EFFECT OF COGNITIVE TASK DIFFICULTY ON POSTURAL CONTROL

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ABSTRACT

EFFECT OF COGNITIVE TASK DIFFICULTY ON POSTURAL CONTROL

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Human posture control is accompanied usually in daily life with other tasks, such as cognitive tasks. This thesis is on the effects of cognitive task difficulty on postural control, the postural control mechanisms, attention and its relation to posture control and finally the dual task environments for posture control. The experiment's set an individualized difficulty level for each participant. Results indicate that when motor and challenging cognitive tasks are completed under dual task conditions, dual task interference was observed.

Keywords: Posture Control, Cognitive Task, Dual Task Paradigm, Dual Task Interference, Difficulty of Cognitive Task

ÖZ

BİLİŞSEL GÖREV ZORLUĞUNUN POSTÜR KONTROLÜ ÜZERİNE ETKİSİ

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İnsan postürünün kontrolü genellikle günlük yaşamda başka görevler ile birlikte icra edilir. Bu görevlerden bir tanesi bilişsel görevlerdir. Bu tez, bilişsel görev zorluğunun postür kontrolüne etkisini araştırmaktadır. Her bir katılımcı için özelleştirilmiş zorluk derecesi belirlenerek çalışmadaki zorluk parametresinin işlerliği kontrol edilmiştir. Sonuç olarak motor ve bilişsel görevin aynı anda icra edildiği durumlarda yeterli zorluk seviyesine erişildiği takdirde ikili görev çakışmasının meydana geldiği gözlenmiştir.

Anahtar Kelimeler: Postür Kontrolü, Bilişsel Görev, İkili Görev Paradigması, İkili Görev Çakışması, Bilişsel Görev Zorluğu

To Source of Joy

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LIST OF ABBREVIATONS

COP	Center of Pressure
COM	Center of Mass
COG	Center of Gravity
CT	Cognitive Task
AP	Anteroposterior
ML	Mediolateral
VS	Voluntary Sway
QS	Quiet Stance

CHAPTER 1

INTRODUCTION

This Introduction chapter is divded into two parts, first one being a general introduction tackling lightly the issues of attention and dual task paradigm, the second one being an introduction to postural control concept itself. All these issues will be discussed furthermore in Literature Review Chapter.

1.1. An Entrance

From a gymnast balancing on two hands in a competition, a basketball player who jumps high to score a point and lands on both feet, a businesswoman rushing to her meeting and as she is running with her high heels on a crowded street to an old grandfather who has difficulty climbing up the stairs, a blind person trying to find his way to the train station, a child with cerebral palsy trying to eat as he sits down- the diversity of humans and their lives have one common thing: we all move even if it is within the boundaries of our capabilities and limitations. And every move is accompanied by a certain posture, whether it is the most commonly used one among humans or it is a compensation for a lacking sense or a limb. No move is without posture. Actually as Denny-Brown wrote, “there are no separate mechanisms for posture and movement. Postural reactions are fundamental in neural organization, and movement in its most elementary form is seen as a modification of posture” (Denny-Brown, 1964). Spending most of our daily lives on two feet, human bipedal stance is the core of human posture. Except for the tasks that require sitting and lying down, most of our daily tasks require us to control our bodies in an erect posture on our two feet. We might spend a day not sitting for a second, but it is almost unthinkable to not stand on feet for 24 hours. Even a public servant or an office worker who sits around 8 hours per day needs to go to the supermarket, walk to his car or the bus stop, do house chores standing, transport from one place to another on two feet. Whether sitting or standing or being on fours or laying prone on a bed, human posture control accompanies movement or non-movement in every moment of life. That sounding very abstract to our ears, what is posture? How is it controlled?

First, human postural control can be defined as the ability to maintain equilibrium and orientation in a gravitational environment. For these reasons, postural control has two main purposes: postural orientation and postural stability. The system that controls stability and orientation of posture is a complex one, which organizes related senses and commands muscles to act on the musculoskeletal system (Horak, 1987). Postural orientation is the active control of body alignment and tone with respect to gravity, support surface, visual environment, and internal references. Postural stability is the coordination of sensorimotor strategies to stabilize the CoM (Center of Mass) during voluntary or externally triggered disturbances (Horak, 2006). According to Massion (Massion, 1994) postural control system has two main functions: firstly, it is for creating a resistance against the gravity and making sure the balance is maintained. Secondly, fixing the orientation and position of body segments with respect to the external environment. Basically, either being stationary or moving, or stabilizing after a voluntary or an involuntary move, taking a stance for completing a task are all controlled by the Postural Control System. Since the human posture is almost never the task itself in daily life and it is accompanied by other tasks, traditional views on posture control claim that it is achieved without paying attention to it and its organization is done automatically by numerous systems working together and this work is completed unnoticed. But is that the case? How is the postural control system working? Is it truly an automatically occurring process or do we need to organize specifically to achieve it and pay attention to it? If posture is like the “shadow of movement” (Hunt, 1922), then does it mean it needs very little attention to be planned? If human bipedal stance is very well learned task (Dault, Frank and Allard, 2001), then does it take up any space at all in our attentional sources? This belief that posture control requires very little attention was challenged in the past years. Kerr et al. (Kerr, Condon and McDonald, 1985) concluded that cognitive processing might rely on neural mechanisms which are also used for posture regulation, after making participants complete a balance task with a visuospatial cognitive task. Andersson (1998) et al. concluded that they observed a deterioration in the mental performance when accompanied by a demanding balance task. They stated that healthy participants swayed less when they were assigned the cognitive task but participants with vertigo/dizziness swayed more with a cognitive task. In the quest of finding answers, the literature has adopted dual task paradigms for determining the distribution of attentional sources for completing multiple tasks. Such designs are referred to as “dual task studies” where two time-sharing tasks are concurrently performed. Dual tasks provide the opportunity for studying attentional demands of either task and they allow observing the possible interference tasks. Usually, one task is a cognitive one and the other one is a motor one. The idea behind this design is that central processing capacity has a limit and it needs to be distributed among the concurrent tasks. As can be seen in Figure 1, for the attentional capacity to cope with all the tasks successfully, the capacity should be available for all the tasks.

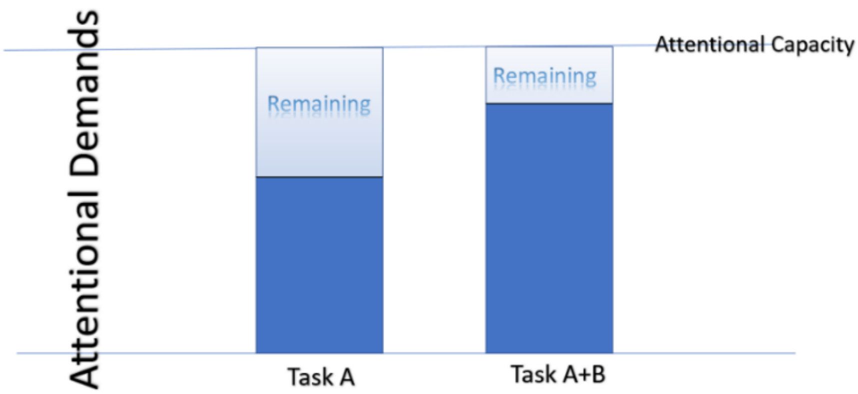

Figure 1. Central Processing Capacity

Although central processing is thought to have a capacity, there are opposing voices to it. Some claim that the capacity of attention may vary depending on the task requirements (Kahneman, 1973). Some claim that central processing does not use one limited capacity but multiple sources (Navon & Gopher, 1979). Figure 2 shows the perspective of multiple resources theory of attention. Different and non-related sources are used for the task completion and dual task interference can only occur when two tasks use the same resource (Guttentag, 1989).

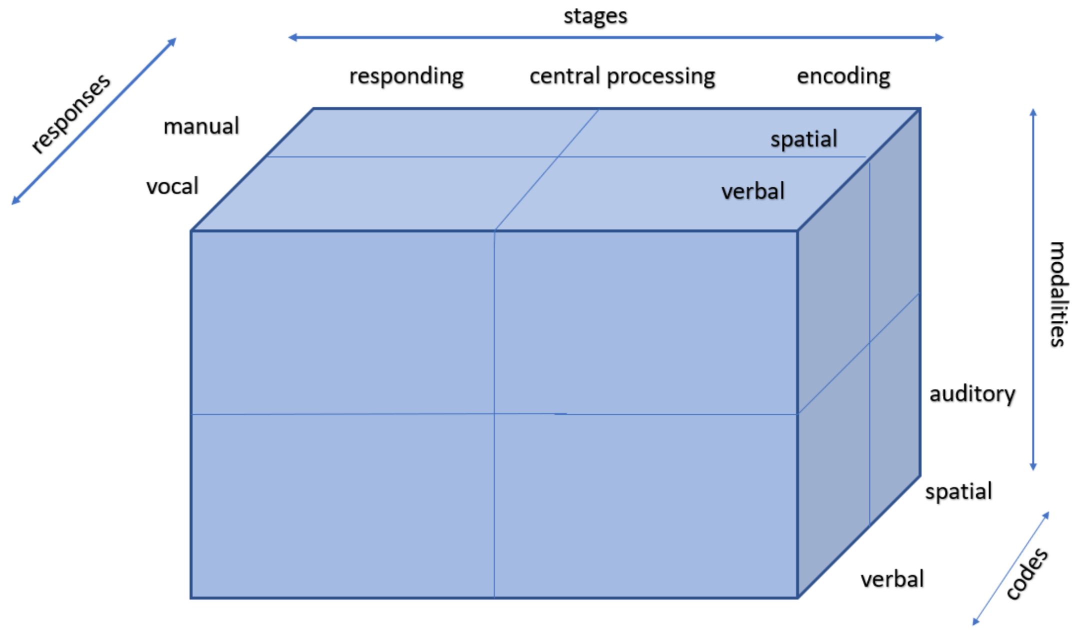

Figure 2. Multiple Resource Model (Wickens, 1992)

The literature offers different suggestions on the effect of a cognitive task on postural tasks. While some claim that focusing on an additional task enhances the control of posture, other claim it to deteriorate. It is believed that for understanding the role of attentional sources in postural control, the attentional capacities should be challenged and it can be done by increasing the difficulty of either or both tasks. In this study, instead of choosing different cognitive tasks for varying the difficulty, individualized difficulty levels in the chosen cognitive task was set with the aim of understanding whether there might be an interference between motor and cognitive tasks. It is believed that different cognitive tasks load cognitive functions in different manners and it should be preferred to use the same task but different difficulty levels.

1.2. An Introductory Look at Postural Control

Moving our legs, hands, head, eyes for a voluntary action, for communicating with other humans, making changes in the environment we live in and still keeping balance and posture is a result of a complex organization of a conversation between motor and sensory systems (Ghez and Krakauer 2000). In order to perform any activity, controlling of posture is necessary to change direction and then stabilize the body. So, what is postural control? Postural Control is defined as controlling the body's position in space for dual purposes of stability and orientation (Shumway-Cook, 162). Orientation and stability must be briefly mentioned. Postural orientation is defined as the active control of body alignment and tone with respect to gravity, support surface, visual environment and internal references (Horak, 2006). The vestibular system is responsible for the relationship with gravity, the somatosensory system is in charge of the relationship between different body segments and the visual system controls the relationship of the body with environment. Postural stability is often used interchangeably with balance. Balance can be defined as the control of center of mass (COM) over the base of support (BOS). Center of mass can be defined as the center of total body mass, which is a hypothetical point located approximately to anterior the second sacral vertabra. Base of support is the contact point with the surface of the body. In this thesis, COM will be interchangeably used with center of gravity (COG), which is the projection of COM vertically. COG can be regarded as the reflection of COM and thus it is used to do measurements related to center of mass, it is a key variable for CNS for postural control (Scholz et al. 2007). All actions of humans include an environment and most of the times a task is present. Although stability and orientation demands for each task may vary, it can be assumed that postural control affected by these two factors: environment and task. To give an example, "eating a sandwich" can be appropriate. If a person sits on a chair and eats a sandwich, the base of support is bigger than that of a person who stands to eat. The requirements for stability for both conditions are different. And if the person tries to eat a sandwich, while standing on a moving bus, the stability conditions get even more difficult. Due to the fact that our body mass is located two thirds of body height above the ground, we inherited this unstable system, which is supposed to continuously act for controlling the desired posture (Winter 1995). Now that introductory terms were mentioned, we can mention briefly what kinds of components postural control has. Firstly, the hardware of postural control is *mechanical components*, like muscles, tendons, ligaments and motor neurons to realize the necessary actions, to generalize the required amount of force and torque. For example, the COP is controlled by ankle plantar/dorsi flexors torque in sagittal plane and hip adductor/abductor torque in frontal plane (Winter 1998). The intended action is realized through the organization and coordination of all the limbs and torso, using the mechanical components. Secondly, the body needs to receive the information about the current situation in the environment and also its own position in space, the relative positioning of its own segments. All this type of information is provided by the *somatosensory components*, like vestibular, visual and proprioceptive systems (Fitzpatrick and McCloskey 1994). Thirdly, a main base, a center is needed to receive all the information from somatosensory systems, to interpret them, to make decisions and to commands the necessary parts of the body to act in a particular way. This role belongs to the Central Nervous System (CNS). It coordinates between the first two components to maintain a stable or a dynamic posture, through neural pathways- with feedback and feedforward series.

1.3. Problem Statement

The traditional view on postural control suggests it to occur automatically. However recent studies indicate opposing results to the traditional view. The load on cognitive processes seem to overwork attentional capacity, causing different effects on the execution of motor task (postural control). Polskaia and Lajoie (2016), Donker (2007), Murillo et al. (2012) and Sciadas (2016) found out that addition of cognitive task deteriorated the postural control performance, while others such as Pellecchia (2005 and 2014), Bergamin (2014) and Swan (2004, 2016) have concluded that adding a concurrent cognitive task enhances the postural control performance. One main argument in the literature is that the difficulty level of cognitive task is a determinant for investigating the effects of cognitive task on postural control. However, the difficulty level of cognitive task might vary for each individual. Therefore, it is believed that setting an individualized difficulty level for each subject is necessary for examining the interaction of motor and cognitive tasks.

1.4. Research Questions

To find the answers of abovementioned questions, the study was designed to detect the interference between motor and cognitive task. It is intended to observe the change in parameters of COP. Therefore, the research questions are:

- Are postural control parameters affected by the difficulty level of concurrent cognitive task?
- Which sway/quiet stance parameters are affected by the dual task performance?

1.5. Hypotheses

- The presentation of a difficult cognitive task performed concurrently with the postural task will result in deterioration of postural task.
- There will be a dual task interference between motor and cognitive tasks, either task’s difficulty will have an effect on the other.

1.6. Significance of the Study

The unique feature of this study is that it set a personal, individualized difficulty level for the cognitive task for each participant with the intention of ensuring the difficulty of cognitive task, instead of setting a standard level of difficulty which may not be challenging enough for every individual. The literature suggests that in order to observe the effects of cognitive task on postural task, the cognitive task needs to be difficult enough for creating a challenge. The difficulty level of cognitive task varies because of individual differences like talent, personal interests or hobbies. For this exact reason, our study intends to set a personal difficulty level for each participant and make it challenging enough to observe whether an interference occurs or not.

1.7. Limitations

This study has potential limitations. Such as:

- The participants were limited to Hacettepe University graduate or undergraduate students.
- Although no professional athlete was included in the experiment, different levels of physical activity may affect coordination abilities for Voluntary Sway condition in terms of keeping up with rhythm of metronome.

1.8. Operational Definitions

Center of Pressure (CoP, COP): The center of pressure is the projection on the ground plane of the centroid of the vertical force distribution (Cavanagh, 1978). It is usually measured on a force platform during posture or gait trials (Benda et al., 1994).

Center of Gravity (CoG, COG): The center of gravity (CoG, COG) is the point at which the total body mass can be assumed to be concentrated without altering the body's translational inertia properties (Benda et al., 1994).

Postural Control: According to Shumway-Cook and Wollacot, posture is a biomechanical alignment of body and the orientation of it in an environment. Postural control is defined as controlling the body's position in space for dual task purposes of stability and orientation (Shumway-Cook and Woollacott, 2007, p. 164). Postural control is achieved through the complex collaboration of musculoskeletal components, internal representations, adaptive mechanisms, anticipatory mechanisms, sensory strategies, individual sensory systems and neuromuscular synergies. Postural control also involves postural orientation, stability and balance by default.

Cognitive Task: In this thesis, cognition is linked to mental action, rather than being defined as a learning concept. Cognitive task is occupying attentional resources with a cognition only task in order to better understand the possible interference between motor and cognitive tasks. Cognitive tasks have great variety in the literature but for practical reasons, we keep it limited to a series of arithmetic calculation.

Sway: Sway is the flush movement of COG (Center of Gravity) while standing still. Sway is not an indicator of a weak command of balance or control. (Davidson, Madigan, Nussbaum, 2004). Rather than that, it is an inseparable part of keeping the desired posture.

CHAPTER 2

LITERATURE REVIEW

2.1. Postural Control

2.1.1. Postural Control Mechanisms

In order to understand how the postural control works, it is a must to understand the systems that work to achieve it. As the components of postural control were briefly mentioned before in Introduction Chapter, this chapter will elaborate on the roles of each one (Figure. 3) for controlling the posture.

2.1.2. Biomechanics and Musculoskeletal Components of Postural Control

Imagine the Japanese art of balancing rocks on top of each other. There is the need for perfect alignment of center of mass of all the rocks, over the base of support (the last rock that contacts the surface). This is a similar kind of imagery when it comes to biomechanics of postural control. The body is aligned in such a way that the gravitational forces cannot disturb its desired position. The gravity on earth constantly acts against human body and the human body creates an opposite but equal force to gravity for maintaining the static posture. If at some point the forces are not equal to each other then a perturbation or acceleration will occur depending on the magnitude of the force, which will result in the change of COM. The CNS constantly re-estimates the changes in COM and commands for necessary actions, optimizing internal and external forces, maintaining balance (Winter, 1998). If we are to come back to the imagery of rocks, the human body is not made up of independent, completely unattached segments like rocks; rather it is a product of coordination of many different systems, one of them being musculoskeletal system. Musculoskeletal components can be identified as the skeletal muscles, ligaments, tendons, joints, cartilages, bones etc.

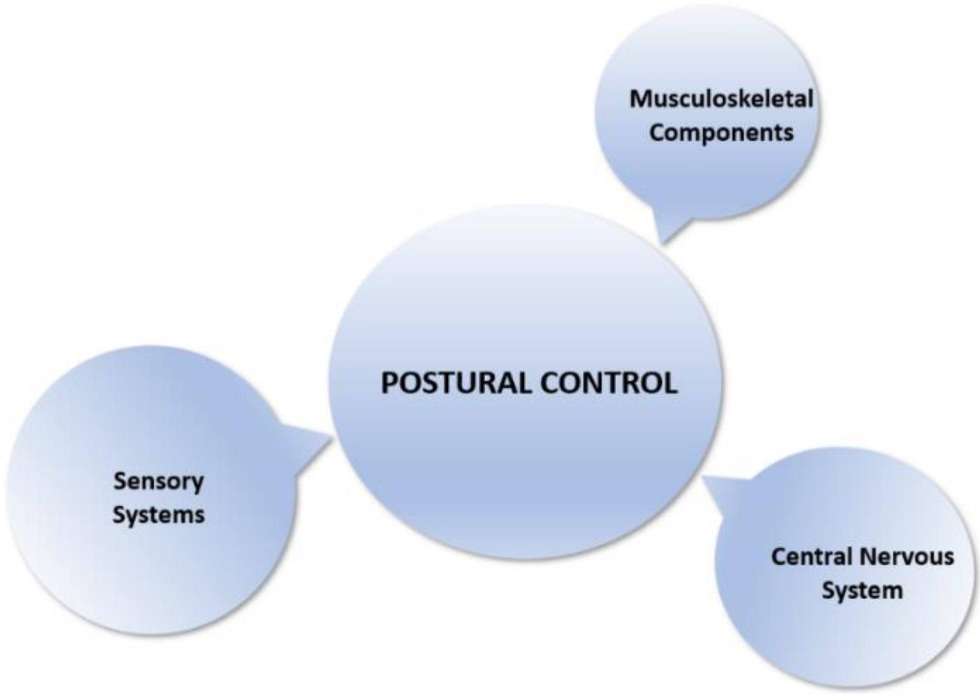

Figure 3. Postural Control Mechanisms

When the flexibility or the range of motion in joints are put together, they set up the biomechanical relationship of body segments. Like balancing the rocks on top of each other and creating an ideal alignment for an erected figure that defies gravity, a perfectly aligned posture has an ideal vertical line against the force of gravity. So, this ideal vertical line (as shown in Fig.4) crosses points in the human body laterally mastoid process, a point just in front of the shoulders, the hip joint, a point just in front of the center of the knee joints and a point just in front of ankle joints (Basmajian and Deluca, 1985).

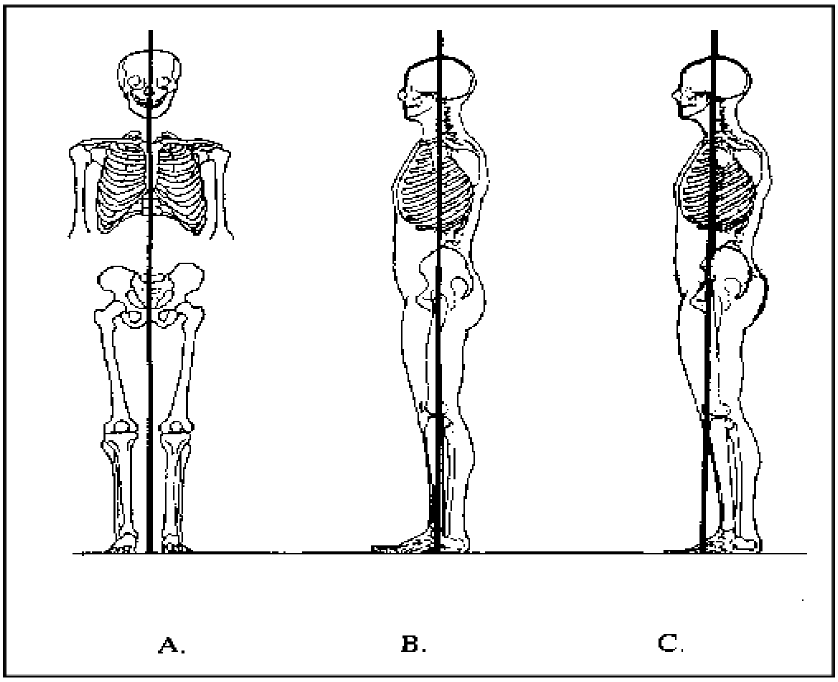

Figure 4. Ideal Alignment of Erect Posture

The tonically active muscles when standing erect are: Erector spinae, Iliopsoas, Gluteus Medius, Bicep Femoris, Gastrocnemius, Abdominals, Tensor Fascia Lattae, Tibialis Anterior and Soleus (Kendall and McCreary, 1984). The line that falls slightly in front of knee and ankle joints is controlled by Gastrocnemius and Soleus muscles. When there is a slight sway posteriorly, Tibialis Anterior is activated to maintain the posture. Gluteus Medius and Tensor Fascia Latae, Iliopsoas that is responsible for blocking the hip from hyperextension and Erector Spinae group because the line falls in front of the spinal column. These are the tonically active muscles during erect and static posture of humans. In the literature, standing erect and keeping a stable, static posture is termed as "Quiet Stance." Unlike what the term connotes, quiet stance is not very quiet for the body. Human posture has been described and perceived as an upside-down pendulum in the literature but recent research has shown that it resembles more to a two-segmented pendulum that uses different strategies to keep the erect posture (Creath et al., 2005). This so-called quiet stance is even affected by the internal processes of body, like respiration (Jeong, 1991), as the respiration rate increases body sway also increases. In quiet stance, the human body tries to fight against gravitational forces that try to change the center of mass. A good alignment of body segments is one way for fighting against these forces. However, alignment on its own is not enough to achieve that.

Muscle tone and postural tone also accompany the alignment for further corrections made. Muscle tone is a reference to the force with which the muscle resists being lengthened (Basmajian and Deluca, 1985). A neural contribution of stretch reflex is present for the muscle tone, which also resists lengthening of the muscle. Postural tone, on the other hand, is when the antigravity muscles resist against gravity when erect (Tibialis Anterior, Gastrocnemius, Soleus, Gluteus Medius, Tensor Fascia Latae, Iliopsoas and Erector Spinae). Of course, sensory inputs are present for the postural tone. Vestibular input is used when the position of head changes, and postural tone is distributed between limbs and neck. This distribution also occurs when somatosensory input from neck is sent. Soles of feet send cutaneous inputs and necessary postural tone adjustments are made, like using extensors more or flexors more in the foot. Postural tone is regarded as a low cost-activity for the body (Ivanenko & Gurfinkel, 2018).

2.1.3. Sensory Systems and Postural Control

Musculoskeletal components are not sufficient on their own when it comes to controlling the posture or in general terms of movement. The human nervous system is responsible for the preparation, execution and control of movement. The nervous system is categorized into two main parts: Central Nervous System (CNS) and Peripheral Nervous System (PNS). The CNS includes the brain and the spinal cord while the PNS is the nerves that are extensions of brain and spinal cord, like a transmitter of information to the CNS. The Peripheral Nervous System is further divided into sensory and motor divisions: The sensory division carries information from the environment to the CNS and the motor division carries commands from CNS to relevant body parts. The CNS is provided with necessary information from sensory systems for comprehending and interpreting the environment, the body's own position and location in space and the relationship between body's segments. In a healthy human body, the CNS is constantly provided with numerous and various information and each sensory receptor is sensitive to different stimuli. As the information available is numerous and various, so are the sensory receptors. The sensory receptors can be divided into 3 categories: Exteroreceptors, Interoreceptors and Proprioreceptors. Exteroceptors are responsible for the information collecting from environment, like pressure, touch, temperature, hearing, smell, taste and vision. Interoreceptors are responsible for collecting information about the internal environment of the body, like hunger. Proprioceptors are responsible for collecting information about body's position in space and the relationship between parts of body, by spotting the changes in muscle tension and joint position. Proprioception literally means "sense of self" ("own" in Latin: "Proprius") which implies the group of sensory modalities that enable us to understand positions of our bodies' limbs in space and also to detect/assess the magnitudes of movements and forces without the need of vision (Macefield, 2009). After this brief introduction to the CNS and PNS, we can proceed to the relationship of sensory systems, CNS and postural control. The sensory sources of information for Postural Control can be defined as the *visual system, somatosensory system and vestibular system*. As with other types of sensory information, the information from these systems are integrated and interpreted in the CNS to comprehend and interpret the environment. As the environment changes, the comprehension and interpretation of all the data are re-evaluated and re-organized. The environmental constraints and demands of a task constantly affect the information sent to CNS and CNS is kept updated about these changes. The sensory systems provide the CNS with information about the position of head (vestibular system), the environment (visual system) and also a reference for position of body (somatosensory systems).

As mentioned above, humans depend on visual, proprioceptive and somatosensory information but the contribution of these sources may vary according to internal or external conditions (Peterka, 2002). Peterka investigated the use of somatosensory and vestibular systems for postural control (balance and orientation) with subjects who are blindfolded by excluding vision. The subjects were young healthy adults and also adults with vestibular loss. Subjects' sway was measured as they stood on a tilting platform. The platform was moving with a random magnitude of up to 8 degrees. For young healthy adults, the movement of the platform and their sway were similar when amplitude was as low as 2 degrees, which means that they kept their balance and orientation stable even when the platform was moving. On the other hand, when amplitude was larger than that, the healthy participants could still keep the vertical posture and minimize the sway. However, when it comes to participants who are blindfolded and have loss of vestibular function, the results suggest that the low magnitude move of platform did not affect their balance, but large magnitude moves of the platform caused loss of balance in subjects with loss of vestibular function. It is concluded that healthy adults under low magnitude condition relied on their somatosensory information but higher magnitude conditions required use of vestibular system more than somatosensory system. On the other hand, for the participants with vestibular loss, it is concluded that they also relied on their somatosensory systems in low magnitude condition but when platform was moving with a higher magnitude they could not rely on their vestibular system. Therefore, they lost their balance. In other words, in subjects with loss of vestibular function, visual and vestibular systems' absence in larger magnitude platform resulted in imbalance. This study by Peterka shows how the CNS uses the sensory information, re-weighing the distribution of sources at all times to achieve the control of posture. For keeping the Postural Control, the CNS receives these numerous and various inputs from all these systems and puts them together to comprehend the body's current position. But the use of these information changes according to what the postural task is. Therefore, quiet stance and a perturbed stance and their relationship with the CNS are handled in two separate sections in this thesis.

2.1.4. Central Nervous System and Postural Control

The Central Nervous System creates a picture of the body in the context of environment by using numerous sensory data (Horak and Macpherson 1996). To be exact, there are sets of sensory systems that provide all the feedback: the visual system, the vestibular system and the somatosensory system. The information available to the CNS is then integrated together and interpreted for the task. The result of this process can decide what the body's position is, what the relationship of its segments with each other is and what the relationship of the body with external surroundings is. Also, when an external factor (like the environment) or an internal factor (like body itself, due to an injury or a disease) changes, the CNS reassesses the current situation and reweighs the sensory systems to act accordingly. But the requirements for each condition are to be analyzed separately since they all require the CNS to act differently. Here, the sections provided are the CNS and quiet stance, perturbed quiet stance and perturbances.

2.1.4.1. Role of Central Nervous System in Quiet Stance

Central Nervous System receives many types of information from many different sources and organizes them in such a way that postural control (any many other motor tasks are) is achieved without us realizing it. But what kind of sources provide what kind of information to CNS? First one is the visual system. Humans depend on the visual information in their daily tasks, although it is not essential for most of the tasks, it is a good information provider. The same goes for its role in postural control: it is not absolutely necessary, but it provides sensory information for balance. Researchers attempted understanding the exact role of vision in postural control and in 1975, Lee and Lishman (Lee and Lishman 1975) designed a room whose floor was fixed but the walls could move forward or backward without subjects knowing it. This moving created the illusion of swaying in subjects. In their study, in all the conditions that the room was not stationary, their sway was more than when the room was stable. Visual proprioception increased balance in all the conditions and visual proprioception was more useful than vestibular and ankle-foot proprioceptive system. The manipulation of visual system was so powerful that Lee and Lishman called the subjects “visual puppets” meaning they are easily manipulated by a change in visual input. Other than vision, CNS uses inputs from somatosensory systems. These systems are concerned with the perceiving of touch, movement, vibration, temperature, pressure etc. and these information pieces come from muscles, skin, fascia and joints. Somatosensory information from all over provide the CNS with necessary data required for postural control and also orientation of body in space.

Jeka and Lackner (1994) studied the effect of light finger touch when standing still. Subjects were under open eyes or closed eyes condition. They touched a rigid metal bar with a light contact, with a higher pressure contact and for the third condition they had no contact. The light touch contact was as effective as higher pressure contact when it came to reducing body sway when compared to no contact and eyes closed condition. High pressure finger touch was acting like a counter-balance element for body sway. Also, they realized the delay of time between body sway and light finger touch was larger which suggests fingertip provides information allowing anticipatory mechanisms to reduce the sway. The forces produced by far-away muscles (far away from fingertips, like trunk and legs) were guided with the sensory information given by cutaneous receptors of fingertips and the proprioceptive information given by the position of arm. As many data as possible are sent to CNS to provide the most accurate perception of the current, updated situation. Last but not least, contribution for postural control is from vestibular system, which is both a sensory and a motor system. As sensory system it provides information to CNS to divide the position and movement of body and also the environment. It supplies CNS with position of head, with respect to gravity and other forces like moving fast in a car. All the information is interpreted together with the other systems to draw a clear picture of the moment.

2.1.4.2. Role of Central Nervous System in Perturbed Quiet Stance

Central nervous system controls the actions to be made when the stance is disturbed by an external force. Direction or the magnitude of perturbance play a key factor in choosing the strategy for restoring the balance. Ankle strategy is one of the first patterns to be identified when controlling the sway in A-P direction. In short it can be defined as the strategy used where the COM is kept stable when perturbed. It is preferred when the perturbation is low and slow. Nashner et al. (1988) suggested that the ankle strategy is used to exert torque about the ankle, while the hip strategy is used when torque about the ankle is not sufficient for making the necessary corrections, causing the person to depend on the shear force generated by the hip for restoring equilibrium. Also, if the perturbation is on mediolateral direction, the ankle’s limited range of motion transfers the mission of regaining balance to hip joint since its range of motion is wider than the ankle. So hip strategy is seen when either the perturbation or its amplitude is large, or it is seen when the direction of perturbation requires a medial/lateral movement. On the other hand, the stepping strategy occurs when the ankle and hip strategies are insufficient for regaining balance or the center of mass suddenly moves away from base of support. The alignment is achieved by placing center of mass over the base of support through these commonly used strategies. Since the environment we live in is not a stationary and predictable one, conditions change all the time and unexpected perturbations can be observed at all times. Adapting to the environment, postural control is achieved under easy and difficult conditions in daily life or sports/exercise context. The central nervous system puts all the necessary information together to interpret the current situation as in quiet stance, but this time for recovering balance from a perturbation. Generally speaking, from the literature it can be said that the fastest information is retrieved from somatosensory system. Vision and vestibular system hands over information in a relatively slower fashion while somatosensory inputs are processed very rapidly. Dietz et al. (1991) detected that vestibular system’s contribution is smaller than the contribution of somatosensory systems with an experiment. Muscles responses were recorded in terms of onset latency and amplitude under two different conditions: first one was on a forward-backward moving support surface (for the stimulation of somatosensory systems) and the second condition was the manipulation of 2kg load, attached to head (for the stimulation of vestibular system). As seen from the results of this experiment, somatosensory system's input caused a 10 times faster response than that of vestibular system, which suggests that the latter plays a more minor role.

2.2. Attention & Postural Control

It is believed that, within this triangle of postural control, motor task and cognitive task, there is an invisible member that deserves scrutiny: Attention. Throughout the history there have been different views on the nature of attention that claimed different ways of defining it. As implied by James (1890) it can be interpreted as "what we are aware of any given time." Being conscious and being unconscious seem to be a key factor in defining the term. When information is processed, some info is processed consciously and some unconsciously. Therefore, we can infer that there are tasks which we need to pay attention to and there are some that do not require that much of attention. Or is that really the case?

2.2.1. Brief Theory on Attention

If we want to examine how chronologically attention was handled, we can see that researchers and scientists speculated on how attention is achieved and what its nature is. Some brief explanation of these theories is a must before we proceed. Broadbent (1958) claimed that attention is "all or nothing" meaning it is *not* selective. The stimuli are not selected or analyzed for meaning. Treisman's model (1960) on the other hand is slightly different than that of Broadbent. Treisman claims that stimuli to be attended are selected and semantically analyzed. The 1963 model of Deutsch and Deutsch suggests that all stimuli are filtered to be paid attention or not, then they are grouped or segregated to be attended. According to these categories, the more important stimuli are paid more importance. These were all bottleneck theories where some information can "pass" through the control point and some cannot. They are regarded as early theories of attention. Keele's Late filter theory claims (1978) that information processing is parallel and does not require attention during the stimulus identification and response selection stages. Selective attention determines which stimuli are in contact with memory and which ones will receive processing. Other than filter theories, there are some who claimed that there is a fixed capacity for attention. The capacity is used according to the task requirements. Kahneman (1973) suggests capacity for attention changes as the task changes. If two task requirements increase simultaneously and exceed maximum capacity, decrements occur in one or more of the tasks. Other theories (Norman and Bobrow, 1975; Posner and Synder, 1975; Navon and Gopher, 1979) on the other hand, suggest that parallel processing is possible and probably the relative importance of tasks decide the trade-off between two simultaneous tasks. The most recent view on the attention is presented since 1980s. Selection for action approach of Allport (Allport, 1985) is a goal-directed, action-oriented view on selection, implying that the attentional mechanisms are arranged with the intention of completing the tasks presented to the subject. Allport wrote that (Visual Attention, 1989, Allport)

> The primary purpose of an attentional system must be to ensure the coherence of behavior under these often-conflicting constraints. Coherent, goal-directed behavior requires processes of selective priority assignment and coordination at many different levels (motivational, cognitive, motor, sensory). Together this set of selective and coordinative processes can be said to make up the effective attentional engagement (or attentional set) of an organism at any moment.

Interpreting Allport's article, unlike the traditional view, when we perform two concurrent tasks at the same time, we organize and coordinate in many levels to complete a set of tasks. For the very reason why this conflict of views occurs, we need to tackle attention and postural control together and understand their interaction. This is the reason we need to examine the two concepts together.

2.2.2. Attention and Postural Control

Postural control can be categorized under 3 contexts of movement (Blanchard et al. 2005). First one being the *static maintenance of a posture*, second one being *a dynamic one* like voluntarily changing posture and the last one being the result of *a reaction to an unexpected situation*. During stationary stance, the posture is controlled by the closed-loop feedback (Woolacoott-Cook, 1985) and that depends on visual and proprioceptive systems. On the other hand, non-stationary postural tasks seem to be handled by the open-loop system (feedforward) which indicates an assumption of possible perturbances (Massion, 1992). This kind of approach to postural control implies that it is reflexive and automatic and reflects the traditional view. Traditional views claim that because of its automatic nature, posture does not require attention and therefore there is no need for a cognitive activity.

But the study by Woollacoot-Cook claims the other way around (Woollacoot-Cook, 2000). In the study that both older and younger subjects participated, it became evident that with proceeding age with history of falls, if sensory information available is decreased, the attentional needs for keeping the posture increased. In fact, not being able to assign desired amount of attention might cause the failure of postural control, which can cause falls in the Elderly. Older adults with healthy background were affected in their sway when their visual and somatosensory information sources were removed. Woollacott and Cook claim (Woollacott-Cook, 2002) that "The attentional demands of balance control vary depending on the complexity of the task and the type of secondary task being performed." This meaning that when a postural task and a secondary task are performed together, there can be an exceed of limit in the attentional capacity. On the other hand, the results of studies can be interpreted in different ways. When one of the assigned tasks fail or is incomplete, this might mean one of the tasks is sacrificed. The nervous system slows down the information processing of the "non-prioritized" task, which results in its delayed or impaired execution. Then after all, attentional requirements of postural control are not nonexistent, unlike how traditionally was assumed. This brings us to the question of what the nature of attention is. Is it like a cup with a limited container that overflows when filled? Can it be fully occupied? Can attention be divided among many tasks and if so, how many tasks of what kind? We will try to explore the answers to these questions by examining researches that tackle postural control with an addition of a concurrent cognitive task.

2.3. Dual Task and Dual Task Interference in Potural Control

In order to understand the role of attention in postural control, dual task methodology has been used to compare the performance with a single-task design. In many research designs, besides the postural task, an added cognitive task is presented to the subjects to understand the extent of effect of cognitive load on attentional needs of postural control. Such dual task designs provide evidence that the two concurrent tasks might cause an interference, which might mean simultaneous execution of two tasks may result in the deteriorated performance of at least one of the tasks. Not only deterioration but a complete failure of one of the tasks is also a possibility. This concept is the definition of "Dual Task Interference". But as mentioned above, does not this conflict in a way with the recent ideas that Allport brought to the area? If we can organize and coordinate for a coherent pattern of movement/task completion, why should dual task interference occur? Allport answers to these questions in his Visual Attention (1989) work:

> Every goal-directed action has a range of conditions needed for its successful execution. When the conditions for two or more intended actions conflict, then one or both must be modified sufficiently to enable their continued execution. Failing that, one activity must be given priority while the other is postponed or abandoned.

Similarly, Neumann tackled the same issue of attention with an action-oriented point of view in his work (Neumann, 1987) claiming that when two seemingly independent actions are executed simultaneously, they are processed as one unit of task in action planning. When we fail in completing two actions together, this might be the fault of insufficient coordination of the tasks, which are expected to be categorized later as a single unit of action. On the other hand, if the difficulty level of one of the components (of tasks) is manipulated, it can only deteriorate the execution only if the whole action planning is affected. In other words, if the general action planning is not threatened by the new difficulty level, the performance will remain unchanged, unaffected. One of the questions that we remain with is whether anticipatory changes in one of the tasks (say, postural control) occur when we plan two/or more actions (say, cognitive task) to be performed simultaneously. Quoting Neumann, can we define and detect the relationship between increased difficulty level of cognitive task and changes in postural control? As addressed before, when humans are presented with two simultaneous tasks, the presence of one task might affect the execution of the other. This effect can be an increase of performance quality in one or both tasks, and it also can be a decrease or a failure of at least one of the tasks. The studies indicating deterioration or enhancement of postural control are presented below.

2.3.1. Interference in Postural Task Under Dual Task Conditions

The study by Szturm (Szturm, 2013) investigated the cognitive and motor task demands on gait, balance and cognition on young healthy adults. They investigated whether divided attention affects locomotor rhythm, stability, and cognitive performance. The young participants (N=20) did a visuo-spatial cognitive task in sitting and while treadmill walking at 2 different kinds of speeds: 0.7 and 1.0 m/s. Cognitive load did not have a significant effect on gate variable of COP but variation of gait variables were higher during dual-task walking. Treadmill speed had a significant effect on temporal gait variables and ML-COP excursion. Divided attention when walking at a constant speed resulted in decreased performance of a visuo-spatial cognitive task and an increased variability in locomotor rhythm.

2001 study by Hove (Hove, 2001), investigated whether postural control positively affects cognitive performance and visual perception. The multisensory perceptual stimulation is regarded as required for postural control and it might use the central processing capacity. Researchers argue that there might be functional relations between body motion and visual performance and controlled changes in sway could be used to facilitate the performance of visual tasks. They examined the sway during performance of visual and cognitive tasks (visual task was to detect a signal where critical signals were identified and the cognitive task was mental arithmetic). Both tasks had the same difficulty level according to NASA task load index, which is a measure of mental workload. As seen from the results, postural sway was reduced in the visual condition but not in arithmetic condition. Sway was influenced by the demands of signal detection and not by overall processing load. The following study by Bergamin et al. (2014) examined dual task conditions by using various secondary task types. They adopted the cognitive tasks of Spatial-memory brooks test (SMBT), Counting backwards aloud test (CBAT) and Mental arithmetic task (MAT). Different types of secondary tasks were chosen because of their different visual, verbal and cognitive load, respectively.

Bergamin (Bergamin, 2014) examined adults and older adults during their sway when the sway was accompanied by different types of task. They created a dual-task environment for each subject group and observed the changes in their sway. 15 males and 15 females (18-24yrs old) and 15 males and 15 females (64> yrs old) participated. At the beginning, they all stood still in an upright position on a stabilometric platform with their eyes open and feet together. This was the single task condition. For the dual task condition, participants were assigned three different cognitive tasks, which were presented auditorily. The duration of the secondary tasks was 30 seconds. The cognitive tasks were: Spatial-memory brooks test (SMBT), Counting backwards aloud test (CBAT) and Mental arithmetic task (MAT). The verbal assignment (CBAT) sparked higher request for postural adaptation regardless of age. They also concluded that even though the sway increases with age, there was no interaction between the age and the type of secondary task. The magnitude of difference between old and young adults was not significant. Results indicated that the verbal secondary task influenced the postural balance the most. The increase in respiration frequency increased the center of pressure length. It still remains unclear though, whether it stems from the counting backwards or verbally being included in the task caused this change (increase) in COP Velocity and SA (sway area). SMBT and MAT conditions scored better performances (decrease in COP velocity and sway area) in antero-posterior and medio-lateral sways. Dual task conditions affect the participants' balance variables differently independent of their age as observed in their COP velocity and sway area. The study concluded that verbal task of counting backward aloud was the most influential on COP velocity and sway area, the dual task conditions have different effects on the postural task, independently of age. They concluded that CBAT caused an increase on parameters while MAT and SMBT caused a decrease, suggesting to further investigate the influence of secondary task choices under dual task designs.

Study by Ceyte (Ceyte, 2014) suggests that in classical terms maintaining postural control and completing a cognitive task together should use the "limited capacity of attention" and therefore either one or both are impaired. 71 young adults participated in their study. The task was to maintain the upright stance as stable as possible. They combined three visual conditions: Vision, no vision and moving visual surround with two support conditions: fixed or moving support surface. Vision condition required participants to look straight ahead at a picture. They also made some calculations. They repeated the number that was told out loud before subtracting backward by 3 or 13 and also they were told to complete this cognitive task as quickly and accurately as possible to provide some sort of distraction. At the end of each trial, they were asked what the result was to verify that the task was carried out. In the study, the main quest was to figure out whether sensory contacts that were established with the environment have influence on balance control during a calculation task (cognitive task). According to the results, adding a calculation task while standing increased the body sway compared to simple quiet stance. In the single condition with open eyes, the participants were told to look at a picture and therefore they fixed their gaze in the environment. Regardless of its difficulty level, the body sway did not change depending on the calculation activity. Doing a cognitive task did not require any contact with the environment. And therefore, visual attention could be reoriented from external landmarks to internal visual images of the cognitive task and this implies that the visual anchorage required to control balance is impaired. According to the literature, old people tend to prioritize the postural task when there is also a cognitive task to be completed. Meanwhile, as shown in this current study, younger people as in the experiment, tend to prioritize the cognitive task rather than the postural one. And lastly, the main result of the current study suggests that when a calculation task that requires no visual contact with environment explains the increase in body sway. We need to further study the sensory contacts and postural control relationship and try to explain better under what conditions postural and suprapostural tasks exist together without interfering with each other.

The study by Teasdale et al. (2001) studied whether postural adjustment requires cognitive processing and balance. Eight young and nine older adults attended the study. An auditory reaction time test was done while sitting and afterwards standing with feet together on a force plate where their COP was examined (for sway rate). Reaction time was tested under these four conditions: vision+normal surface, no vision+normal surface and vision+foam surface and no vision+foam surface. The results indicated that for both groups the reaction time slowed down as the complexity of the postural control increased (no vision, standing and foam surface). When there is no vision however in older adults, their reaction time delayed even more than that of younger participants which indicates that older individuals rely more on the sensory information provided from the environment. The conclusion is that when there is less sensory information available, then more attentional capacity is needed for a proper postural control.

A study by Lajoie and Teasdale et. al (1996) examined whether attentional requirements for maintaining the upright posture and walking in older adults change through normal aging. An auditory reaction task was given to 8 young and 8 older adults in seated position and upright position and when walking. The upright standing position was in a broad or narrow support. The lesser the base of support, the more time it required for the elderly to complete the reaction time task (RTT). Walking and completing the RTT modified the speed of the elderly to a slower pace than that of young participants, admitting to have been done for a securer gait. It is observed that even when the pace is slowed down, this did not change the fact that their reaction time was slower than the young participants. We can conclude that normal aging brings a greater need of attention for meeting the demands of postural tasks.

2.3.2. Facilitation of Postural Control Under Dual Task Conditions

The study by Patel et al. (2014) looked whether the type of cognitive task and walking speed has an effect on cognitive-motor interference during dual task walking. Fifteen healthy adults participated in the study. Visuomotor reaction time task, word list generation task, serial subtraction task, and the Stroop task while sitting and during walking at preferred-speed and slow-speed. Gait speed was recorded to determine effect on walking. Motor and cognitive costs were measured. At preferred speed, motor task cost was the lowest in visuomotor reaction time task and highest in stroop task. And on the contrary, at slow speed, visuomotor task had the highest cost and stroop task had the lowest. Slow walking gave the result of an increase in motor cost and decrease in cognitive cost for stroop task. Complexity of cognitive task, therefore, affects the cognitive cost of a task. The preferred speed for individuals make the subjects prioritize complex cognitive tasks because they require higher attentional demand and processing resources over walking. When performing visuomotor task, subjects preferred more complex walking because it has a less motor task and greater cognitive cost. We can infer that walking at a slow pace enables individuals to divert more attention for complex tasks and also it improves performance while walking.

Vuillerme and Vincent (2006) looked whether a cognitive task would affect the foot pressure displacements during bipedal quiet standing. Since there are many divergent results of studies about the postural control and how it is affected by a concurrent cognitive task, they took a careful look at the procedures of studies in the literature and concluded that the design of such experiments should be carefully thought to be cleared by other possible intrusive elements. Vocal articulation, manual responses or visual fixation are seen as elements that might impair balance measurements during data collection. They included 13 young adults to perform an easy and a difficult calculation task during bipedal quiet standing. There was also a control condition requiring no concurrent task. COP displacement were processed along the experiment. They stood barefoot on a force platform with their natural position. Their COP displacements were measured. They listened to a 52-second audio recording presenting an arithmetic problem in single digit numbers like add 7 plus2; subtract 3 etc. Easy one consisted of 13 steps and digits were presented every 4 seconds, and difficult one had 26 steps presenting digits in 2 seconds. Each trial had different series of numbers. The mental task started 10 seconds before the 32-second data collection and ended 10 seconds after it. They did it in order to ensure that participants continue to effectively perform the task. They were told to stay silent and reply at the end of the trial what the result was. If the correct result is not found, then the data were not taken into consideration because it would mean that they actually failed in completing the cognitive task for the sake of postural control. According to the results, AP directioned COP displacements decreased when participants performed the most difficult mental arithmetic test. Contrary to some part of the literature the results indicate that postural control increased with focusing on the other task, the cognitive task. It may be the proper use of difficulty level, meaning in this case: difficult. The present experiment claims that when performing a difficult mental arithmetic task concurrent with keeping the posture actually enhances postural control.

Andersson et al. (2002) examined the effects of balance task, where the posture was perturbed while performing a silent mental arithmetic task (backwards counting). Secondly, they investigated the effect of mental task on balance. The number of subjects was 30 adults (mean age=27.4) in Experiment 1; the number of subjects was 20 adults (mean age=30.1) in Experiment 2. The postural task was to maintain balance and the cognitive task was to count silently backwards in seven steps as fast and accurately as possible, beginning from randomly selected numbers for the duration of 20 seconds. The balance was perturbed by vibrators attached to the gastrocnemius muscle. The four conditions were: standing on a (force) platform; standing on a platform and simultaneously counting backwards; standing on a platform with calf stimulation only; standing on a platform with calf stimulation and simultaneously counting backwards. The experiment 1 was these four conditions while in the Experiment 2, the subjects were told to direct their attention towards their balance when they were not completing the mental task. Results of AP-direction torque variance indicated that in Experiment 1, subjects swayed less when doing the mental task. The effect of vibration was evident in both with and without the mental task conditions, resulting in more sway when stimulated with vibration. In the Experiment 2, no significant differences were found between with and without mental task conditions, again the effect of vibration being evident in both conditions. It is concluded that controlling the body sway and cognitive functions are not results of two independent systems, supporting the principle “Posture first.”

Lastly, Swan et al. (2004) addressed the conflicting results & interpretations of secondary cognitive tasks’ effect on postural control and they wanted to examine the changes in balance when a cognitive task is presented. The participants (young and older ones) were asked to stay as still as possible on a force platform and their sway was measured while they were trying to complete the Brooks’ spatial or non-spatial memory task. Each trial was 20 seconds. There were four balancing conditions: Eyes Open+Fixed force plate, Eyes Closed+Fixed force plate, Eyes Closed+Force plate Sway-referenced and Eyes Open+Force plate Sway referenced. The sway referenced means that the force plate could tilt anterio-posteriorly according to the participant’s sway, unlike the fixed and immovable condition of the force plate. The force plate could not move in medio-lateral direction and that is the reason why they could not include this plane of motion in the study. They claim that most of the sway occurs in anterio-posterior direction anyways, and it is not a problem causing issue for the study. The eyes closed condition was to blindfold the eyes of participants. The cognitive task preferred was Brooks' spatial and non-spatial test. According to the results, spatial and non-spatial memory tasks of Brooks improved the balance in older adults under the most difficult balancing task. They suggest that lessening of CoP displacements is the result of external focus of attention, therefore indicating more automatic control the posture.

2.4. Cognitive Function and Postural Control

Among the factors affecting postural control, the relationship between the cognitive function and postural control is dependent on other elements like aging and different types of cognitive tests. Therefore, these two concepts are discussed below.

2.4.1. Cognitive Function and Aging

The quiet stance is an everyday postural task and is very often accompanied by cognitive tasks of all kinds; like reading on a tram, paying for something and getting the change back, holding a conversation, looking for the keys in a bag. The attentional resources required for these two combined tasks (quiet standing and an additional cognitive task) are considered quite low in healthy adult humans (Lajoie, 1993) but this case can change when older adults perform the same combination of tasks. The postural and cognitive tasks which are performed simultaneously have been reported to be affected by aging of sensorimotor systems, due to the decreased control of balance (Horak, 1989).

The study by Bernard-Demanze et al. (2009) investigated thoroughly the effects of age and dual-tasking by loading subjects with low and high cognitive demand tasks accompanied by postural performance, under static and dynamic conditions. The participants were 12 older healthy adults (Mean Age=75.6), 10 healthy middle-aged adults (Mean Age=40.7) and 8 healthy younger subjects (Mean Age=28.0). Subjects were tested under two conditions: single postural task condition and dual task conditions, which included a cognitive task performed simultaneously with the postural task. In the dual-task conditions, the postural task was either static or dynamic. Static condition was to stand quietly, and the dynamic condition was maintaining balance on a moving platform. The cognitive task either a low-demand one (mental arithmetic task-MA) or a high-demand one (spatial memory task-ST). The arithmetic task was based on single digit calculations selected randomly and the spatial memory task was based on a 2D spatial task where subjects completed a multi-step translation on a 3x3 cell grid, starting in the center of the cells, following verbal commands to remember the new location on the grid. None of the cognitive tasks allowed talking to avoid destabilizing effects of articulatory processes. The study showed that postural tasks' performance in relatively easier conditions for quiet standing without cognitive task is age-independent. On the other hand, dual task conditions (with a cognitive task, be it mental arithmetic or spatial memory task) improved postural control in younger and middle-aged subjects but decreased in older subjects. Also, dual task conditions' effects were dependent on the cognitive task complexity in younger and older subjects, with greater impact under spatial memory task than mental arithmetic task.

Maylor and Wing (2001) investigated whether postural stability is controlled automatically or not in younger and older adults. The research question was whether cognitive activity is important for the stability or is the instability related to aging, rather than the nature of cognition? In their study 70 participants took part, ages ranging from 20 to 79. They were required to stand as still as they can on a force platform while performing either no cognitive task, a spatial memory task or a nonspatial memory task. The standing still was coded as postural control task. The participants performed the cognitive tasks in a seated position to compare with the postural task condition. Results reported that cognitive tasks (memory recall) decreased in performance as age increased regardless of the body position. Whether they stood up or sat down did not change the memory recall test (cognitive activity) results. Also, the stability of participants declined as age increased. The instability was more when nonspatial task was performed. Overall the results suggest that cognitive tasks can affect postural control in composite manners, the effect may depend on the age or the type of cognitive task. Deteriorations in sensorimotor and cognitive functions with older age is a general agreement and these may be the explanation of why postural control also becomes more challenging in older people. Unlike the younger subjects of this study, older subjects showed a decreased performance when postural task difficulty was increased. For older subjects it was more difficult to maintain equilibrium on a moving platform, while under quiet stance condition their postural control strategies were similar to those of younger and middle-aged subjects. So, if dual task conditions and more difficult postural tasks disturb postural control, it can be concluded that attentional demands for postural control increases under certain conditions for older adults to avoid loss of balance. But how does sensory reintegration play a role in this change?

Teasdale and Simoneau (2001) investigated the effects of aging on sensory integration within the context of attentional demands. Young and older adults were asked to keep their static upright position as they stand on a force platform. The visual and proprioceptive information were removed and abruptly reinserted. Their reaction time (RT) was recorded also with their vocal reaction to an unpredictable audio stimulus. For the study, the reaction time was an indicator of attentional demands crucial for postural system. 80 older (mean age=68.0) and 80 younger subjects (mean age=24.8) participated in the experiment. A force platform was sued to watch the center of foot pressure (CP). The blocking of ankle proprioception was done by means of vibratory stimulation. Vibrators were a fixed on the tendons of Tibialis Anterior and Soleus muscles and this condition is referred to as perturbed proprioception condition. Also, subjects were wearing headphones and translucid liquid-crystal goggles the entire time and their eyes we open at all times. The computer-controlled goggles could manipulate the subject’s vision by changing opacity. The audio stimuli were sent through the headphones and their reaction time was recorded through the microphone attached to the headphones. As for the postural tasks, sitting and standing upright were the two conditions. The main task of the experiment was to maintain an upright or standing posture. The secondary task was reacting vocally to an audio stimulus as rapidly as possible. Subjects knew that the primary and the most important task was the primary task. For no vision condition, the older subjects exhibited greater CP increase compared to younger adults. On the other hand, with vision condition showed that the older subjects showed an increased speed in CP but this was not statically significant. The attentional demands of the experiment were observed through reaction time. Older subjects were slower in reacting than the younger subjects and analysis showed that reaction time was faster in all seated conditions. It is concluded that postural task was not automatic for both groups and it requires certain amount of cognitive resources available. Analysis of RT for switching sensory input conditions showed that reaction times were no different than no vision condition. Results were clear that under vision and no vision conditions, the faster CP speed in older subjects indicates problem with calibration the postural set. Even though the sensory context was enriched, their behaviour was not more stable than other conditions. Also, results drawn from reaction time data show that postural control requires attention for both age groups. So, what kind of changes cause these alterations in postural control as we age? As mentioned before in previous chapters, postural control is made possible through musculoskeletal, sensory and neuromuscular systems, which are subject to deterioration as years pass by. The muscle strength, the amount of force a muscle produces, decreases with age and it can be reduced to 40% from year of 30 to 80 (Aniansson, 1986). The muscle endurance, capacity of the muscle to contract continuously at submaximal level, is no different than strength. As muscle cells die, they are replaced with connective tissue and fat (Woollacott-Cook, 229). From the perspective of daily life, an old woman barely has the necessary quadriceps strength to get off the chair (Young, 1986). Another source of problem is the loss of available range of motion. Diseases, the toll that working life may take on our bodies and lack of optimum amount of physical activity cause decrease in range of motion of spine and other joints. This decrease in spinal flexibility and range of motion can lead to stooped posture (Katzman, 2007).

According to the 1987 study of Einkauf, spinal flexibility exhibits the greatest decline as we age when compared to other joints in body and the spinal extension is again the greatest loss with 50% less extensor flexibility. Other than spine, Vandervoort (1992) found out that ankle flexibility also declines by 50% in women and 35% in men. Conditions like arthritis may also cause a decrease in ROM, among other diseases and health condition changes. Other than musculoskeletal changes, older people face changes in neuromuscular system that contribute to coordination for postural control.

Toupet et al. (1992) found out that sway in quiet stance increases as we age, actually each decade that passes. Also, neurologic disorders cause increase in sway, which implies loss of stability that may end up in higher risk of falls. Sensory systems affected by age also affects postural control. Tactile sensitivity decreases (Kalisch, 2009), and reduced joint sensitivity causes increased sway. Functions of visual system also deteriorates with age due to the structural changes of the eye. Rosenhall and Rubin (1975) stated that 40% of vestibular hair and nerve cells are lost by the age of 70. Since vestibular system is a reference system for visual and somatosensory systems to compare and calibrate themselves, it can be said that it plays a crucial role in postural control, especially in balance control. All these summarized, very brief reasons can explain why age can be an important factor for postural control. Structural, neural and sensory changes in the body hinders the control of posture, which may lead to falls in the elderly.

2.4.2. Cognitive Test Type

In the experiments in the literature, the postural control tasks are often accompanied by additional tasks when the aim is to understand how the postural control is related to attention and cognitive functioning. Since Multiple Resources Theory suggests that cognitive load is held by many different resources, what kind of cognitive load is presented might have a significant effect on the dual task studies. Maylor and Wing (2001) explored how the difficulty and type of the cognitive task affects the postural control. They included young and older adults to observe the effect of age as well. A digit generating task, Brook's test, backwards digit recall, silent counting and out loud counting by 3 backwards were the 5 different cognitive tasks. Young adults performed better in all cognitive tests except the silent counting one, having shown to be more stable than the older participants in all cognitive tasks. Age related deteriorations in performance were the most obvious in Brook's test and in backward digit recall test, which is known to use also the visuo-spatial memory as the Brook's test. As a conclusion, the visuo-spatial working memory is thought to be closely related to postural control since vision provides a crucial important amount of sensory information.

CHAPTER 3

METHOD

3.1. Subjects

20 voluntary participants took place in the experiment as listed below in Table 1 (Mean Age: 23.57 SD=3.01; Mean Height: 171.12; SD=9.36; Mean Weight:71.12 SD=13.62). All the participants were undergraduate or graduate students of Hacettepe University. Athletes were not included in the experiment for being able to control the unpredictable effects of sports on the motor task. An age limit of 20-30 was set in order to avoid effect of age on cognition. 10 males and 10 females took part, however one of the females was excluded from the experiment due to her measurements' failing to meet the criteria. The subjects gave consent according to the procedures approved by the Hacettepe University Research Ethics Committee.

3.2. Data Collection Procedures and Apparatus

3.2.1. Measurement of Ground Reaction Forces

Ground reaction forces in 3 orthogonal axis (Fx, Fy, Fz) and moments (Mx, My, Mz) were measured via a Force Plate (AMTI OR-6-7) (Fig.5). Tha data were acquired at a sampling rate of 2kHz by using DAQ card (NI, USB-6225 Mass Termination) which was connected to a PC. Data collection algoritm was written in Labview software and post processing was performed with Matlab.

Table 1. Descriptive Statistics of Participants

Subject Number	Age (Years)	Height (cm)	Weight (kg)
1	24	173,5	73
2	26	174	65
3	30	160	66,25
4	21	159	50,5
5	21	178	96,3
6	22	185,5	95,6
7	27	183	72
8	22	187,5	76
9	23	173	60,6
10	20	178,5	90
11	21	167	66
12	23	179,5	81
13	27	165	53,65
14	24	151	51
15	22	164	72,5
16	24	173	75
17	30	173	63
18	21	175	86
19	20	163	58
Mean	23,57	171,71	71,12
Standard Deviation	3,01	9,36	13,62

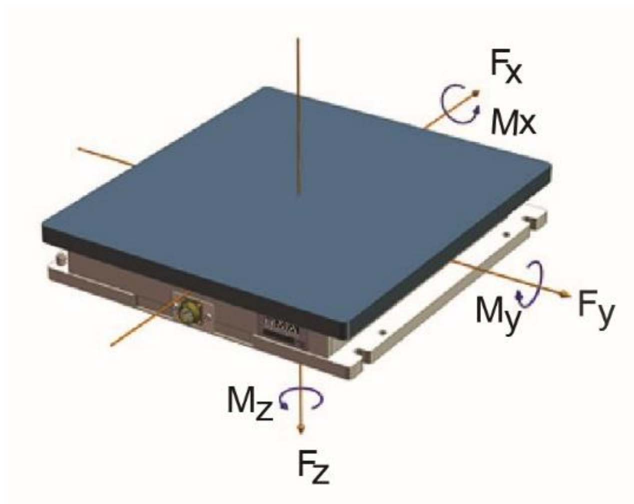

Figure 5.Force Plate (6-dof)

LabView Software was written to acquire force plate signals and provide feedback on COP position. COP Feedback was provided visually during all the postural tasks via computer screen to let them migrate and correct their COP position. Before each trial, force plate data was demeaned to ensure that the data had a zero drift.

Time profiles of COP coordinates were computed by below formula, where h is the height of the sensor over the force plate (h=4.1 cm).

$COPx = (-h \cdot Fx.-My)/Fz$ (Formula 1)

$COPy = (-h \cdot Fy+Mx)/Fz$

Postural sway was investigated through calculating COP Velocity (COP_{Vel}), COP Ellipse Area (COP_{EA}), COP Range and rms values in AP-ML directions ($rmsCOP_x$ and $rmsCOP_y$).

3.2.2. Cognitive Tasks and Difficulty Levels

A math-operation task which consists of a series of simple arithmetic calculations was chosen as the cognitive task. To eliminate the possible effects of processing speed and short term memory, we aimed to control the level of difficulty of the cognitive task individually based on the maximal number of math-operation task completed within one minute. This preliminary task is designed to select appropriate participants among the applicants to take part in the experiment and also to set an individual level of difficulty in the cognitive task. In order to determine the maximal number of math-operation, ten series of arithmetic calculations were articulated by the researchers before the experiment. Each series were started with "0" and followed by a pair of a mathematical operation (i.e. add, substract, multiply, divide) and a single-digit number. Each operation results in a two-digit number. A sound library was created from sound files in ".wav" format with pre-recorded digital vocalization of each operation name and number pair. A custom Labview program was prepeared by the researchers for the digital (vocal) presentation of each pair sequentially in accordance with the order of arithmetic calculations in each series (e.g. add 7, divided by 2 etc). A sequence to be presented was randomly chosen and presented only once to a given subject. Vocal presentation was established by using external speakers. The subject sat on chair in front of a computer screen in a quiet room with their dominant hand placed on a mouse to click on the button. They were required to complete a series of math-operation. After completing each operation, they were asked to press the mouse button to listen a new operation-number pair. Immediately after they pressed the button, the next math operation was presented. An example would be: 1+5=6, 6-2=4, 4x4=16 and so on. Test was terminated after completing 1 minute. If the final result declared by the subject verbally was correct, total number of math operation was recorded. After completing 3 rounds of arithmetics series succesfully, the average number of operation-number pair completed were used to determine the personalized difficulty level of the cognitive tasks to be presented during dual tasks. The applicants who fail in finding correct results after 3 attempts would not be accepted to the experiment. Only one subject failed to complete 3 trials and was excluded from the further experiments. Medium and high difficulty levels of cognitive task (CT) were calculated as %50 and 80% of maximum frequency (MF), respectively. For example, if the subject's MF is 60; then the 80% MF is 48. High CT would be presented as 48 pairs in every 1.25 seconds (60sec/48) within 1 minute, whereas 30 pairs would be presented at 2 second-frequency during Medium CT.

3.2.3. Postural Tasks and Difficulty Levels

Each subject performed seperate static and dynamic postural tasks which were chosen to represent two-levels of difficulty; i) Quiet Stance (QS) as a low difficulty (LD) static condition and ii) Voluntary Sway (VS) Tasks as a high difficulty (HD) dynamic condition. Quiet Stance (QS) task required to maintain upright posture as stable as possible (Figure 6). Voluntary Sway (VS) task was implemented as voluntary shifts of COP in anterior-posterior (AP) directions as an inverted pendulum pivoted at the ankle joint at a pre-determined frequency of 0.5 Hz. The frequency of COP shifts was controlled by a metronome of 30 BPM. Both tasks were performed seperately (single task) and concurrently with cognitive tasks (dual task) as explained in Section 3.2.4. Before the postural tasks, subjects stood on the force platform in neutral position with eyes open. Their feet placed parallel and as wide as they feel comfortable, which was around 20 cm between feet.

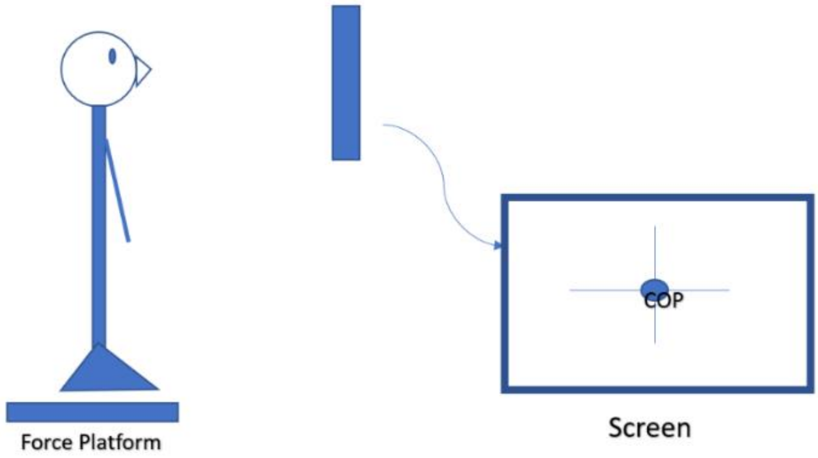

Figure 6. Quiet Stance

In order to provide COP feedback, a computer screen was placed eye level height and the cursor on the screen corresponded instantaneous changes in COP position. During QS trials, subjects were asked to try keeping the cursor at the center and as stable as possible. For VS trials, maximal comfortable anterior and posterior locations of COP were determined and marked by two horizontal lines as the borders of the sway area. To determine the borders, subjects were asked to sway like inverted pendulum around ankle joint forward, and then backward, as further/much as possible without losing balance (Figure 7). During VS trials, subjects were told to migrate the cursor between upper (the most anterior point) and lower borders (the most posterior point). Subjects would be in one of the border when they heard a beep sound of the metronome and they would be in the other when they heard the next beep.

3.2.4. Experimental Procedure: Single and Dual Tasks

Postural tasks were performed separetely both as a single and dual task. A Single Task (No CT) was a postural motor task (QS and VS) performed without a cognitive task.

On the otherhand, A Dual Task was the concurrent performance of a motor task and a cognitive task (Medium and High Difficulty) with two levels of difficulty for each.

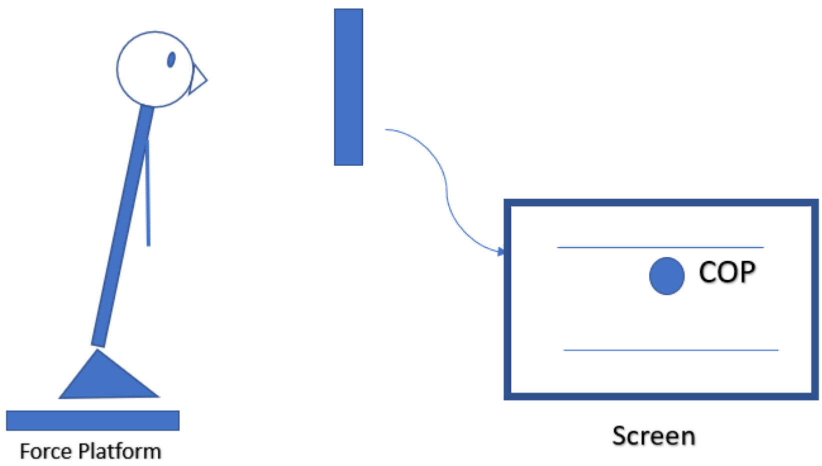

Figure 7. Voluntary Sway

Both single and dual tasks were executed with eyes open and repeated in a random order until the subject succesfully completed three trials per each task. In dual tasks measurements, if the final results of the series of aritmethic calculations had been declared by the subject correctly, that trial was considered as a successfull trial. There was a 1 minute rest between each trials. Maximum number of trials could be five for each subject. If a subject failed to fullfill this criteria, he or she would be excluded from the study. However none of the participants was excluded according to this criteria.

3.2.4.1. Protocol 1. Quiet Stance Trials

Quiet stance (QS) experiment was performed under 3 different cognitive task (CT) conditions: No CT, Medium CT and High CT. The participants were on the force platform and told to stay as still as possible for the duration of 1 minute and keeping the cursor (COP location) as centered as possible.

3.2.4.2. Protocol 2. Voluntary Sway Trials

Voluntary sway (VS) in AP direction was maintained for 1 minute accompanied by metronome set at 30 BPM. They were asked to keep up with the metronome under 3 different cognitive task (CT) conditions: No CT, Medium CT and High CT. The participants could follow their COP from the screen as in the QS task.

3.3. Data Processing and Analysis

Force plate signals were filtered with a 2nd order low-pass zero lag Butterworth filter at 10-Hz prior to processing and each time series were detrended by substracting the mean from raw data. The first and the last 10 seconds of data were eliminated. The 40-second long COP shifts were processed offline using Matlab software package.

3.3.1 Analysis of Quiet Stance

For each COP trajectory, following postural sway characteristics were quantified separately for the AP and ML directions; COP velocity (COP_{Vel}), COP Ellipse area (COP_{EA}), COP Range and rms values ($rmsCOP_x$ and $rmsCOP_y$). Those parameters reflects following features;

- COP velocity: sway-path normalized to signal duration.
- COP Elipse area: the area of ellipses containing 85.35% of the data.
- COP range: maximal deviation of COP in AP and ML directions.
- Rms COP: root mean square COP displacement relative to the mean COP location.

Figure 8, Figure 9 and Figure 10 show representative examples of time profiles of the COP shift in the AP (panel A) and ML direction (panel B) during quite stance.

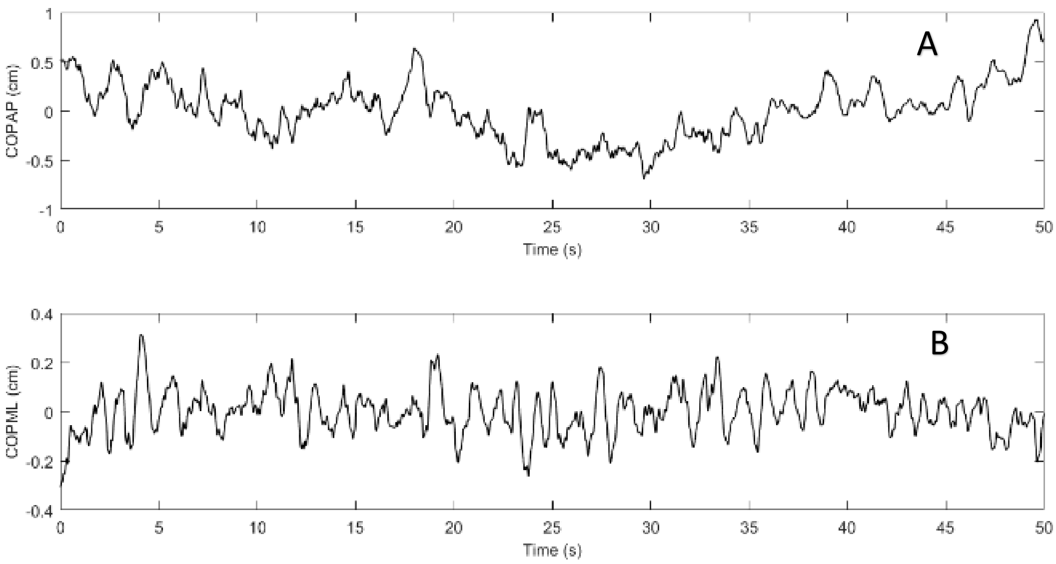

Figure 8. COP Trajectories in AP(A) and ML(B) direction for 0CT Condition

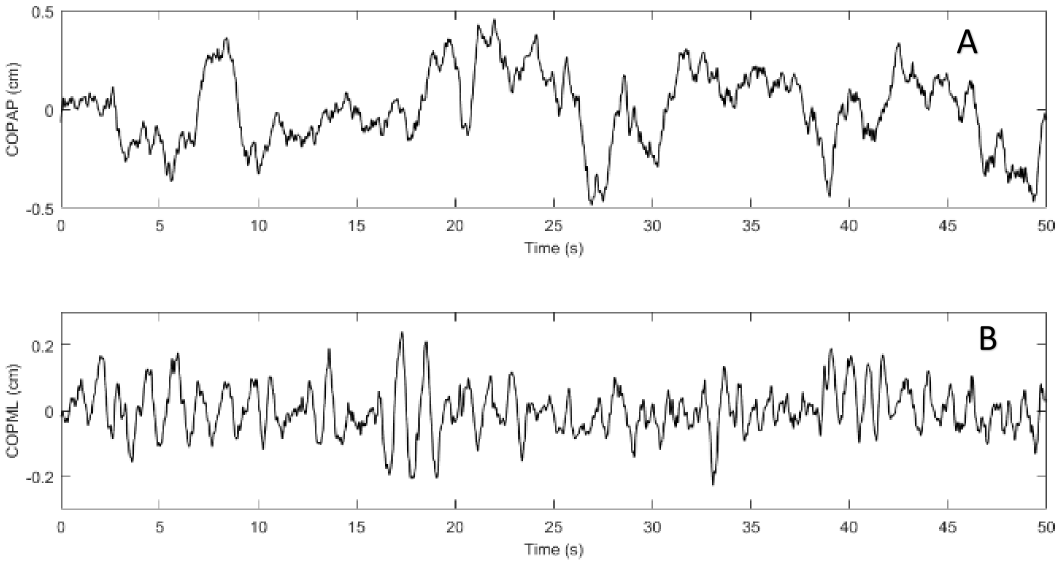

Figure 9. COP Trajectories in AP(A) and ML(B) direction for Medium CT Condition

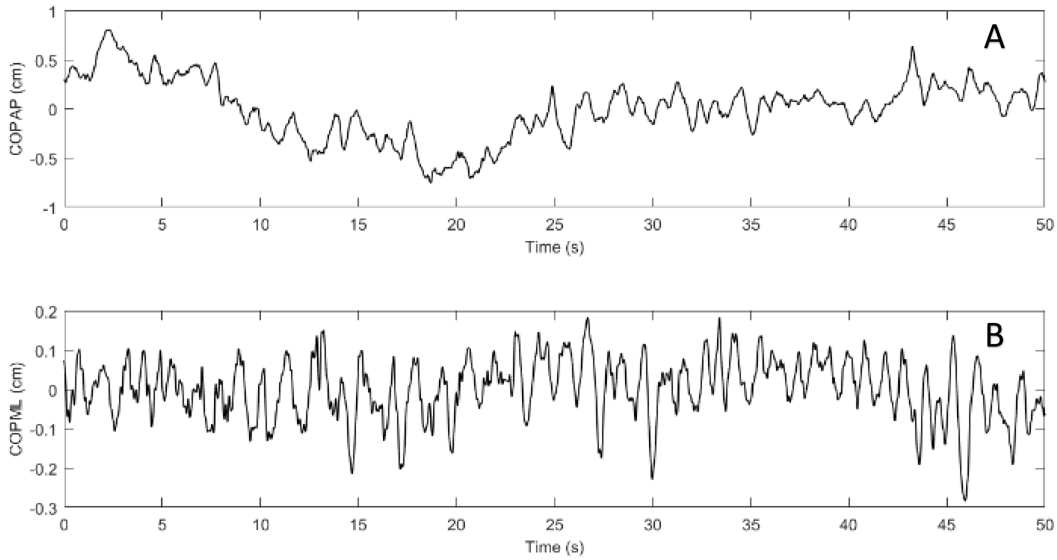

Figure 10. COP Trajectories in AP(A) and ML(B) direction for High CT Condition

3.3.2 Analysis of Voluntary Sway

Voluntary sway analysis is performed according to the method proposed by Latash et al. (2003) which based on an assumption that voluntary shift of the COP and postural sway during quiet stance are independent processes corresponding voluntary and involuntary actions. Therefore, the data underwent a series of signal processing stages for extracting certain characteristics of voluntary sway;

- Peaks and valleys of the COP signal were detected (Figure 11)

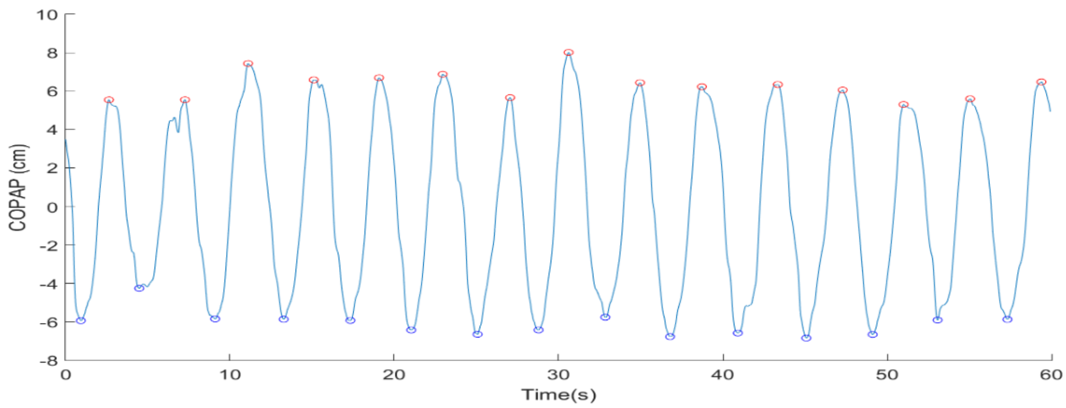

Figure 11. Exemplary trial of voluntary sway in antero-posterior direction

- Determination of half cycles of COP shift: All ascending (UM_{UP}) and descending (UM_{DOWN}) trajectories connecting two consecutive points were determined, aligned by their peak points and averaged (UM_{AV}). Average time profile of each UM_{AV} was time-scaled as in Figure 9.

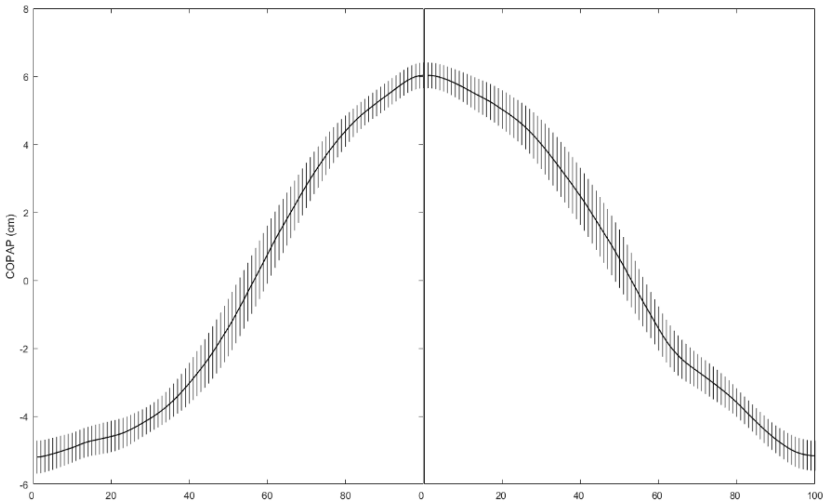

Figure 12. Average ascending and descending unitary movements

- Elimination of the voluntary pattern of COP shift: The scaled UM_{AV} was subtracted, point-by-point, from each UM. The residuals (ΔUM_i) formed a new detrended COP time series ($\Delta COP(t)$).

Figure 13 shows representative examples of time profiles of the voluntary COP shift in the AP direction (panel A), of the corrected COP (residual COP) trajectory (panel B) during voluntary sway.

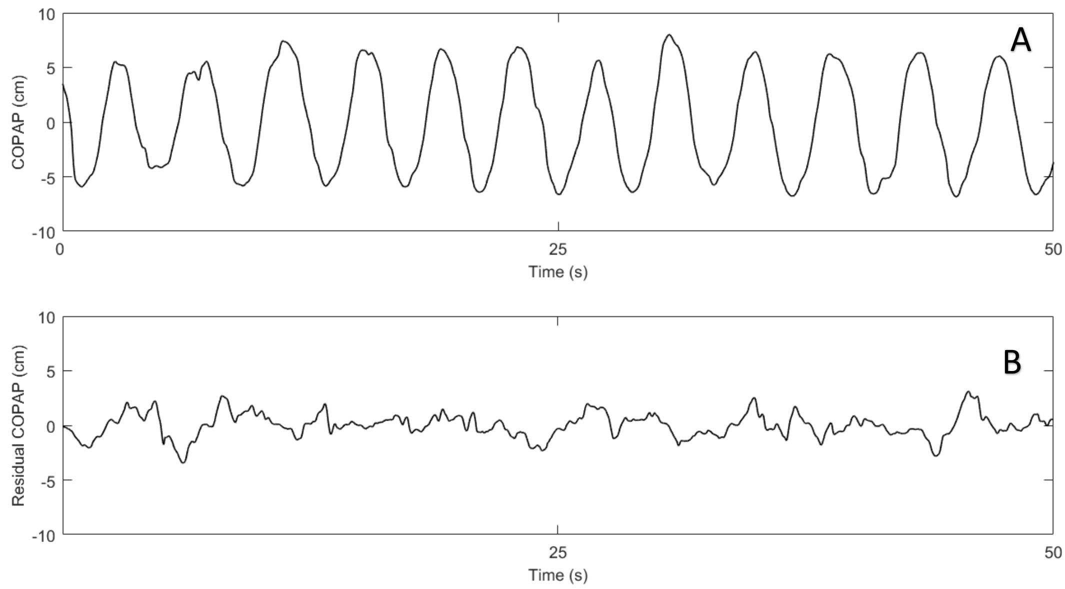

Figure 13. Exemplary time series of voluntary shifts in AP direction(A), Corrected COP trajectory and COP time series during quiet stance(B)

3.4. Statistical Analysis

Parameters were COP velocity (COPVel), COP Ellipse area (COP_{EA}), COP Range and rms values in AP-ML directions ($rmsCOP_x$ & $rmsCOP_y$) for the analysis. Since CoP Velocity and CoP Area are widely used parameters in postural studies they were the main indicators to be interpreted. The analysis was conducted depending on the average of 3 identical trial values so as to reduce the variability of subject. The alpha level of significance was set to $p<.05$. Postural Control variables (COP velocity, COP Ellipse area, COP Range & rms values in AP-ML directions) were analysed with Cognitive Task as a factor (0%, 50% & 80%). Because the Mauchly's sphericity test was violated in repeated measures ANOVA and we failed in meeting all the assumptions of repeated measures ANOVA, we went on with the Friedman Test for analysis and Wilcoxon Test for following up. The randomly selected subject group was measured multiple times and the dependent variable is measured at a continuous level (COP velocity, COP Ellipse area, COP Range and rms values in AP-ML directions). The samples were not normally distributed.

CHAPTER 4

RESULTS

4.1. Descriptive Statistics

The means and SD of the COP parameters are presented in the table below (Table 2).

Table 2. The means and SD of COP Parameters in Voluntary Sway (VS) and Quiet Stance (QS)

	COP Parameters	0 CT (No CT)	50% CT (Medium CT)	80%CT (High CT)	SD (±)
VS	COP_{VEL}*	23,63	21,85	20,54	1,26
	COP_{range} AP*	79,96	73,58	68,93	4,52
	COP_{range} ML	25,66	25,17	24,70	0,39
	COP_{AREA}	1079,61	995,59	942,50	56,44
	RMS_{AP}*	12,29	11,24	10,58	0,70
	RMS_{ML}	4,48	4,52	4,54	0,02
QS	COP_{VEL}	7,43	7,30	7,11	0,13
	COP_{range} AP	16,38	15,50	14,84	0,63
	COP_{range} ML	8,09	7,97	7,98	0,05
	COP_{AREA}	98,30	91,43	86,86	4,70
	RMS_{AP}	29,28	30,23	29,33	0,43
	RMS_{ML}	15,93	14,70	12,44	1,44

4.2. Main Findings

The results of Friedman Test have indicated decrease in CoP Velocity, Sway Range in AP direction and Sway rms in AP direction.

- *Voluntary Sway-CoP Velocity:* The non-parametric Friedman test of differences was conducted and rendered a Chi-Square value of 9,579 which was significant (p=.008). Wilcoxon Test was conducted to see the differences between pairs. Zero CT, Medium CT and High CT conditions were significantly different from each other. When participants were presented with different levels of cognitive tasks, their velocity when swaying changed. The difference between high CT and 0 CT task conditions was the most different pair. Their velocity decreased as the cognitive task became more difficult.
- *Voluntary Sway-Range in AP direction:* The non-parametric Friedman test of differences was conducted and rendered a Chi-Square value of 9,579 which was significant (p=.008). Wilcoxon Test was conducted to see the differences between pairs. Zero CT, Medium CT and High CT conditions were significantly different from each other. The most different pair in the sway range in antero-posterior direction was high and 0 cognitive task pair. The participants' range in AP direction shrunk as the cognitive task became more difficult.
- *Voluntary Sway rms in AP direction:* The non-parametric Friedman test of differences was conducted and rendered a Chi-Square value of 6,737, which was significant (p=.034). Wilcoxon Test was conducted to see the differences between pairs. Zero CT, Medium CT and High CT conditions were significantly different from each other, excluding the pair of Medium CT-High CT. The root mean square in the AP direction decreased as the difficulty of cognitive task increased.

Wilcoxon Signed Ranks Test was conducted as paired difference test. Results are presented in Table 3.

Table 3. Results of Wilcoxon Signed Ranks Test on selected COP parameters

	Test Statistics			**Asymptotic Significance**		
	Medium CT-0 CT	High CT-0 CT	High CT-Medium CT	Medium CT-0 CT	High CT-0 CT	High CT-Medium CT
COP_{VEL}	-2,53	-3,01	-2,81	0,011	0,003	0,005
COP_{range} AP	-2,65	-2,81	-2,53	0,008	0,005	0,011
RMS_{AP}	-2,49	-2,65	-2,29	0,013	0,008	0,022

As reported below, the results of Friedman Test have indicated no significant difference in range in ML direction, COP Area, rms in ML direction for Voluntary Sway; COP Velocity, range in AP direction, range in ML direction, Area, rms in AP direction, rms in ML direction for Quiet Stance.

- Voluntary Sway Range in ML direction: The non-parametric Friedman test of differences was conducted and rendered a Chi-Square value of 1,263 which was not significantly different (p=.53)
- Voluntary Sway COP Area: The non-parametric Friedman test of differences was conducted and rendered a Chi-Square value of 1,684 which was not significantly different (p=.431)
- Voluntary Sway rms in ML Direction : The non-parametric Friedman test of differences was conducted and rendered a Chi-Square value of .105 which was not significantly different (p=.949)
- Quiet Stance COP Velocity: The non-parametric Friedman test of differences was conducted and rendered a Chi-Square value of 2,947 which was not significantly different (p=.229)
- Quiet Stance Range in AP Direction: The non-parametric Friedman test of differences was conducted and rendered a Chi-Square value of 2,947 which was not significantly different (p=.229)
- Quiet Stance Range in ML Direction: The non-parametric Friedman test of differences was conducted and rendered a Chi-Square value of 2,000 which was not significantly different (p=.368)
- Quiet Stance Area: The non-parametric Friedman test of differences was conducted and rendered a Chi-Square value of 1,368 which was not significantly different (p=.504)
- Quiet Stance rms in AP Direction: The non-parametric Friedman test of differences was conducted and rendered a Chi-Square value of .421 which was not significantly different (p=.810)

- Quiet Stance rms in ML Direction: The non-parametric Friedman test of differences was conducted and rendered a Chi-Square value of 5,474 which was not significantly different (p=.065)

Below, Descriptive Statistics, Mean Rank and Friedman Test Results of Voluntary Sway in Zero, Medium and High Cognitive Task conditions are presented in Table 4.

Table 4. Descriptive Statistics, Mean Ranks & Friedman Test Results of Voluntary Sway

Voluntary Sway		**Descriptive Statistics**					**F-Test**	
		Mean (M)	Std. Dev.	Min.	Max.	Mean Rank	Chi-Square	Assym. Sig.
COP_{VEL} *	0 CT	23,63	7,85	11,15	40,08	2,47		
	Medium CT	21,85	6,7	9,81	36,37	2,05	9,579	0,008
	High CT	20,54	6,48	8,87	31,88	1,47		
COP_{range} AP*	0 CT	79,96	28,51	35,7	133,86	2,53		
	Medium CT*	73,58	25,79	35,44	130,86	1,95	9,579	0,008
	High CT*	68,93	25,7	32,48	114,84	1,53		
COP_{range} ML	0 CT	25,66	8,46	13,69	48,92	2,21		
	Medium CT	25,17	7,94	13	47,5	1,89	1,263	0,532
	High CT	24,7	7,11	13,19	38,32	1,89		
COP_{AREA}	0 CT	1079,61	637,63	351,12	2594,64	2,21		
	Medium CT	995,59	571,48	378,39	2425,85	2	1,684	0,431
	High CT	942,5	512,05	350,86	1918,41	1,79		
RMS_{AP}*	0 CT*	12,29	4,47	6,49	22,25	2,42		
	Medium CT*	11,24	3,76	6,01	20,91	2	6,737	0,034
	High CT*	10,58	3,57	5,36	17,57	1,58		
RMS_{ML}	0 CT	4,48	1,45	2,33	7,86	1,95		
	Medium CT	4,52	1,33	2,36	7,7	2	0,105	0,949
	High CT	4,54	1,31	2,44	7	2,05		

* significantly different result (p<.05)

Below, Descriptive Statistics, Mean Rank and Friedman Test Results of Quiet Stance in Zero, Medium and High Cognitive Task conditions are presented in Table 5.

Table 5. Descriptive Statistics, Mean Ranks & Friedman Test Results of Quiet Stance

Quiet Stance		**Descriptive Statistics**					**F-Test**	
		Mean	St. D.	Min.	Max.	Mean Rank	Chi-Square	Assym. Sig.
COP_{VEL} *	0 CT	7,43	2,61	4,75	14,61	2,11		
	Medium CT	7,3	2,26	4,4	12,79	2,21	2,947	0,229
	High CT	7,11	2,19	4,45	11,65	1,68		
COP_{range} AP*	0 CT	16,38	6,71	8,21	37,34	2,21		
	Medium CT*	15,5	5,53	8,27	30,23	2,11	2,947	0,229
	High CT*	14,84	5,23	7,95	25,1	1,68		
COP_{range} ML	0 CT	8,09	3,69	3,97	17,91	2,11		
	Medium CT	7,97	3,43	3,76	17,47	2,16	2	0,368
	High CT	7,98	3,78	3,49	17,45	1,74		
COP_{AREA}	0 CT	98,3	99,51	22,11	424,11	2,16		
	Medium CT	91,43	85,6	18,55	384,08	2,05	1,368	0,504
	High CT	86,86	76,2	19,74	280,46	1,79		
RMS_{AP}*	0 CT*	29,28	20,08	5,08	75,03	1,89		
	Medium CT*	30,23	20,73	7,6	73,95	2,11	0,421	0,81
	High CT*	29,33	20,32	6,19	78,96	2		
RMS_{ML}	0 CT	15,93	14,253	2,13	66,63	2,32		
	Medium CT	14,7	13,78	2,3	64,27	2,11	5,474	0,065
	High CT	12,44	10,56	1,69	50,33	1,58		

* significantly different result (p<.05)

CHAPTER 5

DISCUSSION

This dual task paradigm study was conducted for understanding the interference between the postural task difficulty and cognitive task (CT) difficulty. We inquired how the postural task would be affected by the presence of a zero/medium/hard cognitive task. As mentioned in the Problem Statement, the literature indicates different results on the effect on cognitive tasks' effects on postural control. Some claim cognitive task addition to enhance the control of posture, some claim it to interfere with it. One main outcome from our literature review was that cognitive task's effect on postural control could be observed when CT is difficult enough to possibly cause dual task interference. Therefore, the intention of this thesis was to control the difficulty aspect of the cognitive task by setting an individualized difficulty level. Varying the difficulty with different cognitive tasks would mean the possibility of loading different areas of working memory, therefore instead of choosing different standard secondary tasks, a pre-determined single task was used with different difficulty levels. Varying the difficulty was the frequency of math calculation steps, which was a quantifiable parameter.

The first hypothesis was that the presentation of a difficult cognitive task performed concurrently with the postural task would result in deterioration of postural task. The first part of experiment was to quietly stand with no cognitive task, then 50% of MF of CT (medium difficulty), then 80% MF of CT (high difficulty) in order to observe whether there are significant changes in the trajectories of CoP. It was expected that the presence of CT would significantly affect the postural control, causing dual task cost. However, presentation of cognitive task did not indicate any significant differences in COP parameters under quiet stance condition. Why have not any dual task costs been observed in quiet stance condition? Why isn't there any dual task interference between motor (quietly standing) and cognitive task, having significant effect on either one? One explanation could be that the performance of one specific task is not dependent only on its difficulty but also dependent on the existence of another task with which it is time-shared (Nickerson, 1981). In the quiet stance conditions, medium or high level of cognitive task presentation did not have any significant effect on the CoP trajectories. It is speculated that for the dual task interference to occur, one or both tasks should exceed the limit of attention and in this case, the postural control was not disturbed by the cognitive task. Quietly standing, like sitting, is a daily life activity that requires less attention than swaying with the rhythm of metronome. Therefore, it is not accidental that this postural task remained unaffected by an additional task. To interpret further, completing a series of arithmetics as quietly standing was no different than completing the series as sitting on a chair, just like the very first part of experiment.

Pellecchia (2003) pointed out that as cognitive tasks became more difficult, postural control deteriorated, causing dual task interference. In our case, the cognitive task difficulty failed in affecting the motor task since the motor task was not attentionally demanding enough for dual task interference to occur. Had the muscle activity data were collected and processed, we could have reached more clear results like Maki and McIlroy (1996) since they detected an increase muscle activity in Tibialis Anterior muscle when subjects were quietly standing as they were completing mental arithmetic tasks. The parameters that were measured in this thesis fail to reach more information about the changes that occur when completing a secondary task under quiet stance condition. How about voluntary sway condition? CoP_{Vel}, CoP_{Range} in AP direction and rms in AP direction indicated significant results ($p<.05$) rendering Chi

Values of 9.57, 9.57 and 6.73, respectively. There might be several explanations of these results, such as freezing effect due to joint stiffness, external focus of attention, overwork of attentional capacity or Allport's goal directed approach on attention. Each possibility is discussed below. The velocity, speed with a direction, decreased as the cognitive task became more difficult, which may indicate the freezing effect of the additional task.

The fact that participants' speed dropped might mean that an increase in co-contraction of muscles that act on ankle joint occurred. This is referred to as joint stiffness. Joint stiffness is the relationship between the relevant joint and the torque produced (Lang & Kearney, 2014). In this case, ankle stiffness, which indicates the ankle strategy for recovering from perturbances, is a strategy preferred when the perturbances are small. (Creath, Kiemel, Horak, Peterka & Jeka, 2005). The sway motion that happens in antero-posterior direction is controlled by dorsi and plantar flexors of ankle joint. But what can be the reasons behind the use of ankle strategy? Huffman et al. (2009) proposes that ankle stiffness happens when there is need to control the posture under a threat, which leads to a boost in available cognitive resources. McNevin and Wulf (2002) suggest that when ankle stiffness happens, it is caused by the external focus of attention in order to make cognitive resources more available for other tasks.

On the other hand, Dault et al. (2001) observed a tighter control in posture, which was because of decrease in amplitude of sway, when subjects were completing working memory tasks. Dault et al. (2001) support the general capacity limitation hypothesis with their experiment, claiming that stiffness happens to make more attentional resources available because co-contraction requires less attention. Morasso and Sanguineti (2002) believe that co-contractions in ankle joint occur to help to restore posture when it is disturbed. They claim the stiffness to be an energetically expensive action of ankle muscles, which is a compensatory action done with the intention on stabilization. Instead of a reciprocal work between plantar and dorsi flexors, all muscles are involved to co-contract and stabilize. All these views on why ankle stiffness occurs, therefore why ankle strategy is used, have one thing in common: they point out the need for freeing up available attentional resources. It is possible that, the participants of this experiment preferred their attention to be allocated to the cognitive task, rather than paying attention to the sway task as much as they did when there was no cognitive load. Referring back to Neumann (1987) and Allport's (1985) theories of attention (action selection approach), when one action is preferred over the other one, the first action may be delayed, deteriorated or abandoned completely. When the preferred task is to be executed, the other task may not be able to remain unaffected since attention is allocated to another task. In the case of our experiment, the completion of cognitive task was preferred over the postural task. However this preference did not result in the abandonment of one of tasks, rather it resulted in a decrease in some of CoP parameters. Further experimental setups are needed to define the reasons behind the decrease, like EMG measurements on muscles that act on ankle joint for detecting whether there can be in deed a freezing effect.

Plummer et al. (2013) claims that there can be four types of changes when a motor and a cognitive task are concurrently performed: motor task facilitation, motor task interference, cognitive task facilitation and cognitive task interference. There might be also a combination of these four possibilities. In our study there was an interference of two tasks. Among the dual task conditions, motor and cognitive interference is a specific one and during such dual task performances, and difference from the base single task condition shows interference. This is known as dual task cost (Friedman et al., 1982). The dual task cost was observed in many other studies. Szturm (2013) researched the cognitive and motor task demands on gait and concluded that divided attention when walking at a constant speed resulted in decreased performance of a visuo-spatial cognitive task and an increased variability in locomotor rhythm. Bergamin et al. (2014) made their research on adults and older adults under a dual task environment. They used various cognitive tasks like Spatial-memory brooks test (SMBT), Counting backwards aloud test (CBAT) and Mental arithmetic task (MAT). They conclude that dual task conditions affect the participants' balance variables differently depending on their age, like an increase (counting backwards aloud) or a decrease (arithmetic and spatio-visual memory tasks) in their COP velocity and sway area.

Ceyte et al. (2014) suggest that when postural task and a cognitive task are performed together, a limit will be reached in the capacity for attention. They included participants of older and younger age in the study to quietly stand under three different visual conditions (vision, no vision and moving visual surrounding with two support condition: fixed or moving surface). According to the results, adding a cognitive task during quiet stance, increased the body sway compared to single task condition. The motor task was affected by the secondary task. They also concluded that younger adults preferred the cognitive task over the motor task, unlike what literature suggests on the preference of older adults who put posture first over the cognitive tasks. Teasdale et al. (2001) studied the reaction time under different visual and surface conditions. Participants were young and old adults. Their CoP was observed for sway rate. The results showed a slowing down of reaction time as postural task difficulty increased (no vision and standing on a foam surface). However, in older adults, reaction time was even slower under no vision condition, which might mean a higher reliance on sensory information from environment. The absence of sensory information required more attentional resources in order to maintain the quiet stance.

Maylor and Wing (2001) investigated the difficulty of cognitive task and its effect on postural control. They chose 5 different cognitive tasks to be completed by young and older adults. Younger adults scored better in all cognitive tasks except one (silent counting). Age related decrease in performance was the most in Brook’s Test and Backward Digit Recall test, which is also a visuospatial memory test like Brook’s test. Maylor and Wing conclude that visuospatial working memory is closely related to postural control because vision is a crucial source of sensory information. Lajoie and Teasdale (1996) studied attentional requirements for standing and walking with a reaction time task. 8 young and 8 older participants were told to walk in a broad support and a narrower support. When base of support became narrower, the reaction time completion time increased in the older participants. When they were asked why they think it might have happened, their answer was to have more security during walking. Even when their walking pace was slowed down, this did not change the fact that reaction time still increased. Their study confirm that postural tasks require greater attention when aging. Attentional demands for postural control is present but they become more evident as we age. Such similar findings in the literature suggest that dual task interference occurs due to a need for greater attentional resources during cognitive tasks, but especially the ones that take up visuospatial working memory. When the cognitive task occupies similar resources that postural task also occupies, the interference becomes more distinct. However, there are some other findings in the literature that claim to observe an increase in postural control performance under dual task conditions.

Patel et al. (2014), Swan et al. (2004) and Vuillerme and Vincent (2006) conclude that when the secondary task is difficult enough, then postural control increases. After contemplating on such experiments, we would like to approach differently to the results of these studies. The decrease in COP displacements are interpreted as an increase in postural control. Reduced sway rates are thought to be an indication of a higher control. We believe that muscle activity measurement can offer good information on why this descrease of sway occurs. The less degree of freedom in postural task might show a freeze effect. McNevin and Wulf (2002) suggested that their participants showed less movements by displaying increase in freeze/joint stiffness. Stiffening of ankle joint when face with a threat, therefore having less variable trajectories in CoP, has been interpreted as more need for attentional resources by many others as in many other dual task design studies (Brown, 2006; Carpenter, 2001; Carpenter 1999). The freezing behavior and less CoP displacement can also be observed in animals under threat (Facchinetti, 2006). The dual task design studies that focus on the effect of cognitive task on postural control and the effect of anxiety on postural control show similar findings of decreased CoP displacement due to stiffening of ankle joint or freezing effect.

On the other hand, according to McNevin and Wulf (2002), the decrease in CoP displacement is a result of external focus of attention, rather than being the result of ankle stiffness or freezing effect. External focus of attention makes automatic control processes free cognitive resources. Also Dault et al. (2001) concluded that decreased CoP trajectories are result of less attentionally demanding co-contraction of muscles. However, Stins et al. (2001) found no support for McNevin and Wulf (1992) and Vuillerme and Vincent (2006) 's interpretations on CoP displacement, who suggest that less trajectories stem from more automatically controlled processes. In the context of balance and anxiety, the lessening of CoP displacements is interpreted as a tight control of balance that functions as a protective mechanism. Since joint stiffness is achieved through increased co-contraction of muscles and tighter feedforward control mechanisms, at this point it is believed that that different interpretations of CoP displacements can be guided better by collecting muscle activity data.

Last but not least, one of speculations why dual task interference was observed might be on attention. The attentional system strives for coherent behavior and a goal directed action planning. As Allport (Allport, 1989) noted in his work Visual Attention, goal-directed behaviors require prioritizing tasks and coordination of these tasks under motivational, cognitive, motor and sensory levels. The participants in our study may have prioritized the cognitive task over the motor one. The selective nature of attention might have caused the participants to compute cognitive task as more important than the motor task. Also, since coordination of tasks is a determining factor, we might have seen different results under the same experimental design, after practicing hours provide them a chance to coordinate between those two different tasks. If the participants were cued that the postural task was more important to be completed than the cognitive task, we also might have observed interference in the cognitive task. Woollacott and Cook (Woollacott-Cook, 2002) stated that the control of motor task depends on the complexity of secondary task. Complexity of a secondary task also connoted difficulty.

The task difficulty, as suggested in Allport (1989)'s work, may have increased the attentional demands of coordination of both tasks for the participants in our study. Since the control of motor task had an interference as difficulty of cognitive task increased, it can be concluded that the control of posture was affected by presentation of cognitive task. The successful execution of goal directed actions required one action to be modified to made it possible to complete general action planning. Again to quote Allport (1989), for the successful completion of goal directed action, one of the actions (motor task of voluntary swaying) was modified and had less range of motion in AP direction and less velocity. The modification happened in in "space" element of the task, rather than "time". Since COP parameters which were measured were partly belonging to space and partly belonging to time elements; it can be concluded that the cue of keeping up with the metronome ensured the stability of "time" element. The "space" element, on the other hand was modified (decrease in COP trajectories) in order to complete the single whole task of "swaying with a metronome beat of 30 BPM while calculating auditorily presented arithmetic calculations". Since an interference was observed, further studies might explore the trade off between time and space under dual task conditions. This concept of trade-off agnates the speed-accuracy trade-off; likewise congitive load caused modification of one of accuracies (time & space). Participants were completing their postural and cognitive tasks under space and time elements but a modification in range of motion, therefore "space", was observed and although our study is not sufficient to explore the reasons why, the reasons behing this modification can be further examined.

CHAPTER 6

CONCLUSION

It was observed that there was a dual task interference between the motor task, which was swaying in accordance with a metronome beat, and a concurrently presented cognitive task, which was arithmetic calculations. As the difficulty of cognitive task increased from medium (50% of maximum frequency) to high, (80% of maximum frequency) the parameters of COP (Velocity, range and rms values in AP direction) trajectories showed significant changes as cognitive task difficulty gradually became more difficult. The cognitive load had a significant effect on motor task resulting in dual task cost. The attentional sources had to be freed up for a simultaneous cognitive task to be completed. On the other hand, quietly standing task remained unaffected by the presence of cognitive task and none of the parameters showed significant differences from no cognitive task condition. It is speculated that quiet stance did not count for a challenging motor task for attentional sources. Since quietly standing is a very common daily life posture, there was no dual task cost when cognitive task was presented to participants.

6.1. Further Studies

Further studies that tackle the issue of postural control and cognitive task under dual task conditions can include not only data obtained from force platforms on CoP, but also simultaneous muscle activation data to reach clearer conclusions. In this thesis, the data could be cultivated from Tibialis Anterior and Gastrocnemius muscles to reflect on the ankle movement because the task of swaying occurs in ankle joint but also ankle strategy is the first one to be used for micro sways that happen in quiet stance. Also, monitoring the execution of cognitive tasks, whether they are accomplished or abandoned or interfered can contribute to the literature, e.g. controlling the cognitive task error rates. Using different types of cognitive tasks might help detecting the underlying mechanisms for dual task interference, for example when two tasks are of domains using similar pathways (Leone et al. 2017). For further studies, we would like to suggest controlling the motor task (postural task) difficulty and cognitive task difficulty to observe how the dual task interference might occur. Also, adding psychologically different (anxiety, threat etc.) environmental settings can have guiding function in interpreting the results in the perspective of freezing effect.

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APPENDICES

A: AVERAGES OF COP PARAMETERS

Below are tables (Table 6-17) that show the averages of COP parameters in Voluntary Sway and Quiet Stance for each subject under 3 different cognitive task condition.

Table 6. Averages of COP Parameters: VS-Velocity

VS COP_{Vel}	No CT	Medium CT	High CT
S01	20,94984594	20,1570675	18,0795541
S02	21,81547479	21,30658509	20,44433069
S03	26,94927647	23,39165116	22,17138126
S04	11,14840138	9,809040141	8,865238107
S05	15,76283326	16,02862159	14,51983455
S06	22,04854842	22,63869465	23,51240679
S07	40,0781067	31,45258989	31,87943808
S08	29,5776564	30,06904379	30,51274412
S09	13,43891443	13,73133909	12,88811616
S10	37,75755068	36,36810068	30,20904382
S11	30,58380444	21,97260167	18,26461892
S12	15,94823261	16,28445917	15,61140235
S13	20,52893959	21,37411583	21,44371291
S14	17,18374175	14,0721259	12,94243279
S15	26,19497031	25,96814169	27,28198682
S17	20,08495078	19,54040248	18,56235725
S18	23,93446704	21,52404231	19,18719929
S19	22,36397668	19,45205343	17,2540666
S20	32,65356856	30,07903972	26,65832543
Mean:	23,63175054	21,85366925	20,54148369
St. D.	7,649699458	6,525505257	6,314632692

Table 7. Averages of COP Parameters: VS-Range in AP

VS COP_{Range} AP	No CT	Medium CT	High CT
S01	72,71019478	70,65304667	58,88243819
S02	81,32395912	74,57637877	70,61468598
S03	101,3319046	83,77720818	76,64541389
S04	35,69676615	35,43791122	33,48559761
S05	56,92692249	55,14277588	46,84929142
S06	45,75298615	47,74260627	50,29699889
S07	130,328603	114,5592459	114,839946
S08	88,41021638	92,92580791	101,4412266
S09	45,89000289	48,05566238	42,15246822
S10	133,8616532	130,8607099	109,908303
S11	98,1742953	67,82251734	58,52617041
S12	52,612171	55,76876476	57,32532294
S13	69,8853384	70,80458084	74,82399632
S14	57,58685132	41,0334364	32,4761076
S15	116,247444	110,8434694	111,8996959
S17	67,63095044	60,87497616	54,21123982
S18	72,4982534	66,22600122	61,34300164
S19	90,75537045	78,22853754	66,3710768
S20	101,6252833	92,86420534	87,57740934
Mean:	79,96048244	73,58936011	68,93002056
St. D.	27,7561914	25,10705262	25,0228724

Table 8. Averages of COP Parameters: VS-Range in ML

VS COPRange ML	VSRANGEML-VS0CT	VSRANGEML-VS50CT	VSRANGEML-VS80CT
S01	26,72669	25,37932	20,73619627
S02	24,61955	24,62674	19,67792988
S03	20,92932	18,61641	20,74598046
S04	23,41431	19,93833	18,44912554
S05	16,8627	17,56633	16,11716574
S06	19,29565	22,85621	24,58640327
S07	23,06077	22,74904	24,982389
S08	35,74317	35,77206	38,31929884
S09	18,35241	18,2367	17,31553494
S10	33,62796	31,04039	32,04059324
S11	32,25116	28,10174	21,73038895
S12	13,69061	13,00097	13,19224787
S13	26,88776	29,14747	28,24337441
S14	19,50002	16,30842	18,39569604
S15	18,97306	24,16794	33,71536714
S16			
S17	24,2126	24,6967	25,12954679
S18	24,76241	26,38521	29,37399049
S19	35,71841	32,16058	32,05660338
S20	48,91566	47,49678	34,49739273
Mean:	25,66022	25,17091	24,700275
St. D.	8,235454	7,731385	6,921594788

Table 9. Averages of COP Parameters: VS-Area

VS COP_{Area}	No CT	Medium CT	High CT
S01	870,142	827,0692643	629,7749663
S02	1065,137	976,8865596	836,0739128
S03	943,265	734,6946862	744,593827
S04	524,7953	451,1289701	394,2638034
S05	456,9686	502,4885765	466,0228886
S06	429,3069	594,4128816	768,9717011
S07	1401,396	1139,021151	1331,866078
S08	1452,652	1558,808903	1645,142493
S09	403,4483	456,0404372	407,6950775
S10	2594,64	2425,850797	1793,95705
S11	1750,561	959,3135515	675,612461
S12	351,1157	378,3852578	376,4837657
S13	911,4528	969,4010619	1003,371562
S14	607,8758	388,4375973	350,8628376
S15	990,5011	1375,471595	1918,414973
S17	871,1534	800,1097123	735,2023382
S18	958,1344	917,8770276	1030,374931
S19	1593,471	1290,809226	1090,329775
S20	2336,665	2170,151403	1708,574171
Mean:	1079,615	995,5978241	942,5046638
St. D.	620,6266	556,2459397	498,3908014

Table 10. Averages of COP Parameters: VS-rms in AP

VS rms AP	No CT	Medium CT	High CT
S01	10,0511	9,94911	8,999714
S02	13,00282	11,74926	11,76735
S03	15,54695	12,5873	11,35381
S04	6,485685	6,01244	5,762276
S05	9,137958	9,232146	8,44744
S06	7,180842	7,509323	8,511576
S07	21,10748	17,12742	17,28549
S08	13,05841	13,74773	14,55883
S09	7,154952	7,693663	7,005193
S10	22,25258	20,91417	17,5678
S11	14,64373	9,700742	8,599036
S12	8,117919	8,642011	8,27262
S13	9,861598	10,27098	10,66742
S14	8,945869	6,860994	5,355761
S15	15,40756	15,03417	15,47341
S17	10,30868	9,521787	8,807088
S18	11,40856	10,19941	9,486709
S19	14,26584	12,36613	10,31647
S20	15,75567	14,47016	12,94478
Mean:	12,29969	11,24152	10,58857
St. D.	4,353939	3,66707	3,475012

Table 11. Averages of COP Parameters: VS-rms in ML

VS rms ML	No CT	Medium CT	High CT
S01	4,719988	4,513339	3,7294
S02	4,566794	4,646756	3,833092
S03	3,206016	2,969474	3,30245
S04	4,411831	4,045897	3,612429
S05	2,711787	2,967914	3,027093
S06	3,248726	4,239777	4,955792
S07	3,592884	3,642919	4,128108
S08	5,918978	6,05589	6,036531
S09	3,141701	3,245498	3,119497
S10	6,311715	6,23111	5,626696
S11	6,314433	5,401368	4,122293
S12	2,330376	2,363137	2,436431
S13	5,026164	5,097813	5,161603
S14	3,492706	3,099835	3,625606
S15	3,444394	4,796197	6,683206
S17	4,540688	4,522643	4,454036
S18	4,526011	4,810952	5,901998
S19	5,920754	5,65767	5,671668
S20	7,856794	7,702096	7,001536
Mean	4,488565	4,526857	4,548919
St. D.	1,417072	1,301268	1,282156

Table 12. Averages of COP Parameters: QS-Velocity

QS COPVel	No CT	Medium CT	High CT
S01	5,56674	5,523111384	5,080429537
S02	4,754077	4,40118389	4,450260633
S03	7,198533	7,099098253	6,668427229
S04	6,583143	6,800993364	6,08439057
S05	7,055631	7,868391132	7,801263174
S06	10,50118	10,97668775	11,37908066
S07	9,232447	8,802206638	8,751495105
S08	14,61178	12,78552784	11,6528132
S09	7,705717	8,265138204	8,659042655
S10	10,02012	8,930665266	8,777279263
S11	10,25055	9,48647659	8,494316638
S12	5,189872	5,265268367	5,042022141
S13	9,33307	8,488428698	8,674864156
S14	5,456087	5,780023695	5,989009919
S15	5,437402	5,52148288	4,868569229
S17	5,564215	5,229722613	5,083704862
S18	4,757499	4,763179261	4,872060058
S19	5,310504	5,356931171	5,337243495
S20	6,668601	7,527265122	7,470636282
Mean:	7,43143	7,309041164	7,112468884
St. D.	2,541698	2,200273752	2,139395975

Table 13. Averages of COP Parameters: QS-Range in AP

QS COP_{Range} AP	No CT	Medium CT	High CT
S01	11,51749	10,65072	9,621498
S02	13,92926	12,17287	10,22004
S03	12,28156	10,19325	8,699968
S04	14,54491	15,13463	13,52678
S05	17,54793	14,05491	14,13065
S06	15,29672	15,6628	15,82035
S07	13,83853	15,01213	15,3693
S08	37,33579	30,2344	25,09995
S09	13,8088	13,60846	17,39138
S10	26,33428	21,93955	22,67607
S11	18,25354	18,97577	16,44868
S12	8,214974	8,265468	8,829297
S13	23,7709	24,78419	24,71564
S14	13,82465	13,96002	12,95607
S15	12,46529	12,69407	10,71142
S17	9,721142	8,695903	7,948079
S18	13,04648	13,17704	12,20429
S19	18,51525	18,44916	17,5962
S20	17,10421	17,00059	18,08791
Mean:	16,38693	15,50873	14,84493
St. D.	6,532709	5,384586	5,090526

Table 14. Averages of COP Parameters: QS-Range in ML

QS COP_{Range} ML	No CT	Medium CT	High CT
S01	6,457668	7,073712	6,328685
S02	3,973228	4,973708	6,57843
S03	7,542418	5,522668	4,85413
S04	8,497924	10,17345	9,42058
S05	7,941617	8,356781	7,299206
S06	9,034693	8,100649	8,605838
S07	6,906022	7,257897	6,38868
S08	17,90654	17,47462	15,48746
S09	5,089164	6,479656	6,707051
S10	15,38142	14,07636	17,45045
S11	10,17168	10,52623	11,96233
S12	5,230028	3,761978	3,941297
S13	12,58512	10,14535	11,75807
S14	5,866902	5,130194	4,354643
S15	4,129588	3,87789	3,490531
S17	6,046089	5,85585	5,436247
S18	6,297005	7,308218	6,879451
S19	6,003003	6,78133	6,447757
S20	8,716144	8,734772	8,391268
Mean:	8,093487	7,979543	7,988531
St. D.	3,601277	3,339032	3,681651

Table 15. Averages of COP Parameters: QS-Area

QS COP_{Area}	No CT	Medium CT	High CT
S01	43,77769	49,22196	45,20066231
S02	32,81935	35,14547	40,69676591
S03	47,87231	30,28148	22,88814062
S04	72,89198	93,72297	91,50492092
S05	94,38553	87,4196	65,8916543
S06	92,8866	72,48731	73,34903325
S07	59,44692	67,817	58,65980329
S08	424,1101	384,082	254,5751132
S09	39,47668	51,72913	65,69266148
S10	263,7066	200,8915	280,4618656
S11	108,4919	112,7969	128,7490723
S12	22,11311	18,55313	19,73726832
S13	198,3794	167,4918	189,1432121
S14	60,74873	46,31791	32,65379324
S15	26,29777	25,94226	19,80471344
S17	37,05964	28,24023	23,58060599
S18	50,14128	68,77401	70,95765782
S19	78,15298	80,96284	65,54369495
S20	115,0702	115,3795	101,2772724
Mean:	98,30678	91,43458	86,86146903
St. D.	96,85862	83,31792	74,17342031

Table 16. Averages of COP Parameters: QS-rms in AP

QS rms AP	No CT	Medium CT	High CT
S01	11,25242	8,200824	16,17943
S02	25,13667	27,75045	26,93262
S03	18,49021	22,52977	14,40148
S04	5,084747	9,11626	8,735146
S05	49,12969	37,79769	42,32064
S06	19,86508	20,94465	23,5344
S07	12,96385	7,874689	6,191553
S08	10,47665	20,01473	17,1599
S09	9,137405	7,59722	11,91396
S10	42,34023	36,50109	21,19738
S11	13,31047	13,03594	13,14314
S12	24,15444	24,4288	22,39357
S13	37,28165	45,53753	43,15494
S14	44,11628	60,86362	56,49572
S15	70,0795	73,94896	78,96117
S17	40,21457	45,99129	48,58688
S18	29,01926	24,34069	21,98965
S19	75,03118	70,11812	63,28534
S20	19,35825	17,89448	20,85172
Mean:	29,28645	30,23615	29,33835
St. D.	19,5529	20,17736	19,77909

Table 17. Averages of COP Parameters: QS-rms in ML

QS rms ML	No CT	Medium CT	High CT
S01	4,327401	5,384952	3,60957
S02	23,0147	20,10987	17,99025
S03	18,37568	13,99335	11,34896
S04	25,25014	25,17983	15,74939
S05	8,312721	5,339063	2,542701
S06	16,61418	17,94247	15,26801
S07	8,887058	13,76006	15,18479
S08	15,8565	9,930255	8,466464
S09	11,92378	13,75767	14,77678
S10	9,936988	10,18721	11,38786
S11	28,78304	22,63104	16,60895
S12	4,311762	2,296138	1,693527
S13	9,135076	7,145783	5,274846
S14	7,495385	11,10817	11,91533
S15	16,08255	9,603478	12,72538
S17	9,547373	3,971803	3,560068
S18	66,63074	64,26514	50,32698
S19	2,134751	2,921205	5,098853
S20	16,09824	19,78495	12,91519
Mean:	15,93253	14,70065	12,44442
St. D.	13,87327	13,41343	10,2847

B: APPROVAL OF ETHICS COMMITTEE

T.C.
HACETTEPE ÜNİVERSİTESİ
Girişimsel Olmayan Klinik Araştırmalar Etik Kurulu

Sayı : 16969557 – 388
Konu : ARAŞTIRMA PROJESİ DEĞERLENDİRME RAPORU

Toplantı Tarihi	: 14 MART 2017 SALI
Toplantı No	: 2017/07
Proje No	: GO 17/197 (Değerlendirme Tarihi: 28.02.2017)
Karar No	: GO 17/197- 17

Orta Doğu Teknik Üniversitesi Eğitim Fakültesi Beden Eğitimi ve Spor Bölümü öğretim üyelerinden Doç. Dr. Sadettin KİRAZCI' nın sorumlu araştırmacı olduğu, Yrd. Doç. Dr. Pınar Arpınar AVŞAR ile birlikte çalışacakları ve Zeren G. BAMPATZİMOPOULOS' un yüksek lisans tezi olan, GO 17/197 kayıt numaralı, ***"Bilişsel Görevin Statik Postür Kontrolü Üzerine Etkisi"*** başlıklı proje önerisi araştırmanın gerekçe, amaç, yaklaşım ve yöntemleri dikkate alınarak incelenmiş olup, etik açıdan uygun bulunmuştur.

1.Prof. Dr. Nurten AKARSU (Başkan)	10 Prof. Dr. Oya Nuran EMİROĞLU (Üye)
2. Prof. Dr. Sevda F. MÜFTÜOĞLU (Üye)	11 Yrd. Doç. Dr. Özay GÖKÖZ (Üye)
3. Prof. Dr. M. Yıldırım SARA (Üye)	12. Doç. Dr. Gözde GİRGİN (Üye)
4. Prof. Dr. Necdet SAĞLAM (Üye)	13. Doç. Dr. Fatma Visal OKUR (Üye)
5. Prof. Dr. Hatice Doğan BUZOĞLU (Üye)	14.Yrd. Doç. Dr. Can Ebru KURT (Üye)
6. Prof. Dr. R. Köksal ÖZGÜL (Üye)	15. Yrd. Doç. Dr. H. Hüsrev TURNAGÖL (Üye)
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C: TURKISH SUMMARY/TÜRKÇE ÖZET

BİLİŞSEL GÖREV ZORLUĞUNUN POSTÜR KONTROLÜNE ETKİSİ

GİRİŞ

Ellerinin üzerinde duran bir cimnastikçiden iki ayağı üzerinde sıçrayıp iniş yapan bir basketbol oyuncusuna, topuklu ayakkabıları ile bir toplantıya yetişmeye çalışan bir kadından zorlanarak günlük hayatın rutini içinde yürümeye çalışan bir yaşlıya, tren istasyonunu bulmaya çalışan görme engelli bir bireyden serebral palsili bir çocuğun yemek yemesine kadar açılan bu geniş insan hareketi yelpazesinde bir ortaklık mevcut: hepimiz kendi sınırları ve becerileri doğrultusunda hareket ediyoruz. İşte tüm bu sayılan ve sayılmayan insan hareketlerinin herbirisinin en görünmez eşlikçisi postür. Bu postür herkes tarafından kullanılan bir postür de olabilir yahut var olmayan bir uzvun eksikliğinin hissedilmemesi için yapılan bir telafi de olabilir. Her ne olursa olsun insan hareketi ve postür birbiri içine geçmiş iki kavramdır. Denny-Brown'ın bahsettiği gibi "postür ve hareket için farklı mekanizmalar yoktur" (Denny-Brown, 1964). Hareket bir açıdan da postürün bir modifikasyonu olarak görülebilir. Günlük yaşamının çoğu zamanını iki ayak üzerinde geçiren insanlar olarak iki ayaklı postür bizler için temeldir. Oturmak ve uzanmak gibi duruşlar gerektiren görevlerin haricinde, günlük yaşantımızın birçok anı erekte bir omurga ve iki ayak üzerinde dengelenerek geçer. Günlerimiz oturmadan geçebilir ancak iki ayak üzerinde durmayı gerektirmeyecek bir görevi olmayan sağlıklı bir birey düşünülemez. Günlük sekiz saat ofiste çalışan bir memur bile eve gitmek için, arabasına binmek veya alışveriş etmek için ayakta duracaktır. Ayakta, oturarak ve uzanarak olsun postür, insan yaşamına hareket ve hareketsizlikle eşlik eder. Kulağa bu kadar soyut gelen, tanımlanması güç gibi görünen bu postür öyleyse nedir? Onu kontrol etmek nasıl mümkündür?

Öncelikle, insan kontrolü yerçekimli ortamda denge ve oryantasyon amaçları ile dengenin sağlanma becerisi olarak ifade edilebilir (Horak, 1987). Bu sebeplerle postürün iki amacı olduğu çıkarımını yapabiliriz: oryantasyon ve stabilite. Bu iki amacı gerçekleştiren sistemler bütünü karmaşıktır ve ilgili duyu ve emirleri, kas ve iskelet sistemini koordine eder. Postürel oryantasyon, yerçekimi, destek yüzeyi, çevre ve iç referanslar ile ilişkili olarak bedenin hizasını ve tonusunu kontrol etmektir. Postürel stabilite ise sensorimotor stratejilerinin, kütle merkezini istemli veya beklenmedik pertürbasyonlar süresince koordine etmesidir (Horaki 2006). Massion'a göre (Massion, 1994) postürel kontrol sisteminin iki temel işlevi vardır: ilki, yerçekimine karşı bir direnç oluşturarak dengenin korunmasıdır. İkincisi ise beden segmentlerinin oryantasyon ve pozisyonunu çevre koşullarına göre sabitlemektir. Temel olarak, sabit veya hareketli bir hareket süresi veya sorasında yapılan herbir eylem postürel kontrol mekanizmaları tarafından yönetilir. Günlük yaşantıda insan postürü neredeyse hiçbir zaman tek başına bir görev olarak yer almaz. Tam da bu sebeple literatür uzun yılları boyu postür kontrolünün dikkat gerektirmeyen, birlikte çalışan birçok sistemin fark edilmeden organize olduğu bir süreç olarak tanımlanagelmiştir. Fakat öyle midir? Gerçekten de postür kontrolü bizim dikkatimize gerek duymayacak kadar otomatik şekilde mi gerçekleşir? Eğer postür Hunt'un söylediği gibi (Hunt, 1922) "hareketin gölgesi" ise, bu onun planlanması için hiçbir dikkat unsuru gerekliliği barındırmayan bir süreç olduğu anlamına mı gelir? Eğer insanın iki ayak üzerinde durma eylemi çok iyi öğrenilmiş ve otomatik hale gelmiş bir eylem ise, dikkatimizde hiçbir yer kaplamamakta mıdır? Kerr ve diğerleri (Kerr, Condon and McDonald, 1985), bilişsel süreçlerin aynı zamanda postür regülasyonu için de kullanılan nöral mekanizmaları kullandığını ileri sürmektedir. Andersson (1998) ise yaptığı çalışmada talepkar bir denge görevinin icra edilmesi esnasında verilen bilişsel görevin başarılmasında zorluk gözlemişlerdir. Bu dikkat ve postür ilişkisinin sorgulandığı noktada literatür dikkat kaynaklarının paylaştırılması hususunu araştırmak üzere ikili görev paradigmalarını kullanmaya başlamıştır. Bu çalışmalar ikili görev çalışmaları olarak adlandırılmakta ve iki adet görevin aynı zaman diliminde gerçekleştirilmesi gerekmektedir. Bu sayede oluşabilecek olan "çatışma"lar gözlenebilmektedir. Verilen görevlerin bir tanesi motor ve diğeri bilişsel olabilir. Merkezi işleme kapasitesinin var olduğunu sayan dikkat literatürü, görevler arasındaki dağılımı inceleyebilmek için ikili görev paradigmasını kullanmaktadır. Bütün bu tartışmaların bir adım gerisinde bahsedilmesi ilk gereken nokta postür kontrolünü sağlayan bazı elementlerdir.

POSTÜR KONTROLÜ MEKANİZMALARI

Taşları birbiri üzerine dizerek dengede kalmaları ile güzel bir görüntü oluşturan Japon taş dizme sanatını düşünelim. Tüm taşların kütle merkezlerinin birbiri üzerinde hizalanmasını. Bu imge her ne kadar birebir olmasa da, insan bedeninin ayakta postürüne benzemektedir. Beden parçaları birbiri ile öyle bir hizalıdır ki yerçekimi kuvveti bu istemli gerçekleştirilmiş hizayı bozamaz. Dünyanın yerçekimine karşı bedenimiz, yerçekimine eş bir kuvvet uygulayarak istenen pozisyonu korur. Eğer bir noktada bu kuvvetler birbirine eş olmaktan çıkar ise bir pertürbasyon veya bir hızlanma görülür. Bu hızlanma veya pertürbasyon sonucu kütle merkezi istemli ve istemsiz şekilde yer değiştirir. Merkezi sinir sistemi kütle merkezindeki değişikliklerden sürekli haberdar olarak iç ve dış kuvvetleri optimize ederek dengeyi korur (Winter, 1998). Eğer Japon taş dizme sanatına dönecek olursak, tabi ki insan bedeni birbirinden tamemen bağımsız birçok segmentten bir araya gelmemektedir. İnsan bedeninin eylemleri ve duruşu birçok systemin birlikte çalışması ile mümkün olmaktadır. Bu sistemlerden ilk bahsedilecek olan kas ve iskelet sistemidir. Kas ve iskelet sisteminin bileşenleri ligamanlar, tendonlar, eklemler, kartilajlar, kemikler, kaslar vb. olarak anılabilir. Eklemlerdeki hareket açıklığı sayesinde beden parçalarının biyomekanik ilişkisi kurulur. İdeal şekilde hizalanmış bir insan postürü yere dik bir açı yaparak yerçekimine karşı gelir. Bu hizalanmış posture yandan bakıldığında ve yukarıdan aşağı doğru bir çizgi çizildiğinde, bu çizgi şu noktaları geçer: mastoid çıkıntı, omzun hemen önündeki nokta, kalça eklemi, diz ekleminin ve ayak bileği ekleminin hemen önü (Basmajian ve Deluca, 1985). İnsan ayakta postüründeki aktif kaslar şunlardır: Erektör Spinae grubu, iliopsoas, gluteus medius, biseps femoris, abdominal kaslar, tensor fascia lattae, tibialis anterior ve soleus (Kendall and McCreary, 1984). Diz ve ayak bileği ekleminin hemen önünden geçen bu ideal hizalanma çizgisi, gastroknemius ve soleus kasları tarafından yönetilir. Eğer posterior doğru bir yönlenme varsa tibialis anterior bu çizgiyi kontrol etmek için aktive olur. Gluteus medius ve tensor fascia lattae kasları ise kalça ekleminin hiperekstansiyonunu engeller. Literatürde bu kasların insan bedenini düz bir çizgi halinde tuttuğu ideal postür “sakin duruş” olarak adlandırılmaktadır. Bu duruşa verilen adın aksine sakin duruşun pek de sakin olduğunu söylemek doğru olmayabilir. Literatür insan postürünü ters duran bir sarkaca benzetegelmiştir ancak yeni çalışmalar bedeni daha çok iki segmenti olan ve dik duruşu sağlamak adına farklı stratejiler kullanan iki sarkaca benzetmektedir (Creath, 2005). Bu sözde sakin duruşun, respirasyon gibi bazı içsel süreçler tarafından bile kolayca etkilendiği görülmüştür (Jeong, 1991). İnsan postürünün kontrolü için musküloskeletal bileşenler kendi başlarında elbette yeterli değildir. İnsanın sinir sistemi hazırlık, icra ve hareket kontrolü gibi süreçlerden sorumludur. Sinir sistemi iki ana kola ayrılır: Merkezi Sinir Sistemi ve Çevresel Sinir Sistemi. Merkezi sinir sistemi omurilik ve beyinden oluşurken, çevresel sinir sistemi sensöri ve motor olarak ikiye ayrılır: sensöri ve motor kısımlar. Sensöri kısım çevreden merkezi sinir sistemine bilgi aktarımı yaparken, motor kısım ise merkezi sinir sisteminden ilgili beden parçalarına icra edecekleri görevleri iletir. Merkezi sinir sistemi, sensöri sistemler sayesinde çevreyi yorumlayacağı bilgileri edinir, bedenin kendi segmentleri arasındaki ilişkiyi algılar ve uzaydaki konumunu belirler. Postür kontrolünde en çok kullanılan sensöri bilgi kaynakları görsel (vizüel) system, somatosensöri system ve vestibüler sistemdir. Diğer sensöri bilgi aktarımlarında olduğu gibi bu sistemlerden gelen tüm bilgiler merkezi sinir sistemi tarafından güncel durumu algılamak açısından yorumlanır. Çevre koşulları, beden konumu veya bedenin kendi parçaları arasındaki ilişki değiştikçe, merkezi sinir sistemine aktarılan bilgiler sayesinde yeniden yorumlanma ve algılama dolayısıyla da yeniden organize olma meydana gelir. Bir görevin gerektirdikleri ve çevresel kısıtlamalar merkezi sinir sistemine aktarılan bilgilere yansır ve merkezi sinir sistemi bu değişiklikleri algılar. Merkezi sinir sistemi, başın pozisyonu hakkında bilgiyi vestibüler sistemden, çevre hakkındaki bilgiyi vizüel sistemden ve bedenin referans pozisyonuna dair bilgiyi somatosensöri sistemlerden alır.

LİTERATÜR TARAMASI

DİKKAT

Postür kontrolü, bilişsel ve motor görev üçlüsünün gözden kaçan önemli bir elemanı var: Dikkat. Tarih boyunca birçok disiplin dikkati farklı şekillerde tanımlamıştır. Bu tanımların en bilindiklerinden birisi şudur: herhangi bir anda farkında olduğumuz şey (James, 1890). Farkında olmak veya olmamak bu tanımlamada anahtar rol oynamaktadır. Bazı bilgiler farkında olunmadan işlenirken, bir kısmı ise farkında olunarak işlenir. Bu durumda bazı görevlerin dikkat gerektirdiği ve bazı görevlerin de dikkat gerektirmediği sonucu çıkarılabilir. Peki durum gerçekten de öyle midir?

DİKKAT VE POSTÜR KONTROLÜ

Postürel kontrol üç hareket bağlamında categorize edilebilir (Blanchard ve ark., 2005). İlki static postürün korunması, ikincisi istemli hareketlerden oluşan dinamik postür kontrolü ve üçüncüsü ise beklenmedik durumlar karşısında bir reaksiyon işlevinde olan reaksiyonel postür kontrolüdür. Statik postür duruşunda postür, vizüel ve propriyoseptif sistemlere dayanarak çalışan kapalı döngü geribildirim ile çalışır (Woolacoott-Cook, 1985). Öte yandan sabit olmayan postürel görevlerin, mümkün pertürbasyonların ön görüldüğü açık döngü ileri besleme sistemleri ile çalıştığı düşünülmektedir (Massion, 1992). Bu tarz yaklaşımlar postür kontrolünün refleksif ve otomatik olarak tanımlandığı geleneksel görüşleri destekler niteliktedir. Geleneksel postür kontrolü literatürü, postürün otomatik doğası sebebiyle dikkat gerektirmediği ve dolayısıyla da bilişsel aktivitenin gerek duyulmadığı görüşlerini savunur. Woollacoot-Cook (Woollacott-Cook, 2002) ise “denge kontrolünün talep ettiği dikkat miktarının, birincil ve ikincil görevlerin karmaşıklığına bağlı olduğunu” ileri sürmektedir. Bu görüş, postürel görev (motor görev) ve bilişsel görevlerin bir arada icra edildiği durumlarda, dikkat kapasitesinde bir aşım meydana gelebileceği yönündedir. Öte yandan farklı çalışmaların öne sürdüğü yorumlamalar da mevcuttur. Bir görevin tamamlanamaması ve eksik olarak icra edilmesi bu görevin bir kenara bırakıldığı anlamına gelebilir. Böyle durumlarda “öncelik verilmeyen” görevlerin işlenmesi ertelenebilir veya tamamen bırakılabilir, ki bu da görevde gecikme veya zarar görme ile sonuçlanabilir. Sonuç olarak postür kontrolü görevlerinde dikkat unsuru yok değildir.

İKİLİ GÖREV VE İKİLİ GÖREV ÇAKIŞMASI

Dikkatin postür kontrolündeki rolünü anlamak amacıyla, tek görevli dizaynlarla kıyaslamak üzere ikili görev dizaynları tasarlanmıştır. Bu ikili görevler, bir önceki cümlede bahsedilen amaç doğrultusunda bir adet motor görev ve bir adet bilişsel görev olarak belirlenmiştir. Bilişsel görevin kaplayacağı alan, dikkat ve bilgi işleme süreçlerinde gözlenebilmektedir. Bu tarz çalışmalar ikili görevlerin her ikisinin de tamamlanması ile sonlanabilirken aynı zamanda bu iki görevin çakışması ile de sonlanabilir. Bu çakışma sonucunda görevlerden birisinin icra edilmesi kalitesi düşebilir veya bu görev tamamlanmaktan aciz kalabilir. Bu iki olasılığın gerçekleştiği durumlara ikili görev çakışması adı verilir. Allport'un bahsettiği gibi (Allport, 1989) eğer insanlar görevleri tek tek, birer birim olarak değil de tüm görevleri bir bütün olarak tanımlıyor ve o şekilde birçok görevi aynı anda icra edebiliyor ise eğer, bu ikili görev çakışması niçin gözleniyor? Yine kendisinin cevapladığı üzere "her amaç odaklı hareketler bütünü tamamlanması için ideal durumlara muhtaçtır." Eğer icra edilecek olan görevler birbiri ile çelişir ise, bu görevlerden bir tanesinin modifiye edilmesi gerekebilir. Eğer modifiye edilen görev de yeterli olmaz ise başka bir göreve öncelik verilebilir ve kalan görev veya görevler ertelenir yahut bir kenara bırakılır. Benzer şekilde Neumann da aynı konuyu ilintili şekilde ele almıştır. Neumann'a göre (Neumann, 1987) ikisi de birbirinden bağımsız görünen eylemler aynı anda icra edildiğinde, bu iki bağımsız görev tek bir birim olarak algılanır ve eylem planlaması bu doğrultuda gerçekleştirilir. Eğer bu iki görevin bir arada yapılması bir şekilde sekteye uğrarsa, tek bir birim olarak algılanması gereken bu iki görevin koordine edilmesi hususu başarısızlığın sebebi olarak gösterilebilir. Öte yandan, görevlerin bileşenlerinden "zorluk" bir şekilde manipüle edilirse, bu durumda görevlerin icrası da değişecektir. Başka bir deyişle, genel eylem planı yeni zorluk derecesi ile tehdit altına girmez ise, görevlerin performansı aynı, değişmemiş şekilde kalacaktır.

POSTÜR KONTROLÜ VE BİLİŞSEL GÖREV IÇEREN İKİLİ GÖREV PARADIGMASI

Postür kontrolü ve bilişsel görevin birlikte icra edildiği çalışmaların bir kısmı, bilişsel görev varlığının postür kontrolünü iyileştirdiğini önce sürerken, bir kısmı ise postür kontrolü ile bilişsel görevin çakıştığı sonucuna varmaktadır. Cetye ve ark. (2014) postür kontrolünün sağlanması ve eş zamanlı olarak bilişsel görevin icra edilebilmesi için kullanılan dikkat kapasitesinin limitli olduğunu idda etmektedirler. Yaptıkları çalışmada 71 genç erişkin yer almıştır. Verilen motor görev ayakta sakin duruşu pozisyonunu olabildiğince sabit tutmaktır. Üç farklı vizüel durum yaratılmıştır: Görüş var, görüş yok ve var olan görüş alanının iki farklı şekilde (sabit veya hareketli destek yüzeyi) manipüle edildiği durum. Görüşün var olduğu durumda katılımcılara bir resme bakmaları söylenmiştir. Bu motor görevlerin icrası esnasında katılımcılara, mümkün olan en hızlı ve doğru şekilde tamamlamaları salık verilerek bir bilişsel görev verilmiştir: kendilerine verilen numaraya 3 veya 13 sayılarını kullanarak sürekli olarak çıkarma işlemi yapmak. Her denemenin sonunda ise eriştikleri sayıyı sesli olarak söylemeleri talep edilmiştir, ki bu da bilişsel görevin tamamlanıp tamamlanmadığı hakkında bilgi vermektedir. Çalışmanın sonuçlarına göre, bilişsel görevin eklenmesi yalnızca sakin duruş görevine göre salınımı artırmıştır. Gözlerin açık olduğu ve resme bakılan durumda katılımcılar bakışlarını bir noktaya sabitledikleri için, bilişsel görevin salınıma anlamlı etki etmediği görülmüştür. Bilişsel görevin çevreyle herhangi bir etkileşimi gerektirmediği, bu sebeple de bakışın bir noktaya sabitlenerek bilişsel göreve odaklanılabildiği sonucuna varılmıştır. Literatürde yaşlı bireylerin postürel görevi bilişsel görevin önüne koydukları bilinmektedir; bu çalışmada ise genç bireyler bilişsel görevi postürel görevin önüne koyarak öncelik verdikleri gözlenmektedir. Öte yandan, bir önceki çalışmada iddia edildiği üzere bilişsel görevin postür kontrolü ile çakıştığı savının aksine, Vuillerme and Vincent (2006)'in çalışması ise ayak baskı değişimlerinin bilişsel görevin varlığı ile etkilenip etkilenmediğini araştırmaktadır. Postür kontrolünün bilişsel görevin eşliği tarafından nasıl etkilendiğine dair birçok çalışma olduğu üzere, Vuillerme ve Vincent literatürde yapılan çalışmalarda sesli olarak sorulara cevap verilmesi, manuel cevaplar verilmesi ve bakışların sabitlenmesi durumlarını, dengeye etki eden ve dolayısıyla çalışmaların sağlığını etkileyen durumlar olarak tanımlamışlardır. Çalışmada 13 yetişkin yer almıştır. İki ayak üzerinde sakin duruş durumunun yanında, bir adet zor ve bir adet kolay bilişsel görev belirlenerek toplamda 3 durum yaratılmıştır. Katılımcılar çıplak ayakla ve nötr konumda kuvvet platformu üzerinde sakin duruş görevlerini yapmışlardır ve sonucunda basınç merkezi değişimleri ölçülmüştür. Bilişsel görevlerin de bu postürel göreve eklendiği durumlarda katılımcılara 52 saniye süren bir ses kaydı dinletilmiş ve bu ses kaydında aritmetik işlemler dizisi sunulmuştur. Her işlem dizisinin basamakları rakamlar ile bölme, çarpma, çıkarma ve toplama olmak üzere dört işlemdir. Kolay olan bilişsel görevde 4 saniyede bir olmak üzere toplam 13 işlemin sunulmasıdır. Zor olan bilişsel görevde ise her 2 saniyede bir olmak üzere toplamda 26 adet işlem sunulmuştur. Heri seri farklı işlemlerden oluşmaktadır. Bilişsel görev katılımcıların herbir işlemi yaptığından emin olmak amacıyla, very toplama süresi olan 32 saniyeden 10 saniye önce başlamış ve 10 saniye sonra bitmiştir. Respirasyondaki değişimin basınç merkezinde değişimlere yol açtığı bilindiğinden, katılımcılara bu süre zarfında konuşmamaları söylenmiş ve işlemlerin sonucu sürenin sonunda sesli olarak talep edilmiştir. Denemenin sonunda katılımcıların doğru cevap verip vermediği, postürel kontrole öncelik verilip verilmediği ve bilişsel görevin başarıyla tamamlanıp tamamlanmadığını kontrol etmek amacıyla kaydedilmiştir. Sonuçlara göre AP yönündeki basıç merkezi değişimleri, katılımcılar zor bilişsel görevi icra ederken azalmıştır. Bu çalışma, literatürde bilişsel görevin varlığının postür kontrolü ile çakıştığı iddialarının aksine, bu ikili durumun postür kontrolünü iyileştirdiğini iddia etmektedir. Vuillerme ve Vincent'e göre çalışmalarda kullanılan zorluk derecesi önemli bir faktördür ve bilişsel görev yeterince zor değil ise postür kontrolü üzerine olan etkisi incelenemeyebilir. Çalışma, yeterince zor bilişsel görevlerin aslında postür kontrolünü iyileştirdiği sonucuna varmıştır.

METOD

Hacettepe Üniversite'sinde lisans, yüksek lisans ve doktora öğrenimine devam eden 20-30 yaş arası, profesyonel sporcu olmayan 20 kişi çalışmaya katılmıştır.

Protokol 1: Çalışmaya Dahil Edilme ve Bilişsel Görev Zorluğunun Bireysel Olarak Belirlenmesi

Test öncesinde araştırmacılar tarafından matematikte dört işlemi içeren ve sonucu en fazla iki haneli ve 50 sayısını geçmeyecek şekilde; bir işlem (+,-,x,/) ve bir tam sayılardan oluşan üç adet işlem seti hazırlanmıştır. Test "0" rakamına sayı eklenmesi ile başlar ve gelişigüzel sırayla sunulan işlemlerin sırasıyla yapılması istenir (ör. +2, x5). Teste alınan kişi butona bastıkça yapması gereken bir sonraki işlem ve sayı kendisine bildirilmiştir. Test süresince kişinin sadece işlemleri yapması ancak test süresince hiçbir zaman ara sonuçları sesli olarak söylememesi istenmiştir. 1 dakika sonunda test sona erer ve kişi tüm işlem dizisi sonunda ulaştığı sonucu sesli olarak dile getirir. Sonuç doğru ise katılımcının 1 dk içinde tamamladığı işlem sayısı kayıt edilmiştir. Kişiye 3 hak verilip, en az bir işlem setini doğru olarak tamamladığı deneme ardından test sona erdirilmiş ve kişi araştırma grubuna dahil edilmiştir. Başarısız denemeler arasında 2 dk dinlenme süresi verilmiştir. 3 işlem setini de başarıyla tamamlayamayan kişiler araştırmaya dahil edilmemiştir. Teste alınan kişi test öncesinde bir sandalyede ayakları yere basar, sırtı dik yere ve destekli şekilde dirseği 90 derece açıda yere paralel konumda masa üzerinde destekli şekilde, dominant eli pronasyon pozisyonunda işaret parmağı "buton" üzerinde ve basmaya hazır şekilde beklemektedir. Kişi butona bastığında yapılması gereken işlem sesli olarak hoparlör aracılığıyla sunulmuştur. Kişinin 1 dk içinde butona basma sayısı bilişsel işlem maksimum sınırı olarak kabul edilir ve araştırmanın postür kontrolünün araştırıldığı deneysel dizaynı kapsamında bilişsel uyaranın sunulması sırasında işlem sıklığının bireysel olarak değişiklik göstermesinin anlamlı olup olmadığının belirlenmesinde kullanılmıştır.

Protokol 2: Sakin Duruş ve İstemli Salınım Görevleri Esnasında Postür Kontrolünün İncelenmesi

Aşağıda açıklanan iki farklı postür kontrol denemesi 3 tekrar olarak uygulanmıştır. Her tekrar arasında 2 dk pasif dinlenme verilmiştir.

- Sakin Duruş: Ayakta nötral pozisyonda, ayaklar birbirine paralel ve omuz genişliğinde açık, gövde dik ve baş karşıya bakar pozisyonda mümkün olduğunca hareketsiz ve sakin şekilde kuvvet platformu üzerinde durulması istenmiştir.
- İstemli Salınım: Ayakta nötr pozisyonda, ayaklar birbirine paralel ve omuz genişliğinde açık, gövde yere dik ve baş karşıya bakar pozisyonda duran katılımcı, anterior-posterior yönde topukları ve ayak parmakları yerden kalkmayacak şekilde ve sadece ayak bileği ekleminde frontal eksende öne arkaya salınım hareketi gerçekleştirmiştir. 1 dk süreli alışma evresinde salınım devri metronom ile işitsel olarak sunulmuş ve tüm katılımcılar için öne-arkaya bir yarım devir 1 sn içerisinde gerçekleşecek şekilde sabit bir ritme uyulması istenmiştir.

Protokol 3: Bilişsel Görevin Postür Kontrolü Üzerine Etkisinin İncelenmesi

Sakin duruş ve istemli salınım denemeleri sırasında kendisine işitsel olarak sunulan ve Protokol 1'de detayları yer alan bir matematik işlemi dizisini sesli bir reaksiyon vermeden yapmış ve işlem sonucunu deney sona erdiğinde araştırmacılara iletilmiştir. Sonucun doğru olması durumunda söz konusu deneme araştırma verisi olarak kayıt edilmiştir. Her katılımcı en fazla 5 tekrar yapmıştır. 3 başarılı deneme gerçekleştiğinde ölçüm sona erdirilmiştir. Her katılımcının kendi bilişsel kapasitesinin %60'ına denk gelen sıklıkta işlem için Protokol 3 gerçekleştirilmiştir. Buna göre, bilişsel kapasitenin ölçüldüğü Protokol 1'de her katılımcı için maksimum işlem sayısı referans değer olarak kullanılarak, zor olan bilişsel görev durumunda kişinin bilişsel kapasite testinde 1 dk tamamladığı işlem basamağı sayısının %80'i kadar işlem basamağı 1 dk süreli postür kontrol görevlerine ek olarak sunulmuştur (örn: kişi 1 dakika içinde 30 adet işlem yaptıysa, postür kontrolü sırasında eş zamanlı olarak 1 dk içinde 2.5 sn ara ile 24 adet işlem basamağını yapması istenmiştir). Öte yandan, bilişsel kapasitenin ölçüldüğü Protokol 1'de her katılımcı için maksimum işlem sayısı referans değer olarak kullanılarak, zor olan bilişsel görev durumunda kişinin bilişsel kapasite testinde 1 dk tamamladığı işlem basamağı sayısının %50'si kadar işlem basamağı 1 dk süreli postür kontrol görevlerine ek olarak sunulmuştur (örn: kişi bir dakika içinde 30 adet işlem yaptıysa postür kontrolü sırasında eş zamanlı olarak 1 dk içinde 4 sn ara ile 15 adet işlem basamağını yapması istenmiştir). Bireylerin COP değişimi ile, bilişsel kapasite testi verileri birlikte yorumlanarak, postüral kontrol görevinin yanında sunulan bilişsel görevin zorluğunun anlamlı etkisinin olup olmadığı incelenmiştir.

Verilerin Toplanması ve Analizi

Laboratuvarda ayakta gerçekleştirilen sakin duruş ve istemli salınım hareketleri kuvvet platformu (AMTI, ABD) üzerinde gerçekleştirilmiştir. Bu sayede, postür kontrolü sırasında yer tepki kuvvetlerinde meydana gelen değişimler ve basınç merkezi (COP) değişimleri incelenmiştir. Salınım hareketleri sırasında salınım frekansının sabitlenmesinde metronom kullanılmıştır. Salınım hareketinin istenilen aralıkta olması için hareketin öğrenilmesi aşamasında kişinin göz hizasında 1 m uzaklıktaki monitor aracılığı ile basınç merkezi değişimine ilişkin görsel geri bildirim verilmiştir. Kinetik verilerin analizinde Hacettepe Ünversitesi lisanslı MATLAB R2016b (Mathworks) yazılımı kullanılmıştır. Yumuşatma, linear envelope, integral, rms hesaplama gibi matematiksel işlemler ve sinyal işleme tekniklerinden faydalanılarak veriler zaman ve büyüklük ekseninde incelenerek ve sinyal büyüklüğü ve referans zaman noktaları belirlenmiştir. Yer tepki kuvvetlerine ait sinyaller kullanılarak anterio-posterior ve medio-lateral yönde basınç merkezi (COP) değişimleri analiz edilmiştir. İstatistiksel analizler kapsamında, statik ve dinamik iki farklı salınım hareketi sırasında bilişsel görevin postür kotrolü üzerine etkisi parametrik olmayan Friedman Test ile yapılmıştır. İstatistiksel analizlerde Hacettepe Üniversitesi lisanslı SPSS paket programı kullanılmıştır.

ANA BULGULAR

Friedman test sonuçlarına göre basınç merkezi değişimlerinde hız, AP yönünde salınım aralığı ve AP yönündeki salınımda rms değerleri anlamlı şekilde azalma göstermiştir. Sakin duruş basınç merkezi değişimlerinde anlamlı fark bulunamamıştır. Aşağıdaki Tablo 1'de İstemli salınım için betimsel istatistik, sıra ortalaması ve Friedman Test sonuçları sunulmuştur.

Tablo 1. İstemli Salınım (İS) ve Sakin Duruş (SD) için Basınç Merkezi Değişimleri Parametreleri Standart Sapma ve Ortalamaları

	Basınç Merkezi Parametreleri	0 BG (BG Yok)	%50 BG (Orta BG)	%80 BG (Yüksek BG)	Standard Sapma (±)
İS	COP_{VEL}*	23,63	21,85	20,54	1,26
	COP_{range} AP*	79,96	73,58	68,93	4,52
	COP_{range} ML	25,66	25,17	24,70	0,39
	COP_{AREA}	1079,61	995,59	942,50	56,44
	RMS_{AP}*	12,29	11,24	10,58	0,70
	RMS_{ML}	4,48	4,52	4,54	0,02
SD	COP_{VEL}	7,43	7,30	7,11	0,13
	COP_{range} AP	16,38	15,50	14,84	0,63
	COP_{range} ML	8,09	7,97	7,98	0,05
	COP_{AREA}	98,30	91,43	86,86	4,70
	RMS_{AP}	29,28	30,23	29,33	0,43
	RMS_{ML}	15,93	14,70	12,44	1,44

TARTIŞMA ve ÖNERİLER

Bu ikili görev çalışması, postürel görev ve bilişsel görevin (iki farklı zorluk derecesi ile) aynı anda icra edildiği durumlarda birbirleriyle "çakışma" oluşturup oluşturmadığını gözlemek amacıyla tasarlanmıştır. Postür kontrolünün bililşsel görev (BG) yokluğunda, orta düzey ve yüksek düzey zorluklarında nasıl etkilendiği gözlenmiştir. Literatürde bu alanda bulunan farklı çalışmaların ve bulunan benzer sonuçların farklı şekilde yorumlanması sebebiyle böyle bir çalışma yapılması ihtiyacı duyulmuştur.

Basınç merkezi değişimi parametlerinin, BG varlığı ile azalması kimi araştırmacılar tarafından postür kontrolünde iyileşme, kimileri tarafından bir "çakışma" olarak yorumlanmıştır. Bu farklı yorumların bir sebebinin de BG zorluğunun kişilere özgü olarak tasarlanmaması sebebiyle zorluk faktöründen yeterince faydalanılmadığı düşüncesidir. Bu sebeple çalışmada herbir bireyin kendi yapabildiği işlem sıklığı baz alınarak bir tasarım yapılmıştır. Öte yandan, BG zorluğu ve sakin duruş birleştiğinde anlamlı bir fark bulunamamıştır. Bu da önceden bahsedilen Allport'un dikkat literatürüne katkı sağladığı üzere, iki farklı görevin tek bir birim görev olarak algılanarak bu iki görevin birleşiminin yeterince zorluk oluşturarak her iki görevi de etkilemekten yoksun kalması olarak yorumlanabilir. Verilere bakıldığında istemli salınım ve BG'in aynı anda icra edildiği durumlarda, BG arttıkça basınç merkezi değişiklikleri zorluk arttıkça azalmıştır. Bu azalma düşünüldüğünün aksine bir iyileşme değil de hareket açısında bir daralma olarak yorumlanmaktadır.

Sakin duruş, tıpkı çalışmanın başında yapılan oturarak bilişsel işlem sayısının belirlenmesi süreci gibi, katılımcıları bilişsel ve motor görevler açısından zorlayan bir süreç olmamıştır. Diğer açıdan, istemli salınımın belirli bir ritmde (30 BPM) yapılması gerekliliği ve otomatik olarak sunulan orta ve yüksek düzey zorlukta BG'lerin etkisiyle basınç merkezi değişiklikleri gözlenmiş ve parametlerin azaldığı görülmüştür. Dikkat sistemi, tutarlı, amaçlı bir hareket planı arzular. Allport'un belirttiği üzere (Allport, 1989) amaç odaklı hareketlerin icrası, verilen görevlerin motivasyonel, bilişsel, motor ve sensöri düzeylerlerde koordinasyonunu gerektirir. Çalışmadaki katılımcılar, bu sebeple, bilişsel görevi öncelik haline getirmiş olabilirler. Dikkatin seçici doğası sebebiyle motor görev genç erişkin katılımcılarda, tıpkı yaşlı bireylerin postür kontrolünü öne koyması gibi, bilişsel görevin gerisinde kalmış olabilir. Woollacott ve Cook'un (Woollacott-Cook, 2002) öne sürdüğü gibi motor görevin tamamlanması ikinci görevin karmaşıklığına bağlıdır. Çalışmamızda gözlendiği üzere ikinci görev karmaşıklaştıkça motor görev bundan etkilenmiş ve bir "çakışma" meydana gelmiştir. Yine Allport'un iddia ettiği üzere tüm görevlerin başarıyla tamamlanması için bir modifikasyon gerekebilir ve çalışmamızda bu modifikasyon postürel görevde yapılmıştır. Bu modifikasyon zaman boyutunda gerçekleşemeyeceği için (belli bir ritimle, 30 BPM ile salınma görevi sebebi ile) hareket aralığı parametresinde gerçekleşmiştir. Bu modifikasyon akla “hız-kesinlik değiş tokuşunu” akla getirmektedir. Bilişsel görevin varlığı ve gittikçe zorlaşması, katılımcıları bir değiş tokuşa zorlamış ve uzay zaman boylamlarındaki elementlerden birisi modifiye edilmiştir.

Bu çalışma, kas aktivitesini ölçmediği için bazı spekülasyonlarda bulunulabilir ancak salınım ve sakin duruşta denge kaybı olmadığından ve basınç merkezi ayak bileği ekleminden kontrol edildiğinden, ayak bileği ekleminde bulunan kasların (örn: Tibialis Anteriör ve Gastroknemius) aktivitesi ölçülerek bir kokontraksiyon oluşup oluşmadığı gözlenerek bu hareket açısındaki daralmanın sebepleri araştırılabilir. Ayrıca, farklı bilişsel görevler kullanılarak çalışma hafızasının postür kontrolüne etkisi gözlenebilir. Bir aritmetik işlem yerine Brook’s test gibi görsel hafıza kanallarını kullanan görevler tercih edilebilir. Benzer şekilde farklı çevresel dizaynlar tasarlanarak diğer sensöri sistemlerin bilişsel görev ile etkileşimi çalışılabilir.

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