Cerebral Palsy (CP). Although it has been shown in studies that virtual reality applications performed in these diseases give better results compared to traditional treatment, there is no gold standard for VR applications. In addition, there is a need for research on parameters such as which training devices are more useful in which disease, frequency and intensity of education (72,81).

However, virtual reality applications that involve movements where treatment parameters cannot be individualized, difficulty levels cannot be changed, and movements that are not physically possible in the real environment can be dangerous for motor learning. The abundant, frequent and rewarding feedback provided by virtual reality may cause addiction to the person. In addition, it may be insufficient to perceive the small developments recorded by the person. This condition may result in discouragement for the user (82).

Additionally, there is a need for studies on the transfer of motor skills obtained with virtual environment to the real environment. There is no consensus on which motor learning variable is more important for treatment and how this transference can be achieved better. Moreover, complications of patients in order to increase their game performance should also be taken into consideration. For this, in virtual reality treatment, the physiotherapist should take an active role in evaluating the quality of the movement, deciding the appropriateness of the treatment and the progress of the training (82).

2.3.5. Use of VR in Postural Control Assessment

VR is used for objective evaluation of postural control by manipulating environments as well as for rehabilitation. Thanks to VR, environments can be manipulated in the real world in a way that is possible or unsafe. In this way, postural control can be evaluated in many different conditions in people with balance problems. However, it is limited to evaluate the contribution of sensory systems to postural control in the real environment (83).

In addition, people can feel as if they are navigating real-life scenarios under manipulated conditions provided through VR, and lifelike postural reactions can be achieved in the lab. It can use many different difficulty levels for postural control assessment with virtual reality applications (84). Especially in patients with balance problems and fear of falling, dangerous conditions that are not safe to be performed in a real environment can be presented safely through VR. VR significantly contributes to the evaluation of motor-sensory incompatibilities of neurological patients through sensory perturbations. In VR-based postural control assessments, both visual and vestibular stimuli can be further complicated compared to sensory interventions such as eyes open-closed, soft-hard ground, which are limited in the real environment (83,85).

Such assessment devices can contain VR applications such as the Wii balance board, or can be presented externally to patients with visual resources such as HMD that stimulate sensory stimuli. Additionally, many different types of posturography are used to evaluate postural control by changing visual, vestibular and somatosensory stimuli with the VR method (84). In this way, it is ensured that postural control is evaluated in all planes and a personalized treatment is programmed accordingly (86).

3. MATERIALS AND METHOD

3.1. Participants

This study was conducted with healthy young volunteers between the ages of 18-30 between January 2021 and September 2021. The sample size of the study was determined as 20 using GPower program, type 1 error value (α) = 0.05, Power (1-β) = 0.80 and effect size f value as 0.25 by calculating from the moderate reference article. The participants of the study were recruited from Yeditepe University students who volunteered after the study was introduced with a leaflet (Figure 3.1.). The voluntary participants who agree to participate in the study were informed about the study and a signed consent form was obtained from the participants (Appendix 1). The study protocol was approved by the Yeditepe University Ethical Committee with the issue number of 202106077 (Appendix 2). Inclusion and Exclusion criteria of this study were mentioned below.

Figure 3.1 Leaflet introducing the study used to identify volunteer participants

Participants of the study were selected according to the following criteria:

Inclusion Criteria

- Being between the ages of 18-30
- The absence of any medical diagnosis

- Having visual acurity or corrected visual acurity
- Being volunteer

Exclusion Criteria

- The presence of any medical diagnosis
- The presence of any neurologic symptoms
- The presence of any sensory problems
- The presence of any balance problems
- The presence of any vestibular problems
- Previous ortophedic surgery
- The use of an additional assistive device

3.2. Evaluations

3.2.1. Demographic characteristics of the participants

Demographic and clinical information of the participants were collected with a form called "General Information Evaluation Form". The questionnaire was applied face to face to the participants. The information was obtained from participants are as follows: (Appendix 3).

- Participant's age, height (cm), weight (kg), body mass index (BMI),
- Gender (female / male),
- Dominant side,
- Whether there is any medical diagnosis,
- Whether they have neurological, sensory, balance or vestibular problems,
- Whether there is any surgical applications,
- Whether there is an additional assistive device used,
- Drug use
- HES codes

3.2.2. Evaluation of Hand Dominance

Hand Dominance of the participants was determined by Edinburgh Handedness Questionnaire with Turkish validity and reliability (87) (Appendix 4). Participants were asked which hand they preferred in 10 activities involving different motor tasks that they use in their daily lives.

The activities included in the questionnaire were:

- Writing
- Drawing
- Throwing
- Using scissors
- Using tootbrush
- Using knife
- Using spoon
- Using broom
- Attracting attention (for example, when calling the waiter)
- Opening the box or jar lid

The Edinburgh Handedness Questionnaire was delivered to the participants over the internet via Google Forms and they were asked to complete it. The resulting data were calculated according to the Geschwind scoring (Tan, 1988). According to this scoring, +10 points for each right hand answer, -10 point for each left hand answer and 0 point for both hands equal answers were given. As a result, participants with +40 points and above were recorded as right hand dominant, with -40 points and below recorded as left hand dominant, and with scores between +40 and -40 were recorded as both-handed.

3.3. The Study Protocol

After the demographic characteristics of the participants such as age, gender, height, body weight, dominant hand and other information were obtained, their static balance was evaluated using the Prokin PK 252 device under five conditions. Data of postural control variables were obtained through the computer connected to the device. Each trial repeated 3 times for 30 seconds for each condition. The duration of evaluation for all conditions took approximately 40 minutes with resting parts. The obtained data were averaged and recorded. The trials of each condition were applied in different orders to prevent the order effect.

The study protocol consisted of five conditions with real and virtual environment visual stimuli. Real environment consisted of two conditions as open and closed eyes. The VR environment included three conditions, the first in which the real laboratory environment was projected into the virtual reality environment, and the second and third, in which positive and negative feedback was added to it. The image to which the feedback was added contained two different visual feedback conditions as positive and negative. Positive and negative feedbacks created as two separate VR condition. All feedback was set to appear in the image at 5th, 10th, 15th, 20th and 25th seconds of the static balance assessment.

The visual stimuli that constitute five different conditions used in the evaluation of static balance are as follows and are shown in the flow chart. (Figure 3.2.)

1. Eyes open (EO)

2. Eyes closed (EC)

3. Virtual Reality without feedback (LVR)

4. Virtual Reality with positive visual feedback (LVR+)

5. Virtual Reality with negative visual feedback (LVR-)

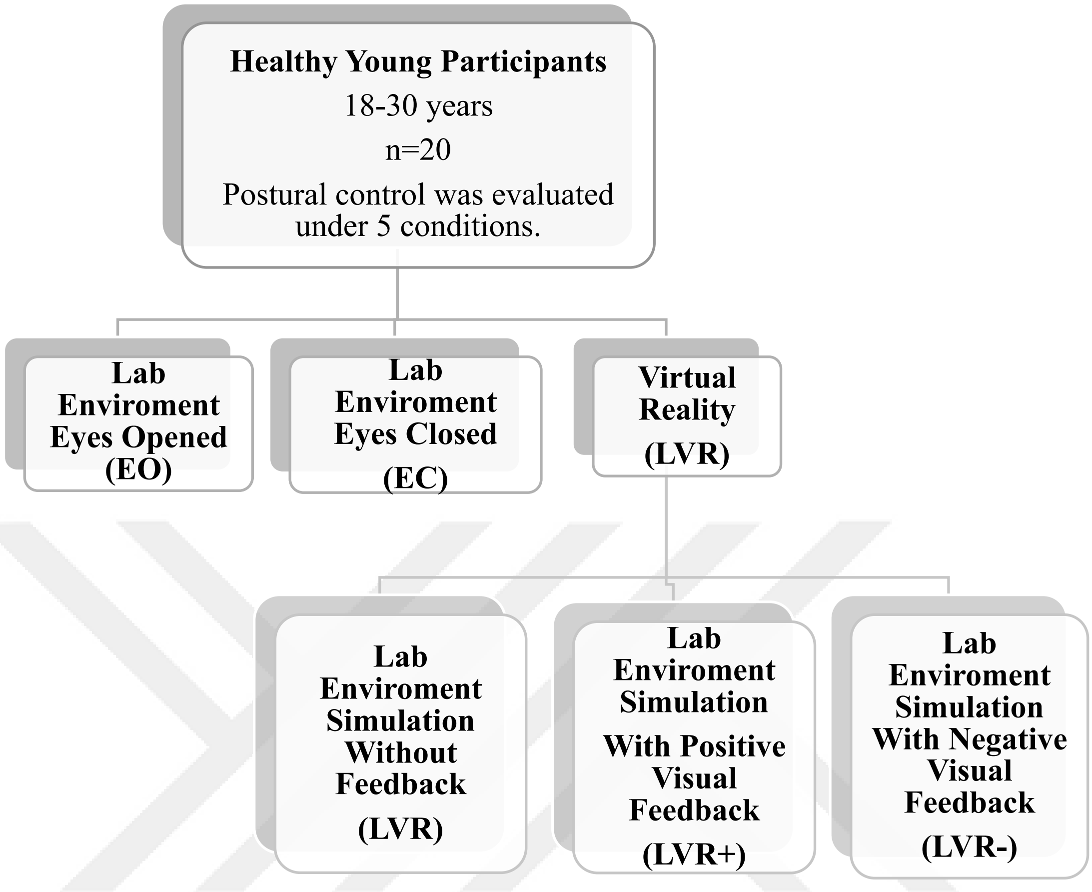
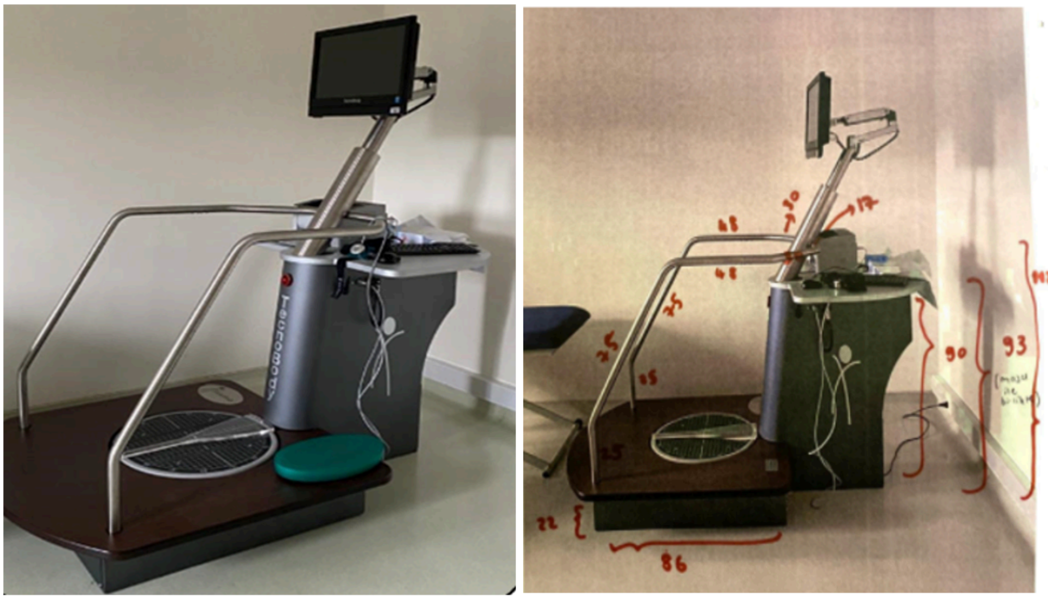


Figure 3.2 The protocol of study

3.3.1. Creating the Image of Laboratory Environment

The measurements of the laboratory environment where the study will take place and the PK 252 Prokin device were taken and modeled in SketchUp Software Pro (Figure 3.3.). The modeled environment was reflected into a virtual reality environment to be used (Figure 3.4.).



a) b)

Figure 3.3. Prokin PK 252 device a) using in the study to evaluate postural control b) taking measurements to create the virtual image.

a) b)

Figure 3.4 Reflecting Prokin PK 522 device to virtual reality image a) the screen of the device b) the platform of the device.

In order to prevent neck flexion and extension angle due to height difference of participants while looking the computer screen, a software has been added to the virtual reality application that allows the position of the screen to be adjusted according to the participant's height (Figure 3.5.). Thus, the taller participants were prevented from neck flexion and the shorter participants were prevented from neck extension during the assessment.

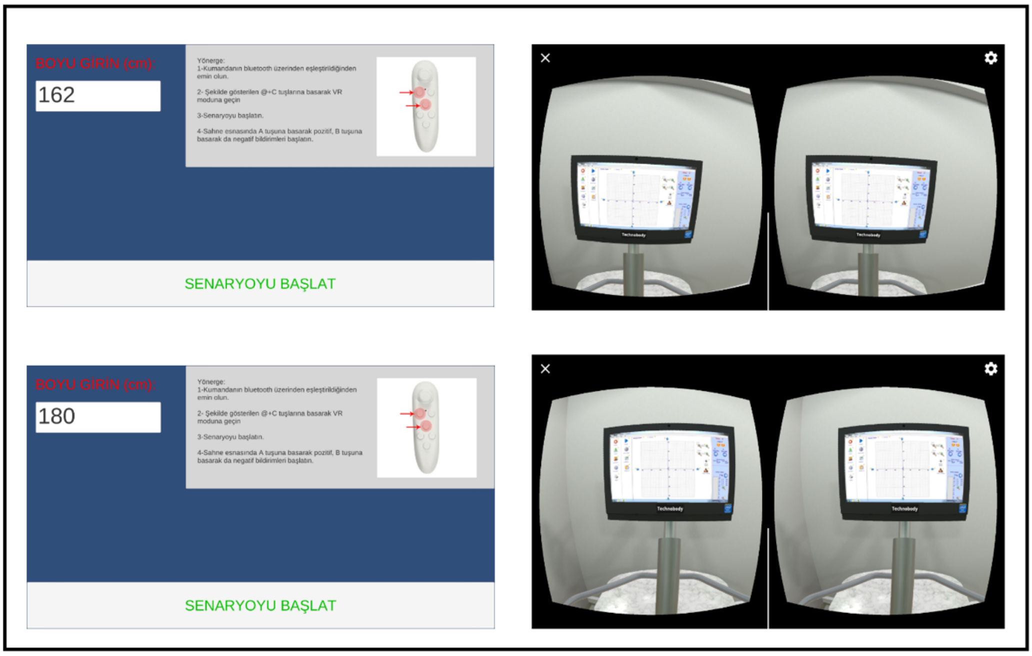


Figure 3.3 Changing the position of the VR screen according to the height of the participant.

In addition to the prepared visual stimulus, positive and negative feedback that will occur independently of the participant's balance results during the evaluation was added to this image. These added feedbacks were used separately as positive and negative and formed the other two visual stimuli.

Positive feedback phrases were included as following:

- Wonderful
- Well done
- You are doing very well
- Excellent
- Congratulations

Negative feedback phrases were included as following:

- It can be better
- Good deal
- Below average
- You are losing control
- You are going bad

The feedbacks used were presented to the participants visually in a virtual reality image. Although it was thought that the participants' feedback sentences were given specifically in response to their static balance, in fact, feedback stimuli were used as an independent variable.

3.3.2. Application of Virtual Reality

Visual stimuli were applied to the participants via VR-Box Virtual Reality Glasses which can be managed by remote control. The dimensions of the virtual reality glasses used in the study are 19.5 x 14 x 11 cm and have a weight of 820 gr. The glasses has 2 bands as one horizontal and one vertical. Thanks to the bands, the virtual reality glasses were worn on the participants' heads and the virtual reality image was presented to the participants.

The VR conditions, which was turned into a mobile phone application, was reflected to the virtual reality glasses via a smart phone. When the participants were on the platform of the static balance assessment device, the application was started on the phone, placed the virtual reality glasses and the participants were asked to wear virtual reality glasses with bands after their height was recorded.

The positive and negative stimuli used were initiated by the remote control of the virtual reality glasses. The virtual reality image in the phone was operated simultaneously with the remote control via bluetooth (Figure 3.6.).

Figure 3.4 VR BOX glasses with a remote control used in the study.

3.4. Evaluation of Static Balance

The Prokin device was used for the assessment for static balance through “Static Stability Assessment Program”. Prokin PK 252, the proprioceptive-stabilometric assessment device, is a proprioceptive system used for static and dynamic balance assessment and training (Figure 3.6.). It provides detailed and precise data through stabilometry platform and the sensor placed on the trunk.

Stabilometry allows to participants to be evaluated in static situation with the oscillation of the CoP. CoP sways of the participants are detected by the platform of the Prokin PK 252 device and the postural control data are transferred to the computer screen.

The data were obtained from PK 252 system are as follows (88).

- Average CoP X (mm)
- Average CoP Y (mm)
- Average Forward-Backward Velocity (mm/sec)
- Average Medium-Lateral Velocity (mm/sec)
- Perimeter (total covered distance of COP [mm])
- Ellipse area, (total area, which is circumscribed by the COP [mm2])

Bipedal static balance assessment was performed under 5 different conditions including eyes open, eyes closed, virtual reality without feedback, with positive feedback and negative feedback. Evaluations were carried out 3 times for 30 seconds for each visual stimuli. The average of the obtained data was taken and recorded.

The assessment was performed by following the steps below;

- After the assessment was explained to the participants, they were asked to reach the platform without shoes in accordance with the reference points.
- Participants were asked to be in a position facing the screen opposite, with their arms at the side of the body and 10 cm distance between their feet and form an angle of 15–30°.
- The participants were registered on the computer to which the Prokin device is connected.
- During the assessment, participants were asked to hold their position while looking forward with the head is in a neutral position for 30 seconds.
- Assessments were conducted with eyes open, eyes closed and using 3 virtual reality images in different orders (Figure 3.7.)
- Each experiment was carried out 3 times and the average of the data were calculated.
- Between each assessment, the participants were asked to sit down and rest while the device is recalibrated.
- At the end of the assessment, the data were printed through the printer of the computer to which the Prokin device is connected.

a) Eyes Open b) Eyes Closed c) Virtual Reality

Figure 3.5 Application of visual stimuli during postural control assessment.

3.5. Statistical Analysis

SPSS (Statistical Package for Social Sciences) version 26 was used to evaluate the data obtained from the study. Mean, SD, median, minimum and maximum values were used for the presentation of continuous variables (quantitative variables) and frequency and percentage values were used for the presentation of categorical variables (qualitative variables). Repeated measures one way analysis of variance (ANOVA) within subjects test was used to investigate the difference between postural control variables of participants under 5 different conditions. In addition, sphericity and distribution were tested with Mauchly's test**.** Bonferroni test was used at 95% confidence interval in multiple comparisons. In all statistical analyses, $p < 0.05$ was accepted as the level of significance.

4. RESULTS

4.1. Descriptive Characteristics of Participants

This study was conducted with healthy young volunteers (n=20) between the ages of 18-30 between December 2020 and June 2021. The demographic characteristics of participants includes, values of mean age, weight, height and BMI are presented in Table 4.1.

Table 4.1 The demographic characteristics of participants

Measure	Mean	SD
Age (years)	22.80	1.82
Weight (kg)	77.44	27.61
Height (cms)	174.75	11.16
BMI	24.98	7.19

4.2. Hand Dominance of Participants

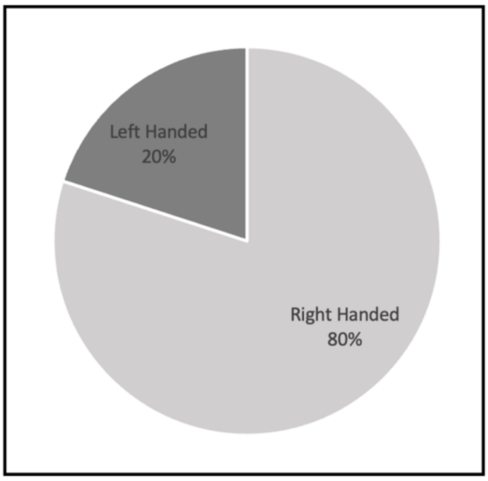


Figure 4.1 Hand dominance distribution of the participants

According to the Edinburgh Handedness Questionaire, 80% of the participants in this study were right-hand dominant (n=18: right-handed, n=2: left-handed) (Figure 4.1).

4.3. Comparison of the distance from the center of the average of CoP values of the participants under 5 different conditions.

The CoP values of the participants are distributed in different ways in 5 different conditions (EO, EC, LVR, LVR-, LVR+) on the coordinate plane. The distribution of the average CoP values of the participants in the coordinate plane according to the conditions is presented in Figure 4.2.

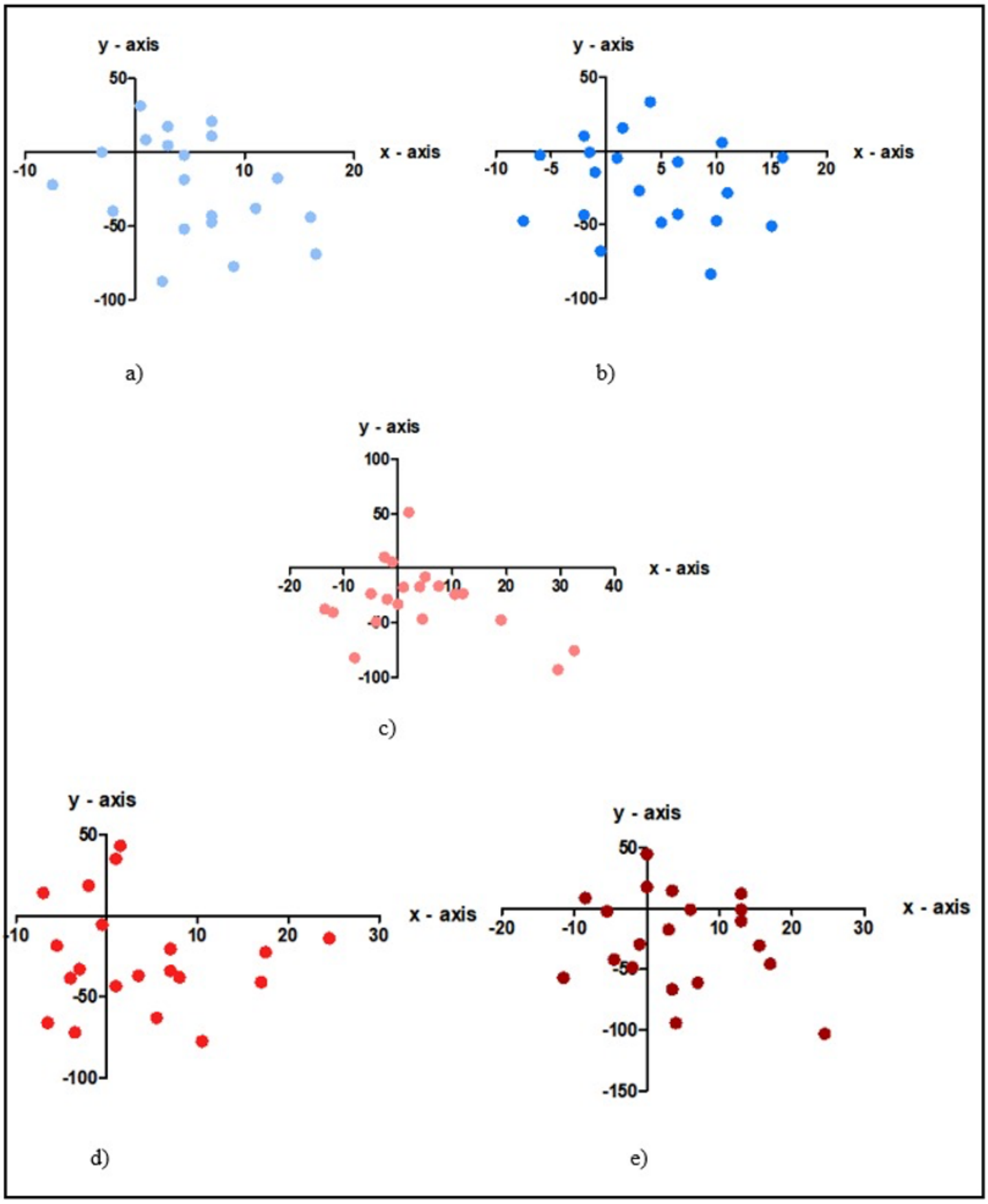


Figure 4.2 Distribution of the average of the CoP values of the participants according to the conditions a) Eyes Open (EO) b) Eyes Closed (EC) c) Virtual Reality without feedback (LVR) d) Virtual Reality with Negative Feedback (LVR-) e) Virtual Reality with Positive Feedback (LVR+)

The graph of CoP values in the VR condition was repeated by removing 2 participants with left hand dominance, and the left shift of CoP values in the X axis continued (Figure 4.3.).

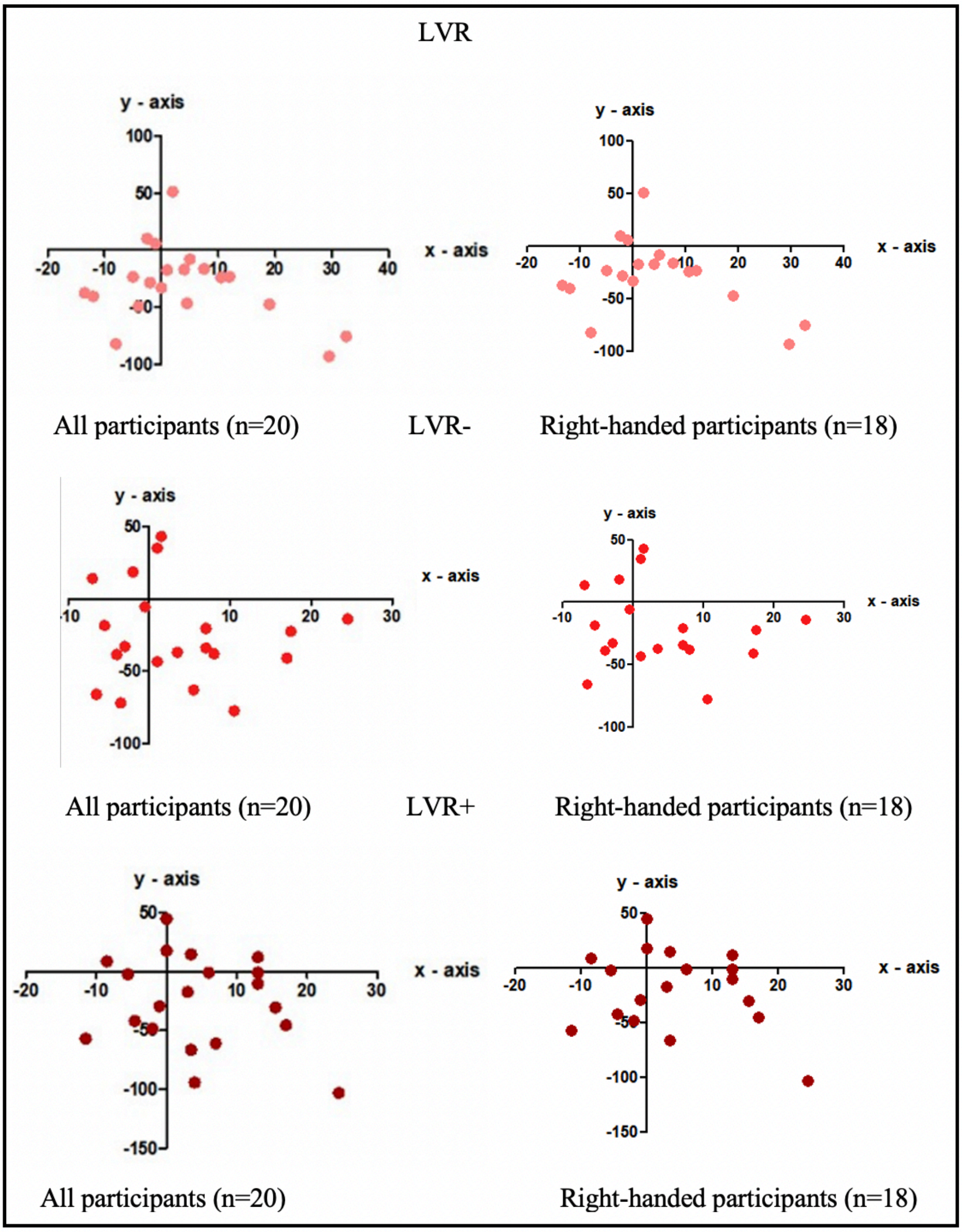


Figure 4.3 Comparison of CoP values of all participants and right-handed only participants in the VR condition.

The graph comparing the distance of the participants' average CoP values to the center under 5 different conditions is presented in Figure 4.4.

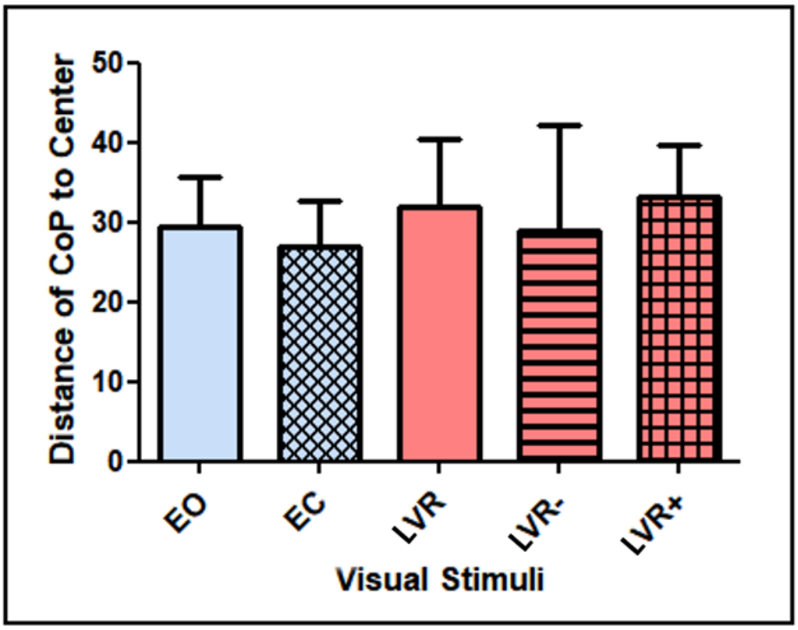


Figure 4.4 Comparing the distance of the participant's average CoP values to the center under 5 different visual stimuli.

The mean and SD of the distance of CoP to center (cm) under 5 difference conditions are presented in Table 4.2. There was no significant difference between conditions in terms of the distance of the participants' average CoP values to the center (respectively 33.85±24.74, 31.04±22.93, 37.94±25.63, 38.29±19.31, 37.77±28.52) ($p>0.05$).

Table 4.2 Comparison of the distance from the center of average of CoP values of the participants under 5 different conditions.

Postural Control Variables	Repeated ANOVA (Within subject)						
	Lab Enviroment		**VR Enviroment**				
	EO mean±sd	**EC mean±sd**	**LVR mean±sd**	**LVR- mean±sd**	**LVR+ mean±sd**	**F**	**P value**
CoP values (distance to center)	33.85±24.74	31.04±22.93	37.94±25.63	38.29±19.31	37.77±28.52	.69	0.60

EO: Eyes open, EC: Eyes Closed LVR: The image of the laboratory environment reflected in the virtual reality environment without feedback LVR-: The image of the laboratory environment reflected in the virtual reality environment with negative visual feedback LVR+: The image of the laboratory environment reflected in the virtual reality environment with positive visual feedback.

4.4. Comparisons of the A-P Sway Velocity and M-L Sway Velocity of participants under 5 different conditions.

The mean and SD of the sway velocities of the participants in the A-P and M-L directions under 5 different conditions are presented in Table 4.3.

There was a significant difference between the sway velocities of participants in A-P and M-L directions among EC, EO, LVR, LVR-, LVR+ applied to the participants (respectively A-P: 5.95 ±1.91, 10.25 ±3.96, 8.85±3.04, 8.17 ±2.46, 8.07 ±2.97 M-L: 4.17 ±1.96, 5.25 ±2.35, 5.02 ±1.77, 4.77 ±1.55, 4.77 ±1.85) ($p<0.05$).

Sway velocity was found significantly decreased in EO condition compared to all EC, LVR, LVR- and LVR+ conditions in A-P direction (respectively 5.95 ±1.91, 10.25 ±3.96, 8.85±3.04, 8.17 ±2.46, 8.07 ±2.97) ($p<0.05$). In addition, there was a significant difference between the EC condition and the LVR- and LVR+ conditions (respectively 10.25 ±3.96, 8.17 ±2.46, 8.07 ±2.97) ($P<0.05$).

Sway velocity in the M-L direction was found to be significantly lower in the EO condition compared to the EC and LVR conditions (respectively 4.17 ±1.96, 5.25 ±2.35, 5.02 ±1.77) ($p<0.05$). However, no significant difference was found between other situations ($p>0.05$).

Table 4.3 Comparison of the A-P Sway Velocity and M-L Sway Velocity values of the CoP values of participants under 5 different conditions.

Postural Control Variables	Repeated ANOVA (Within subject)							Post-Hoc Bonferronni (Between Subject)	
	Lab Enviroment		VR Enviroment						
	EO mean±sd	**EC mean±sd**	**LVR mean±sd**	**LVR- mean±sd**	**LVR+ mean±sd**	**F**	**p value**	**Conditions (EO, EV, LVR, LVR-, LVR+)**	**p value**
A-P Sway Velocity	5.95 ±1.91	10.25±3.96	8.85±3.04	8.17 ±2.46	8.07 ±2.97	16.52	**0.00***	EO-EC EO-LVR EO-LVR- EO-LVR+ EC-LVR EC-LVR- EC-LVR+ LVR-LVR- LVR-LVR+ LVR+-LVR-	**0.00*** **0.00*** **0.00*** **0.003*** 0.15 **0.006*** **0.002*** 0.55 0.50 1.00
M-L Sway Velocity	4.17 ±1.96	5.25 ±2.35	5.02 ±1.77	4.77 ±1.55	4.77 ±1.85	4.56	**.01***	EO-EC EO-LVR EO-LVR- EO-LVR+ EC-LVR EC-LVR- EC-LVR+ LVR-LVR- LVR-LVR+ LVR+-LVR-	**0.00*** **0.04*** 0.13 0.10 0.26 0.14 0.07 0.34 0.29 1.00

EO: Eyes open, EC: Eyes Closed LVR: The image of the laboratory environment reflected in the virtual reality environment without feedback LVR-: The image of the laboratory environment reflected in the virtual reality environment with negative visual feedback LVR+: The image of the laboratory environment reflected in the virtual reality environment with positive visual feedback.

Graphs comparing A-P Sway Velocity and M-L Sway Velocity under 5 different visual stimuli are presented in Figure 4.5.

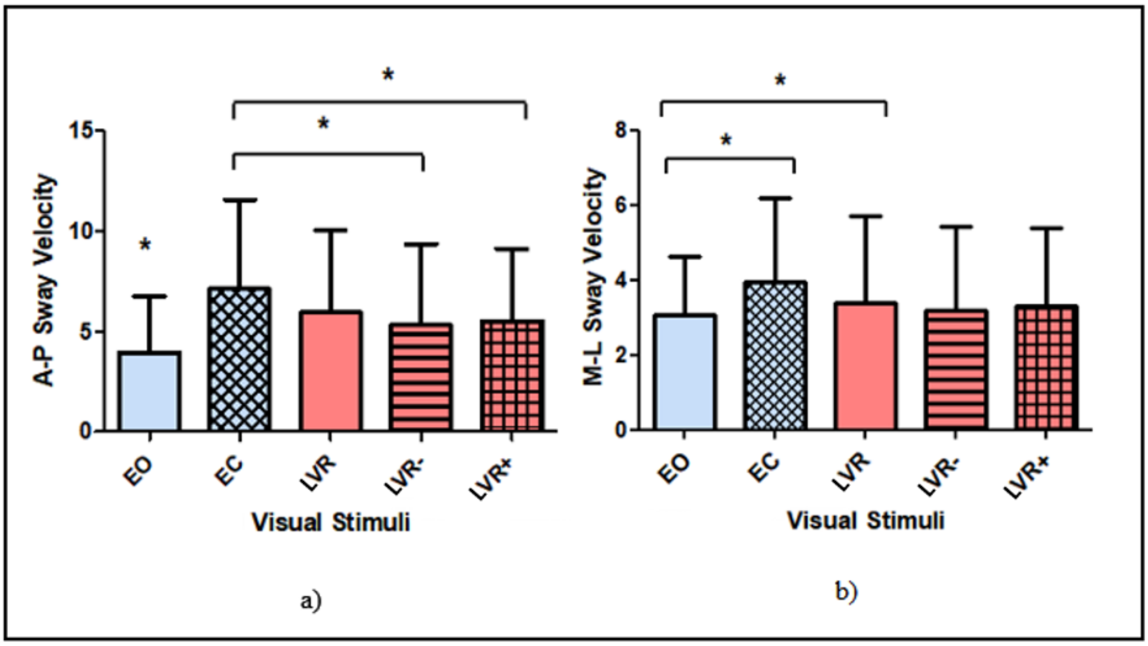


Figure 4.5 Comparing A-P Sway Velocity and M-L Sway Velocity under 5 different visual stimuli.

4.5. Comparison of the Sway Area and Perimeter values of the participants under 5 different conditions.

The mean and SD of the Sway Area and Perimeter of CoP under 5 different conditions are presented in Table 4.4.

Sway area was found significantly decreased in EO condition compared to all other conditions (respectively 118.82±74.23, 282.25±153.60, 257.57±143.79, 250±152.06, 292.55±207.69) ($p<0.05$). Perimeter decreased significantly in the EO condition compared to other conditions, whereas it increased significantly in the EC condition (respectively 258.10±75.56, 404.70±130.30, 341.57±100.42, 320.60±83.60, 319.62±96.76) ($p<0.05$).

Table 4.4 Comparison of the Sway Area and Perimeter values of the participants under 5 different conditions.

Postural Control	Repeated Anova (Within subject)							Post-Hoc Bonferronni (Between Subject)	
	Lab Enviroment		VR Enviroment						
	EO mean±sd	EC mean±sd	LVR mean±sd	LVR- mean±sd	LVR+ mean±sd	F	p value	Conditions (EO, EV, LVR, LVR-, LVR+)	p value
Sway Area	118.82±74.23	282.25±153.60	257.57±143.79	250±152.06	292.55±207.69	2.31	**.00***	EO-EC	**0.001***
								EO-LVR	**0.00***
								EO-LVR-	**0.001***
								EO-LVR+	**0.012***
								EC-LVR	1.00
								EC-LVR-	1.00
								EC-LVR+	1.00
								LVR-LVR-	1.00
								LVR-LVR+	1.00
								LVR+-LVR-	1.00
Perimeter	258.10±75.56	404.70±130.30	341.57±100.42	320.60±83.60	319.62±96.76	5.03	**.00***	EO-EC	**0.00***
								EO-LVR	**0.00***
								EO-LVR-	**0.001***
								EO-LVR+	**0.008***
								EC-LVR	**0.005***
								EC-LVR-	**0.00***
								EC-LVR+	**0.00***
								LVR-LVR-	0.77
								LVR-LVR+	0.54
								LVR+-LVR-	1.00

EO: Eyes open, EC: Eyes Closed LVR: The image of the laboratory environment reflected in the virtual reality environment without feedback LVR-: The image of the laboratory environment reflected in the virtual reality environment with negative visual feedback LVR+: The image of the laboratory environment reflected in the virtual reality environment with positive visual feedback.

Graphs comparing Sway Area and Perimeter values under 5 different visual stimuli are presented in Figure 4.6.

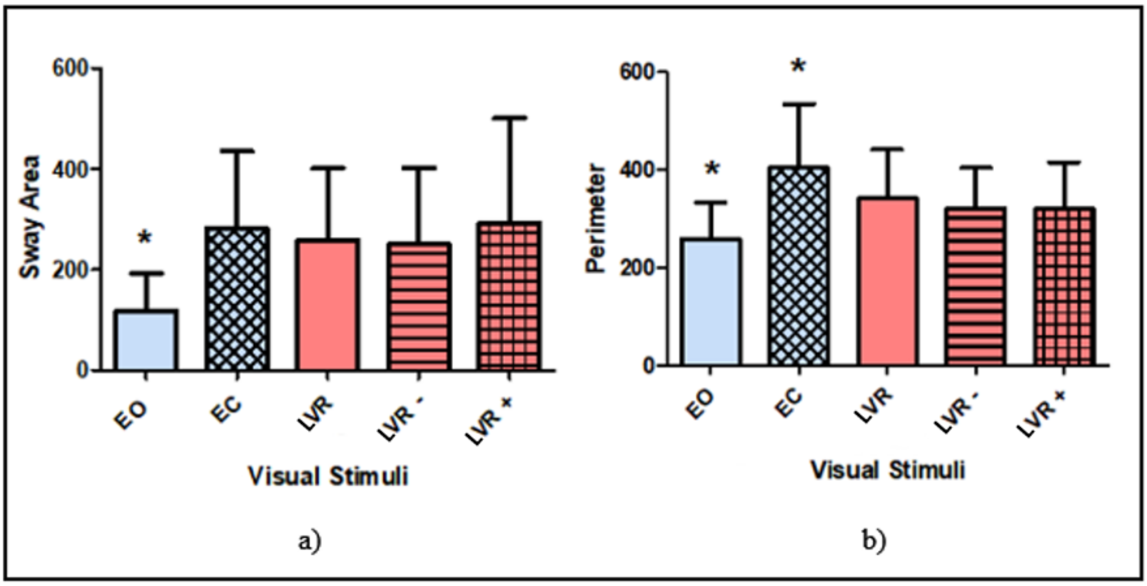


Figure 4.6 Comparing Sway Area and Perimeter values under 5 different visual stimuli.

5. DISCUSSION

The aim of our study was to investigate the effect of the real environment image reflected in the virtual reality environment and the positive and negative feedbacks added to it on postural control. For this purpose, 3D postural control variables such as the distance from the center, area, perimeter and velocity of the CoP were obtained in 2D on the platform under five visual conditions.

The distance of the average CoP values of the participants from the center is greater in VR environment than the real environment, Although no significant difference was found between five conditions (EO, EC, LVR, LVR-, LVR+). Considering the average CoP values of the participants in the coordinate plane, it was noted that there was more intensity on the left side of the x-axis in the VR environment compared to the real environment. In this regard, according to the study conducted by Cioncoloni et al. It has been suggested that the dominant hemisphere plays a critical role in the selection of the appropriate postural control strategy and there is a functional asymmetry between both primary motor areas (89).

In the present study, according to the Edinburgh Handedness Questionaire, 80% of the participants in this study were right-handed predominantly (n=18: right-handed, n=2: left-handed). After that, according to the results of the analysis performed by excluding the two left-handed participants, the left shift of the CoP values in the X-axis continued. Thus, it was concluded that this situation did not occur only due to left-handed participants. Therefore, our current study does not provide evidence that the leftward shift in the X-axis seen in the VR condition may be associated with hemisphere dominance. In addition, since this situation is not related to the main question of our study, it is thought that there is a need for further studies on this subject.

In this study, it was determined that there was a significant increase in the sway velocity values in both A-P and M-L directions in the VR environment compared to the EO condition. Since the sway velocity represents the sway degree per second, the higher value obtained indicates impaired postural control. In parallel with our study, in the study of Chander et al., the sway velocity has been found to be significantly higher in VR environment compared to the real environment (14). However, in the study conducted by Imaizumi et al., although there was an increase in sway velocity in the A-

P direction in the VR environment compared to real environment, no significant difference was found between these two condition in the M-L (90). In addition, In the study of Park et al., sway velocity was evaluated in real environment and two different VR environments (fixed or moving). Accordingly, it has been observed that the sway velocity increases only in the moving VR environment compared to the real environment (91).

In another study, Assländer et al. used the laboratory environment as a VR image. They evaluated postural control in four different conditions: EO, EC, VR1 (photo-realistic copy of lab environment) and VR2 (abstract image of lab environment). Contrary to our results, the sway velocity was found to be similar with in real laboratory environment and photo-realistic virtual copy of the laboratory environment. However, a significant increase in sway velocity was found in an abstract VR environment of laboratory environment (92).

Looking at the values of sway velocity in condition with eyes closed, in the current study found that there was no significant difference between EC and VR conditions in terms of sway velocity. The virtual reality environment has shown almost similar effects with the EC condition. Similar to our study, Luo et al. also showed that there was no significant difference in sway velocity between the EC and VR conditions in both the A-P direction and the M-L direction (18). In addition, Horlings et al. found that there was no significant difference between EC and VR conditions in terms of sway velocity regardless of whether the surface is firm or foam (93). However, unlike our study, the sway velocity was evaluated based on the shoulder sway.

Sway area is expressed as the total area (mm^2) covered by the participants' CoP sway. In this manner, an increase in this value indicates that the CoP sway over a period of time spreads over a larger area. In the study, sway area significantly increased in the VR environment compared to the EO condition. Nevertheless, there were no significant difference between the EC and the VR conditions in terms of sway area.

The study by Imaizumi et al. found that the sway area increased significantly in VR environment like our study. Unlike our study, they also evaluated the effect of proprioceptive stimulation created by the VR glasses. They examined the sway area both with EC while wearing or not VR glasses. As a result, they found that the sway area did not increase significantly in the VR glasses with EC condition, as in the VR glasses with EO condition. Thus, they suggested that the proprioceptive input created by VR glasses was not effective on the increase in sway area alone (90). Gotardi et al. evaluated balance by following eye movements. As a result, it was found that the haptic effect caused by whether or not a head-mounted eye tracker was attached made a significant difference in terms of CoP value in the ML direction (94). According to the study conducted by Schmuckler et al., It was concluded that even the non head-mounted haptic input decreases the mean velocity, and the more stable the haptic input the mean velocity decreases at the same rate (15).

In contrast, in our study, when the same environment is reflected in virtual reality, the visual stimulation provided through the VR-Box glasses increased body sway under all conditions. On the other hand, the effect of proprioceptive information created by VR-Box glasses on postural control alone was not examined in our study.

In the another study, where a moving visual stimulus is provided through VR as expected and unexpected visual perturbation, it has been found that the sway area increases significantly compared to the real environment only when it is provided unexpected (14). Although visual perturbation was not used in our study, a significant difference was observed between EO and VR conditions in terms of sway area. This situation made us think that even the use of VR alone can be perceived as perturbation.

In the present study, perimeter variable was found to be significantly increased in VR environment compared to real environment. Additionally, unlike the sway area, a significant difference was found between the EC and the VR condition. The mentioned perimeter variable represents the distance covered by the CoP values of the participants (mm).

In the study of Chander et al., The perimeter variable was expressed as CoP displacement and investigated separately in the A-P and M-L directions. According to the results of the study, although there was no significant difference between the real and the VR environment in terms of CoP displacement in the M-L direction, there was a difference in A-P direction between the real and VR environment only in the unexpected condition. Additionally, it was emphasized that when visual perturbation is anticipated, CoP displacement is similar to the baseline condition. In addition, in another study by

Norris et al. investigating the effects of altered visual input and auditory stimulation on balance, the reason for the A-P sway being higher than the M-L sway was attributed to the greater support surface in the M-L direction in human posture. In the study conducted by Imaizumi, CoP displacement was found to be significantly increased in both A-P and M-L directions in VR environment compared to the real environment. In the study conducted by Park et al., The perimeter variable was stated as the sway length. When the visual stimuli provided with VR are moving, a significant difference was found in terms of sway length compared to the real environment. However, fixed visual stimuli did not significantly alter the sway length variable.

Additionally, the current study observed that positive or negative feedback added to VR did not have any significant effect on the postural control between VR conditions. As far as is known, there is no study in the literature investigating the effect of different feedback provided through VR on postural control. On the other hand, Tossavaienen et al. compared the real environment with four VR environments. It has been shown that certain visual stimuli had more disruptive effects on postural control (95).

Although different results were obtained in the literature, the fact that the perimeter variable increased in the VR environment compared to the EO condition in the current study might be indicates that postural control is impaired in the VR environment compared to the real environment. In addition, the perimeter variable was found to be significantly increased in the EC condition compared to the VR environment might be indicates that the VR environment is not as impaired as the EC condition.

Due to the differences in the terms expressing the postural control variable in the literature, the measurement devices and the measurement data, the use of different stimuli in the study models also creates difficulties in the interpretation of the results obtained. Although the use of VR technology in the medical field is rapidly becoming widespread, it is seen that the effects of visual stimuli in VR studies on balance are still not clear. Insufficient information in the literature and differences in study designs create difficulties in interpreting the results. According to the results obtained in this study, we can state that the VR environment has a negative effect on the balance in terms of CoP sways compared to the real environment. It is clear that future studies are needed to understand the effects of the virtual environment on balance.

As a technical limitation of this study, a VR glasses with higher resolution could be used to provide visual stimuli. In addition, the proprioceptive effect of VR glasses alone on postural control could be demonstrated by adding a condition in which the VR glasses were applied with the closed eyes.

6. CONCLUSION

In present study, it was found that there is a significant difference between the real environment and reflection of the real environment to the VR environment in terms of postural control variables. Thereby, findings of this study corroborated our hypothesis.

The effect of the visual stimulus provided by VR on postural control might be between the EO and EC condition.

Positive and negative feedback provided by VR did not have any significant effect on postural control variables.

More studies are needed on this subject in order to shed light on VR training in the field of physiotherapy.

7. REFERENCES

1. Bell, F. (1998). *Principles of mechanics and biomechanics*. Nelson Thornes.
2. Hall, S. (1991). Basic Biomechanics. St. Louis, MO: Mosby-Year Book.
3. Ivanenko, Y., & Gurfinkel, V. S. (2018). Human postural control. *Frontiers in Neuroscience*, *12*(MAR), 1–9. https://doi.org/10.3389/fnins.2018.00171
4. D A Winter PhD, Pe. (1995). Human balance and postural control during standing and walking. *Gait & Posture*, *3*, 193–214.
5. Pollock, A. S., Durward, B. R., Rowe, P. J., & Paul, J. P. (2000). What is balance? *Clinical Rehabilitation*, *14*(4), 402–406. https://doi.org/10.1191/0269215500cr342oa
6. Şimşek, T. T., & Şimşek, İ. E. (2020). Balance and postural control. *Comparative Kinesiology of the Human Body*, 467–475. https://doi.org/10.1016/b978-0-12-812162-7.00026-6
7. Peterka, R. J. (2002). Sensorimotor integration in human postural control. *Journal of Neurophysiology*, *88*(3), 1097–1118. https://doi.org/10.1152/jn.2002.88.3.1097
8. Paillard, T., & Noé, F. (2015). Techniques and Methods for Testing the Postural Function in Healthy and Pathological Subjects. *BioMed Research International*, *2015*. https://doi.org/10.1155/2015/891390
9. Pirôpo, U. S., Rocha, J. A. dos S., Passos, R. da S., Couto, D. L., Santos, A. M. dos, Argolo, A. M. B., Casotti, C. A., & Pereira, R. (2016). INFLUENCE OF VISUAL INFORMATION IN POSTURAL CONTROL : IMPACT OF THE USED STABILOMETRIC ANALYSIS METHODS Uanderson Silva Pirôpo ; José Alberto dos Santos Rocha ; CONTROL POSTURAL : IMPACTO DE LOS MÉTODOS. *European Journal of Human Movement*, *37*, 21–29.
10. Palmieri, R. M., Ingersoll, C. D., Stone, M. B., & Krause, B. A. (2002). Center-of-pressure parameters used in the assessment of postural control. *Journal of Sport Rehabilitation*, *11*(1), 51–66. https://doi.org/10.1123/jsr.11.1.51
11. Norris, N., Hackney, S., Creek, B., Carolina, N., Advisor, F., & Bunn, J. A. (2016). *The Impact of Altered Visual Input and Auditory Stimulations on Balance and Postural Stability The Impact of Altered Visual Input and Auditory Stimulations on Balance and Postural Stability*. *October*.

12. Aman, J. E., Elangovan, N., Yeh, I. L., & Konczak, J. (2015). The effectiveness of proprioceptive training for improving motor function: A systematic review. *Frontiers in Human Neuroscience*, *8*(JAN), 1–18. https://doi.org/10.3389/fnhum.2014.01075
13. Kogler, A., Lindfors, J., Ödkvist, L. M., & Ledin, T. (2000). Postural stability using different neck positions in normal subjects and patients with neck trauma. *Acta Oto-Laryngologica*, *120*(2), 151–155. https://doi.org/10.1080/000164800750000801
14. Chander, H., Arachchige, S. N. K. K., Hill, C. M., Turner, A. J., Deb, S., Shojaei, A., Hudson, C., Knight, A. C., & Carruth, D. W. (2019). Virtual-reality-induced visual perturbations impact postural control system behavior. *Behavioral Sciences*, *9*(11), 1–12. https://doi.org/10.3390/bs9110113
15. Schmuckler, M. A., & Tang, A. (2019). Multisensory factors in postural control: Varieties of visual and haptic effects. *Gait and Posture*, *71*(November 2018), 87–91. https://doi.org/10.1016/j.gaitpost.2019.04.018
16. Yang, W. C., Wang, H. K., Wu, R. M., Lo, C. S., & Lin, K. H. (2016). Home-based virtual reality balance training and conventional balance training in Parkinson's disease: A randomized controlled trial. *Journal of the Formosan Medical Association*, *115*(9), 734–743. https://doi.org/10.1016/j.jfma.2015.07.012
17. Prasertsakul, T., Kaimuk, P., Chinjenpradit, W., Limroongreungrat, W., & Charoensuk, W. (2018). The effect of virtual reality-based balance training on motor learning and postural control in healthy adults: A randomized preliminary study TCTR20180430005 TCTR 17 Psychology and Cognitive Sciences 1701 Psychology 11 Medical and Health Sciences 1106 Hum. *BioMedical Engineering Online*, *17*(1), 1–17. https://doi.org/10.1186/s12938-018-0550-0
18. Luo, H., Wang, X., Fan, M., Deng, L., Jian, C., Wei, M., & Luo, J. (2018). The effect of visual stimuli on stability and complexity of postural control. *Frontiers in Neurology*, *9*(FEB). https://doi.org/10.3389/fneur.2018.00048
19. Cech, D. J., & Martin, S. "Tink." (2012). Posture and Balance. *Functional Movement Development Across the Life Span*, 263–287. https://doi.org/10.1016/b978-1-4160-4978-4.00012-0

20. Shepherd, G. M., & Shepherd-Barr, K. (2008). Proust Effect. *Encyclopedia of Neuroscience*, 3212–3335. https://doi.org/10.1007/978-3-540-29678-2_4852
21. Nashner, L. M. (2018). *The organisation of human postural movements A formal basis and experimental synthesis..pdf*. *1985*, 135–172.
22. Afschrift, M., van Deursen, R., De Groote, F., & Jonkers, I. (2019). Increased use of stepping strategy in response to medio-lateral perturbations in the elderly relates to altered reactive tibialis anterior activity. *Gait and Posture*, *68*(January), 575–582. https://doi.org/10.1016/j.gaitpost.2019.01.010
23. DeVore, R. B. (1978). Center of gravity and stability. *The Physics Teacher*, *16*(7), 506–506. https://doi.org/10.1119/1.2340053
24. Benda, B. J., Riley, P. O., & Krebs, D. E. (1994). Biomechanical Relationship Between Center of Gravity and Center of Pressure During Standing. *IEEE Transactions on Rehabilitation Engineering*, *2*(1), 3–10. https://doi.org/10.1109/86.296348
25. Davidovits, P. (2019). Static Forces. *Physics in Biology and Medicine*, 1–20. https://doi.org/10.1016/b978-0-12-813716-1.00001-x
26. Wollseifen, T. (2011). Different methods of calculating body sway area. *Pharmaceutical Programming*, *4*(1–2), 91–106. https://doi.org/10.1179/175709311x13166801334271
27. Krebs, D. E., Goldvasser, D., Lockert, J. D., Portney, L. G., & Gill-Body, K. M. (2002). Is base of support greater in unsteady gait? *Physical Therapy*, *82*(2), 138–147. https://doi.org/10.1093/ptj/82.2.138
28. Ofluoglu, D., Esquenazi, A., & Hirai, B. (2003). Temporospatial Parameters of Gait After Obturator Neurolysis in Patients with Spasticity. *American Journal of Physical Medicine and Rehabilitation*, *82*(11), 832–836. https://doi.org/10.1097/01.PHM.0000091986.32078.CD
29. Nam, H.-S., Kim, J.-H., & Lim, Y.-J. (2017). The Effect of the Base of Support on Anticipatory Postural Adjustment and Postural Stability. *The Journal of Korean Physical Therapy*, *29*(3), 135–141. https://doi.org/10.18857/jkpt.2017.29.3.135

30. Wu, A., March, L., Zheng, X., Huang, J., Wang, X., Zhao, J., M.Blyth, F., Smith, E., Buchbinder, R., & Hoy, D. (2020). Center of pressure excursion as a measure of balance performancein patients with non-specific low back pain compared to healthycontrols: a systematic review of the literature. In *Nature* (Vol. 388, pp. 1–14).
31. Pau, M., Ibba, G., & Attene, G. (2014). Fatigue-induced balance impairment in young soccer players. *Journal of Athletic Training*, *49*(4), 454–461. https://doi.org/10.4085/1062-6050-49.2.12
32. Sullivan, E. V., Rose, J., & Pfefferbaum, A. (2006). Effect of vision, touch and stance on cerebellar vermian-related sway and tremor: A quantitative physiological and MRI study. *Cerebral Cortex*, *16*(8), 1077–1086. https://doi.org/10.1093/cercor/bhj048
33. Cho, K., Lee, K., Lee, B., Lee, H., & Lee, W. (2014). Relationship between postural sway and dynamic balance in stroke patients. *Journal of Physical Therapy Science*, *26*(12), 1989–1992. https://doi.org/10.1589/jpts.26.1989
34. Duarte, Marcos, S. M. S. F. F. (2010). Revision of posturography based on force plate for balance evaluation. *Rev Bras Fisioter*, *14*(3), 183–192. https://doi.org/10.1007/s00391-018-1441-5
35. Angin, S., Karadibak, D., Yavuzşen, T., & Demïrbuken, I. (2014). Unilateral upper extremity lymphedema deteriorates the postural stability in breast cancer survivors. *Wspolczesna Onkologia*, *18*(4), 279–284. https://doi.org/10.5114/wo.2014.44120
36. Lee, C. H., & Sun, T. L. (2018). Evaluation of postural stability based on a force plate and inertial sensor during static balance measurements. *Journal of Physiological Anthropology*, *37*(1), 1–16. https://doi.org/10.1186/s40101-018-0187-5
37. Panjan, A., & Sarabon, N. (2012). Review of Methods for the Evaluation of Human Body Balance. *Sport Science Review*, *19*(5–6), 131–163. https://doi.org/10.2478/v10237-011-0036-5
38. Asanome, M., Matsuyama, K., & Mori, S. (1998). Augmentation of postural muscle tone induced by the stimulation of the descending fibers in the midline area of the cerebellar white matter in the acute decerebrate cat. *Neuroscience Research*, *30*(3), 257–269. https://doi.org/10.1016/S0168-0102(98)00006-6

39. Deliagina, T. G., Zelenin, P. V., Beloozerova, I. N., & Orlovsky, G. N. (2007). Nervous mechanisms controlling body posture. *Physiology and Behavior*, *92*(1–2), 148–154. https://doi.org/10.1016/j.physbeh.2007.05.023
40. Matsuyama, K., & Drew, T. (2000). Vestibulospinal and reticulospinal neuronal activity during locomotion in the intact cat. II. Walking on an inclined plane. *Journal of Neurophysiology*, *84*(5), 2257–2276. https://doi.org/10.1152/jn.2000.84.5.2257
41. Deliagina, T. G., Orlovsky, G. N., Zelenin, P. V., & Beloozerova, I. N. (2006). Neural bases of postural control. *Physiology*, *21*(3), 216–225. https://doi.org/10.1152/physiol.00001.2006
42. Samuel, A. J. (2015). A Critical Review on the Normal Postural Control. *Physiotherapy and Occupational Therapy Journal*, *8*(2), 71–75. https://doi.org/10.21088/potj.0974.5777.8215.4
43. Hirabayashi, S. ichi, & Iwasaki, Y. (1995). Developmental perspective of sensory organization on postural control. *Brain and Development*, *17*(2), 111–113. https://doi.org/10.1016/0387-7604(95)00009-Z
44. Rani, S., Archana, R., & Kumari, S. K. (2018). Vestibular modulation of postural stability: An update. *Biomedical Research (India)*, *29*(17), 3385–3388. https://doi.org/10.4066/biomedicalresearch.29-18-972
45. Kingma, H. (2016). Posture , balance and movement : Role of the vestibular system in balance Posture , équilibre , mouvement : caractérisation et conséquences de l ' instabilité motrice au cours de la marche Posture , balance control , movement : Involvement in vestibular. *Neurophysiologie Clinique/Clinical Neurophysiology*, *46*(4–5), 238.
46. MacDougall, H. G., Moore, S. T., Curthoys, I. S., & Black, F. O. (2006). Modeling postural instability with Galvanic vestibular stimulation. *Experimental Brain Research*, *172*(2), 208–220. https://doi.org/10.1007/s00221-005-0329-y
47. Gaerlan, M. G. (2010). The role of visual, vestibular, and somatosensory systems in postural balance. *University of Nevada Las Vegas*, 69. http://digitalscholarship.unlv.edu/thesesdissertations
48. Shaffer, S. W., & Harrison, A. L. (2007). Aging of the somatosensory system: A translational perspective. *Physical Therapy*, *87*(2), 193–207. https://doi.org/10.2522/ptj.20060083

49. Ehrenfried, T., Guerraz, M., Thilo, K. V., Yardley, L., & Gresty, M. A. (2003). Posture and mental task performance when viewing a moving visual field. *Cognitive Brain Research*, *17*(1), 140–153. https://doi.org/10.1016/S0926-6410(03)00088-0
50. Berthoz, A., Lacour, M., Soechting, J. F., & Vidal, P. P. (1979). The Role of Vision in the Control of Posture During Linear Motion. *Progress in Brain Research*, *50*(C), 197–209. https://doi.org/10.1016/S0079-6123(08)60820-1
51. Lord, S. R. (2006). Visual risk factors for falls in older people. *Age and Ageing*, *35*(SUPPL.2), 42–45. https://doi.org/10.1093/ageing/afl085
52. T.M.H. Dijkstra, G. Schöner, C. C. A. M. G. (1993). *Temporal stability of the action-perception cycle for postural control in a moving visual environment*. 477–486.
53. S. Glasauer, E. Schneider, K. Jahn, M. Strupp, T. B. (2005). How the eyes move. *NEUROLOGY*, *65*, 1291–1293.
54. Billot, M., Handrigan, G. A., Simoneau, M., & Teasdale, N. (2015). Reduced plantar sole sensitivity induces balance control modifications to compensate ankle tendon vibration and vision deprivation. *Journal of Electromyography and Kinesiology*, *25*(1), 155–160. https://doi.org/10.1016/j.jelekin.2014.06.003
55. Hoffman, M. A., & Koceja, D. M. (1997). Dynamic balance testing with electrically evoked perturbation: A test of reliability. *Archives of Physical Medicine and Rehabilitation*, *78*(3), 290–293. https://doi.org/10.1016/S0003-9993(97)90036-8
56. Paillard, T., Bizid, R., & Dupui, P. (2007). Do sensorial manipulations affect subjects differently depending on their postural abilities? *British Journal of Sports Medicine*, *41*(7), 435–438. https://doi.org/10.1136/bjsm.2006.032904
57. Stål, F., Fransson, P. A., Magnusson, M., & Karlberg, M. (2003). Effects of hypothermic anesthesia of the feet on vibration-induced body sway and adaptation. *Journal of Vestibular Research: Equilibrium and Orientation*, *13*(1), 39–52.
58. Chiang, J. H., & Wu, G. (1997). The influence of foam surfaces on biomechanical variables contributing to postural control. *Gait and Posture*, *5*(3), 239–245. https://doi.org/10.1016/S0966-6362(96)01091-0

59. Demura, S., Yamaji, S., Kitabayashi, T., Yamada, T., & Uchiyama, M. (2008). Attention of postural control on foot somatosensor disturbance caused by the compression of blood vessels. *Journal of Human Ergology*, *37*(2), 91–102. https://doi.org/10.11183/jhe1972.37.91
60. Hagio, K., Obata, H., & Nakazawa, K. (2020). Effects on Postural Kinematics of Performing a Cognitive Task During Upright Standing. *Perceptual and Motor Skills*, *127*(4), 639–650. https://doi.org/10.1177/0031512520919543
61. Woollacott, M., & Shumway-Cook, A. (2002). Attention and the control of posture and gait: A review of an emerging area of research. *Gait and Posture*, *16*(1), 1–14. https://doi.org/10.1016/S0966-6362(01)00156-4
62. Schaefer, S. (2014). The ecological approach to cognitiveâ€“motor dual-tasking: findings on the effects of expertise and age. *Frontiers in Psychology*, *5*(October), 1–9. https://doi.org/10.3389/fpsyg.2014.01167
63. Liebherr, M., Schubert, P., Schiebener, J., Kersten, S., & Haas, C. T. (2016). Dual-tasking and aging—About multiple perspectives and possible implementations in interventions for the elderly. *Cogent Psychology*, *3*(1), 1–14. https://doi.org/10.1080/23311908.2016.1261440
64. Craig, A. B., Sherman, W. R., & Will, J. D. (2009). Introduction to Virtual Reality. *Developing Virtual Reality Applications*, 1–32. https://doi.org/10.1016/b978-0-12-374943-7.00001-x
65. Keshner, E. A. (2004). Virtual reality and physical rehabilitation: A new toy or a new research and rehabilitation tool? *Journal of NeuroEngineering and Rehabilitation*, *1*, 1–2. https://doi.org/10.1186/1743-0003-1-8
66. Dulau, E., Botha-Ravyse, C. R., & Luimula, M. (2019). Virtual reality for physical rehabilitation: A Pilot study How will virtual reality change physical therapy? *10th IEEE International Conference on Cognitive Infocommunications, CogInfoCom 2019 - Proceedings*, 277–282. https://doi.org/10.1109/CogInfoCom47531.2019.9089980
67. Merians, A. S., Jack, D., Boian, R., Tremaine, M., Burdea, G. C., Adamovich, S. V, Recce, M., & Poizner, H. (2002). *Merians AS 2002 Virtual reality-augmented rehabilitation for patients following stroke.pdf*. *82*(9).

68. Morel, M., Bideau, B., Lardy, J., & Kulpa, R. (2015). Advantages and limitations of virtual reality for balance assessment and rehabilitation. *Neurophysiologie Clinique*, *45*(4–5), 315–326. https://doi.org/10.1016/j.neucli.2015.09.007
69. Saposnik, G., & Levin, M. (2011). Virtual reality in stroke rehabilitation: A meta-analysis and implications for clinicians. *Stroke*, *42*(5), 1380–1386. https://doi.org/10.1161/STROKEAHA.110.605451
70. Langhorne, P., Coupar, F., & Pollock, A. (2009). Motor recovery after stroke: a systematic review. *The Lancet Neurology*, *8*(8), 741–754. https://doi.org/10.1016/S1474-4422(09)70150-4
71. Mouawad, M. R., Doust, C. G., Max, M. D., & McNulty, P. A. (2011). Wii-based movement therapy to promote improved upper extremity function post-stroke: A pilot study. *Journal of Rehabilitation Medicine*, *43*(6), 527–533. https://doi.org/10.2340/16501977-0816
72. Cano Porras, D., Siemonsma, P., Inzelberg, R., Zeilig, G., & Plotnik, M. (2018). Advantages of virtual reality in the rehabilitation of balance and gait: Systematic review. *Neurology*, *90*(22), 1017–1025. https://doi.org/10.1212/WNL.0000000000005603
73. Laver, K., George, S., Thomas, S., Deutsch, J. E., & Crotty, M. (2012). Virtual reality for stroke rehabilitation. *Stroke*, *43*(2). https://doi.org/10.1161/STROKEAHA.111.642439
74. Molina, K. M. (2013). Encyclopedia of Behavioral Medicine. In *Encyclopedia of Behavioral Medicine*. https://doi.org/10.1007/978-1-4419-1005-9
75. Zwicker, J. G., & Harris, S. R. (2009). A reflection on motor learning theory in pediatric occupational therapy practice. *Canadian Journal of Occupational Therapy*, *76*(1), 29–37. https://doi.org/10.1177/000841740907600108
76. Barnett, M. L., Ross, D., Schmidt, R. A., & Todd, B. (1973). Motor skills learning and the specificity of training principle. *Research Quarterly of the American Association for Health, Physical Education and Recreation*, *44*(4), 440–447. https://doi.org/10.1080/10671188.1973.10615224

77. Molier, B. I., Prange, G. B., Krabben, T., Stienen, A. H. A., van der Kooij, H., Buurke, J. H., Jannink, M. J. A., & Hermens, H. J. (2011). Effect of position feedback during task-oriented upper-limb training after stroke: Five-case pilot study. *Journal of Rehabilitation Research and Development*, *48*(9), 1109–1118. https://doi.org/10.1682/JRRD.2010.07.0128
78. Molier, B. I., Van Asseldonk, E. H. F., Hermens, H. J., & Jannink, M. J. A. (2010). Nature, timing, frequency and type of augmented feedback; Does it influence motor relearning of the hemiparetic arm after stroke? A systematic review. *Disability and Rehabilitation*, *32*(22), 1799–1809. https://doi.org/10.3109/09638281003734359
79. Chen, L., Lo, W. L. A., Mao, Y. R., Ding, M. H., Lin, Q., Li, H., Zhao, J. L., Xu, Z. Q., Bian, R. H., & Huang, D. F. (2016). Effect of Virtual Reality on Postural and Balance Control in Patients with Stroke: A Systematic Literature Review. *BioMed Research International*, *2016*. https://doi.org/10.1155/2016/7309272
80. Virk, S., & Valter McConville, K. M. (2006). Virtual reality applications in improving postural control and minimizing falls. *Annual International Conference of the IEEE Engineering in Medicine and Biology - Proceedings*, 2694–2697. https://doi.org/10.1109/IEMBS.2006.260751
81. Juras, G., Brachman, A., Michalska, J., Kamieniarz, A., Pawłowski, M., Hadamus, A., Białoszewski, D., Błaszczyk, J., & Słomka, K. J. (2019). Standards of Virtual Reality Application in Balance Training Programs in Clinical Practice: A Systematic Review. *Games for Health Journal*, *8*(2), 101–111. https://doi.org/10.1089/g4h.2018.0034
82. Levac, D. E., & Sveistrup, H. (2011). *Motor Learning and Virtual Reality*. *Room 3028*, 25–46. https://doi.org/10.1007/978-1-4939-0968-1
83. Canning, C. G., Allen, N. E., Nackaerts, E., Paul, S. S., Nieuwboer, A., & Gilat, M. (2020). Virtual reality in research and rehabilitation of gait and balance in Parkinson disease. *Nature Reviews Neurology*, *16*(8), 409–425. https://doi.org/10.1038/s41582-020-0370-2
84. Cesaroni, S., Silva, A. M. da, Ganança, M. M., & Caovilla, H. H. (2021). Postural control at posturography with virtual reality in the intercritical period of vestibular migraine. *Brazilian Journal of Otorhinolaryngology*, *87*(1), 35–41. https://doi.org/10.1016/j.bjorl.2019.06.015

85. Chiarovano, E., de Waele, C., MacDougall, H. G., Rogers, S. J., Burgess, A. M., & Curthoys, I. S. (2015). Maintaining balance when looking at a virtual reality three-dimensional display of a field of moving dots or at a virtual reality scene. *Frontiers in Neurology*, *6*(JUL), 1–9. https://doi.org/10.3389/fneur.2015.00164
86. Ferhan, S. (2020). Technological methods used in evaluating the balance. *International Journal of Spine Research*, *2*, 060–063. https://doi.org/10.17352/ijsr.000016
87. Uysal, S. A., Ekinci, Y., Çoban, F., & Yakut, Y. (2019). Edinburgh El Tercihi Anketi Türkçe güvenirliğinin araştırılması. *Journal of Exercise Therapy and Rehabilitation*, *6*(2), 112–118.
88. Moghadam, M., Ashayeri, H., Salavati, M., Sarafzadeh, J., Taghipoor, K. D., Saeedi, A., & Salehi, R. (2011). Reliability of center of pressure measures of postural stability in healthy older adults: Effects of postural task difficulty and cognitive load. *Gait and Posture*, *33*(4), 651–655. https://doi.org/10.1016/j.gaitpost.2011.02.016
89. Cioncoloni, D., Rosignoli, D., Feurra, M., Rossi, S., Bonifazi, M., Rossi, A., & Mazzocchio, R. (2016). Role of brain hemispheric dominance in anticipatory postural control strategies. *Experimental Brain Research*, *234*(7), 1997–2005. https://doi.org/10.1007/s00221-016-4603-y
90. Imaizumi, L. F. I., Polastri, P. F., Penedo, T., Vieira, L. H. P., Simieli, L., Navega, F. R. F., Monteiro, C. B. de M., Rodrigues, S. T., & Barbieri, F. A. (2020). Virtual reality head-mounted goggles increase the body sway of young adults during standing posture.
91. Park, S. H., & Lee, G. C. (2020). Full-immersion virtual reality: Adverse effects related to static balance. *Neuroscience Letters*, *733*(March), 21–24. https://doi.org/10.1016/j.neulet.2020.134974
92. LorenzAssla ̈nderID1*, StephanStreuber1, 2. (2020). *Assla.pdf*. PLOS ONE. https://doi.org/https://doi.org/10.1371/journal.pone.0241479
93. Horlings, C. G. C., Carpenter, M. G., Küng, U. M., Honegger, F., Wiederhold, B., & Allum, J. H. J. (2009). Influence of virtual reality on postural stability during movements of quiet stance. *Neuroscience Letters*, *451*(3), 227–231. https://doi.org/10.1016/j.neulet.2008.12.057

94. Gotardi, G. C., Rodrigues, S. T., Barbieri, F. A., Brito, M. B., Bonfim, J. V. A., & Polastri, P. F. (2020). Wearing a head-mounted eye tracker may reduce body sway. *Neuroscience Letters*, *722*(February), 134799. https://doi.org/10.1016/j.neulet.2020.134799
95. Tossavainen, T., Juhola, M., Pyykkö, I., Aalto, H., & Toppila, E. (2003). Development of virtual reality stimuli for force platform posturography. *International Journal of Medical Informatics*, *70*(2–3), 277–283. https://doi.org/10.1016/S1386-5056(03)00034-0

8. APPENDICES

8.1. Appendix 1. Informed Voluntary Consent Form

BİLGİLENDİRİLMİŞ GÖNÜLLÜ OLUR FORMU

Sayın katılımcı,

Davet edildiğiniz "Sanal Gerçeklik Ortamı ile Sağlanan Farklı Görsel Uyaranların Sağlıklı Kişilerde Postural Kontrol Üzerine Etkisi" isimli bu çalışma; Yeditepe Üniversitesi Sağlık Bilimleri Enstitüsü Fizyoterapi ve Rehabilitasyon Bölümü tarafından yürütülmektedir. Araştırmacının yürütücüsü Fzt Sahra Şirvan Can ve Sorumlu araştırmacı Dr. Öğr. Üyesi Çiğdem Yazıcı Mutlu'dur.

Bu çalışmanın temel amacı, gerçek ortam ve sanal gerçeklik ortamı ile sağlanan görsel uyaranların sağlıklı kişilerde postürel kontrol üzerindeki etkisini karşılaştırmaktır. Bu çalışmada katılımcılar, Prokin PK 252 Denge Cihazı'nda görsel girdiler değiştirilerek 5 farklı koşulda değerlendirilecektir. Değerlendirme testleri her biri 30 saniye sürecek şekilde 3'er kez tekrarlanıp, toplam 30 dakika sürecektir. Değerlendirmelerden elde edilen postural salınım hızı, basınç merkezinin taradığı alan ve çevre verileri bilgisayara kaydedilecek ve sonuçlar analiz edilecektir. Katılımcıların kimlikleri ve verileri gizli tutularak kamuoyuna açıklanmayacaktır. Bu çalışmaya klinik tanısı olmayan 20 katılımcıyı kaydetmeyi hedefliyoruz.

Katılımın isteğe bağlı olduğunu ve katılmayı reddetmenin herhangi bir cezaya veya herhangi bir menfaat kaybına yol açmayacağını belirtmek isteriz. Aynı şekilde istediğiniz zaman araştırmadan çekilebilirsiniz. Araştırmamızda katılımcılara uygulanan değerlendirmelerin bilinen herhangi bir zararı bulunmamaktadır. Değerlendirme sürecinde herhangi bir beklenmedik hasar olması durumunda, bilgiler size derhal verilecektir. Katılımcıların herhangi bir zarar görmesi durumunda gerekli başvurular herhangi bir rücu olmaksızın araştırmacılar tarafından karşılanacaktır. Bunun için ne sizden ne de sosyal güvenlik sigortanızdan herhangi bir ücret talep edilmeyecektir. Araştırmaya katılmak size hemen yardımcı olmamakla birlikte, araştırma sonuçlarımızın gelecekte organizasyon, toplum veya bilim için faydaları olacağı umulmaktadır. Araştırmanın amaçları veya bağlı olduğunuz sosyal güvenlik kurumu için sizden herhangi bir ücret alınmayacaktır.

Danışman:	**Araştırmacı:**
Dr. Öğr. Üyesi Çiğdem Yazıcı Mutlu	**Fzt. Sahra Şirvan Can**
Yeditepe Üniversitesi	Yeditepe Üniversitesi
Sağlık Bilimleri Fakültesi	Sağlık Bilimleri Enstitüsü
Fizyoterapi ve Rehabilitasyon Bölümü	Fizyoterapi ve Rehabilitasyon Yüksek Lisans Programı
Tlf:	Tlf:

Onay Formu

Bilgilendirme formundaki tüm açıklamalan okudum. Bana, yukanda konusu ve amacı belirtilen çalışma ile ilgili yazılı ve sözlü açıklama araştırmacı tarafından yapıldı. Araştırmaya katılmaya gönüllü olduğumu, istediğim zaman gerekçeli veya gerekçesiz olarak araştırmadan ayrılabileceğimi biliyorum. Söz konusu çalışmaya hiçbir baskı ve zorlama olmaksızın kendi rızamla katılmayı ve sonuçlarımın kullanılmasını kısıtlamamayı, yayın, rapor ve benzeri bilimsel dokümanlarda kullanılmasını kabul ediyorum.

Gönüllünün Adı Soyadı Adres Telefon Numası Tarih İmzası

Tanık Adı Soyadı Adres Telefon Numası Tarih İmzası

Yürütücü Araştırmacı Adı Soyadı Adres Telefon Numası Tarih İmzası

Sorumlu Araştırmacı Adı Soyadı Adres Telefon Numarası Tarih İmzası

Katılımcıya çalışma ve yapılacak işlemler hakkında gerekli bilgileri verdim. Katılımcının bu bilgileri anladığına, sormak istediği soruları sorduğuna, özgür iradesiyle süreci kabul ettiğine inanıyorum.

Araştırmacı: Fzt. Sahra Şirvan Can Adres: Yeditepe Üniversitesi Tlf

Email: Tarih: İmza:

8.2. Appendix 2. Ethical Committee Approval

T.C. YEDİTEPE ÜNİVERSİTESİ
GİRİŞİMSEL OLMAYAN KLİNİK ARAŞTIRMALAR
ETİK KURULU

Versiyon No
1.0
Sayfa 2 / 2

BAŞVURU NUMARASI: 202106077

KARAR 4.08.2021

☒ **KABUL**	☐ **RET** ☐ *KAPSAM DIŞI (GİRİŞİMSEL)* ☐ *BİLİMSEL VE/VEYA ETİK KURALLARA AYKIRI* ☐ *BİR SORUMLU ARAŞTIRMACININ (TEZ İSE TEZ DANIŞMANI), BİR TOPLANTIYA **İKİ (2) ADETTEN FAZLA ÇALIŞMA BAŞVURUSUNDA** BULUNMASI* ☐ *KURUM İÇİ BAŞVURULARINDA **YEDİTEPE UZANTILI E-POSTA HESABI** İLE GİRİŞ YAPILMAMIŞ OLMASI* ☐ *ŞARTLI KABULDE BELİRTİLEN REVİZYONLARIN ZAMANINDA VE/VEYA İSTENİLDİĞİ ŞEKİLDE YAPILMAMIŞ OLMASI*

Prof. Dr. Didem ÖZDEMİR ÖZENEN **Başkan**	**Doç. Dr. Gökhan ERTAŞ** **Başkan Yardımcısı**	**Doç. Dr. Elif SUNGURTEKİN EKÇİ** **Raportör**
Katılım: ☐Var ☐Yok / İlişki: ☐Var ☐Yok	Katılım: ☐Var ☐Yok / İlişki: ☐Var ☐Yok	Katılım: ☐Var ☐Yok / İlişki: ☐Var ☐Yok
Prof. Dr. Feryal SUBAŞI **Üye**	**Prof. Dr. Şenay UZUN** **Üye**	**Doç. Dr. Mehmet Engin CELEP** **Üye**
Katılım: ☐Var ☐Yok / İlişki: ☐Var ☐Yok	Katılım: ☐Var ☐Yok / İlişki: ☐Var ☐Yok	Katılım: ☐Var ☐Yok / İlişki: ☐Var ☐Yok
Dr. Öğr. Üyesi E. Çiğdem ALTUNOK **Üye**	**Dr. Öğr. Üyesi Binnur OKAN BAKIR** **Üye**	**Dr. Öğr. Üyesi E. Nur ÖZDAMAR** **Üye**
Katılım: ☐Var ☐Yok / İlişki: ☐Var ☐Yok	Katılım: ☐Var ☐Yok / İlişki: ☐Var ☐Yok	Katılım: ☐Var ☐Yok / İlişki: ☐Var ☐Yok

Araştırmanın Başlığı	Sanal Gerçeklik Ortamı ile Sağlanan Farklı Görsel Uyaranların Sağlıklı Kişilerde Postural Kontrol Üzerine Etkisi
Araştırmacılar	Can S., Yazıcı Mutlu Ç.

KARAR FORMU

4.08.2021

ETİK KURUL BİLGİLERİ	Etik Kurulun Adı	Yeditepe Üniversitesi Girişimsel Olmayan Klinik Araştırmalar Etik Kurulu
	Açık Adres	Yeditepe Üniversitesi Diş Hekimliği Fakültesi, Bağdat Cad. No. 238 Göztepe 34728 Kadıköy, İstanbul
	İnternet Sayfası	http://goetik.yeditepe.edu.tr/
	Telefon	0216 363 60 44
	E-posta	goetik@yeditepe.edu.tr

DEĞERLENDİRİLEN BELGELER	Islak imzalı başvuru dosyası, CD'si ve elektronik başvuru	☒
	Araştırma başlığı ve araştırmacıların isimleri	☒
	Başvuru dilekçesi	☒
	Araştırmanın;	☒
	• Niteliği	☒
	• Önemi ve özgün değeri	☒
	• Amaç ve hedefleri	☒
	• Yöntemi	☒
	• Yönetimi	☒
	• Yaygın etkisi	☒
	• Araştırma bütçesi (Mevcutsa)	☒
	• Süresi ve uygunluğu (Zaman cetveli)	☒
	• Kaynakları	☒
	Araştırma izin belgesi / belgeleri	☒
	Bilgilendirilmiş Gönüllü Olur Formu (yapılan araştırmaya özel olarak hazırlanmış)	☒
	Taahhütname-1 Dünya Tıp Birliği Helsinki Bildirgesinin son versiyonunun ve Sağlık Bakanlığı'nın ilgili tüm kılavuzlarının okunmasına dair taahhüt	☒
	Taahhütname-2 Daha önce yapılmış etik kurul başvuruları mevcut olup olmadığına dair taahhüt	☒
	Taahhütname-3 Araştırma sırasında araştırma bütçesinde yer almayan ve gönüllünün kendisine veya Sosyal Güvenlik Kurumuna ek yük getirecek hiçbir işlem uygulanmayacağına dair taahhüt	☒
	Taahhütname-4 COVID-19 hastalarında tedavi yaklaşımları ve bilimsel araştırmalar genelgesi okunmasına dair taahhüt	☒
	Araştırmacıların her birisine ait özgeçmiş formu	☒
	Ek belgeler (Varsa kullanılan ölçek izinleri vb.)	☒

KARAR BİLGİLERİ	Başvuru Numarası	202106077
	Toplantı Tarihi	18.06.2021
	Toplantı Yeri	Çevirim içi (Google Meet)
	Karar No	19

Araştırmanın Başlığı	Sanal Gerçeklik Ortamı ile Sağlanan Farklı Görsel Uyaranların Sağlıklı Kişilerde Postural Kontrol Üzerine Etkisi
Araştırmacılar	Can S., Yazıcı Mutlu Ç.

8.3. Appendix 3. Demographic Form

……/……/……

GENEL BİLGİLER

Adı-Soyadı:

Yaş:

Cinsiyet:

Boy:

Vücut Ağırlığı (kg):

VKI:

Dominant Taraf: Sağ (   ) Sol (   )

1. **Herhangi bir tıbbi teşhisiniz var mı?**

(   ) Evet – Eğer evet ise, nedir? ________________

(   ) Hayır

2. **Düzenli olarak kullandığınız herhangi bir ilaç var mı?**

(   ) Evet – Eğer evet ise, nedir? ________________

(   ) Hayır

3. **Herhangi bir ameliyat geçirdiniz mi?**

(   ) Evet

(   ) Hayır

Eğer evet ise, lütfen hangi işlem olduğunu belirtiniz.___________________

Operasyon ne zaman yapıldı?_____________________

4. Herhangi bir yardımcı cihaz kullanıyor musunuz?

( ) Evet

( ) Hayır

5. Herhangi bir sistemik (kalıcı) bir hastalığınız var mı?

( ) Hayır

( ) Vestibüler (Denge ile ilgili) hastalıklar

( ) Kardiyovasküler Hastalıklar (kalp yetmezliği, ritim bozukluğu, tansiyon, anemi vb.)

( ) Solunum Hastalıkları (Astım, Alerji, KOAH vb.)

( ) Kulak Bozuklukları (İşitme sorunları vb.)

( ) Sinir sistemi Bozuklukları (Vertigo, epilepsi, nöropati, his kaybı vb.)

( ) Enfeksiyon Hastalıkları (Bademcik iltihabı, otitis vb.)

( ) Hormonal Bozukluklar (Diyabet, guatr, insülin direnci vb.)

( ) Kas İskelet Hastalıkları (Kas, Eklem, Tendon, Romatoid hastalıkları vb.)

( ) Sindirim Sistemi, Metabolizma Bozuklukları (Gastrit, ülser, ülser, bağırsak hastalıkları vb.)

( ) Görme Bozukluğu

AKTİVİTE BİLGİLERİ

6. Egzersiz yapıyor musunuz? Evet ise, ne sıklıkla egzersiz yaparsınız?

( ) Yapmıyorum

( ) Haftada 1-2 kez

( ) Haftada 3-4 kez

( ) Her gün

( ) Ayda 3 günden az

Egzersiz yapıyorsanız, her egzersiz en az kaç dakika sürer? ___________

7. Yapmayı tercih ettiğiniz spor nedir?

( ) Futbol ( ) Basketbol ( ) Voleybol ( ) Tenis ( ) Koşu ( ) Yüzme

Diğer _________________

8. Spor yapanlar için, sporunuz her seferinde kaç dakika sürüyor?

( ) 20 dakika veya daha kısa

( ) 21-30 dakika

( ) 31-50 dakika

( ) 50 dakikadan daha fazla

ALT EKSTREMİTENİN DEĞERLENDİRİLMESİ (KALÇA, DİZ, AYAK BİLEĞİ, AYAK)

9. Son altı ayda alt ekstremitelerinizden (kalça, diz, ayak bileği, ayak) yaralandınız mı?

( ) Hayır

( ) Kalça ( ) Diz ( ) Ayak bileği ( ) Ayak

10. Son altı ayda alt ekstremite (kalça, diz, ayak bileği, ayak) ameliyatı oldunuz mu?

( ) Hayır ( ) Evet - Evet ise lütfen belirtiniz. ________________________

11. Hiç ayak bileği burkulmanız oldu mu?

( ) Evet ( ) Hayır (Hayır ise, 17. soruya geçin)

12. Hangi tarafta burkulma yaşadınız?

( ) Evet ( ) Hayır

13. Burkulma ne kadar önce oldu?

( ) Son 1 ay ( ) Son 6-12 ay ( ) Son 12-24 ay ( ) 24 aydan daha fazla

14. Hiç aynı ayak bileğinizde tekrarlayan bir burkulma oldu mu?

( ) Evet – Evet ise, kaç kez?

( ) Hayır

15. Burkulma şikayetinizden sonra fizik tedavi gördünüz mü?

( ) Evet

( ) Hayır – Hayır ise, 17. soruya geçin.

16. Fizik tedavi aldığınız tarih nedir?________________

17. Please write your HES code. ____________________

Teşekkür ederiz.

8.4. Appendix 4. Edinburgh Handedness Inventory

Edinburg El Tercihi Anketi

Cevaplarınız bizim için çok önemli. Bu yüzden lütfen faaliyetleri daha önce deneyimlediyseniz, hayal ederek en doğru cevabı vermeye çalışın.

* Gerekli

1. E-posta *

2. Ad-Soyad *

Lütfen aşağıdaki faaliyetlerde el kullanımındaki tercihlerinizi belirtin. Lütfen tüm soruları yanıtlamaya çalışın ve yalnızca SİZİN tüm nesne veya görev konusunda deneyiminiz yoksa boş bırakın.

3. Hangi eli tercih ediyorsunuz?

Her satırda yalnızca bir şıkkı işaretleyin.

	Her zaman sağ	Genellikle sağ	Her iki el eşit	Genellikle sol	Her zaman sol
Yazma					

4. Hangi eli tercih ediyorsunuz?

Her satırda yalnızca bir şıkkı işaretleyin.

	Her zaman sağ	Genellikle sağ	Her iki el eşit	Genellikle sol	Her zaman sol
Çizme					

5. Hangi eli tercih ediyorsunuz?

Her satırda yalnızca bir şıkkı işaretleyin.

	Her zaman sağ	Genellikle sağ	Her iki el eşit	Genellikle sol	Her zaman sol
Atma	⬭	⬭	⬭	⬭	⬭

6. Hangi eli tercih ediyorsunuz?

Her satırda yalnızca bir şıkkı işaretleyin.

	Her zaman sağ	Genellikle sağ	Her iki el eşit	Genellikle sol	Her zaman sol
Makas kullanımı	⬭	⬭	⬭	⬭	⬭

7. Hangi eli tercih ediyorsunuz?

Her satırda yalnızca bir şıkkı işaretleyin.

	Her zaman sağ	Genellikle sağ	Her iki el eşit	Genellikle sol	Her zaman sol
Diş fırçası kullanımı	⬭	⬭	⬭	⬭	⬭

8. Hangi eli tercih ediyorsunuz?

Her satırda yalnızca bir şıkkı işaretleyin.

	Her zaman sağ	Genellikle sağ	Her iki el eşit	Genellikle sol	Her zaman sol
Bıçak kullanımı (çatal olmadan)	⬭	⬭	⬭	⬭	⬭

9. Hangi eli tercih ediyorsunuz?

Her satırda yalnızca bir şıkkı işaretleyin.

	Her zaman sağ	Genellikle sağ	Her iki el eşit	Genellikle sol	Her zaman sol
Kaşık kullanımı					

10. Hangi eli tercih ediyorsunuz?

Her satırda yalnızca bir şıkkı işaretleyin.

	Her zaman sağ	Genellikle sağ	Her iki el eşit	Genellikle sol	Her zaman sol
Süpürge kullanımı (üst el)					

11. Hangi eli tercih ediyorsunuz?

Her satırda yalnızca bir şıkkı işaretleyin.

	Her zaman sağ	Genellikle sağ	Her iki el eşit	Genellikle sol	Her zaman sol
İlgi çekme (örneğin garsonu çağırırken)					

12. Hangi eli tercih ediyorsunuz?

Her satırda yalnızca bir şıkkı işaretleyin.

	Her zaman sağ	Genellikle sağ	Her iki el eşit	Genellikle sol	Her zaman sol
Kutunun veya kavanozun kapağını açma					