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The Effect of Eye and Vision on the Body's Balance System

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ABSTRACT

It is estimated that our eyes, one of our five senses, perceive 80% of the sensory information received from the environment. One-fourth of the brain is used to process this data in the brain. Visual perception consists of three main sections: the optics of the eye, photon detection and initial image processing in the retina, signal transmission in the visual cortex and advanced processing. Visual perception begins at birth and develops over time. In order for the eyes, which are the gateway to visual perception, to work in harmony, there are muscles that provide movement in the eye, as in the rest of our body. Six of these muscles control eyeball movement, two adjust the iris, and one is the ciliary muscle for accommodation. These nine muscles work in harmony for left and right eye movement. Different eye movements occur as a result of the movements of these muscles in the same and different directions. The fact that the eye muscles have a certain tone even during relaxation allows these muscles to move quickly [1]. The body's balance system depends on the harmony of various sensory and motor systems. These are the central nervous system, vestibular system, visual system and proprioception. Due to this condition, patients with vestibular, proprioceptive and cerebellar disorders experience increased body sway and loss of balance. In addition, loss of muscle mass, slower reflexes and deteriorating vision due to aging can negatively affect balance. In neurological diseases, a decrease in walking speed, an increase in step width, and frequent falls can be observed due to balance and walking disorders [2-4].

Accordingly, people with neurological diseases become more dependent in daily life activities and the quality of life of these patients decreases [5-7]. Sometimes, fractures occur in the body due to these falls, and it is estimated that visual impairment is an important risk factor for this condition. The effect of visual impairment on falls and fractures was examined in a study in 2004 with the participation of 1509 elderly men and women. This study showed that visual impairment is an independent risk factor for both recurrent falls and fractures [8]. The study conducted by Squirrell et al. on 89 patients with hip fractures also supported this situation. According to the study by Squirrell et al., 33% of these patients were classified as visually impaired, while 58% had vision problems [9]. Both of these studies showed that visual impairment caused loss of balance and related falls. This article explains the "The Effect of Eye and Vision on the Body's Balance System". The study has been realized within the scope of a Ph.D. lesson which is lectured by Asst. Prof. Dr. Emin Taner ELMAS. The name of this Ph.D. lesson is "Medical Engineering and Advanced Biomechanics" and taught at the Major Science Department of Bioengineering and Bio-Sciences at Iğdır University, Turkey. Servet KAYA is a Ph.D. student and he is one of the students taking this course. This article has been prepared within the scope of this Ph.D. lecture [1-62].

Keywords: Medical Technique; Medical Engineering; Biomechanics; Biomechanical Analysis; Bioengineering; Medicine; Eye; Vision System; Hearing System; Body Balance

Introduction

The Effect of Eye and Vision on the Body's Balance System

It is estimated that our eyes, one of our five senses, perceive 80% of the sensory information received from the environment. One-fourth of the brain is used to process this data in the brain. Visual perception consists of three main sections: the optics of the eye, photon detection and initial image processing in the retina, signal transmission in the visual cortex and advanced processing. Visual perception begins at birth and develops over time. In order for the eyes, which are the gateway to visual perception, to work in harmony, there are muscles that provide movement in the eye, as in the rest of our body. Six of these muscles control eyeball movement, two adjust the iris, and one is the ciliary muscle for accommodation. These nine muscles work in harmony for left and right eye movement. Different eye movements occur as a result of the movements of these muscles in the same and different directions. The fact that the eye muscles have a certain tone even during relaxation allows these muscles to move quickly [1].

Vision plays a role, along with the other senses, in maintaining postural balance. Vision reduces naturally occurring body sway by 50 percent [10,11], and the increased balance with eyes open, as in the Romberg test [12], in patients with proprioceptive sensory dysfunction or cerebellar ataxia, illustrates the importance of vision in postural stability. The body's balance system depends on the harmony of various sensory and motor systems. These are the central nervous system, the vestibular system, the visual system and the sense of proprioception. Due to this condition, patients with vestibular, proprioceptive and cerebellar disorders experience increased body sway and loss of balance. In addition, loss of muscle mass, slower reflexes and deteriorating vision due to aging can negatively affect balance. Certain health problems such as inner ear disorders, hearing loss, heart rhythm disorders and neuropathy (nerve damage that causes weakness, numbness and pain) can also impair balance [13]. However, when visual input is increased, most patients' postural stability and balance also increase. A similar situation applies to healthy individuals. If a healthy person is asked to perform a movement with their eyes closed, the movement will become difficult [14]. Visual stimulus conflict can have a significant effect on balance. Moving visual environments can cause postural changes and loss of balance in healthy adults. Patients with vestibular disorders may be more affected by these stimuli [1-62].

Method, Findings and Discussion

There are two main senses that make up the body's balance system. These are proprioception and vestibular sense. These two senses will be discussed below.

Propriosepsies

As the human body ages, postural instability and loss of balance occur due to structural and functional deteriorations in the somatosensory systems. Joint position sense, movement and touch senses are completed thanks to sensory information from receptors in muscles, tendons and joints. The sense of proprioception emerges when these functions come together. This sense has a very important place in standing balance because it transmits the pressure center speed in the lower extremities to the central nervous system more sensitively and earlier than other senses. [15]. During walking, each step is planned and information is provided for the placement of the foot thanks to proprioception. Muscle spindles provide information about muscle length and contraction speed during movement, allowing the perception of joint position and kinesthesia. In addition, the Golgi tendon organ and joint receptors contribute to proprioception, which is necessary for the correct understanding of movement. The Golgi tendon organs are located at the junction of the muscle and tendon and are sensitive to changes in muscle tension that occur with active contraction or passive stretching. Mechanoreceptors located in the joint area respond to the stretching and deterioration of the joint capsule and ligaments. There are four mechanoreceptors located under the hairless skin: the Meissner corpuscles, which perceive touch, the Pacinian corpuscles, which perceive vibration, the Merkel disc, which perceives pressure and adapts slowly, and the Ruffini endings, which perceive stretch. These receptors, together with hair cells, provide important feedback about the environment and assist with proprioception and movement [16].

Vestibular Sense

The vestibular system perceives the position and movement of the head in space and produces a series of corrective movements to prevent imbalance. Information about the angular acceleration of the head in any direction is transmitted by the three semicircular canals, while linear accelerations and the inclination of the head relative to gravity are reported by the utricular and saccular organs of the otolithic system. The vestibulo-ocular reflex helps the eye to look fixedly at a point during head movements by producing eye rotations. Vestibulospinal reflexes stabilize the head by stimulating the muscles in the neck, trunk and extremities and help maintain upright posture [17]. In addition, vestibulocollic and cervicocollic reflexes help to stabilize the head in an upright position by initiating neck movements during position changes. The vestibular system's response occurs in different ways depending on the type of balance disturbance. For example, patients with defective vestibular input give normal postural muscle responses in the event of a forward fall. However, if the head position is disrupted instead of the foot position, these patients cannot give normal protective and corrective responses and experience loss of

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balance [16]. This situation causes falls and often leads to injuries. The effect of vision on balance is also used as a differential diagnostic method for some diseases. The best example of this is the Romberg test.

Romberg Test

The Romberg test is named after a European neurologist, Mortis Romberg. This test has been described by scientists such as Marshall Hall, Moritz Romberg and Bernardus Brach [18]. The Romberg test is described as follows: if the patient is asked to remain motionless while standing upright, they immediately start moving from side to side and the oscillations reach such a level in a short time that if they are not supported, the patient falls to the ground. The same thing happens when the body is supported and the patient is in a sitting position and they slide off the chair. The eyes of such patients are their regulators or feelers. Therefore, Romberg stated that the patient's balance would be disrupted when they were asked to stand with their eyes closed and associated the test with tabes dorsalis. This last situation indicates that the pathways that provide proprioception are damaged [19]. Initially, this sign was associated with patients who showed a neurological sign of late-stage disease. Over time, the Romberg sign has become a definitive test for determining the integrity of the dorsal column pathway of the brain and spinal cord that controls proprioception in late-stage neurological patients. Proprioception is the sense of awareness of the position of the body's extremities and movement in space. According to Romberg, this sign was defined as a severe balance disorder in diseases caused by damage to the posterior dorsal column of the spinal cord, seen in a dark room environment or with the eyes closed. In the Romberg test, the patient has a balance problem when in a dark environment or with the eyes closed.

While the Romberg test often resembles the symptoms of cerebellar disease, the test is usually positive in posterior column diseases. In a person, vision, proprioception and the vestibular system work in harmony for normal balance. Sometimes, when the true level of proprioception is evaluated, it can be confused with vestibular function. Since the visual and vestibular components are eliminated in the Romberg test, it is not possible to evaluate the balance solely proprioception is evaluated. Therefore, a positive Romberg test may indicate a neurological disease related to proprioception. In the Romberg test, the person can initially stand with their eyes open and feet together, but when they close their eyes, they shake or fall. This test is said to be positive in a patient who has eliminated visual cues [18]. The Romberg test has been used as an important tool in neurological diagnosis since 1846. It is used by neurologists as well as other physicians in the relevant field. The reasons for this situation are that the test is easy to apply and safe. Various authors have tried to increase the reliability of this test over time [20]. The balance problem of patients with vestibular system disorders improves with vision. Reducing the effect of pathological nystagmus positively affects balance. Researchers have investigated how eye movements affect balance instead of retinal shift and have found that slow eye movements increase postural sway and imbalance [21].

In a study conducted to determine whether the establishment and maintenance of balance changes depending on the movement of the eye, balance was measured in three ways: fixed eye, saccadic eye movements and smooth pursuit eye movements. In order to measure balance, the aim was to keep the platform on which the subjects were standing within 5 degrees of the horizontal plane. In this study conducted with 35 healthy women, it was found that eye movements have a great effect on balance. The best balance was achieved when the eyes were fixed, while the weakest balance was achieved when the balance was performed together with saccadic eye movements. These results may be useful in diseases accompanied by loss of balance. Focusing on a point while walking will increase balance, while the opposite situation impairs balance. [22] This situation may be a suggestion that will make daily life easier for patients with ataxia-like balance problems. Patients with vestibular disorders often experience loss of balance in moving visual environments. In a study conducted with different visual stimuli, the standing balance of healthy adults and patients with vestibular disorders was examined. It was found that patients with vestibular disorders made significantly higher postural sway than healthy individuals while watching central optic flow stimuli. Sinusoidally expanding and contracting optic flow caused postural sway at the stimulus frequency in both patients and controls; however, there was a much greater increase in sway at frequencies close to the stimulus frequency in patients.

These results show that postural control in patients with vestibular disorders is particularly affected by optic flow stimuli directed to the central region of the visual field [23]. Therefore, skills that are usually acquired by the patient through the rehabilitation process in the cliniccan be lost again in social areas. This situation provides guidance for rehabilitators. According to the study conducted by Kahiel et al. in Canada on 12 thousand people for 3 years, the decrease in visual acuity decreased one-legged stance balance. Participants who had 60 seconds of one-legged balance at the beginning of the study had a 15% higher probability of failing the balance test due to the decrease in visual acuity. At the same time, those who had previously or currently diagnosed with cataract had difficulty passing the test during the next test. Age-related macular degeneration and glaucoma were not found to be associated with failure in the balance test [24]. Edwards investigated the relationship between body sway and vision in a 13-experiment study conducted in 1946. According to the results of the study, eliminating vision by closing the eyes or in complete darkness increased sway by an average of 2-fold. When tested under low illumination, smaller increases in sway were obtained. Small increases in body sway were also obtained when participants were asked to follow moving objects. Following a swinging pendulum caused a significant increase in lateral sway in particular. When participants were asked to focus on stationary objects near or far, a significant decrease in sway was obtained [11].

Nashner and colleagues (1982) studied patients with vestibular disorders who were exposed to several different support surfaces and visual environments while standing without support. A six-degree-of-freedom platform using moving support surfaces for each foot and a moving visual environment deprived patients of the normal inputs obtained from a fixed-level support surface and a stationary environment. They described changes in the patients' proprioceptive, vestibular, and visual inputs with various tests using EMG, force, and body movement recording. The patients' greatest performance deficit was that orientation information was impaired and movement and balance were impaired as a result of decreased visual and proprioceptive inputs. Thus, the less severely affected patients experienced imbalance not because of a loss of direct vestibular input to posture but because of inappropriate responses to proprioceptive input and vision. These results indicated that vestibular input can affect the processing of proprioceptive and visual inputs [25]. In a study measuring balance parameters in elderly and young individuals, the ability to stand on one leg with eyes open and eyes closed was measured in these two groups. As a result, one-legged balance with eyes closed in the elderly group made balance more difficult than in the young group [26].

This helps explain the effect of vision on balance.Robins and Hollands investigated the effects of vision on turning following walking. The aim of the study was to elucidate the effects of vision and eye movements on whole-body coordination during turns by observing the effects of either removing visual information separately or suppressing eye movements during the turn. The results of the study showed that blocking eye movements altered both the timing and spatial properties of axial segment and foot rotation. When gaze was fixed, gait onset was delayed compared to both full vision and no-vision turns, but axial segment rotation was not delayed. When eye movements were blocked, the predictable relationship between the extent to which head rotation directed the body and peak head angular velocity was eliminated, suggesting that anticipatory head movements normally support gaze behavior. In addition, the frequency of stepping was significantly reduced when gaze was fixed but not during the no-vision condition, suggesting that oculomotor control is linked to stepping behavior [27].

Visual impairments such as strabismus negatively affect upright balance in children, but the effects of strabismus on the oculomotor system and on balance in children are not fully known. Telci et al. aimed to determine the potential effects of oculomotor functions on balance skills in children with strabismus in their study. In the study in which a total of 30 children between the ages of 6 and 10 were included, 15 children were included in the strabismus group (8.07 ± 1.33 years) with a diagnosis of strabismus and 15 healthy children without any vision problems were included in the control group (8.03 ± 1.49 years). The Pediatric Balance Scale (PBS) assessment test was applied to evaluate balance function in children. As a result, it was understood that strabismus negatively affects balance in children and even an increase in the strabismus angle can disrupt balance more. The low scores obtained in the Pediatric Balance Scale scores of the strabismus group showed that strabismus can negatively affect balance skills in daily life activities [14]. In order to investigate the effect of visual and hearing impairment on standing balance, the participants were followed for 1 year in terms of the incidence of falls among 428 women aged 63-76. As a result, the negative effect of visual impairment on balance increased when accompanied by hearing impairment. The probable reason for this situation is that the compensatory information needed for balance cannot be obtained from other sensory sources [1-62].

Conclusion

This article describes "The Effect of Eye and Vision on the Balance System of the Body". The study was carried out within the scope of a PhD course given by Asst. Prof. Dr. Emin Taner ELMAS. The name of this PhD course is "Medical Engineering and Advanced Biomechanics" and is given in the Department of Bioengineering and Sciences, Institute of Graduate Education, Iğdır University, Turkey. Servet KAYA is a PhD student and one of the students taking this course. This article was prepared within the scope of this PhD course.In neurological diseases, due to balance and gait disorders, a decrease in walking speed, an increase in step width, and frequent falls can be observed [2-4]. Accordingly, people with neurological diseases become more dependent in daily life activities and the quality of life of these patients decreases [5-7]. Sometimes, fractures occur in the body due to these falls, and it is estimated that visual impairment is an important risk factor for this condition. The effect of visual impairment on falls and fractures was examined in a study in 2004 with the participation of 1509 elderly men and women. This study showed that visual impairment is an independent risk factor for both recurrent falls and fractures [8]. This situation is also supported by the study conducted by Squirrell et al. on 89 patients who had hip fractures. According to the study by Squirrell et al., 33% of these patients were classified as visually impaired, while 58% had vision problems [9]. Both of these studies showed that visual impairment caused loss of balance and related falls [1-61].

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