EFFECT OF ACHILLES TENDON VIBRATION AT ADAPTING TO DIFFERENT SENSORY CONDITIONS

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

EFFECT OF ACHILLES TENDON VIBRATION AT ADAPTING TO DIFFERENT SENSORY CONDITIONS

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The aim of the study is to investigate the effect of Achilles tendon vibration (ATV) on postural sway behavior and backward body tilt (fall) response at adapting to different sensory conditions. The effect of anticipation on postural responses during ATV is also examined. Two different somatosensory environments are created which are without and with bodily somatosensory (touch) cue, respectively. In these different sensory environments, bipedal quiet stand test is applied on a force platform in both eyes-open and eyes-closed conditions, in the absence and the presence of ATV, respectively. The experiments were conducted on two sports groups (handball players and swimmers) and one control group (sedentary subjects). Center of pressure value in antero-posterior direction (CoPx) was computed and used in data validation and interpretation of the results. The results showed that independent from the groups, ATV always altered the proprioceptive information resulting backward body tilt (fall) and an increase in postural sway at adapting to all designed sensory conditions. However, it was observed that the anticipation of the vibration reduced the effect of ATV. Furthermore, independent from the groups, the contribution of touch information to reduce the effect of ATV was found more than the contribution of visual information. The most interesting result of this study was that when visual and touch information were supplied together to the sensory negative feedback mechanism, inter-group differences in terms of postural responses during ATV were vanished.

Keywords: Bipedal Quiet Stance, Posture Control, Proprioception, Somatosensory System, Tendon Vibration

ÖZ

DEĞİŞİK FİZİKSEL ÇEVRELERE / DUYSAL ŞARTLARA ADAPTASYONDA AŞİL TENDONUNA UYGULANILAN TİTREŞİMİN ETKİSİ

Carlak, Renan Arda
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Bu çalışmanın amacı, görme ve dokunma bilgileri ile oluşturulan farklı duysal ortamlara adaptastonda Aşil tendon vibrasyonunun (ATV) postür salınımı ve postürün geriye meyli üzerindeki etkisini incelemektir. Buna ek olarak, vibrasyonun tekrar geleceği ile ilgili beklentinin postür cevaplarına olan etkisi de incelenmektedir. Bu amaçla, deneklerin, somatosensör algı (dokunma) ipuçları almadığı ve aldığı iki farklı deney ortamı hazırlanmıştır. Kuvvet platformu üzerinde iki ayak üzerinde sabit dik duruş testi, bu iki farklı ortamda hem göz açık hem de göz kapalı olarak, Aşil tendon vibrasyonu varlığında ve de yokluğunda uygulanmıştır. Deneyler hentbol oyuncuları ve yüzücülerden oluşan iki spor grubu ve sedanterlerden oluşan kontrol grubu üzerinde yürütülmüştür. Veri değerlendirmeleri ve sonuçların yorumlanması için basınç merkezinin ön-arka doğrultusundaki değeri (CoPx) hesaplanmış ve kullanılmıştır. Sonuçlar, gruplardan bağımsız olarak, tüm dizayn edilmiş duysal ortamlara adaptasyonda, ATV'nin propriyoseptif bilgiyi değiştirerek postürün geriye meyline ve postür salınımının artmasına yol açtığını göstermiştir. Buna karşın, vibrasyonun tekrar geleceği ile ilgili beklentinin, ATV'nin postür üzerindeki etkisini azalttığı gözlemlenmiştir. Bununla birlikte, gruplardan bağımsız olarak, dokunma bilgisinin görsel bilgiye kıyasla, ATV'nin postür üzerindeki etkisini azaltmada daha

etkili olduğu görülmüştür. Çalışmanın en ilgi çekici sonucu ise ATV uygulanırken postür kontrolü sırasında, dokunma ve görsel bilgi birlikte kullanıldığında, gruplar arası postürel cevap farklarının kaybolduğudur.

.

Anahtar Kelimeler: Ayakta Sabit Dik Duruş, Postür Kontrolü, Propriyosepsiyon, Somatosensori Sistem, Tendon Vibrasyonu

To my fiancee Esra and our future

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LIST OF ABBREVIATIONS

ABBREVIATIONS	
CNS	Central Nervous System
CoP	Center of Pressure
CoPx	Center of Pressure Data in Antero-Posterior Coordinate
Fx	X Component of Ground Reaction Force
Fy	Y Component of Ground Reaction Force
Fz	Z Component of Ground Reaction Force
Mx	X Component of Moment
My	Y Component of Moment
Mz	Z Component of Moment
EC	Eyes-Closed
EO	Eyes-Open
TC	Touch-Closed / Without Bodily Somatosensory Cue
TO	Touch-Open / With Bodily Somatosensory Cue
AP	Anterior-Posterior
LR	Left-Right
ML	Medio-Lateral
APA	Anticipatory Postural Adjustments
CPA	Compensatory Postural Adjustments
ANOVA	Analysis of Variances

e	Epoch
Eqn	Equation
RMS	Root Mean Square
QS	Quiet Stance
PS	Perturbed Stance
S.D.	Standard Deviation
MODSİMMER	METU-TAF Modeling and Simulation R&D Center
MS	Muscle Spindle
ATV	Achilles Tendon Vibration

LIST OF SYMBOLS

SYMBOLS

Δ	Delta

CHAPTER 1

INTRODUCTION

1.1. Literature Review and Motivation of the Study

Chronological summary of the milestones and significant indications of the previous researches and publications which is yielded by an extensive literature survey is submitted below with the intent of presenting a historical perspective of the field of this study.

Postural control mechanisms were started to study in terms of systematical experiments over a century ago by Goldscheider [74] who compared even minimal joint rotations by quantifying systematically the awareness of body part positions and orientations and published his results that ankle joint has the highest threshold where the shoulder exhibits the lowest threshold in 1889. Shortly after that, the term "proprioception" is defined for the first time from Sherrington [58] in 1906 [25]. Systematic experimental studies were further developed and pioneering work of human upright stance (quiet stance) began to be researched and investigated with force platforms by Nashner in 1976 [75]. Allum [37] in 1983, conducted human postural control studies to examine evoked characteristic postural responses by employing transient stimuli (e.g., sudden support surface motions). In 1990, Horak, Nashner and Diener [49] conducted the experiment in quiet stance during somatosensory and vestibular loss condition to understand the role of vestibular and somatosensory (consisting of proprioceptive information) information in postural control. They emphasized the significance of the role of somatosensory information from the feet and ankles and the necessity of the vestibular information in the maintenance of equilibrium. Horak and Macpherson [44] in 1996, manipulated the vision and somatosensory information for dyslexic and non-dyslexic children to illuminate mechanisms of balance control with both biomechanical and neurophysiological approaches. Prieto, Myklebust, Hoffmann, Lovett, and Myklebust [72] published a study that investigate the differences between postural steadiness with respect to eye conditions (eyes-closed (EC) and eyes-open (EO)) in a young and old adult groups by the evaluation of relative sensitivity of center-of-pressure (CoP) measurement. Postural responses against galvanic vestibular stimulation was examined by Watson and Colebatch [73]. Soon afterwards, artificial stimulation of individual sensory receptors (muscle or tendon vibration) was applied to understand postural control mechanism in case of illusory input implication [28]. Then, inverted pendulum model was described by Jeka, Oie, Schöner, Dijkstra, Henson [22] and Peterka [11] for human upright stance mechanism where human body is such a pivoting tool around the ankles during quiet standing; moreover, the notion of sensorimotor integration was stated and presented to investigate further. By the way, Ashton-Miller, Wojtys, Huston, and Fry-Welch [25] investigated the relationship between the proprioception and the physical exercise by including athletes in their experimental participants and therefore, they tried to find an answer to the question: “Can proprioception really be improved by exercises?”

Inspiring all these previous researches and publications, the motivation of the study is to investigate the effect of Achilles tendon vibration on the postural sway behavior and backward body tilt (fall) response at adapting to different sensory conditions and its relation with the sportive background. Moreover, the effect of the anticipation on postural responses during ATV is also examined.

1.2. Human Upright Stance

Collinear structure of the longitudinal axis of the lower limbs with that of the body is the particular feature of human upright stance which distinguishes humans from other animals having bipedal locomotion. Maintaining this erect posture is a complex developmental task for humans such that having small support surface (foot area), high position of the center of gravity and forward-backward asymmetry are the factors that make the human orthograde posture inherently unstable. The study of regulation of the orthograde posture is a vital topic of motor control [31] because of the great significance of the mechanisms involved in both to maintain the static posture, and to ensure body stability during various locomotory movements [15].

Because of the fact that bipedal upright stance is inherently unstable, a small deviation from a perfect orthograde position results in a torque due to gravity that accelerates the body further away from the upright position; thus, destabilizing torque due to gravity must be applied by the feet against the support surface to maintain upright stance. Deviation of body orientation from a certain reference position is detected by multisensory system of the postural control mechanism, and individual error signals are summed and an appropriate corrective torque is generated as a function of this summed signal [11].

Sway, defined as horizontal movement of the body's center of mass even when a person is standing still [17]. The studies have verified that stimulation of visual [32, 33], vestibular [34, 35, 36], and proprioceptive [28, 37] systems evoke body sway. There has to be a limit of any backward or forward body deviations for free stance in order to be stayed in the limits of postural equilibrium and not to fall [2]. Sway is limited by appropriate corrective torques produced by muscles, primarily at the hip for sway in the frontal (left-right, LR) plane and at the ankle for sway in the sagittal (anterior-posterior, AP) plane [38]. It is suggested that sway behavior of human upright stance differs in terms of the anatomical planes of the body movement. Figure 1.1. demonstrates the anatomical planes of motion for the human body below. It is indicated that body deviations in the sagittal (anterior-posterior, AP) plane are typically twice as much as in the frontal (left-right, LR) plane; hence, the sagittal plane shows more inherent instability property in comparison with the frontal plane [17]. As in this thesis, the majority of the experiments of the postural sway studies of human quiet stance are conducted according to the sagittal plane [39, 40].

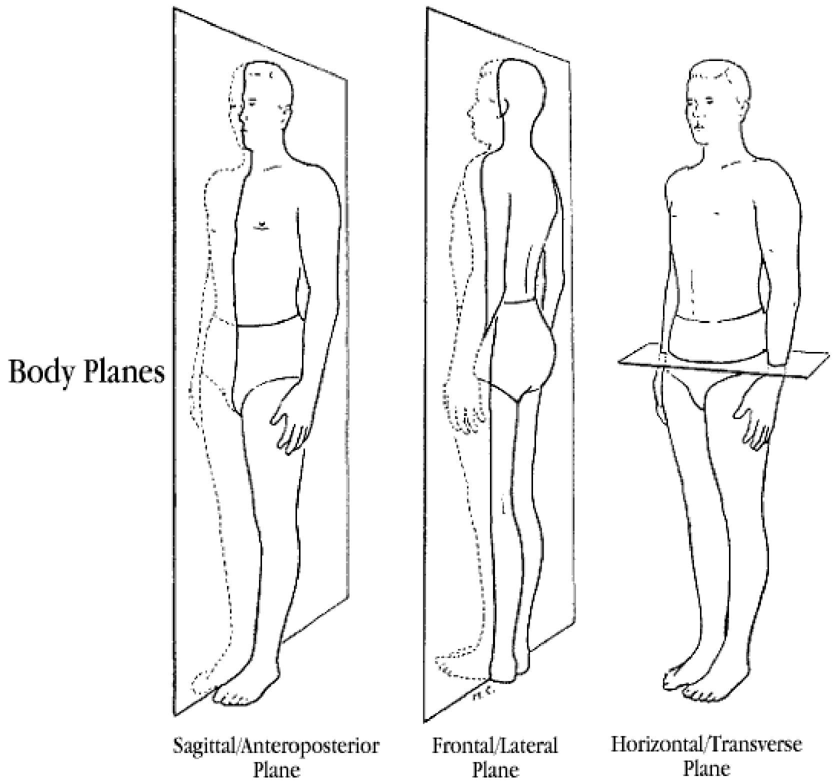

Figure 1.1. Anatomical planes of motion for the human body [41]

1.3. Postural Control

Human orthograde stance is maintained by a posture control mechanism the goal of which is to align body segments upright with respect to gravity vertically by continuous muscular corrections that are realized by receiving and integrating multisensory information from visual sensors of the eyes, vestibular sensors of the inner ears, proprioceptive sensors of the muscles and tendons, and somatosensory senses from skin receptors are regularly fed into the central nervous system (CNS) [20, 21, 42, 43]. In other words, human posture is controlled by the integration of information from the visual, vestibular, proprioceptive, and somatosensory systems [21]. Hence, human stance control can be explained by continuous sensory feedback system [11, 19, 43].

Horak and MacPherson stated that posture serves two main behavioral goals of the body: balance and orientation [44]. Postural control system has two main functions: the first one is to build up posture against gravity and ensure that balance is maintained and the second is fix the orientation and position of the segments of the body. The first function is actually mechanical antigravity function that built up stance (reference posture) and maintain equilibrium. The second one provides that the position and orientation of body segments such as the head, trunk or arms serves as a reference frame for perception and action with respect to the external world [21].

1.3.1. Balance

In biomechanics, balance is defined as the ability to maintain the body's center of mass within the base of support with minimal posture sway [45]. In human upright stance condition, maintenance of equilibrium (balance) is achieved by keeping body's center of mass projection within a limited zone of the total support area which is located 3-5 cm in front of the axis of the ankle joint without exceeding the mean deviation of 1-1.5 cm. This depicted center of mass projection is an essential characteristic property of posture which is not modified by loading the body with additional weight or by active trunk movements [15]. Maintenance of equilibrium during human upright stance depends on not only the collecting commands from CNS, but also the availability as well as accuracy of somatosensory (proprioceptive sensors on the muscle, joint, and skin; pressure receptors), visual and vestibular inputs (motion, equilibrium, spatial orientation) [44,46].

There are two main mechanism of CNS to maintain balance in the case of distortion by a perturbation. The first one is feed forward control, which is the anticipatory postural adjustments (APA) prior to the expected body perturbations and the second one is feedback control, which is the compensatory postural adjustments (CPA) initiated by the sensory feedback signals after the perturbations [44]. The distinction between these two strategies can be emphasized that APAs have a function of minimizing the displacement of the body's center of mass and orienting the body so as to reduce the effects of gravitoinertial forces prior to the expected body perturbations while CPAs work as a restoration mechanism of the body's center of mass after a perturbation has already occurred [1]. The effect of altered proprioceptive information on CPAs is investigated and the studies show that bilateral Achilles tendon vibration affects body kinematics and CoP displacements [47] (see Section 1.6.).

1.3.2. Orientation

Multisensory (visual, vestibular, proprioceptive and cutaneous) inputs contribute to orienting the body segments with respect to both each other and the vertical gravity vector (external world). The intended and actual body position is continuously monitored by 'postural body scheme' that provides an internal representation of the body geometry to crosscheck the body orientation with respect to verticality [21].

1.3.2.1. Postural Body Scheme

"Postural body scheme" is defined as an unconscious representation of the body's configuration and dynamics [15]. According to Gurfinkel [48], internal representation of the body (postural body scheme) deals with the body kinematics and kinetics as well as the orientation of the body with respect to the vertical; nevertheless, it is not primarily based on sensory information. "It is used for the perception of body position and its orientation in space and is also used for motor control, including reactions directed towards maintaining stable body position".

1.3.2.2. Reference Frame

It is suggested that postural body scheme may form a reference frame [15] which is originated from an unconscious representation of the body’s orientation and relationships with the external world and continuously used by CNS to restore the body's balance and whole-body orientation [44] and postural verticality. CNS operates via information that is supported by reference frame such as on the dynamics and geometry of the body, body’s center of mass motion relative to each sensory reference (i.e., the direction of gravity for vestibular cues, visual world orientation for visual cues, and support surface orientation for proprioceptive cues) [11]. Moreover, the information about the ankles organizes posture in a bottom-up frame of reference [28] in particular when the body is perturbed at low frequencies [49]. Mergner, Hlavacka, and Schweigart [50] stated that the role of vestibular and proprioceptive inputs in human self-motion perception in space also depends on the reference frame.

1.4. Sensory Systems

Human postural control is achieved by the integration of sensory systems that are somatosensory, vestibular, visual, and proprioceptive systems [21].

1.4.1. Somatosensory System and Light Touch

The somatosensory system is a complex system comprising of nerve cells (sensory receptors) that is sensible and respondent to the surfaces of itself or outer of the body that are touched, and changes the internal state of the body. Somatosensory receptors are found in many parts of the body such as skin, skeletal muscles, bones and joints, internal organs, and the cardiovascular system. Somatosensory system is responsible for the perception of touch, pressure, pain, temperature, position, movement, and vibration. [51,52]. The primary role of somatosensory system is to provide somesthetic information about contact surface forces and properties such as texture and friction, and the relative configuration of the body segments [44]. Although the perception of body orientation is often considered to be primarily based on vestibular information and secondarily on somesthetic information, several authors have challenged this view. There are studies that presents the limit of otolith contribution in quasi static body orientation [2]. To illustrate, it is showed that perception of upright body orientation becomes considerably inaccurate when somesthetic information (haptic cues) are changed (by full body water immersion). Thus, it is suggested that the somesthetic system plays a major role in estimating upright body orientation and the threshold of the otolith organs in detecting upright body orientation is higher than that of the somesthetic system [2]. Moreover, Peterka [11] stated, "Somatosensory information is a driving force in balance control." On the other hand, Jeka et al. [22] showed that body sway is sensitive to the position and velocity of a somatosensory stimulus. Additionally, Fitzpatrick and McCloskey [53] are claimed that somatosensory inputs provide the most sensitive information for perception of small increments of the postural sway.

Light touch is mechanically non-supportive touch effect (usually through very small part of the body in contact with the stationary point e.g. index finger). This part of the body in light contact with a stable surface serves as a sensory–motor probe for controlling body position by minimizing force changes at the contact surface, automatically stabilizes the body and maintains sway at levels far below those adequate to stimulate the vestibular system or ankle proprioception [4]. Light contact cues (even from just a single fingertip) provide somatosensory information, enhance postural control and diminish body sway, even so the applied contact forces are physically insufficient to stabilize the body [18]. It is stated that it is as effective as visual information (sight) and vestibular information in controlling body sway during quiet stance [54]. When light touch (fingertip touch) is applied during normal bipedal stance, reduced CoP fluctuations in the (less stable plane in comparison with frontal plane) sagittal (AP) plane is reported. Furthermore, Jeka and Lackner [54] observed that in upright stance control experiment, light touch in no-vision condition is equal or better than in available vision condition in terms of steadiness of balance detected by CoP fluctuations. It is claimed that light contact enhances proprioceptive feedback provided by muscle and joint receptors in the arm, trunk and lower limbs [17]. Light touch is proved as a powerful orientation reference for improved control of upright stance in the light of many studies [18].

1.4.2. Vestibular System

The vestibular system is a complex sensory system to supply sensory information about motion, equilibrium, and spatial orientation that is responsible from maintaining balance and spatial orientation. The vestibular system is constituted by the vestibular apparatus which is located in each ear including the parts: otolith organs (the utricle and saccule), and three semicircular canals (lateral, anterior and posterior). “The utricle and saccule determine gravity (vertical orientation of the body or body segments) and linear movement. The semicircular canals determine rotational movement which are filled with a fluid called endolymph.” [55]. Vestibular system is stimulated by head acceleration and rotation. Otolith organs are responsive to linear acceleration including the direction of gravity and contribute a variety of reflexes that are related to body posture control [4] whereas semicircular canals perceive angular acceleration of the head in three dimensions [10] so that vestibular organ work as an inertial measuring device which provides to sense self-motion with respect to the six degrees of freedom in space, three rotational and three translational, in the absence of external sensory cues, vision etc. Synthesis of these linear and angular motion perception is required since the signals provided by the two subsystems (otolith system and semicircular canal system) are not ideal, due to physical properties of the sensors [12]. The vestibular system sends symmetrical impulses in terms of consistency of the impulses of the right side and the left side of the vestibular apparatus to the brain in proper operation conditions [9].

It is not possible to notice the functions of vestibular system by observation because of the fact that it is not easy to perceive the information receiving from the vestibular apparatus consciously. Vestibular organ is differed from the other senses with this property. Gravitational and inertial forces are measured by vestibular organ and converted a signal that drives our motor system for many cases such as gaze stabilization, balance control, adjusting head directions with respect to gravity. These behaviors are unconscious and automatic actions [10].

1.4.3. Vision

Vision has a significant role in balance and orientation. Visual sensory receptors are located in eyes provides visual information (sight) and form a vital sensory system of our lives. “Sensory receptors in the retina are called rods and cones. While, rods are responsible from improved vision in low light condition (e.g. at night time), cones are responsible from color vision, and the finer details.” [55]. Sensory receptors send impulses to the brain for providing visual cues that identify the position and orientation of oneself relative to other objects and environment [9]. The significance of visual information in postural control is well recognized. It is claimed that approximately one-third of the orientation information is derived from visual inputs (sight) in eyes-open quiet stance [11]. In postural control studies, visual information removal is demonstrated to have increasing effect in body sway. Moreover, Uchiyama and Demura documented that body sway is improving with decrease in visual acuity, and reaching maximum in blindfolded (no-vision) conditions [56]. It is presented that vision has an impact on postural control system as shortening the latency of postural responses [21]. The other finding is about the interaction of vision with vestibular system: “Pretty nearly twenty percent of the nerve fibers from the eyes interact with the vestibular system.” [55].

1.4.4. Proprioception

In daily life activities we are able to respond to the external world and react quickly in altering circumstances thanks to the signals coming from our mobile bodies. We owe the knowledge about position and movement of the limbs to these sensations that allow us to maneuver our way around obstacles in the dark and be able to manipulate objects out of view [14]. The mentioned ability of coordinated movement arises from “proprioception”. In the absence of proprioception, controlled movements would be impossible without continuous visual guidance, maintenance of equilibrium is severely impaired, and a tremor develops [24].

Scaliger was originally described the position-movement sensation as a "sense of locomotion" in 1557. Then, the idea of a "muscle sense" which is accepted as the first description of physiologic feedback mechanisms came from Bell in 1826 [57]. In 1889, Goldscheider [74] became one of the first scientists who systematically quantify the awareness of body segment positions and orientations [25]. As cited by Gibson [23], Goldscheider stated in 1898, “It is known that there is sensitivity to the position of the body and all of its parts relative to one another. This is an articular sense, not a muscle sense, and the joints yield information about joint position as well as joint rotation.” Soon after that the concept of proprioception is named and published by Sherrington in 1906 [58], who coined the term from the Latin propius (one’s own) and (re)ceptus (the act of receiving). As cited by Proske [14], he identified proprioception as sensation of innervation and stated, “In muscular receptivity we see the body itself acting as a stimulus to its own receptors—the proprioceptors.” Proprioception was described as “sixth sense” by Wade [59].

Kinesthesia, a term introduced by Bastian in 1880 [60], is used here to refer to comprise two senses: the sense of limb position and the sense of movement. One of the reasons for combining two sensations as one term is that both senses share inputs from the same receptor, the primary endings of muscle spindles which play major role in kinesthesia with some skin receptors providing additional information. Kinesthesia refers to the ability to detect, without visual input, the spatial position and/or movement of limbs in relation to the rest of the body [14].

1.4.4.1. Proprioception and Postural Control

Visual, vestibular, cutaneous, and muscle proprioceptive sensory systems are involved in postural control [28]. Sensory systems are described that send inputs to CNS to control of posture as the somatosensory system; the vestibular system; and the visual system, and stated that somatosensory system consists of several types of receptors such as mechanoreceptors, thermoreceptors, pain receptors, and proprioceptors [24]. In this view, proprioceptive sensory system is counted as a subsystem of the somatosensory system. With this perception, it is documented that maintenance of upright posture is contributed by somatosensory (including proprioception) (70%), vestibular (20%) and visual (10%) information for healthy subjects in a well-lighted environmental condition with a solid base of support [11]. Proprioception which continuously inform the CNS about the position of each part of the body in relation to the others seems to have a major impact on postural control for the reason that the representation of the body's static and dynamic geometry might be largely based on muscle proprioceptive inputs receiving from proprioceptive receptors distributed throughout the body [28].

1.4.4.2. Proprioceptive Receptors (Proprioceptors)

Proprioception is the cumulative neural input to CNS from specialized nerve endings that receive and transmit afferent information about mechanical stimuli generated within the body, especially from the musculoskeletal framework, called proprioceptors (sensory units responsible for the proprioception), that are located in the joints, capsules, ligaments, muscles, tendons and skin, and supply tissue deformation input to the CNS along with information on shape, size, and mass of body segments to regulate muscle tension and the orientation, position, as well as velocity of our body and limbs during movement [24].

Receptors can sense input that is generated within the organism (interoception), or sense input that forms from external stimulation (exteroception). Proprioception that is the unique sense in terms of supplying internal information of the body such as the relative position of the body's own segments is the only interoceptor among all senses, while the other sensors gather information from outside of the body and classified as extoreceptor [10].

There are three main kinds of proprioceptors that are muscle spindle, Golgi tendon organ, receptors in joint capsules. They supply information about kinesthesia sense and skeletal muscle length, sense of tension in tendon, and the sense of pressure, tension, movement at the joint, respectively [61]. Additionally, emerging views suggest that Golgi tendon organ has a contribution to proprioception through the senses of force and heaviness. Traditionally, the term proprioceptor refers to receptors concerned with conscious sensations, and these include the kinesthetic sense (the sense of limb position and movement), the sense of tension or force, the sense of effort, and the sense of balance [14].

1.4.4.3. Muscle Spindles

Proske and Gandevia [14] suggested that proprioceptors such as muscle spindles and tendon organs also play important roles in the unconscious, reflex control of movements. Muscle spindles are evaluated as the principal proprioceptors.

Goodwin, McCloskey and Matthews [62] proved for the first time that signals from muscle spindles provided sense of limb position and movement (kinesthetic sense). The reason why muscle spindles are able to induce a position signal is the fact that they are stretch reflex receptors and give information about the length of the muscles to be used in conscious judgements of limb position [14]. Muscle length and the spindle discharge is directly proportional. This relationship yields a proportional spindle firing rate that is used by the CNS to derive information about the length of the muscle, and therefore the position of the limb. Hence, it is ordinarily accepted that muscle spindle afferents are mainly responsible for the sense of position and the perception of limb movement [24]. In addition, muscle spindles feature prominently in the control and appreciation of body orientation, body configuration, movement execution, and also sensory–motor adaptation. Lackner and Dizio [4] claimed, "Muscle spindle activity contributes both to limb position sense as well as to perceived body orientation relative to the upright."

In the structure of a skeletal muscle, intrafusal muscle fibers (or spindles) that are innervated by gamma motoneurons of the spinal cord lie parallel with the extrafusal fibers that are innervated by the alpha motoneurons of the spinal cord and responsible from the actual muscle contraction. The intrafusal muscle fibers comprise of sensory receptor endings, namely primary and secondary endings, where the former generates large myelinated Ia afferents and the latter forms myelinated group II afferents. While primaries have sensitivity to both muscle length and velocity (rate of length change of the muscle,) secondaries are sensitive to length alone [4]. Furthermore, the primary endings of spindles are largely responsible for the illusion resulted from vibration [14].

1.4.4.4. Proprioception and Exercise

It is sure that whether the proprioception can really be improved by exercise is an important and in great demand question to be illuminated. Ashton-Miller et al. [25] examined this question and conducted a study including some comparisons among a gymnast who has been training for 10 years and a control group who has not trained specifically. The outcome of the study reflects that sensory receptor density cannot be ascended by any amount of training; however, some proprioception supportive learnings are quite possible. In that case, one may learn (a) routinely increase to fusimotor drive to the spindles during such challenging trainings, (b) regularly to enhance the gain of spinocerebellar and dorsal column-medial lemniscal networks, describes a sensory pathway conducting haptic impulses to the cortex, which receives muscle spindle afference, and (c) to spend uninterrupted attention to perceive related afferent cues with higher possibility and/or enhance proprioceptive somatosensory field in the sensory cortex. In the event of driving any or all of mentioned factors, the gymnast may be able more credibly to direct attention and perceive smaller postural changes after 10 years of training contribution. Consequently, she has experienced successful training oriented to proprioception. Like that proprioceptor density is not an improvable property with the effect of exercise [25], proprioceptive threshold sensitivity is not affected by exercise. Studies demonstrate that kinaesthetic sensitivity does not vary across the groups of gymnasts, non-gymnasts athletes, as well as non-athletes [63] which is proposed that proprioceptive threshold sensitivity is not diminished in gymnasts or athletes [7]. Although there is no threshold low is detected, athletes have showed ascendant standing balance control [64], faster responses to disturbances and greater neuromuscular control [65] in comparison with non-athlete healthy subjects. It is suggested that the improved proprioceptive ability of the athletes is the result of repetitive athletic movements [26, 66].

1.5. Sensorimotor Integration (Multisensory Fusion)

Human orthograde stance that is sustained by feedback mechanisms generating an appropriate corrective torque based on the little, continuous motions around the vertical upright (i.e. postural sway) is a complicated control process such that the control system is tied together by linkages [12] between visual, vestibular, somatosensory and proprioceptive sensory information. Because of the fact that sensory information to contribute the postural control process is not always available (e.g., eyes closed) or accurate (e.g., compliant support surface), postural control system develops a strategy to form and maintain upright stance in a changeable sensory conditions by integrating inputs from multiple sources which is called "sensorimotor integration" [11]. Thus, the control of human upright stance contains the integration of multiple sensory systems.

Visual, vestibular, somatosensory and proprioceptive sensory systems supply convergent and redundant information under normal conditions that yields flexible control of stance. The redundant inputs that are generated by these multiple sources are required for the resolution of perceptual ambiguities about body orientation and motion [44]. To illustrate, a moving image can be alternatively perceived as moving visual environment or as self-motion. CNS integrates visual information and vestibular information to resolve this ambiguity where the latter determines linear acceleration of the head and signalize self-motion rather than moving visual surround. Thus, perceptual ambiguities are resolved by multisensory fusion, namely sensorimotor integration. Consequently, the integration of sensory inputs from multiple sources is necessary even for a simple daily activity. As cited by Jeka, Oie and Kiemel [13], Lackner [67] has clarified the importance and the role of sensorimotor integration with the perspective of vestibular information, "In virtually any terrestrial circumstance involving natural movements, changes in peripheral vestibular activity will be accompanied by changes in the activity of somatosensory, proprioceptive, visual and auditory receptors. Consequently, it is difficult to ferret out a specifically vestibular contribution to orientation (p. 308)."

It is needed to reintegrate sensory information after each modification of the available sensory information by redefining the respective contribution of the particular sources of sensory input for regulation of the posture [7]. Sensory reweighting is a process that CNS designates a weight to each sensory input during reintegration of sensory information. The integration process, sensory reweighting, yields a single sensation as an output which creates a unique and coherent estimation to be used in postural control system [29]. In order to form and maintain orthograde posture as sensory conditions or parameters alter, multisensory inputs are dynamically re-weighted [44]. It is required to increase the weight of certain sensory inputs when synchronically diminishing the weight of others for flexible balance control. In the case of parameter changes (e.g. amplitude) in sensory input, CNS proceeds in two ways as by re-weighting that altering sensory signal as well as by re-weighting other sensory signals whose parameters are constant [8].

Vuillerme, Teasdale and Nougier [7] examined the relationship between the efficiency of the sensorimotor integration and exercise, and suggested that specific exercise such as gymnastics can considerably enhance the efficiency of reweighting of the sensory inputs as a part of sensorimotor integration.

1.6. Balance Evaluation

In postural control studies alteration of proprioception is one of the widely used methods. Tendon vibration is frequently used among the alteration of proprioception techniques. Quantification of the postural control study is a vital necessity to compare and comment on the results of an applied technique which is called posturography. The most common posturographic measure is the quantification of center of pressure (CoP) changes in the anterior-posterior (AP) direction from a single force platform [6].

1.6.1. A Proprioception Alteration Technique: Tendon Vibration

Postural control is supported by proprioception by processing code for endpoint position of a limb from afferent signals generated during a movement [14]. Alterations in the accuracy of proprioceptive information affect the postural control [1].

A number of proprioception alteration techniques have been used in postural control studies which are local anesthesia, cuff compression, lower legs cooling, and relatively easy-to-implement way of proprioception alteration technique: vibrating the muscle tendons [1]. The tendon vibration technique has been widely used to investigate the influence of proprioception by generating illusory limb displacement, especially muscle spindle endings in spatial perception and motor control [2].

In the tendon vibration technique, vibration with sufficient amplitude and frequency is applied to a muscle or tendon which activates mainly the primary spindle endings connected to the large Ia afferent fibres in order to generate a firing rate of spindle which is commented by CNS as stretching of the corresponding muscle [68]. This artificial comment is resulted with illusory sense of joint displacement [62, 68], and/or contraction of the vibrated muscle (tonic vibratory reflex [62]), and/or compensatory postural responses [69,2]. Since perceived proprioceptive information that does not match with the actual body position, the body starts tilting in the direction of the vibrated muscles, besides body sway increases [69,15]. Moreover, alterations in the proprioceptive input clearly changed muscle activation patterns and COP displacements in spite of the presence of vision [1].

In Achilles tendon vibration, a lengthening of the calf muscles is stimulated [68]. These stimuli are perceived by the subject as a forward body tilt. Thus, when Achilles tendon vibration is applied to the freely standing subjects, a backward body displacement is seen [69,28]. This response mimics the postural correction occurred by a natural proprioceptive stimulation in case of a stretching of the calf muscles by a forward sway [2]. In other words, a perceived tilt in the opposite direction of the applied vibration is compensated by leaning in the direction of the applied vibration [62, 28,3].

The maintenance of upright stance during external stimuli of tendon vibration is controlled mainly by a sensory negative feedback mechanism which consists of the inputs from visual, vestibular and ankle angle proprioceptive receptors [19,44].

During Achilles tendon vibration, illusory body movement or body inclination is manifested particularly under eyes-closed condition [69]. Vibration has strong effects on human orthograde stance, not only because of the blurring of the receptor input, but also the subject’s reactions to the illusory of movement caused by vibration [69, 68, 28, 5].

1.6.2. A Posturographic Method: Center of Pressure (CoP) Measurement

Posturography is the technique that is used to measure body sway or to quantify postural control in upright stance. Posturography can be either static, measurement of quiet erect posture of the subject, or dynamic, measurement of the response to a disturbance applied on the subject [30]. The most common posturographic measure used in the control of posture in quiet stance is the quantification of center of pressure (CoP) changes in the anterior-posterior (A/P) direction from a single force platform [6].

Winter, Prince, Frank, Powell, and Zabjek [6] defines the center of pressure (CoP) as a displacement measure to describe the human postural sway and the location of the vertical ground reaction vector that is equal and opposite to a weighted average of all downward (action) forces acting between the feet and the force plate. “The magnitude and location of these forces are under the control of all the muscles associated with posture and balance.” In the case of unipedal standing (one foot is on the ground) the net center of pressure (CoP) lays within that foot. However, in the case of bidepal standing (both feet are in contact with the ground) net CoP lays somewhere between the two feet as a virtual point that depends on the relative weight taken by each foot. Thus, there are separate CoPs under each foot in bidepal standing [70,71]. The CoP measure is quite independent of the center of mass but rather it is the net neuromuscular response to control of the center of the mass [6]. When the subject stands on a force plate the corrective torques and ground reaction forces originated from the effect of gravity are defined in terms of force-torque pairs for each of the x-, y- and z-axes which are represented in terms of the frontal (left-right, LR) and the sagittal (anterior-posterior, AP) components of the centre of pressure (CoP). It is indicated that the fluctuations in the sagittal (anterior-posterior, AP) components of the CoP are typically twice as much as of in the frontal (left-right, LR) component suggesting better inherent stability in the frontal plane than the sagittal plane [17].

1.7. Scope of Thesis & Thesis Statements

Achilles tendon vibration (ATV) technique is an alteration method of the proprioceptive information. This alteration in perception of gravity vertical causes illusional information about one's own upright stance and it is resulted with one's backward fall [5]. Therefore, the maintenance of upright stance during external stimuli of tendon vibration is controlled mainly by a sensory negative feedback mechanism which consists of the inputs from visual, vestibular and ankle angle proprioceptive receptors [19,44]. It is well known that for no-touch condition, backward fall and body sway in EO (Eyes-Open, visual information is available) condition are lower respect to in EC (Eyes-Closed, deprivation of visual information) condition during ATV [56, 27, 16]. In this thesis, it was wanted to reveal the effects of ATV on postural responses during upright stance at adapting to such different sensory conditions that include both EO and EC conditions while providing bodily somatosensory information (touch information) to the sensory negative feedback mechanism. Furthermore, in this thesis, it was also wanted to reveal the effects of different training environments on the evaluation of bodily somatosensory information (touch information) during ATV. In accordance with these purposes, first, two different sports groups were specified as swimmers and handball players where sedentary subjects form the control group, then subject's bodily somatosensors were activated (see Section 2.2 for detail). The reason why the experiments conducted on these sport groups is that swimmers, who train in water, may improve some adaptive features in touch information evaluation different than land athletes (handball players). This difference as we predict, should be originated from an adaptation to water environment. As a land animal, humans are adapted to the atmospheric environment. In atmospheric environment, as a fluid material, air flows over the body with one's movements is sensed by bodily somatosensors and CNS makes some relations between movement directions and air flows sensations. On the other hand, water is a denser material respect to air. Accordingly, water flows over the body causes intenser sensations respect to air. Therefore, adaptation to the water environment may build stronger relation between bodily somatosensory system and proprioceptive systems respect to atmospheric environment.

To enlighten these, experiments were conducted in different sensory conditions (environments) and adaptation differences to these conditions (environments) revealed by the postural sway and the backward body tilt responses during Achilles tendon vibration and its relation with the sportive background.

Hypotheses of the thesis are indicated below.

1. For each group, at adapting to the different sensory conditions (EOTC, ECTC, EOTO, ECTO which are designated at Table 2.1.), ATV alters the proprioceptive information, causes illusion, increase in postural sway and the backward body tilt (fall) response.

2. For each ATV trial, independent from the sensory conditions and the groups, due to the effects of adaptation / learning / anticipation to the ATV, the effect of ATV on postural sway behavior and backward body tilt (fall) response during the second vibration will decrease respect to the first vibration.

3. 1. Independent from the groups and falls, the effect of ATV on postural sway behavior and backward body tilt (fall) response at adapting to touch-open (TO) condition will decrease with respect to touch-closed (TC) condition for both eyes-open (EO) and eyes-closed (EC) conditions (TO, TC, EO, EC are defined in detail at Section 2.2.)

3. 2. For both eyes-open (EO) and eyes-closed (EC) conditions, the maximum trends of change in the effect of ATV on postural sway behavior and backward body tilt (fall) response between adapting to different touch conditions (TO and TC conditions) will be observed in swimmer group.

4. 1. Independent from the groups and falls, the effect of ATV on postural sway behavior and backward body tilt (fall) response at adapting to eyes-closed (EC)

condition will increase with respect to eyes-open (EO) condition for both touch-closed (TC) and touch-open (TO) conditions.

4. 2. As a probable result of the land trainings, somatosensory system of the foot of handball players may become more sensitive.

I. Therefore, for touch-closed (TC) condition, the minimum trends of change in the effect of ATV on postural sway behavior and backward body tilt (fall) response between adapting to different eyes conditions (EO and EC conditions) will be observed in the handball players.

II. Therefore, in touch-closed (TC) condition the handball players demonstrate less postural sway behavior and backward body tilt (fall) response in both visual sensory conditions (EO, EC) during ATV in comparison with the swimmers.

4. 3. Due to the stronger relation between bodily somatosensory system and proprioceptive systems,

I) for touch-open (TO) condition, the minimum trends of change in the effect of ATV on postural sway behavior and backward body tilt (fall) response between adapting to different eyes conditions (EO and EC conditions) will be observed in the swimmers.

II) in touch-open (TO) condition the swimmers demonstrate less postural sway and backward body tilt (fall) response in both visual sensory conditions (EO, EC) during ATV in comparison with the handball players.

5. Athletes show less postural sway and backward body tilt (fall) response in all sensory conditions during ATV in comparison with the sedentary subjects.

6. Due to the contribution of somatosensory information is more than visual information to maintain upright posture [11], during ATV, bodily somatosensory information would contribute to the sensory negative feedback mechanism to control the maintenance of upright stance more than visual information.

1.8. Thesis Outline

In this thesis, experiments are performed in Biomechanics Laboratory of Mechanical Engineering Department at METU and MODSİMMER with the participation of voluntary, healthy, young, male subjects standing on Bertec© force platform which is used for data collection.

Chapter 1 is an introduction that contain a brief literature review to be able to present the historical perspective of the field of the study and clarify the motivation of the thesis, and also give general information about the mechanisms and the main concepts of postural control, sensory systems and sensorimotor integration, posturography and tendon vibration technique as a balance evaluation approach. In Chapter 2, experimental set-up and experimental protocol are indicated. Also, a brief information about participants, data collection equipment and process, and data analysis are covered by the second chapter. Chapter 3 provides detailed experimental results with brief interpretations. Discussion and conclusion part is presented in Chapter 4. Bibliography, Appendices that is consisting of CoPx vs time plots and the subject information table are found at the end of the thesis.

CHAPTER 2

THE EXPERIMENT

2.1. Experimental Set-up

In this thesis, experiments are performed in Biomechanics Laboratory of Mechanical Engineering Department at METU and MODSİMMER; moreover, ground reaction forces measurement system (Bertec© Force Plate) and motion capture system (Xsens MVN BIOMECH©) were used to collect kinetic and kinematic data, respectively.

2.1.1. Bertec© Force Plate

From an isolated perspective, we can say that every joint finds its mechanical balance within self in every orientation. From an integrated approach, in human bipedal upright posture feet are the whole body balance controller.

In this thesis, Bertec© FP4060 Force Plate with a signal amplifier was used to collect the data of the subjects' postural sway behavior. Bertec© FP4060 Force Plate is shown in Figure 2.1.

Figure 2.1. Bertec© FP4060 Force Plate

It collects this kinetic data in the form of three ground reaction force signals as Fx, Fy, Fz (components of the ground reaction forces in x,y,z axes, respectively) and three moment signals as Mx, My, Mz (components of the moment in x,y,z axes, respectively). Fx represents the friction force between the force plate and feet of the subject in AP direction, while Fy is the representation of the friction force between the force plate and feet of the subject in ML direction. Fz is the vertical force applied to the force plate by the subject and therefore, it is equal to the weight of the subject in quiet stance. Three components of the ground reaction forces in x,y,z axes are demonstrated in Figure 2.2.

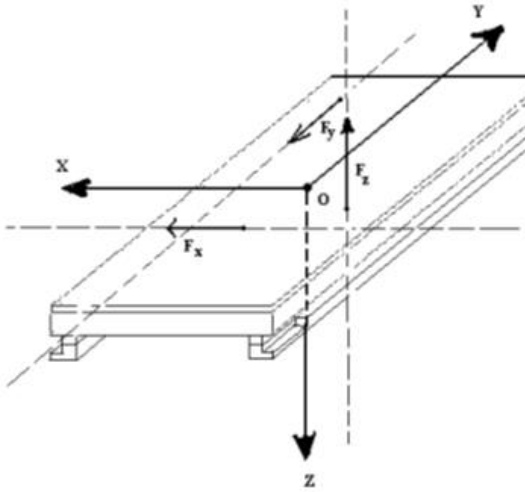

Figure 2.2. Three components of the ground reaction forces in x, y, z axes (Fx, Fy, Fz) [76]

Mx and My represent the moments created by subjects' body sway in AP and ML directions, respectively where Mz is the representation of the torsional moment applied to the force plate by the subject. Three components of the moments in x,y,z axes are demonstrated in Figure 2.3.

It is important to give emphasis that all these described representations are valid for quiet stance condition with no inertial forces to be considered [10].

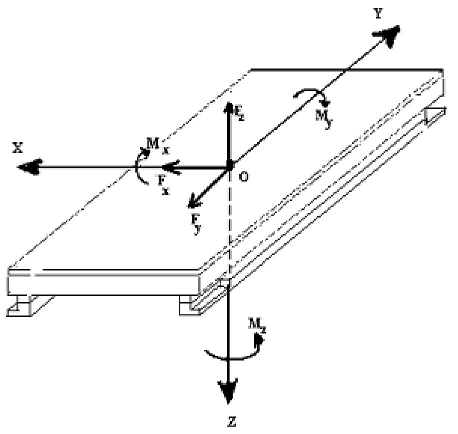

Figure 2.3. Three components of the moments in x,y,z axes (Mx,My,Mz) [76]

2.1.2. Motion Capture System (Xsens MVN BIOMECH©)

Xsens MVN BIOMECH© is an easy-to-use, cost efficient system for full-body human motion capture system which consists of 15 inertial sensors. The system is based on these unique and miniature inertial sensor devices which act as inertial measurement units and measure acceleration, angular velocity and the magnetic field vector. Figure 2.4 demonstrates Xsens MVN BIOMECH© human motion capture system and the inertial sensor.

Figure 2.4. Xsens MVN BIOMECH© human motion capture system and the inertial sensor

Besides the mentioned feature of acting as inertial measurement signals, Xsens MVN BIOMECH© involves algorithms that supply estimations of the sensor's orientation with respect to a global fixed coordinate system by using magnetic field vector for calibration. This orientation information can be represented or stored by a quaternion, a rotation matrix or Euler angles. Therefore, relative and absolute positions of the body portions (foot, limbs, trunk and head) can be computed and estimated in three dimensional space [10]. Xsens MVN BIOMECH© solves the misalignment of the local coordinate axis and physiologically meaningful axis problem which is a fundamental trouble in inertial measurement units used in human motion analysis by using the static posture to specify the coordinates of physically meaningful axes in the upper and lower sensor coordinate system [77].

2.2. Subjects and Experimental Protocol

The experiments are conducted with the participation of voluntary, healthy, young, male, university students as subjects standing on Bertec© force platform which is used for data collection. Age, height, weight, health conditions and sportive background data were recorded for each subject before starting experiments and the table including subject information is presented at Appendices. To keep the subjects in naive state, they were not informed about purposes of the experiment.

Three groups of subjects which consists of two sports (handball players and swimmers) groups and one sedentary (control) group are constituted. Two different somatosensory environment are created which are without (TC / Touch-Closed) and with (TO / Touch-Open) bodily somatosensory cue (touch) respectively. In each trial, subjects wore a harness in order to give subjects bodily somatosensory cue as standing while 1-2% of the subject's weight being suspended by the harness fixed to the ceiling. To manually set the 1-2 % of weight suspension, subjects' weights were measured by the force platform. Figure 2.5 shows a subject who worn the harness which is fixed to the ceiling by attaching to the top of each shoulder of the subject standing quiet with weight suspension that is the representation of TO (Touch-Open) condition for this experiment. On the other hand, TC (Touch-Closed) condition is the condition where subjects wore the harness (no taking off phase between trials), but in this case there is no weight suspension effect and also, the harness is not tighter anymore not to make feel cutaneous sense to the subject.

Figure 2.5. Subject standing quiet in touch-open (TO) condition during experiment

In each trial (during whole experiment), two vibrators were always attached to both Achilles tendons of the subjects to break the expectation of vibration stimuli. Therefore, the sensory environment that contains the composition of three sensory inputs which are visual, haptic and proprioceptive were created.

Each group consists of eight male subjects. Each subject stands on the force platform in quiet stance to collect the center of pressure data in antero-posterior coordinate (CoPx). Eight successive trials were conducted where each trial lasts for 180 seconds as of data recording was started.

The first four trials conducted in eyes-open condition (EO) where visual information is available and eyes-closed condition (EC) where visual information is deprived by voluntarily closing the eyelids for both touch-open (TO) and touch-closed (TC) conditions. This quiet stance (QS) part of the experiments is conducted with the aim of the comparison of the visual and haptic sensory effects in the absence (QS) and the existence (PS) of ATV at adapting to different sensory conditions. The last four trials were the repetition of the first four trials with 80 Hz Achilles tendon vibration. This vibration frequency has been demonstrated to be optimal for revealing postural responses during quiet stance [3]. In the last four trials, whereafter data recording was started, the subject received 10 seconds vibration two times as the first is between 50^{th}-60^{th} and the second is between 120^{th}-130^{th} seconds. Moreover, the time between the first vibration end (60^{th} second) and second vibration start (120^{th} second) is kept constant to observe how learning / anticipation affects postural sway and backward body tilt responses. However, to alter the learning effect for the first vibration there is a random time before the data recording was started in each vibration trial. For each subject, trials were conducted without shuffling, applied in order of the 1^{st} trial to 8^{th} trial in order to maintain the effect of condition changes constant among the subjects. Table 2.1. shows each trial with its sensory conditions.

Table 2.1. QS & PS Trials

Quiet Stance (QS) Trials	Perturbed Stance (PS) / Vibration Trials
1^{st} trial : EOTC (Eyes-Open, Touch-Closed)	5^{th} trial : EOTC (Eyes-Open, Touch-Closed)
2^{nd} trial : ECTC (Eyes-Closed, Touch-Closed)	6^{th} trial : ECTC (Eyes-Closed, Touch-Closed)
3^{rd} trial : EOTO (Eyes-Open, Touch-Open)	7^{th} trial : EOTO (Eyes-Open, Touch-Open)
4^{th} trial : ECTO (Eyes-Closed, Touch-Open)	8^{th} trial : ECTO (Eyes-Closed, Touch-Open)

2.3. Data Acquisition and Data Analysis

2.3.1. CoPx Evaluation

When the subject stands on the force plate the corrective torques and ground reaction forces originated from the effect of gravity are defined in terms of force-torque pairs for each of the x-, y- and z-axes which are represented in terms of the frontal (left-right, LR) and the sagittal (anterior-posterior, AP) components of the center of pressure (CoP).

In this study, in order to interpret the postural sway behaviors and backward body tilt (fall) responses of the subjects in AP direction, CoPx data was computed for each trial which is the center of pressure data in x direction (CoPx), namely the AP component of center of pressure. CoPx is the negative value of the proportion of My to Fz as seen in Eqn. 1. Also, Eqn. 2 describes the CoPy. Because of the fact that data were collected through 180 seconds with 100 Hz for each trial, array size is 18000.

$$CoPx = -\,My(i) / Fz(i)\ ,\ i = 1 \ldots 18000 \qquad \text{(Eqn. 1)}$$

$$CoPy = \ Mx(i) / Fz(i)\ ,\ i = 1 \ldots 18000 \qquad \text{(Eqn. 2)}$$

After CoPx calculations were done, CoPx time series was divided into five time segments for each PS trials. Each segment was named as epoch (e). Table 2.2. shows each epoch with its time interval and vibration situation.

Table 2.2. *Epoch-Time Interval-Vibration relations*

Epoch (e)	Time Interval (seconds)	Vibration
1^{st}	$0 – 50^{th}$	Off
2^{nd}	$50^{th} – 60^{th}$	On
3^{rd}	$60^{th} – 120^{th}$	Off
4^{th}	$120^{th} – 130^{th}$	On
5^{th}	$130^{th} – 180^{th}$	Off

To study postural sway behavior and backward body tilt (fall) response which are originated from the Achilles tendon vibration experienced at the second and fourth epochs of the last four trials, RMS (Root Mean Square) and Delta (Δ) metrics were calculated from CoPx data, respectively. A sample plot of CoPx vs time is shown in Figure 2.6.

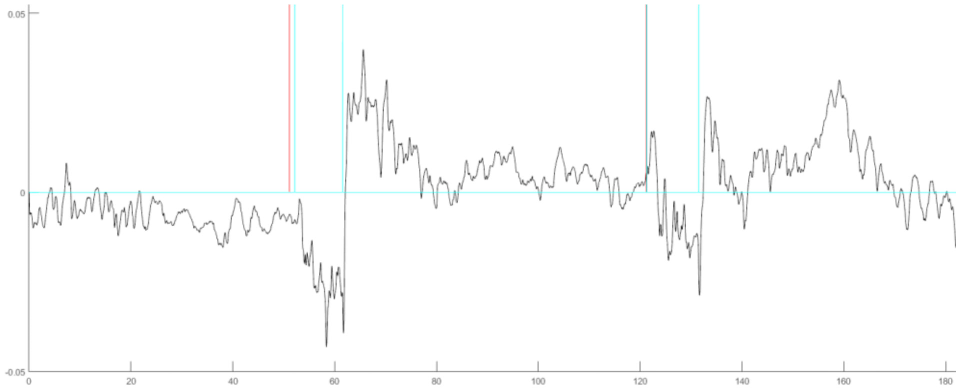

Figure 2.6. A Sample Plot of CoPx vs Time

Delta (Δ):

To evaluate the magnitude of the backward body tilt (fall) response in vibration periods (2nd and 4th epochs), the delta values were calculated by the difference between the minimum value of the CoPx in vibration period (the minimum points of CoPx plot in 2nd and 4th epochs) and the average value of the CoPx in non-vibration period (1st and 3rd epochs). Δ_1 and Δ_2 indicate the first and the second fall respectively (see Eqn. 3, 4 & 5). Delta values are shown with negative numbers. Therefore, increase in the backward body tilt (fall) causes higher negative delta value.

$$\Delta_1 = min(CoP_x)_{e2} - mean(CoP_x)_{e1} \quad \text{(Eqn. 3)}$$

$$\Delta_2 = min(CoP_x)_{e4} - mean(CoP_x)_{e3} \quad \text{(Eqn. 4)}$$

$$mean(CoP_x)_i = \frac{1}{n}\sum_{j=1}^{n}(CoP_x)_j \quad \text{(Eqn. 5)}$$

Root Mean Square (RMS):

To evaluate the postural sway behaviors in vibration periods (2nd and 4th epochs), the RMS values of CoPx were calculated (see Eqn. 6).

$$RMS\ (CoP_x)_i = \sqrt{\frac{x_1^2+x_2^2+\cdots+x_n^2}{n}}, \quad \text{n= 1000} \quad \text{(Eqn. 6)}$$

2.3.2. Statistical Analysis

In this study, for the statistical analysis, mixed type ANOVAs were designed with a significance level of 0.05 by using IBM SPSS Statistics® software. Statistical analyses were conducted with postural sway and backward body tilt (fall) metrics. Designed ANOVAs are listed below:

1. To analyze the QS (quiet stance) postural sway behaviors in between adapting to different sensory conditions, the 3-way mixed ANOVA was formed by two within-subjects factors (independent variables / repeated measures) as eyes conditions (EO, EC) and touch conditions (TC, TO) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).
2. To analyze the effect of ATV on postural sway behavior and backward body tilt (fall) response between adapting to different sensory conditions, the 4-way mixed ANOVAs were formed by three within-subjects factors (independent variables / repeated measures) as eyes conditions (EO, EC), touch conditions (TC, TO) and epoch (2^{nd}, 4^{th}) / delta (Δ_1, Δ_2) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).
3. To analyze the effect of ATV on postural sway behavior and backward body tilt (fall) response between adapting to different touch conditions for both eyes conditions respectively, the 3-way mixed ANOVAs were formed by two within-subjects factors (independent variables / repeated measures) as touch conditions (TC, TO) and epoch (2^{nd}, 4^{th}) / delta (Δ_1, Δ_2) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).
4. To analyze the effect of ATV on postural sway behavior and backward body tilt (fall) response between adapting to different eyes conditions for both touch conditions respectively, the 3-way mixed ANOVAs were formed by two within-subjects factors (independent variables / repeated measures) as eyes conditions (EO, EC) and epoch (2^{nd}, 4^{th}) / delta (Δ_1, Δ_2) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).

5. To analyze the effect of ATV on postural sway behavior and backward body tilt (fall) response between adapting to EOTC and ECTO conditions, 3-way mixed ANOVA was formed by two within-subjects factors as sensory condition (EOTC and ECTO) and epoch (2^{nd}, 4^{th}) / delta (Δ_1, Δ_2) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).
6. To analyze the effect of ATV on postural sway behavior and backward body tilt (fall) response between adapting to different touch conditions for both eyes conditions' each fall respectively, the 2-way mixed ANOVAs were formed by one within-subjects factor (independent variables / repeated measures) as touch conditions (TC, TO) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).
7. To analyze the effect of ATV on postural sway behavior and backward body tilt (fall) response between adapting to different eyes conditions for both touch conditions' each fall respectively, the 2-way mixed ANOVAs were formed by one within-subjects factor (independent variables / repeated measures) as eyes conditions (EC, EO) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).
8. To analyze the effect of adaptation / learning / anticipation to the ATV on postural sway behavior and backward body tilt (fall) response at adapting to different sensory conditions respectively, the 2-way mixed ANOVAs were formed by one within-subjects factor (independent variables / repeated measures) as epoch (2^{nd}, 4^{th}) / delta (Δ_1, Δ_2) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).

CHAPTER 3

RESULTS

3.1. Results for RMS

RMS metric gives information about postural sway behaviors.

3.1.1. RMS Results for QS Trials

Here, to analyze the postural sway behavior in QS (quite stance) in between adapting to different sensory conditions, the 3-way mixed ANOVA was formed by two within-subjects factors (independent variables / repeated measures) as eyes conditions (EO, EC) and touch conditions (TC, TO) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).

This statistical analysis was conducted with RMS metrics of 1^{st}, 2^{nd}, 3^{rd} and 4^{th} trials of all groups together. Figure 3.1. shows RMS data for1^{st}, 2^{nd}, 3^{rd} and 4^{th} trials. Tests of within-subjects effects for 3-way mixed ANOVA for RMS data are shown in Table 3.1. Tests of between-subjects effects for 3-way mixed ANOVA for RMS data are shown in Table 3.2. Also, Table 3.3. shows descriptive statistics for the RMS of 1^{st}, 2^{nd}, 3^{rd}, 4^{th} trials. The results of this analysis are stated below.

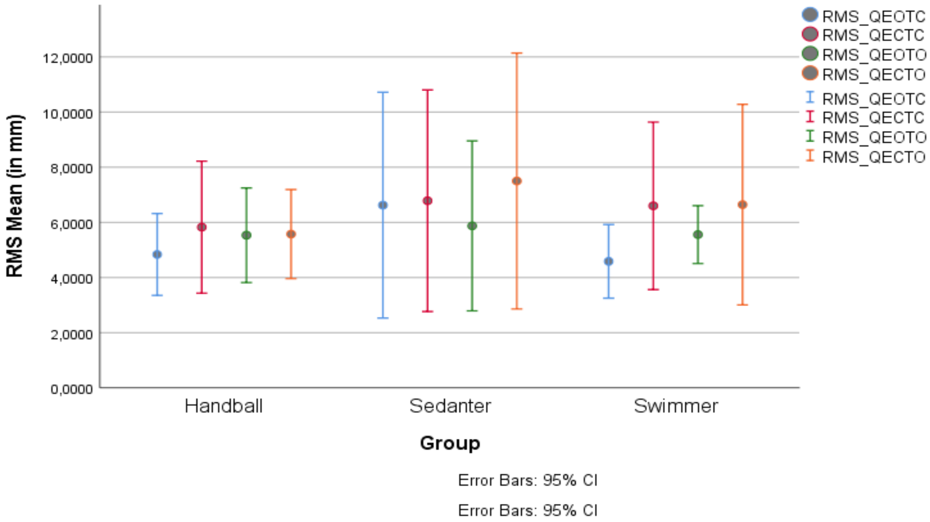

Figure 3.1. RMS Data for 1st, 2nd, 3rd & 4th Trials

Table 3.1. Tests of Within-Subjects Effects for 3-way mixed ANOVA for RMS

Tests of Within-Subjects Effects		
Source	**F**	**p**
Eyes	6.040	0.023
Eyes * Group	0.568	0.575
Touch	0.307	0.585
Touch * Group	0.125	0.883
Eyes * Touch	0.021	0.887
Eyes * Touch * Group	0.720	0.498

Table 3.2. Tests of Between-Subjects Effects for 3-way mixed ANOVA for RMS

Tests of Between-Subjects Effects		
Source	**F**	**p**
Group	0.370	0.695

Table 3.3. Descriptive Statistics for the RMS of 1st, 2nd, 3rd, 4th Trials

Trial	Cond.	Group	Mean	S.D.	N
1st	EOTC	Handball	4.8374	1.7743	8
		Sedentary	6.6248	4.8950	8
		Swimmer	4.5879	1.5955	8
		Total	5.3500	3.1438	24
2nd	ECTC	Handball	5.5340	2.0510	8
		Sedentary	5.8734	3.6864	8
		Swimmer	5.5567	1.2536	8
		Total	5.6547	2.4330	24
3rd	EOTO	Handball	5.8260	2.8618	8
		Sedentary	6.7842	4.8039	8
		Swimmer	6.6004	3.6311	8
		Total	6.4035	3.7025	24
4th	ECTO	Handball	5.5750	1.9318	8
		Sedentary	7.5003	5.5495	8
		Swimmer	6.6428	4.3490	8
		Total	6.5727	4.1125	24

According to the P eyes = 0.023; independent from the groups and touch conditions, postural sway behaviors at adapting to EO condition is significantly different with respect to EC condition. Therefore, during QS, independent from the groups and touch conditions, deprivation of visual information significantly increases the postural sway. This result is also confirmed by literature [27, 16, 17, 56].

According to the P eyes * group = 0.575; independent from touch conditions, between the groups, trends of changes in postural sway behaviors between adapting to EO and EC conditions are similar. This indicates that during QS, independent from touch conditions, evaluations of eyes information show similarities between the groups.

According to the P touch = 0.585; independent from the groups and eyes conditions, postural sway behaviors at adapting to TO condition is similar with TC condition.

Therefore, during QS, independent from the groups and eyes conditions, existence of touch information is not significantly changes the postural sway.

According to the P touch * group = 0.883; independent from eyes conditions, between the groups, trends of changes in postural sway behaviors between adapting to TO and TC conditions are similar. This indicates that during QS, independent from eyes conditions, evaluations of touch information show similarities between the groups.

According to the P eyes * touch = 0.887; independent from the groups, trends of changes in postural sway behaviors between adapting to EOTO and EOTC conditions (or between adapting to EOTC and ECTC conditions) and between adapting to ECTO and ECTC conditions (or between adapting to EOTO and ECTO) are similar. This indicates that independent from the groups, evaluations of touch information show similarities in between EO and EC conditions.

These results indicate that during QS, independent from the groups, postural sway behavior changes between adapting to the different eyes conditions; however, does not significantly change between adapting to the different touch conditions. Moreover, evaluation of both touch and eyes information show similarities between the groups.

3.1.2. RMS Results for PS Trials

Here, to analyze the effect of ATV on postural sway behavior in PS (perturbed stance), which defines the vibration trials, in between adapting to different sensory conditions, the 4-way mixed ANOVA was formed by three within-subjects factors (independent variables / repeated measures) as eyes conditions (EO, EC), touch conditions (TC, TO) and epoch (2^{nd}, 4^{th}) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).

This statistical analysis was conducted with RMS metrics of 1^{st} and 2^{nd} falls of 5^{th}, 6^{th}, 7^{th} and 8^{th} trials of all groups together. Figure 3.2. shows RMS data for 1^{st} and 2^{nd} falls of 5^{th}, 6^{th}, 7^{th} and 8^{th} trials. Tests of within-subjects effects for 4-way mixed ANOVA for RMS data are shown in Table 3.4. Tests of between-subjects effects for 4-way mixed ANOVA for RMS data are shown in Table 3.5. Also, descriptive statistics for the RMS of 5th, 6th, 7th, 8th trials are shown in Table 3.6. The results of this analysis are stated below.

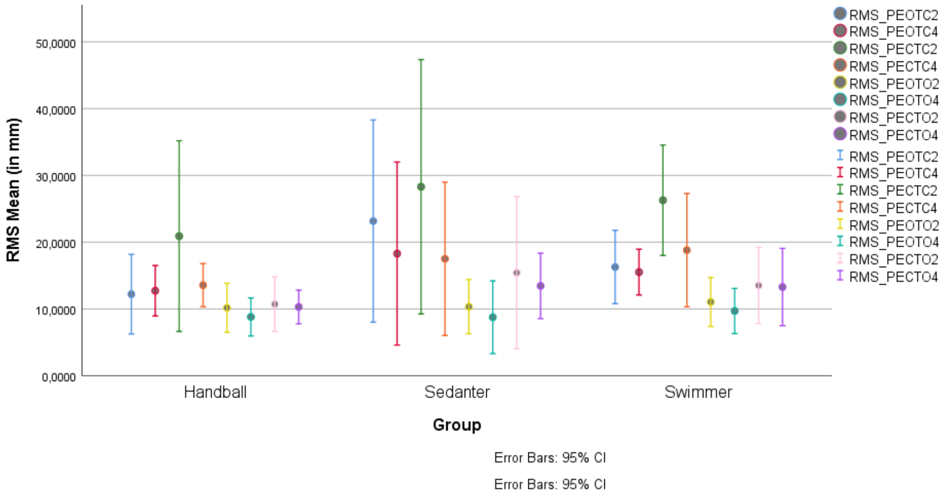

Figure 3.2. RMS Data for 1st & 2nd Falls of 5th, 6th, 7th and 8th Trials

Table 3.4. Tests of Within-Subjects Effects for 4-way mixed ANOVA for RMS

Tests of Within-Subjects Effects		
Source	**F**	**p**
Eyes	24.166	0.0001
Eyes * Group	0.923	0.413
Touch	8.260	0.009
Touch * Group	0.192	0.827
Epoch	8.703	0.008
Epoch * Group	0.621	0.547
Eyes * Touch	0.852	0.366
Eyes * Touch * Group	1.607	0.224
Eyes * Epoch	5.707	0.026
Eyes * Epoch * Group	0.414	0.666
Touch * Epoch	2.908	0.103
Touch * Epoch * Group	0.010	0.990
Eyes * Touch * Epoch	6.457	0.019
Eyes * Touch * Epoch * Group	0.111	0.896

Table 3.5. Tests of Between-Subjects Effects for 4-way mixed ANOVA for RMS

Tests of Between-Subjects Effects		
Source	**F**	**p**
Group	0.781	0.471

Table 3.6. Descriptive Statistics for the RMS of 5th, 6th, 7th, 8th Trials

			1st Fall			2nd Fall			
Trial	Cond.	Group	Epoch	Mean	S.D.	Epoch	Mean	S.D.	N
5th	EOTC	Handball	2nd	12.2152	7.1356	4th	12.7216	4.5243	8
		Sedentary		23.1517	18.1096		18.2861	16.3878	8
		Swimmer		16.2762	6.5692		15.5178	4.0989	8
		Total		17.2144	12.2353		15.5085	9.9229	24
6th	ECTC	Handball	2nd	20.9000	17.0920	4th	13.5628	3.8719	8
		Sedentary		28.2953	22.7888		17.5045	13.7318	8
		Swimmer		26.2755	9.8842		18.8078	10.1404	8
		Total		25.1569	16.9371		16.6250	9.9214	24
7th	EOTO	Handball	2nd	10.1712	4.3911	4th	8.8059	3.4090	8
		Sedentary		10.3373	4.8504		8.7593	6.5144	8
		Swimmer		11.0417	4.3934		9.6950	4.0488	8
		Total		10.5168	4.3648		9.0867	4.6514	24
8th	ECTO	Handball	2nd	10.7171	4.8823	4th	10.3010	3.0177	8
		Sedentary		15.4208	13.6218		13.4494	5.8678	8
		Swimmer		13.5147	6.8144		13.2830	6.9255	8
		Total		13.2175	9.0418		12.3444	5.4801	24

According to the P eyes = 0.0001; independent from touch conditions, epochs and the groups, the effect of ATV on postural sway behaviors at adapting to EO condition is significantly different with respect to EC condition. Therefore, during vibration, independent from touch conditions, epochs and the groups, existence / deprivation of visual information significantly changes the postural sway behaviors.

According to the P eyes * group = 0.413; independent from touch conditions and epochs, between the groups, trends of changes in the effect of ATV on postural sway behaviors between adapting to different eyes conditions (EO and EC) are not significantly different. This indicates that independent from touch conditions and epochs, evaluations of eyes information show similarities between the groups.

According to the P touch = 0.009; independent from eyes conditions, epochs and the groups, the effect of ATV on postural sway behaviors at adapting to TO condition is significantly different with respect to TC condition. Therefore, during vibration, independent from eyes conditions, epochs and the groups, existence / deprivation of touch information significantly changes the postural sway behaviors.

According to the P touch * group = 0.827; independent from eyes conditions and epochs, between the groups, trends of changes in the effect of ATV on postural sway behaviors between adapting to different touch conditions (TO and TC) are very similar. This indicates that independent from eyes conditions and epochs, evaluations of touch information show similarities between the groups.

According to the P epoch = 0.008; independent from the groups, touch and eyes conditions, the effect of ATV on postural sway behaviors is significantly different between 2nd and 4th epochs. Therefore, independent from the groups, touch and eyes conditions, adaptation / learning / anticipation to the ATV significantly changes postural sway behaviors in between 1st and 2nd falls.

According to the P epoch * group = 0.547; independent from touch and eyes conditions, between the groups, trends of changes in the effect of ATV on postural sway behaviors between 2nd and 4th epochs are not significantly different. This indicates that independent from touch and eyes conditions, the effect of adaptation / learning / anticipation to the ATV on postural sway behaviors shows similarities between the groups.

According to the P eyes * touch = 0.366; independent from epochs and the groups, trends of changes in the effect of ATV on postural sway behavior between adapting to EOTO and EOTC conditions (or between adapting to EOTC and ECTC conditions) and between adapting to ECTO and ECTC conditions (or between adapting to EOTO and ECTO) are not significantly different. This indicates that independent from epochs and the groups, evaluations of touch information (or eyes information) show similarities in between EO and EC conditions (or in between TO and TC conditions).

According to the P eyes * epoch = 0.026; independent from touch conditions and the groups, between 2^{nd} and 4^{th} epochs, trends of changes in the effect of ATV on postural sway behaviors between adapting to different eyes conditions (EO and EC) conditions are significantly different. This indicates that independent from touch conditions and the groups, evaluations of eyes information show significantly change in between 1^{st} and 2^{nd} falls.

According to the P touch * epoch = 0.103; independent from eyes conditions and the groups, between 2^{nd} and 4^{th} epochs, trends of changes in the effect of ATV on postural sway behaviors between adapting to different touch conditions (TO and TC) conditions are not significantly different. This indicates that independent from eyes conditions and the groups, evaluations of touch information are not significantly different in between 1^{st} and 2^{nd} falls.

According to the P group = 0,471; independent from epochs and sensory conditions, the effects of ATV on postural sway behaviors is not significantly different between the groups.

Later comparisons are insignificant.

These results indicate that during vibration, independent from the groups, the effect of ATV on postural sway behavior changes both at adapting to the different sensory conditions and adapting to the ATV. Moreover, the effect of adaptation to the ATV and evaluation of both touch and eyes information show similarities between the groups.

Further topics are constituted to specify the current results with detailed analyses.

3.1.2.1. RMS Results for Anticipation Effect

As stated in Section 3.1.2, independent from the groups and different sensory conditions (trials), adaptation / learning / anticipation to the ATV significantly changes postural sway behaviors in between 1st and 2nd falls. Moreover, independent from different sensory conditions (trials) the effect of adaptation / learning / anticipation to the ATV on postural sway behaviors shows similarities between the groups.

Here, to analyze the effect of adaptation / learning / anticipation to the ATV on postural sway behavior at adapting to different sensory conditions (trials) respectively, the 2-way mixed ANOVAs were formed by one within-subjects factor (independent variables / repeated measures) as epoch (2nd, 4th) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).

These statistical analyses were conducted with RMS metrics of 1st and 2nd falls of 5th, 6th, 7th and 8th trials for each group, respectively. The results of this analysis are stated below.

3.1.2.1.a. RMS Results for Anticipation Effect in 5th Trial (e2 vs e4)

Tests of within-subjects effects for 2-way mixed ANOVA for RMS of 5th trial data are shown in Table 3.7. Tests of between-subjects effects for 2-way mixed ANOVA for RMS of 5th trial data are shown in Table 3.8. Also, descriptive statistics for the RMS of 5th trials are shown in Table 3.9.

Table 3.7. Tests of Within-Subjects Effects for 2-way mixed ANOVA for RMS of 5th Trial

Tests of Within-Subjects Effects		
Source	**F**	**p**
Epoch	0.801	0.381
Epoch * Group	0.724	0.497

Table 3.8. Tests of Between-Subjects Effects for 2-way mixed ANOVA for RMS of 5th Trial

Tests of Between-Subjects Effects		
Source	**F**	**p**
Group	1.381	0.273

Table 3.9. Descriptive Statistics for the RMS of 5th Trial

Trial	Cond.	Fall	Epoch	Group	Mean	S.D.	N
5th	EOTC	1st	2nd	Handball	12.2152	7.1356	8
				Sedentary	23.1517	18.1096	8
				Swimmer	16.2762	6.5692	8
				Total	17.2144	12.2353	24
5th	EOTC	2nd	4th	Handball	12.7216	4.5243	8
				Sedentary	18.2861	1.,3878	8
				Swimmer	15.5178	4.0989	8
				Total	15.5085	9.9229	24

According to the P epoch = 0.381; in EOTC condition (5th trial), independent from the groups, the effect of ATV on postural sway behaviors is not significantly different between 2nd and 4th epochs. Therefore, independent from the groups, adaptation / learning / anticipation to the ATV in 5th trial does not significantly change postural sway behaviors in between 1st and 2nd falls (see in Table 3.9).

According to the P epoch * group = 0.497; in EOTC condition (5th trial), between the groups, trends of changes in the effect of ATV on postural sway behaviors between 2nd and 4th epochs are not significantly different. This indicates that the effect of adaptation / learning / anticipation to the ATV on postural sway behaviors in 5th trial shows similarities between the groups.

According to the P group = 0,273; in EOTC condition (5th trial), independent from epochs, the effect of ATV on postural sway behaviors is not significantly different between the groups.

However, as denoted in Table 3.9, in EOTC condition, there are some differences between the means of the groups for both 1st and 2nd falls.

3.1.2.1.b. RMS Results for Anticipation Effect in 6th Trial (e2 vs e4)

Tests of within-subjects effects for 2-way mixed ANOVA for RMS of 6th trial data are shown in Table 3.10. Tests of between-subjects effects for 2-way mixed ANOVA for RMS of 6th trial data are shown in Table 3.11. Also, descriptive statistics for the RMS of 6th trials are shown in Table 3.12.

Table 3.10. Tests of Within-Subjects Effects for 2-way mixed ANOVA for RMS of 6th Trial

Tests of Within-Subjects Effects		
Source	**F**	**p**
Epoch	11.891	0.002
Epoch * Group	0.209	0.813

Table 3.11. Tests of Between-Subjects Effects for 2-way mixed ANOVA for RMS of 6th Trial

Tests of Between-Subjects Effects		
Source	**F**	**p**
Group	0.486	0.622

Table 3.12. Descriptive Statistics for the RMS of 6th Trial

Trial	Cond.	Fall	Epoch	Group	Mean	S.D.	N
6th	ECTC	1st	2nd	Handball	20.9000	17.0920	8
				Sedentary	28.2953	22.7888	8
				Swimmer	26.2755	9.8842	8
				Total	25.1569	16.9371	24
6th	ECTC	2nd	4th	Handball	13.5628	3.8719	8
				Sedentary	17.5045	13.7318	8
				Swimmer	18.8078	10.1404	8
				Total	16.6250	9.9214	24

According to the P epoch = 0.002; in ECTC condition (6th trial), independent from the groups, the effect of ATV on postural sway behaviors is significantly different between 2nd and 4th epochs. Therefore, independent from the groups, adaptation / learning / anticipation to the ATV in 6th trial significantly decreases postural sway in 2nd fall with respect to 1st fall. (see in Table 3.12).

According to the P epoch * group = 0.813; in ECTC condition (6th trial), between the groups, trends of changes in the effect of ATV on postural sway behaviors between 2nd and 4th epochs are very similar. This indicates that the effect of adaptation / learning / anticipation to the ATV on postural sway behaviors in 6th trial shows close similarities between the groups.

According to the P group = 0,622; in ECTC condition (6th trial), independent from epochs, the effect of ATV on postural sway behaviors is not significantly different between the groups.

As denoted in Table 3.12, in ECTC condition, there are some differences between the means of the groups for both 1st and 2nd falls. Adaptation / learning / anticipation to the ATV does not change the mean distribution of the groups and the inter-group differences in 2nd fall.

3.1.2.1.c. RMS Results for Anticipation Effect in 7th Trial (e2 vs e4)

Tests of within-subjects effects for 2-way mixed ANOVA for RMS of 7th trial data are shown in Table 3.13. Tests of between-subjects effects for 2-way mixed ANOVA for RMS of 7th trial data are shown in Table 3.14. Also, descriptive statistics for the RMS of 7th trials are shown in Table 3.15.

Table 3.13. Tests of Within-Subjects Effects for 2-way mixed ANOVA for RMS of 7th Trial

Tests of Within-Subjects Effects		
Source	**F**	**p**
Epoch	2.155	0.157
Epoch * Group	0.006	0.994

Table 3.14. Tests of Between-Subjects Effects for 2-way mixed ANOVA for RMS of 7th Trial

Tests of Between-Subjects Effects		
Source	**F**	**p**
Group	0.118	0.889

Table 3.15. Descriptive Statistics for the RMS of 7th Trial

Trial	Cond.	Fall	Epoch	Group	Mean	S.D.	N
7th	EOTO	1st	2nd	Handball	10.1712	4.3911	8
				Sedentary	10.3373	4.8504	8
				Swimmer	11.0417	4.3934	8
				Total	10.5168	4.3648	24
7th	EOTO	2nd	4th	Handball	8.8059	3.4090	8
				Sedentary	8.7593	6.5144	8
				Swimmer	9.6950	4.0488	8
				Total	9.0867	4.6514	24

According to the P epoch = 0.157; in EOTO condition (7th trial), independent from the groups, the effect of ATV on postural sway behaviors is not significantly different between 2nd and 4th epochs. Therefore, independent from the groups, adaptation / learning / anticipation to the ATV in 7th trial does not significantly change postural sway behaviors in between 1st and 2nd falls (see in Table 3.15).

According to the P epoch * group = 0.994; in EOTO condition (7th trial), between the groups, trends of changes in the effect of ATV on postural sway behaviors between 2nd and 4th epochs are almost the same. This indicates that the effect of adaptation / learning / anticipation to the ATV on postural sway behaviors in 7th trial is almost the same between the groups.

According to the P group = 0,889; in EOTO condition (7th trial), independent from epochs, the effect of ATV on postural sway behaviors is similar between the groups.

Therefore, as denoted in Table 3.15, in EOTO condition, the means of the groups are almost the same.

3.1.2.1.d. RMS Results for Anticipation Effect in 8th Trial (e2 vs e4)

Tests of within-subjects effects for 2-way mixed ANOVA for RMS of 8th trial data are shown in Table 3.16. Tests of between-subjects effects for 2-way mixed ANOVA for RMS of 8th trial data are shown in Table 3.17. Also, descriptive statistics for the RMS of 8th trials are shown in Table 3.18.

Table 3.16. Tests of Within-Subjects Effects for 2-way mixed ANOVA for RMS 8th Trial

Tests of Within-Subjects Effects		
Source	**F**	**p**
Epoch	0.370	0.550
Epoch * Group	0.148	0.864

Table 3.17. Tests of Between-Subjects Effects for 2-way mixed ANOVA for RMS 8th Trial

Tests of Between-Subjects Effects		
Source	**F**	**p**
Group	0.728	0.495

Table 3.18. Descriptive Statistics for the RMS of 8th Trial

Trial	Cond.	Fall	Epoch	Group	Mean	S.D.	N
8th	ECTO	1st	2nd	Handball	10.7171	4.8823	8
				Sedentary	15.4208	13.6218	8
				Swimmer	13.5147	6.8144	8
				Total	13.2175	9.0418	24
8th	ECTO	2nd	4th	Handball	10.3010	3.0177	8
				Sedentary	13.4494	5.8678	8
				Swimmer	13.2830	6.9255	8
				Total	12.3444	5.4801	24

According to the P epoch = 0.550; in ECTO condition (8th trial), independent from the groups, the effect of ATV on postural sway behaviors is not significantly different between 2nd and 4th epochs. Therefore, independent from the groups, adaptation / learning / anticipation to the ATV in 8th trial does not significantly change postural sway behaviors in between 1st and 2nd falls (see in Table 3.18).

According to the P epoch * group = 0.864; in ECTO condition (8th trial), between the groups, trends of changes in the effect of ATV on postural sway behaviors between 2nd and 4th epochs are very similar. This indicates that the effect of adaptation / learning / anticipation to the ATV on postural sway behaviors in 8th trial shows close similarities between the groups.

According to the P group = 0,495; in ECTO condition (8th trial), independent from epochs, the effect of ATV on postural sway behaviors is not significantly different between the groups.

Therefore, as denoted in Table 3.18, in ECTO condition, the means of the groups are close to each other; however, not close as in EOTO condition.

3.1.2.2. RMS Results for Touch Effect

As stated in Section 3.1.2,

- During vibration, independent from eyes conditions, epochs and the groups, existence / deprivation of touch information significantly changes the postural sway behaviors.
- Independent from epochs and the groups, evaluations of touch information show similarities in between different eyes conditions.
- Independent from eyes conditions and the groups, evaluations of touch information are not significantly change in between epochs.
- Independent from eyes conditions and epochs, evaluations of touch information show similarities between the groups.

Here, to analyze the effect of ATV on postural sway behavior between adapting to different touch conditions for both eyes conditions respectively, the 3-way mixed ANOVAs were formed by two within-subjects factors (independent variables / repeated measures) as touch conditions (TC, TO) and epoch (2^{nd}, 4^{th}) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).

These statistical analyses were conducted with RMS metrics of 1^{st} and 2^{nd} falls of 5^{th} and 7^{th} trials for in EO condition and 1^{st} and 2^{nd} falls of 6^{th} and 8^{th} trials for EC condition for each group, respectively. The results of these analyses are stated below.

3.1.2.2.a. RMS Results for Touch Effect in EO Condition (5^{th} vs 7^{th} Trials)

RMS Results for Touch Effect between 5^{th} & 7^{th} Trials (1^{st} & 2^{nd} falls integrated analysis)

Here, to analyze the effect of ATV on postural sway behavior between adapting to different touch conditions for EO condition, the 3-way mixed ANOVA was formed by two within-subjects factors (independent variables / repeated measures) as touch conditions (TC, TO) and epoch (2^{nd}, 4^{th}) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).

This statistical analysis was conducted with RMS metrics of 1^{st} and 2^{nd} falls of 5^{th} and 7^{th} trials for in EO condition for each group, respectively.

Figure 3.3. shows RMS data for 1^{st} & 2^{nd} falls of 5^{th} and 7^{th} trials. Tests of within-subjects effects for 3-way mixed ANOVA for RMS of 5^{th} and 7^{th} trials data are shown in Table 3.19. Tests of between-subjects effects for 3-way mixed ANOVA for RMS of 5^{th} and 7^{th} trials data are shown in Table 3.20. Also, descriptive statistics for the RMS of 1^{st} and 2^{nd} falls of 5^{th}, 7^{th} trials are shown in Table 3.21. The results of this analysis are stated below.

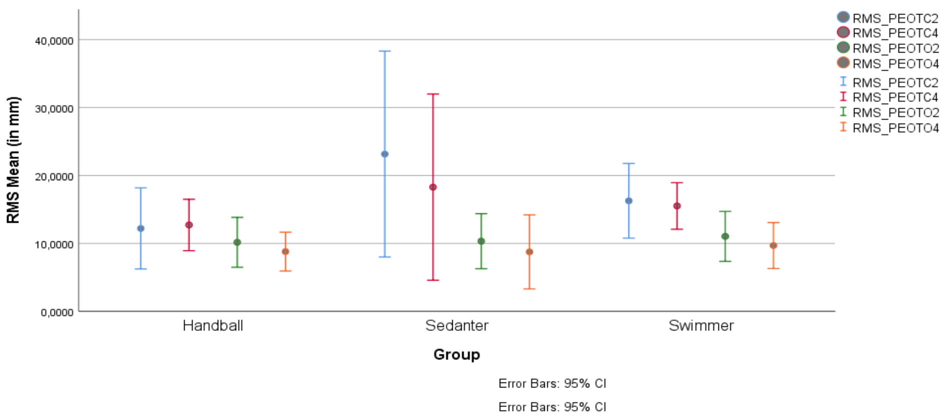

Figure 3.3. RMS Data for 1^{st} & 2^{nd} Falls of 5^{th} & 7^{th} Trials

Table 3.19. Tests of Within-Subjects Effects for 3-way mixed ANOVA for RMS of 5th & 7th Trials

Tests of Within-Subjects Effects		
Source	**F**	**p**
Touch	16.947	0.0005
Touch * Group	2.307	0.124
Epoch	2.778	0.110
Epoch * Group	0.809	0.459
Touch * Epoch	0.014	0.909
Touch * Epoch * Group	0.428	0.658

Table 3.20. Tests of Between-Subjects Effects for 3-way mixed ANOVA for RMS of 5th & 7th Trials

Tests of Between-Subjects Effects		
Source	**F**	**p**
Group	0.809	0.459

Table 3.21. Descriptive Statistics for RMS of 1st & 2nd falls of 5th & 7th Trials

		1st Fall				2nd Fall			
Trial	Cond.	Group	Epoch	Mean	S.D.	Epoch	Mean	S.D.	N
5th	EOTC	Handball	2nd	12.2152	7.13561	4th	12.7216	4.5243	8
		Sedentary		23.1517	18.10966		18.2861	16.3878	8
		Swimmer		16.2762	6.56921		15.5178	4.0989	8
		Total		17.2144	12.23538		15.5085	9.9229	24
7th	EOTO	Handball	2nd	10.1712	4.39110	4th	8.8059	3.4090	8
		Sedentary		10.3373	4.85043		8.7593	6.5144	8
		Swimmer		11.0417	4.39343		9.6950	4.0488	8
		Total		10.5168	4.36484		9.0867	4.6514	24

According to the P touch = 0.0005; in EO condition, independent from epochs and the groups, the effect of ATV on postural sway behaviors at adapting to TO condition (7th trial) is significantly different with respect to TC condition (5th trial). Therefore, during vibration, independent from epochs and the groups, existence of touch information in EO condition significantly decrease the postural sway (see total mean values in Table 3.21).

According to the P touch * group = 0.124; in EO condition, independent from epochs, between the groups, trends of changes in the effect of ATV on postural sway behaviors between adapting to TO (7^{th} trial) and TC (5^{th} trial) conditions are not significantly different. This indicates that independent from epochs, evaluations of touch information in EO condition are not significantly different between the groups.

According to the P epoch = 0.110; in EO condition, independent from the groups and touch conditions, the effect of ATV on postural sway behaviors is not significantly different between 2^{nd} and 4^{th} epochs. Therefore, independent from the groups and touch conditions, adaptation / learning / anticipation to the ATV in EO condition does not significantly change postural sway behaviors in between 1^{st} and 2^{nd} falls (As it is known, from both 5^{th} and 7^{th} trials, there is no anticipation effect observed in postural sway behavior).

According to the P epoch * group = 0.547; in EO condition, independent from touch conditions, between the groups, trends of changes in the effect of ATV on postural sway behaviors between 2^{nd} and 4^{th} epochs are not significantly different. This indicates that in EO condition, independent from touch conditions, the effect of adaptation / learning / anticipation to the ATV on postural sway behaviors shows similarities between the groups (As it is known, from both 5^{th} and 7^{th} trials, similar anticipation effect on postural sway behavior is observed between the groups).

According to the P touch * epoch = 0.909; in EO condition, independent from the groups, between 2^{nd} and 4^{th} epochs, trends of changes in the effect of ATV on postural sway behaviors between adapting to TO (7^{th} trial) and TC (5^{th} trial) conditions are almost the same. This indicates that in EO condition, independent from the groups, evaluations of touch information are almost the same in between 1^{st} and 2^{nd} falls.

According to the P group = 0,459; independent from epochs and touch conditions, the effect of ATV on postural sway behaviors in EO conditions is not significantly different between the groups.

Touch * Epoch * Group comparison is insignificant.

RMS Results for Touch Effect between 5th & 7th Trials (1st & 2nd falls individual analysis)

Here, to analyze the effect of ATV on postural sway behavior between adapting to different touch conditions in EO condition for the each fall respectively, the 2-way mixed ANOVAs were formed by one within-subjects factor (independent variables / repeated measures) as touch conditions (TC, TO) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).

These statistical analyses were conducted with RMS metrics of 1st and 2nd falls of 5th and 7th trials for in EO condition for each group, respectively. Tests of within-subjects effects for 2-way mixed ANOVA for RMS of 5th and 7th trials data are shown in Table 3.22. Tests of between-subjects effects for 2-way mixed ANOVA for RMS of 5th and 7th trials data are shown in Table 3.23. Descriptive statistics for 1st & 2nd falls of 5th & 7th trials were demonstrated in Table 3.21. above. The results of this analysis are stated below.

Table 3.22. Tests of Within-Subjects Effects for 2-way mixed ANOVA for RMS of 5th & 7th Trials

Tests of Within-Subjects Effects				
	2nd epoch (1st fall)		**4th epoch (2nd fall)**	
Source	**F**	**p**	**F**	**p**
Touch	10.394	0.004	11.536	0.003
Touch * Group	2.364	0.119	0.759	0.481

Table 3.23. Tests of Between-Subjects Effects for 2-way mixed ANOVA for RMS of 5th & 7th Trials

Tests of Between-Subjects Effects				
	2nd epoch (1st fall)		**4th epoch (2nd fall)**	
Source	**F**	**p**	**F**	**p**
Group	1.129	0.342	0.383	0.687

According to the P touch $_{(1st\ fall)}$ = 0.004 and P touch $_{(2nd\ fall)}$ = 0.003; in EO condition, independent from the groups, the effect of ATV on postural sway behaviors between adapting to TO condition (7th trial) and TC condition (5th trial) is significantly different for both 2nd and 4th epochs. Therefore, during vibration, independent from the groups, existence of touch information in EO condition significantly decrease the postural sway in both 1st and 2nd falls (see in Table 3.21). P touch values of 1st and 2nd falls are almost the same. It is also stated in integrated analysis of Section 3.1.2.2.a as P touch * epoch = 0.909; independent from the groups, between 2nd and 4th epochs / 1st and 2nd falls, trends of change between TC (5th trial) and TO (7th trial) conditions are almost the same. Because, independent from the groups, adaptation / learning / anticipation to the ATV in 5th and 7th trials does not significantly change postural sway behaviors in between 1st and 2nd falls.

Figure 3.4. demonstrates the statistical effects of anticipation and touch information on sway behavior for EO condition.

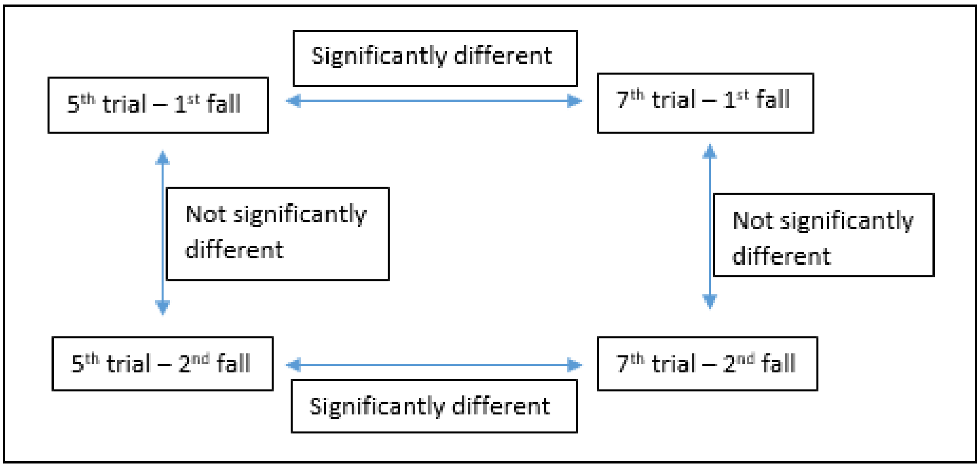

Figure 3.4. Statistical effects of anticipation and touch information on sway behavior for EO condition

According to the P touch * group $_{(1st\ fall)}$ = 0.119 and P touch * group $_{(2nd\ fall)}$ = 0.481; in EO condition, between the groups, trends of changes in the effect of ATV on postural sway behaviors between adapting to TO (7^{th} trial) and TC (5^{th} trial) conditions are not significantly different both in 2^{nd} and 4^{th} epochs (It is also stated in integrated analysis of Section 3.1.2.2.a as P touch * group = 0.124; independent from epochs / falls, between the groups, trends of change between TC (5^{th} trial) and TO (7^{th} trial) conditions are not significantly different). This indicates that evaluations of touch information in EO condition are not significantly different between the groups in both 1^{st} and 2^{nd} falls. However, as it is seen in Table 3.21 and Figure 3.4, sedentary group benefits from evaluation of touch information more than athletes group does and swimmers benefit more than handball players do.

In here, the thing worthy to notice is that in EO condition, independent from the groups belong to athletes or sedentary, in consequence of the existence of touch information, all groups' mean and S.D. values of postural sway both decrease and became almost the same (see in Table 3.21). Decrease in S.D. values state that existence of touch information decrease in-group differences. On the other hand, almost the same mean and S.D. values state that existence of touch information in EO condition, vanish inter-group differences and unites them in terms of postural sway.

According to the P group $_{(1st\ fall)}$ = 0,342 and P group $_{(2nd\ fall)}$ = 0.687; independent from touch conditions, the effect of ATV on postural sway behaviors in EO conditions is not significantly different between the groups in both 1^{st} and 2^{nd} falls (It is also stated in integrated analysis of Section 3.1.2.2.a as P group = 0.459; independent from epochs / falls and touch conditions, between the groups, the effect of ATV is not significantly different).

Therefore, as denoted in Table 3.21, in EOTO condition, inter-group postural sway differences, which are observed in EOTC condition, are vanished by the existence of touch information.

3.1.2.2.b. RMS Results for Touch Effect in EC Condition (6th vs 8th Trials)

<u>RMS Results for Touch Effect between 6th & 8th Trials (1st & 2nd falls integrated analysis)</u>

Here, to analyze the effect of ATV on postural sway behavior between adapting to different touch conditions for EC condition, the 3-way mixed ANOVA was formed by two within-subjects factors (independent variables / repeated measures) as touch conditions (TC, TO) and epoch (2nd, 4th) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).

This statistical analysis was conducted with RMS metrics of 1st and 2nd falls of 6th and 8th trials for in EC condition for each group, respectively. Figure 3.5. shows RMS data for 1st & 2nd falls of 6th and 8th trials. Tests of within-subjects effects for 3-way mixed ANOVA for RMS of 6th and 8th trials data are shown in Table 3.24. Tests of between-subjects effects for 3-way mixed ANOVA for RMS of 6th and 8th trials data are shown in Table 3.25. Also, descriptive statistics for the RMS of 1st and 2nd falls of 6th, 8th trials are shown in Table 3.26. The results of this analysis are stated below.

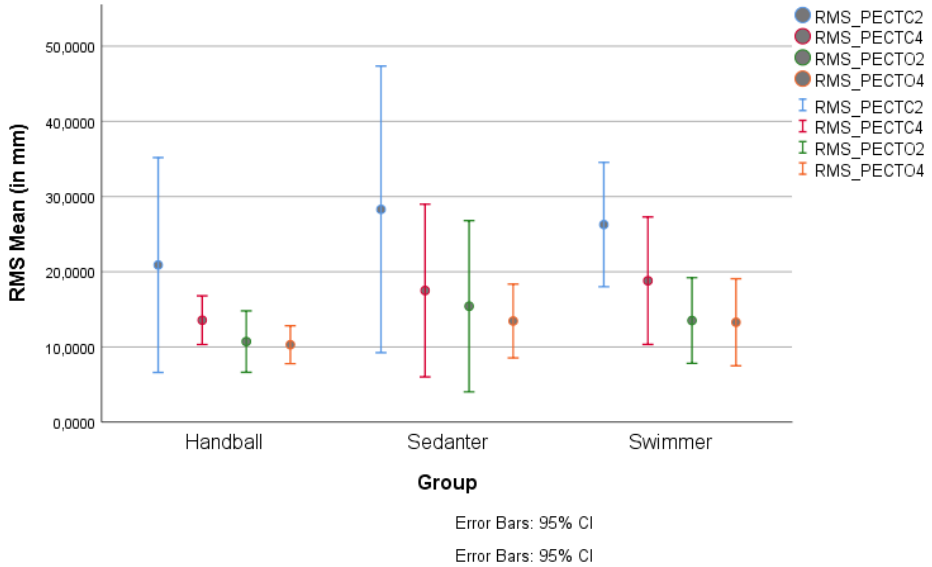

Figure 3.5. RMS Data for 1st & 2nd Falls of 6th & 8th Trials

Table 3.24. Tests of Within-Subjects Effects for 3-way mixed ANOVA for RMS of 6th & 8th Trials

Tests of Within-Subjects Effects		
Source	**F**	**p**
Touch	19.792	0.0002
Touch * Group	0.156	0.856
Epoch	7.218	0.014
Epoch * Group	0.230	0.797
Touch * Epoch	14.264	0.001
Touch * Epoch * Group	0.084	0.920

Table 3.25. Tests of Between-Subjects Effects for 3-way mixed ANOVA for RMS of 6th & 8th Trials

Tests of Between-Subjects Effects		
Source	**F**	**p**
Group	0.627	0.544

Table 3.26. Descriptive Statistics for 1st & 2nd falls of 6th & 8th Trials for RMS

			1st Fall			2nd Fall			
Trial	Cond.	Group	Epoch	Mean	S.D.	Epoch	Mean	S.D.	N
6th	ECTC	Handball	2nd	20.9000	17.0920	4th	13.5628	3.8719	8
		Sedentary		28.2953	22.7888		17.5045	13.7318	8
		Swimmer		26.2755	9.8842		18.8078	10.1404	8
		Total		25.1569	16.9371		16.6250	9.9214	24
8th	ECTO	Handball	2nd	10.7171	4.8823	4th	10.3010	3.0177	8
		Sedentary		15.4208	13.6218		13.4494	5.8678	8
		Swimmer		13.5147	6.8144		13.2830	6.9255	8
		Total		13.2175	9.0418		12.3444	5.4801	24

According to the P touch = 0.0002; in EC condition, independent from epochs and the groups, the effect of ATV on postural sway behaviors at adapting to TO condition (8th trial) is significantly different with respect to TC condition (6th trial). Therefore, during vibration, independent from epochs and the groups, existence of touch information in EC condition significantly decrease the postural sway (see total mean values in Table 3.26).

According to the P touch * group = 0.856; in EC condition, independent from epochs, between the groups, trends of changes in the effect of ATV on postural sway behaviors between adapting to TO (8^{th} trial) and TC (6^{th} trial) conditions are similar. This indicates that independent from epochs, evaluations of touch information in EC condition are similar between the groups.

According to the P epoch = 0.014; in EC condition, independent from the groups and touch conditions, the effect of ATV on postural sway behaviors is significantly different between 2^{nd} and 4^{th} epochs. Therefore, independent from the groups and touch conditions, adaptation / learning / anticipation to the ATV in EC condition significantly changes postural sway behaviors in between 1^{st} and 2^{nd} falls (This result originated from the anticipation effect on the postural sway behavior in 6^{th} trial).

According to the P epoch * group = 0.797; in EC condition, independent from touch conditions, between the groups, trends of changes in the effect of ATV on postural sway behaviors between 2^{nd} and 4^{th} epochs are similar. This indicates that in EC condition, independent from touch conditions, the effect of adaptation / learning / anticipation to the ATV on postural sway behaviors shows similarities between the groups (As it is known, from both 6^{th} and 8^{th} trials, similar anticipation effect on postural sway behavior is observed between the groups).

According to the P touch * epoch = 0.001; in EC condition, independent from the groups, between 2^{nd} and 4^{th} epochs, trends of changes in the effect of ATV on postural sway behaviors between adapting to TO (8^{th} trial) and TC (6^{th} trial) conditions are significantly different. This indicates that in EC condition, independent from the groups, evaluations of touch information are significantly different in between 1^{st} and 2^{nd} falls. (This result originated from the anticipation effect on the postural sway behavior in 6^{th} trial. Anticipation in 6^{th} trial decreases the mean and S.D. of postural sway in 2^{nd} fall with respect to 1^{st} fall. Therefore, the trend of change in between 2^{nd} and 4^{th} delta became significantly different. For this reason, evaluation of touch information is actually not significantly different in between 1^{st} and 2^{nd} falls).

According to the P group = 0,920; independent from epochs and touch conditions, the effect of ATV on postural sway behaviors in EC conditions is almost the same between the groups.

Touch * Epoch * Group comparison is insignificant.

RMS Results for Touch Effect between 6th & 8th Trials (1st & 2nd falls individual analysis)

Here, to analyze the effect of ATV on postural sway behavior between adapting to different touch conditions in EC condition for the each fall respectively, the 2-way mixed ANOVAs were formed by one within-subjects factor (independent variables / repeated measures) as touch conditions (TC, TO) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).

These statistical analyses were conducted with RMS metrics of 1st and 2nd falls of 6th and 8th trials for in EC condition for each group, respectively. Tests of within-subjects effects for 2-way mixed ANOVA for RMS of 6th and 8th trials data are shown in Table 3.27. Tests of between-subjects effects for 2-way mixed ANOVA for RMS of 6th and 8th trials data are shown in Table 3.28. Descriptive statistics for 1st & 2nd falls of 6th & 8th trials are demonstrated in Table 3.26. above. The results of these analyses are stated below.

Table 3.27. Tests of Within-Subjects Effects for 2-way mixed ANOVA for RMS of 6th & 8th Trials

Tests of Within-Subjects Effects				
	2nd epoch (1st fall)		4th epoch (2nd fall)	
Source	**F**	**p**	**F**	**p**
Touch	27.238	0.0000	5.282	0.032
Touch * Group	0.148	0.864	0.127	0.882

Table 3.28. Tests of Between-Subjects Effects for 2-way mixed ANOVA for RMS of 6th & 8th Trials

Tests of Between-Subjects Effects				
	2nd epoch (1st fall)		**4th epoch (2nd fall)**	
Source	**F**	**p**	**F**	**p**
Group	0.468	0.633	0.874	0.432

According to the P touch $_{(1st\ fall)}$ = 0.0000 and P touch $_{(2nd\ fall)}$ = 0.032; in EC condition, independent from the groups, the effect of ATV on postural sway behaviors between adapting to TO condition (8^{th} trial) and TC condition (6^{th} trial) is significantly different for both 2^{nd} and 4^{th} epochs. Therefore, during vibration, independent from the groups, existence of touch information in EC condition significantly decrease the postural sway in both 1^{st} and 2^{nd} falls (see in Table 3.26). The difference between P touch values of 1^{st} and 2^{nd} falls are also stated in integrated analysis of Section 3.1.2.2.b as P touch * epoch = 0.001; independent from the groups, between 2^{nd} and 4^{th} epochs / 1^{st} and 2^{nd} falls, trends of change between TC (6^{th} trial) and TO (8^{th} trial) conditions are significantly different. Because, independent from the groups, adaptation / learning / anticipation to the ATV in 6^{th} trial significantly decreased the postural sway in 2^{nd} fall with respect to 1^{st} fall, the significant difference in between 2^{nd} falls of 6^{th} and 8^{th} trials decreases with respect to 1^{st} falls.

Figure 3.6. demonstrates the statistical effects of anticipation and touch information on sway behavior for EC condition.

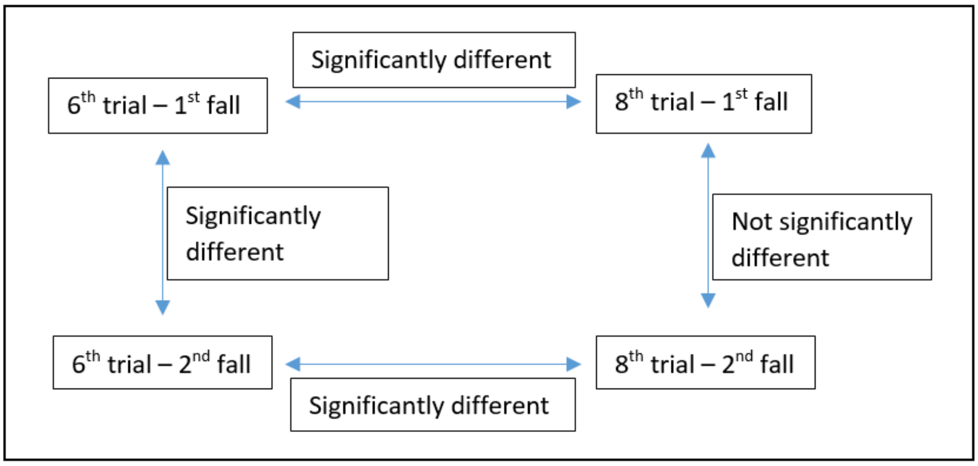

Figure 3.6. Statistical effects of anticipation and touch information on sway behavior for EC condition

According to the P touch * group $_{(1st\ fall)}$ = 0.864 and P touch * group $_{(2nd\ fall)}$ = 0.882; in EC condition, between the groups, trends of changes in the effect of ATV on postural sway behaviors between adapting to TO (8th trial) and TC (6th trial) conditions are very similar in both 2nd and 4th epochs (It is also stated in integrated analysis of Section 3.1.2.2.b as P touch * group = 0.856; independent from epochs / falls, between the groups, trends of change between TC (6th trial) and TO (8th trial) conditions are very similar). This indicates that evaluations of touch information in EC condition are very similar between the groups in both 1st and 2nd falls.

In here, the thing worthy to notice is that in EC condition, independent from the groups belong to athletes or sedentary, in consequence of the existence of touch information, all groups' mean and S.D. values of postural sway decrease. Decrease in S.D. values state that existence of touch information decrease in-group differences. On the other hand, existence of touch information in EC condition did not change the mean distributions of groups, did not change inter-group differences, did not vanish inter-group differences and did not unites them in terms of postural sway as in EO condition (see in Figure 3.5; for the both falls, the slopes between the groups' mean points in 6th trial are almost the same in 8th trial).

According to the P group $_{(1st\ fall)}$ = 0,633 and P group $_{(2nd\ fall)}$ = 0.432; independent from touch conditions, the effect of ATV on postural sway behaviors in EC conditions is not significantly different between the groups in both 1st and 2nd falls (It is also stated in integrated analysis of Section 3.1.2.2.b as P group = 0.920; independent from epochs / falls and touch conditions, between the groups, the effect of ATV is almost the same).

Therefore, as denoted in Table 3.26, in ECTO condition, inter-group postural sway differences, which are observed in ECTC condition, are not vanished by the existence of touch information as in EOTO condition.

3.1.2.3. RMS Results for Eyes Effect

As stated in Section 3.1.2,

- During vibration, independent from touch conditions, epochs and the groups, existence / deprivation of visual information significantly changes the postural sway behaviors.
- Independent from epochs and the groups, evaluations of eyes information show similarities in between different touch conditions.
- Independent from touch conditions and the groups, evaluations of eyes information show significantly change in between epochs.
- Independent from touch conditions and epochs, evaluations of eyes information show similarities between the groups.

Here, to analyze the effect of ATV on postural sway behavior between adapting to different eyes conditions for both touch conditions respectively, the 3-way mixed ANOVA was formed by two within-subjects factors (independent variables / repeated measures) as eyes conditions (EO, EC) and epoch (2nd, 4th) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).

This statistical analysis was conducted with RMS metrics of 1st and 2nd falls of 5th and 6th trials for in TC condition and 1st and 2nd falls of 7th and 8th trials for TO condition for each group, respectively. The results of these analyses are stated below.

3.1.2.3.a. RMS Results for Eyes Effect in TC Condition (5th vs 6th Trials)

<u>RMS Results for Eyes Effect between 5th & 6th Trials (1st & 2nd falls integrated analysis)</u>

Here, to analyze the effect of ATV on postural sway behavior between adapting to different eyes conditions for TC condition, the 3-way mixed ANOVA was formed by two within-subjects factors (independent variables / repeated measures) as eyes conditions (EO, EC) and epoch (2nd, 4th) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).

This statistical analysis was conducted with RMS metrics of 1st and 2nd falls of 5th and 6th trials for in TC condition for each group, respectively. Figure 3.7. shows RMS data for 1st & 2nd falls of 5th and 6th trials. Tests of within-subjects effects for 3-way mixed ANOVA for RMS of 5th and 6th trials data are shown in Table 3.29. Tests of between-subjects effects for 3-way mixed ANOVA for RMS of 5th and 6th trials data are shown in Table 3.30. Also, descriptive statistics for RMS of 1st and 2nd falls of 5th, 6th trials are shown in Table 3.31. The results of this analysis are stated below.

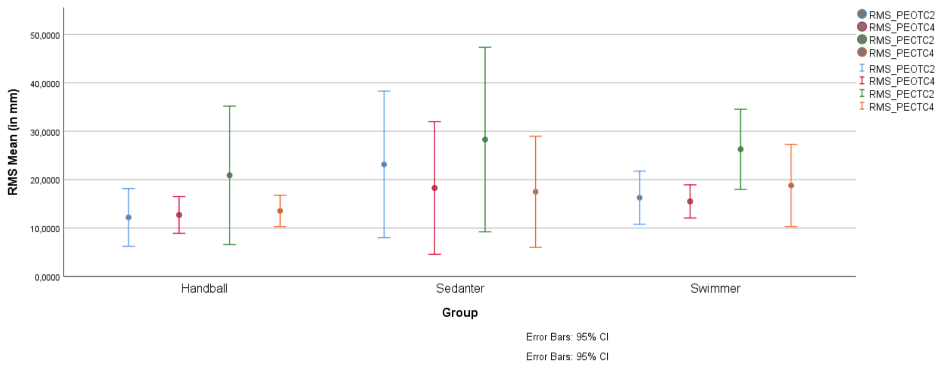

Figure 3.7. RMS Data for 1st & 2nd Falls of 5th & 6th Trials

Table 3.29. Tests of Within-Subjects Effects for 3-way mixed ANOVA for RMS of 5th & 6th Trials

Tests of Within-Subjects Effects		
Source	**F**	**p**
Eyes	6.153	0.022
Eyes * Group	0.502	0.612
Epoch	9.461	0.006
Epoch * Group	0.677	0.519
Eyes * Epoch	5.526	0.029
Eyes * Epoch * Group	0.037	0.964

Table 3.30. Tests of Between-Subjects Effects for 3-way mixed ANOVA for RMS

Tests of Between-Subjects Effects		
Source	**F**	**p**
Group	0.878	0.430

Table 3.31. Descriptive Statistics for RMS of 1st & 2nd falls of 5th & 6th Trials

			1st Fall			2nd Fall			
Trial	Cond.	Group	Epoch	Mean	S.D.	Epoch	Mean	S.D.	N
5th	EOTC	Handball	2nd	12.2152	7.1356	4th	12.7216	4.5243	8
		Sedentary		23.1517	18.1096		18.2861	16.3878	8
		Swimmer		16.2762	6.5692		15.5178	4.0989	8
		Total		17.2144	12.2353		15.5085	9.9229	24
6th	ECTC	Handball	2nd	20.9000	17.0920	4th	13.5628	3.8719	8
		Sedentary		28.2953	22.7888		17.5045	13.7318	8
		Swimmer		26.2755	9.8842		18.8078	10.1404	8
		Total		25.1569	16.9371		16.6250	9.9214	24

According to the P eyes = 0.022; in TC condition, independent from epochs and the groups, the effect of ATV on postural sway behaviors at adapting to EC condition (6th trial) is significantly different with respect to EO condition (5th trial). Therefore, during vibration, independent from epochs and the groups, deprivation of eyes information in TC condition significantly increases the postural sway (see total mean values in Table 3.31).

According to the P eyes * group = 0.612; in TC condition, independent from epochs, between the groups, trends of changes in the effect of ATV on postural sway behaviors between adapting to EC (6^{th} trial) and EO (5^{th} trial) conditions are similar. This indicates that independent from epochs, evaluations of eyes information in TC condition show similarities between the groups.

According to the P epoch = 0.006; in TC condition, independent from the groups and eyes conditions, the effect of ATV on postural sway behaviors is significantly different between 2^{nd} and 4^{th} epochs. Therefore, independent from the groups and eyes conditions, adaptation / learning / anticipation to the ATV in TC condition significantly changes postural sway behaviors in between 1^{st} and 2^{nd} falls (This result originated from the anticipation effect on the postural sway behavior in 6^{th} trial).

According to the P epoch * group = 0.519; in TC condition, independent from eyes conditions, between the groups, trends of changes in the effect of ATV on postural sway behaviors between 2^{nd} and 4^{th} epochs are similar. This indicates that in TC condition, independent from eyes conditions, the effect of adaptation / learning / anticipation to the ATV on postural sway behaviors shows similarities between the groups (As it is known, from both 5^{th} and 6^{th} trials, similar anticipation effect on postural sway behavior is observed between the groups).

According to the P eyes * epoch = 0.029; in TC condition, independent from the groups, between 2^{nd} and 4^{th} epochs, trends of changes in the effect of ATV on postural sway behaviors between adapting to EC (6^{th} trial) and EO (5^{th} trial) conditions are significantly different. This indicates that in TC condition, independent from the groups, evaluations of eyes information are significantly different in between 1^{st} and 2^{nd} falls (This result originated from the anticipation effect on the postural sway behavior in 6^{th} trial. As in discussed in following subtopic individual analysis, due to the compensation of the deprivation of eyes information by the anticipation, mean and S.D. values of 2^{nd} falls of 5^{th} and 6^{th} trials became almost the same. Therefore, trend of change in 2^{nd} delta became significantly different with respect to 1^{st} delta. For this reason, evaluation of eyes information is actually not significantly different in between 1st and 2nd falls).

According to the P group = 0,430; independent from epochs and eyes conditions, the effect of ATV on postural sway behaviors in TC conditions is not significantly different between the groups.

Eyes * Epoch * Group comparison is insignificant.

<u>RMS Results for Eyes Effect between 5th & 6th Trials (1st & 2nd falls individual analysis)</u>

Here, to analyze the effect of ATV on postural sway behavior between adapting to different eyes conditions in TC condition for the each fall respectively, the 2-way mixed ANOVAs were formed by one within-subjects factor (independent variables / repeated measures) as eyes conditions (EO, EC) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).

These statistical analyses were conducted with RMS metrics of 1st and 2nd falls of 5th and 6th trials for in TC condition for each group, respectively. Tests of within-subjects effect for 2-way mixed ANOVA for RMS of 5th and 6th trials data is shown in Table 3.32. Tests of between-subjects effects for 2-way mixed ANOVA for RMS of 5th and 6th trials data are shown in Table 3.33. Descriptive statistics for the RMS of 1st and 2nd falls of 5th, 6th trials were shown in Table 3.31. above. The results of these analyses are stated below.

Table 3.32. Tests of Within-Subjects Effects for 2-way mixed ANOVA for RMS of 5th & 6th Trials

Tests of Within-Subjects Effects				
	2nd epoch (1st fall)		**4th epoch (2nd fall)**	
Source	**F**	**p**	**F**	**p**
Eyes	8.057	0.010	0.408	0.530
Eyes * Group	0.269	0.767	0.458	0.639

Table 3.33. Tests of Between-Subjects Effects for 2-way mixed ANOVA for RMS of 5^{th} & 6^{th} Trials

Tests of Between-Subjects Effects				
	2^{nd} epoch (1^{st} fall)		**4^{th} epoch (2^{nd} fall)**	
Source	**F**	**p**	**F**	**p**
Group	0.961	0.399	0.626	0.544

According to the P eyes $_{(1st\ fall)}$ = 0.010 and P eyes $_{(2nd\ fall)}$ = 0.530; in TC condition, independent from the groups, the effect of ATV on postural sway behaviors between adapting to EC (6^{th} trial) and EO condition (5^{th} trial) is significantly different for 2^{nd} epoch; however, are similar for 4^{th} epoch. Therefore, during vibration, independent from the groups, deprivation of eyes information in TC condition significantly increased the postural sway in 1^{st} fall; however, did not significantly change the postural sway in 2^{nd} fall (see in Table 3.31). The difference between P eyes values of 1^{st} and 2^{nd} falls are also stated in integrated analysis of Section 3.1.2.3.a as P eyes * epoch = 0.029; independent from the groups, between 2^{nd} and 4^{th} epochs / 1^{st} and 2^{nd} falls, trends of change between EO (5^{th} trial) and EC (6^{th} trial) conditions are significantly different. Because, independent from the groups, adaptation / learning / anticipation to the ATV in 6^{th} trial significantly decreases the postural sway behaviors in 2^{nd} fall with respect to 1^{st} fall, the significant difference in between 1^{st} falls of 5^{th} and 6^{th} trials vanishes in between 2^{nd} falls.

Figure 3.8. demonstrates the statistical effects of anticipation and eyes information on sway behavior for TC condition.

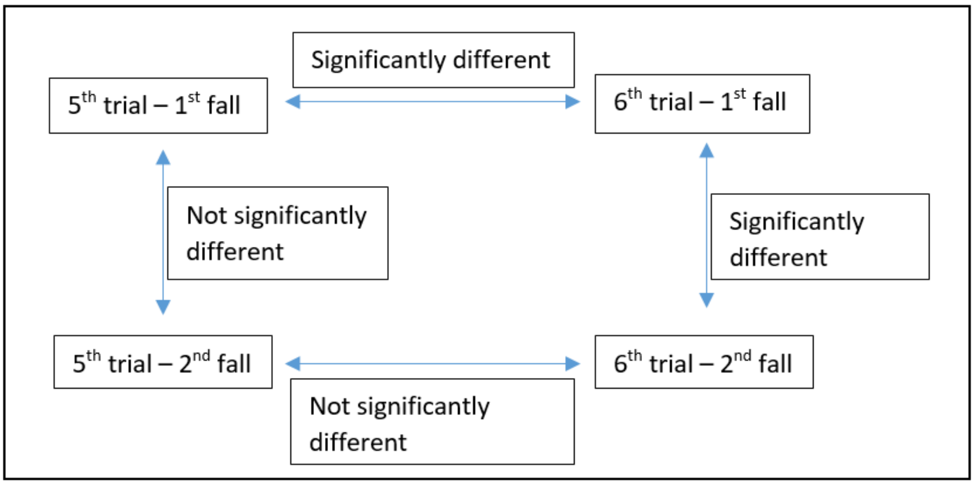

Figure 3.8. Statistical effects of anticipation and eyes information on sway behavior for TC condition

According to the P eyes * group $_{(1st\ fall)}$ = 0.767 and P eyes * group $_{(2nd\ fall)}$ = 0.639; in TC condition, between the groups, trends of changes in the effect of ATV on postural sway behaviors between adapting to EC (6th trial) and EO (5th trial) conditions are similar in both 2nd and 4th epochs (It is also stated in integrated analysis of Section 3.1.2.3.a as P eyes * group = 0.519; independent from epochs / falls, between the groups, trends of change between EO (5th trial) and EC (6th trial) conditions are similar). This indicates that evaluations of eyes information in TC condition are similar between the groups in both 1st and 2nd falls.

In here, the thing worthy to notice is that in TC condition, independent from the groups belong to athletes or sedentary, in consequence of the deprivation of eyes information, all groups' mean and S.D. values of postural sway increase in 1st fall. Increase in S.D. values states that deprivation of eyes information increase in-group differences. However, in TC condition, in consequence of the deprivation of eyes information, the mean distributions of groups and so inter-group differences do not change (see in Figure 3.7; for the 1st fall, the slopes between the groups' mean points in 5th trial are almost the same in 6th trial). On the other hand, adaptation / learning / anticipation to the ATV compensated the deprivation of eyes information and so, mean and S.D.

values of postural sway of each group in 2nd falls of 6th trial become almost the same with 2nd falls of 5th trial. (It is stated in Table 3.31)

According to the P group $_{(1st\ fall)}$ = 0,399 and P group $_{(2nd\ fall)}$ = 0.544; independent from eyes conditions, the effect of ATV on postural sway behaviors in TC conditions is not significantly different between the groups in both 1st and 2nd falls (It is also stated in integrated analysis of Section 3.1.2.3.a as P group = 0.430; independent from epochs / falls and eyes conditions, between the groups, the effect of ATV is not significantly different).

Therefore, as denoted in Table 3.31, for the 1st fall, in EOTC condition, inter-group postural sway differences, which are observed in ECTC condition, are not vanished by the existence of eyes information as in EOTO condition.

3.1.2.3.b. RMS Results for Eyes Effect in TO Condition (7th vs 8th Trials)

<u>RMS Results for Eyes Effect between 7th & 8th Trials (1st & 2nd falls integrated analysis)</u>

Here, to analyze the effect of ATV on postural sway behavior between adapting to different eyes conditions for TO condition, the 3-way mixed ANOVA was formed by two within-subjects factors (independent variables / repeated measures) as eyes conditions (EO, EC) and epoch (2nd, 4th) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).

This statistical analysis was conducted with RMS metrics of 1st and 2nd falls of 7th and 8th trials for in TO condition for each group, respectively. Figure 3.9. shows RMS data for 1st & 2nd falls of 7th and 8th trials. Tests of within-subjects effects for 3-way mixed ANOVA for RMS of 7th and 8th trials data are shown in Table 3.34. Tests of between-subjects effects for 3-way mixed ANOVA for RMS of 7th and 8th trials data are shown in Table 3.35. Also, descriptive statistics for RMS of 1st and 2nd falls of 7th and 8th trials are shown in Table 3.36. The results of this analysis are stated below.

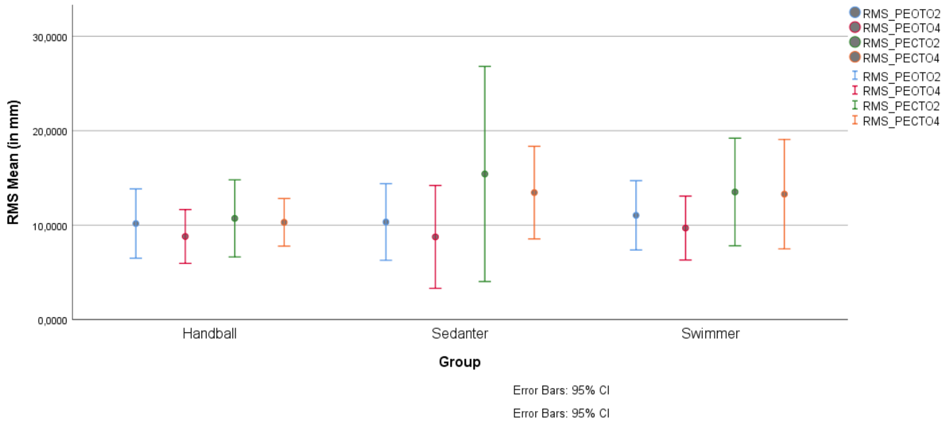

Figure 3.9. RMS Data for 1st & 2nd Falls of 7th & 8th Trials

Table 3.34. Tests of Within-Subjects Effects for 3-way mixed ANOVA for RMS of 7th & 8th Trials

Tests of Within-Subjects Effects		
Source	**F**	**p**
Eyes	5.965	0.024
Eyes * Group	0.838	0.447
Epoch	1.527	0.230
Epoch * Group	0.113	0.894
Eyes * Epoch	0.122	0.731
Eyes * Epoch * Group	0.090	0.915

Table 3.35. Tests of Between-Subjects Effects for 3-way mixed ANOVA for RMS of 7th & 8th Trials

Tests of Between-Subjects Effects		
Source	**F**	**p**
Group	0.456	0.640

Table 3.36. Descriptive Statistics for 1st & 2nd falls of 7th & 8th Trials for RMS

		1st Fall				2nd Fall			
Trial	Cond.	Group	Epoch	Mean	S.D.	Epoch	Mean	S.D.	N
7th	EOTO	Handball	2nd	10,1712	4,3911	4th	8,8059	3,4090	8
		Sedentary		10,3373	4,8504		8,7593	6,5144	8
		Swimmer		11,0417	4,3934		9,6950	4,0488	8
		Total		10,5168	4,3648		9,0867	4,6514	24
8th	ECTO	Handball	2nd	10,7171	4,8823	4th	10,3010	3,0177	8
		Sedentary		15,4208	13,6218		13,4494	5,8678	8
		Swimmer		13,5147	6,8144		13,2830	6,9255	8
		Total		13,2175	9,0418		12,3444	5,4801	24

According to the P eyes = 0.024; in TO condition, independent from epochs and the groups, the effect of ATV on postural sway behaviors at adapting to EC condition (8th trial) is significantly different with respect to EO condition (7th trial). Therefore, during vibration, independent from epochs and the groups, deprivation of eyes information in TO condition significantly increases the postural sway (see total mean values in Table 3.36).

According to the P eyes * group = 0.447; in TO condition, independent from epochs, between the groups, trends of changes in the effect of ATV on postural sway behaviors between adapting to EC (8th trial) and EO (7th trial) conditions are similar. This indicates that independent from epochs, evaluations of eyes information in TO condition show similarities between the groups.

According to the P epoch = 0.230; in TO condition, independent from the groups and eyes conditions, the effect of ATV on postural sway behaviors is not significantly different between 2nd and 4th epochs. Therefore, independent from the groups and eyes conditions, adaptation / learning / anticipation to the ATV in TO condition do not significantly change postural sway behaviors in between 1st and 2nd falls (As it is known, from both 7th and 8th trials, there is no anticipation effect observed in postural sway behavior).

According to the P epoch * group = 0.894; in TO condition, independent from eyes conditions, between the groups, trends of changes in the effect of ATV on postural sway behaviors between 2nd and 4th epochs are similar. This indicates that in TO condition, independent from eyes conditions, the effect of adaptation / learning / anticipation to the ATV on postural sway behaviors is similar between the groups (As it is known, from both 7th and 8th trials, similar anticipation effect on postural sway behavior is observed between the groups).

According to the P eyes * epoch = 0.731; in TO condition, independent from the groups, between 2nd and 4th epochs, trends of changes in the effect of ATV on postural sway behaviors between adapting to EC (8th trial) and EO (7th trial) conditions are similar. This indicates that in TO condition, independent from the groups, evaluations of eyes information are similar in between 1st and 2nd falls.

According to the P group = 0,640; independent from epochs and eyes conditions, the effect of ATV on postural sway behaviors in TO conditions is similar between the groups.

Eyes * Epoch * Group comparison is insignificant.

RMS Results for Eyes Effect between 7th & 8th Trials (1st & 2nd falls individual analysis)

Here, to analyze the effect of ATV on postural sway behavior between adapting to different eyes conditions in TO condition for the each fall respectively, the 2-way mixed ANOVAs were formed by one within-subjects factor (independent variables / repeated measures) as eyes conditions (EO, EC) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).

These statistical analyses were conducted with RMS metrics of 1st and 2nd falls of 7th and 8th trials for in TO condition for each group, respectively. Tests of within-subjects effects for 2-way mixed ANOVA for RMS of 7th and 8th trials data are shown in Table 3.37. Tests of between-subjects effects for 2-way mixed ANOVA for RMS of 7th and

8th trials data are shown in Table 3.38. Also, descriptive statistics for RMS of 1st and 2nd falls of 7th and 8th trials are shown in Table 3.36. above. The results of these analyses are stated below.

Table 3.37. Tests of Within-Subjects Effects for 2-way mixed ANOVA for RMS of 7th & 8th Trials

Tests of Within-Subjects Effects				
	2nd epoch (1st fall)		**4th epoch (2nd fall)**	
Source	**F**	**p**	**F**	**p**
Eyes	3.138	0.091	5.512	0.029
Eyes * Group	0.744	0.487	0.456	0.640

Table 3.38. Tests of Between-Subjects Effects for 2-way mixed ANOVA for RMS of 7th & 8th Trials

Tests of Between-Subjects Effects				
	2nd epoch (1st fall)		**4th epoch (2nd fall)**	
Source	**F**	**p**	**F**	**p**
Group	0.330	0.723	0.544	0.588

According to the P eyes $_{(1st\ fall)}$ = 0.091 and P eyes $_{(2nd\ fall)}$ = 0.029; in TO condition, independent from the groups, the effect of ATV on postural sway behaviors between adapting to EC (8th trial) and EO condition (7th trial) is significantly different for 4th epoch; however, are marginally significantly different for 2nd epoch. Therefore, during vibration, independent from the groups, deprivation of eyes information in TO condition marginally significant and significantly increased the postural sway in 1st and 2nd fall respectively (see in Table 3.36). The similarity between P eyes values of 1st and 2nd falls are also stated in integrated analysis of Section 3.1.2.3.b as P eyes * epoch = 0.731; independent from the groups, between 2nd and 4th epochs / 1st and 2nd falls, trends of change between EO (7th trial) and EC (8th trial) conditions are similar. Because, independent from the groups, adaptation / learning / anticipation to the ATV in 7th and 8th trials did not significantly change postural sway behaviors in between 1st and 2nd falls.

Figure 3.10. demonstrates the statistical effects of anticipation and eyes information on sway behavior for TO condition.

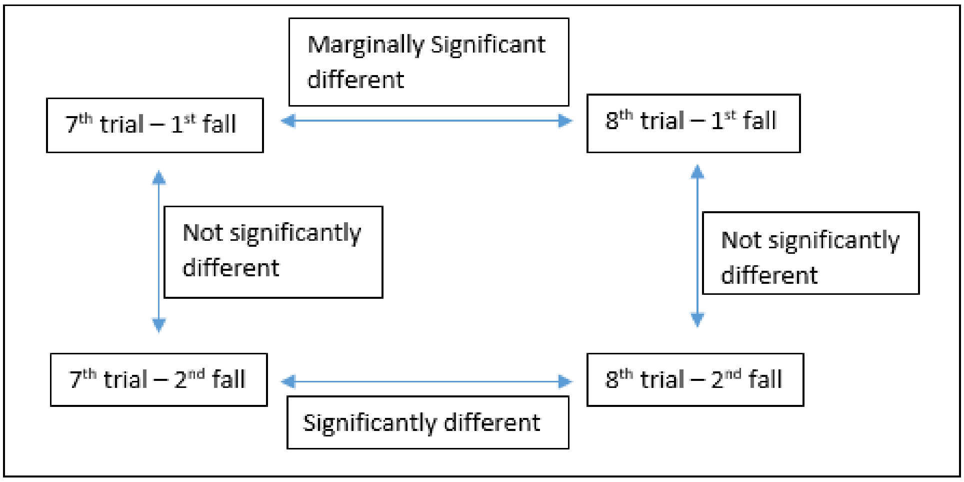

Figure 3.10. Statistical effects of anticipation and eyes information on sway behavior for TO condition

According to the P eyes * group $_{(1st\ fall)}$ = 0.487 and P eyes * group $_{(2nd\ fall)}$ = 0.640; in TO condition, between the groups, trends of changes in the effect of ATV on postural sway behaviors between adapting to EC (8th trial) and EO (7th trial) conditions are similar in both 2nd and 4th epochs (It is also stated in integrated analysis of Section 3.1.2.3.b as P eyes * group = 0.447; independent from epochs / falls, between the groups, trends of change between EO (7th trial) and EC (8th trial) conditions are similar). This indicates that evaluations of eyes information in TO condition are similar between the groups for both 1st and 2nd falls.

In here, the thing worthy to notice is that in TO condition, independent from the groups belong to athletes or sedentary, in the existence of eyes information, all groups' mean and S.D. values of postural sway are almost the same. Therefore, inter-group differences vanished and the groups united in terms of postural sway. On the other hand, in consequence of the deprivation of eyes information in TO condition, all groups' mean and S.D. values of postural sway increase in 1st and 2nd falls. Thus, with deprivation of eyes information in TO condition, inter-group differences formed and in-group differences increased. However, existence of touch information prevents to grow in-group and inter-group differences as much as in TC condition.

According to the P group $_{(1st\ fall)}$ = 0,723 and P group $_{(2nd\ fall)}$ = 0.588; independent from eyes conditions, the effect of ATV on postural sway behaviors in TO conditions is similar between the groups in both 1st and 2nd falls (It is also stated in integrated analysis of Section 3.1.2.3.b as P group = 0.640; independent from epochs / falls and eyes conditions, between the groups, the effect of ATV is similar).

Therefore, as denoted in Table 3.36, in EOTO condition, inter-group postural sway differences, which are observed in ECTO condition, are vanished by the existence of touch information.

3.1.2.4. RMS Results for Touch Vs Eyes Effect

Here, to compare the contributions of bodily somatosensory (touch) and visual (eyes) information to the sensory negative feedback mechanism to control the maintenance of upright stance during ATV, trends of change in the effect of ATV on postural sway behavior between adapting to ECTO (8th trial) and ECTC (6th trial) conditions, EOTC (5th trial) and ECTC (6th trial) conditions, EOTO (7th trial) and EOTC (5th trial) conditions, EOTO (7th trial) and ECTO (8th trial) conditions are analyzed. Tests of within-subjects effects for 3-way mixed ANOVA for RMS data are shown in Table 3.39. Also, descriptive statistics for RMS of 1st and 2nd falls of 5th, 6th, 7th and 8th trials are shown in Table 3.40. These tables were formed by the data under previous topics.

Table 3.39. Tests of Within-Subjects Effects for 3-way mixed ANOVA for RMS

Tests of Within-Subjects Effects			
ANOVA Between	**Source**	**F**	**p**
EOTC (5^{th}) and ECTC (6^{th})	Eyes	6.153	0.022
ECTC (6^{th}) and ECTO (8^{th})	Touch	19.792	0.0002
EOTO (7^{th}) and ECTO (8^{th})	Eyes	5.965	0.024
EOTC (5^{th}) and EOTO (7^{th})	Touch	16.947	0.0005

Table 3.40. Descriptive Statistics for 1^{st} & 2^{nd} falls of 5^{th}, 6^{th}, 7^{th} & 8^{th} Trials for RMS

			1^{st} Fall			2^{nd} Fall			
Trial	Cond.	Group	Epoch	Mean	S.D.	Epoch	Mean	S.D.	N
5^{th}	EOTC	Total	2^{nd}	17.2144	12.2353	4^{th}	15.5085	9.9229	24
6^{th}	ECTC	Total	2^{nd}	25.1569	16.9371	4^{th}	16.6250	9.9214	24
7^{th}	EOTO	Total	2^{nd}	10.5168	4.3648	4^{th}	9.0867	4.6514	24
8^{th}	ECTO	Total	2^{nd}	13.2175	9.0418	4^{th}	12.3444	5.4801	24

According to P touch = 0.0002 and P eyes = 0.022, supplying touch information (ECTO) or visual information (EOTC) as a first sensorial information source to the sensory negative feedback mechanism, which is deprived of visual and touch information (ECTC), cause a significant decrease in the postural sway. However, the difference between P touch = 0.0002 and P eyes = 0.022 values indicates that contribution of touch information to sensory negative feedback mechanism to control postural sway behavior is more than visual information (see in Table 3.40, postural sway in 8^{th} trial is lower than 5^{th} trial, $6^{th} > 5^{th} > 8^{th}$). Moreover, p = 0.036 value (which is obtained from 3-way mixed ANOVA was formed by two within-subjects factors as sensory condition (EOTC and ECTO) and epoch (2^{nd}, 4^{th}) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players)) indicates that independent from epochs and the groups, the effect of ATV on postural sway behaviors at adapting to ECTO condition (8^{th} trial) is significantly lower with respect to EOTC condition (5^{th} trial). Therefore, during vibration, postural sway in ECTO condition (8^{th} trial) is significantly lower than EOTC condition (5^{th} trial) and so, contribution of touch information to sensory negative feedback mechanism to control postural sway behavior is statistically significantly more than visual information.

Supplying touch information (EOTO) or visual information (EOTO) as a second sensorial information source to the sensory negative feedback mechanism, which has either visual (EOTC) or touch (ECTO) information, cause a significant decrease in the postural sway (P touch = 0.0005 and P eyes = 0.024, respectively). As in first sensorial information source, supplying touch information as a second sensorial information source contribute to sensory negative feedback mechanism statistically significantly more than visual information to control postural sway behavior (see in Table 3.40, $6^{th} > 5^{th} > 8^{th} > 7^{th}$ in terms of mean and S.D. values of postural sway).

As it is shown in Table 3.6, Figure 3.6 and Figure 3.8, supplying visual or touch information as a first sensorial information source to the sensory negative feedback mechanism did not change the mean distribution and inter-group differences. However, as it is shown in Table 3.6, Figure 3.4 and Figure 3.10, supplying visual or touch information as a second sensorial information source to the sensory feedback mechanism aggregate means, vanished inter-group differences and unified them.

3.1.2.5. Overall RMS Results

This part includes the overall RMS results and their relations with hypotheses.

1. For each group, at adapting to the different sensory conditions (EOTC, ECTC, EOTO, ECTO), ATV causes increase in postural sway. Therefore, 1^{st} hypothesis is confirmed.

2. Independent from the groups, due to the effect of adaptation / learning / anticipation to the ATV, effect of ATV on postural sway behavior and so postural sway significantly decreases in 2^{nd} fall with respect to 1^{st} fall in 6^{th} trial (ECTC); however, postural sway behavior is not significantly change in between 1^{st} and 2^{nd} falls of 5^{th}

(EOTC), 7^{th} (EOTO) and 8^{th} (ECTO) trials. Therefore, 2^{nd} hypothesis is denied. On the other hand, anticipation could not resist to increase in postural sway during ATV.

3. Effect of adaptation / learning / anticipation to the ATV on postural sway behavior shows similarities between the groups in 5^{th} (EOTC), 6^{th} (ECTC), 7^{th} (EOTO) and 8^{th} (ECTO) trials.

4. Independent from 1^{st} and 2^{nd} falls, between the groups, the effect of ATV on postural sway behavior and so postural sway is not significantly different in 5^{th} (EOTC), 6^{th} (ECTC) and 8^{th} (ECTO) trials and is almost the same in 7^{th} trial (EOTO). Therefore, hypotheses 4.2.II, 4.3.II and 5 is denied.

5. For both EO and EC conditions, independent from 1^{st} and 2^{nd} falls and the groups, the effect of ATV on postural sway behavior at adapting to TO condition is significantly lower with respect to TC condition. Therefore, during vibration, independent from 1^{st} and 2^{nd} falls and the groups, existence of touch information in EO and EC conditions significantly decreases the postural sway. Therefore, hypothesis 3.1 is confirmed.

6. Independent from 1^{st} and 2^{nd} falls, between the groups, trends of changes in the effect of ATV on postural sway behavior between adapting to TO and TC conditions are similar for EC condition and are not significantly different for EO condition. However, as it is seen in Table 3.18 and Figure 3.3, in EO condition, sedentary group has the maximum trends of change. Swimmers and handball players' groups are follow them. Therefore, hypothesis 3.2 is denied.

7. For both TC and TO conditions, independent from 1^{st} and 2^{nd} falls and the groups, the effect of ATV on postural sway behavior at adapting to EC condition is significantly higher with respect to EO condition. Therefore, during vibration, independent from 1^{st} and 2^{nd} falls and the groups, deprivation of eyes information in TC and TO conditions significantly increases the postural sway. Therefore, hypothesis 4.1 is confirmed.

8. In TC condition, independent from 1^{st} and 2^{nd} falls, between the groups, trends of changes in the effect of ATV on postural sway behavior between adapting to EC and EO conditions are similar. Therefore, hypothesis 4.2.I is denied.

9. In TO condition, independent from falls, between the groups, trends of changes in the effect of ATV on postural sway behavior between adapting to EC (8^{th} trial) and EO (7^{th} trial) conditions are similar. Therefore, hypothesis 4.3.I is denied.

10. In TC condition, adaptation / learning / anticipation to the ATV compensates the deprivation of eyes information in terms of the postural sway behavior.

11. Contribution of touch information to sensory negative feedback mechanism to control postural sway behavior is significantly more than visual information.

12. Supplying visual or touch information as a first sensorial information source to the sensory negative feedback mechanism is not change mean distribution and inter-group differences. However, supplying visual or touch information as a second sensorial information source to the sensory feedback mechanism aggregate means, vanish inter-group differences and unify them.

13. During QS, eyes information significantly changes the postural sway; however, touch information does not. On the other hand, during vibration, touch information more effective than eyes information in terms of the change in the postural sway.

3.2. Results for Delta (Δ)

Delta (Δ) metric gives information about the backward body tilt (fall) response.

3.2.1. Delta (Δ) Results for PS Trials

Here, to analyze the effect of ATV on the backward body tilt (fall) response between adapting to different sensory conditions, the 4-way mixed ANOVA was formed by three within-subjects factors (independent variables / repeated measures) as eyes conditions (EO, EC), touch conditions (TC, TO) and delta (Δ_1, Δ_2) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).

This statistical analysis was conducted with delta metrics of 1st and 2nd falls of 5th, 6th, 7th and 8th trials of all groups together. Figure 3.11. shows Delta data for 1st & 2nd falls of 5th, 6th, 7th and 8th trials. Tests of within-subjects effects for 4-way mixed ANOVA for Delta data are shown in Table 3.41. Tests of between-subjects effects for 4-way mixed ANOVA for Delta data are shown in Table 3.42. Also, descriptive statistics for Delta of 5th, 6th, 7th and 8th trials are shown in Table 3.43. The results of this analysis are stated below.

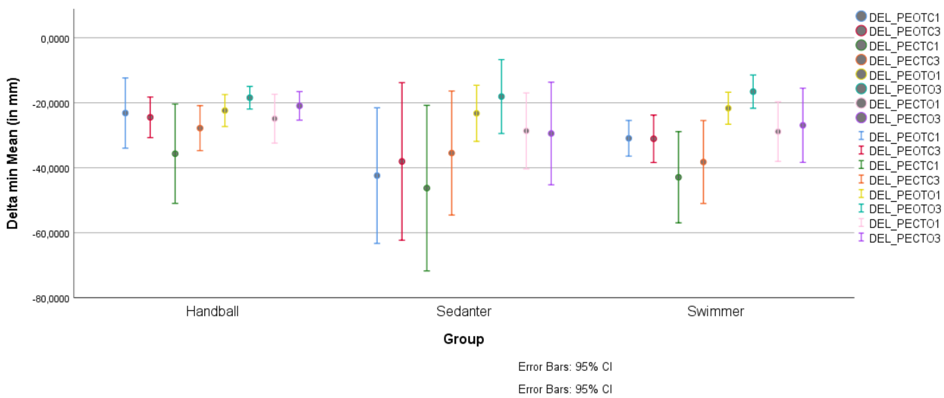

Figure 3.11. Delta Data for 1st & 2nd Falls of 5th, 6th, 7th & 8th Trials

Table 3.41. Tests of Within-Subjects Effects for 4-way mixed ANOVA for Delta

Tests of Within-Subjects Effects		
Source	**F**	**p**
Eyes	31.701	0.0000
Eyes * Group	1.931	0.170
Touch	11.396	0.003
Touch * Group	0.605	0.555
Delta	14.348	0.001
Delta * Group	0.335	0.719
Eyes * Touch	0.035	0.854
Eyes * Touch * Group	1.937	0.169
Eyes * Delta	0.232	0.635
Eyes * Delta * Group	0.787	0.468
Touch * Delta	0.696	0.413
Touch * Delta * Group	0.361	0.701
Eyes * Touch * Delta	5.251	0.032
Eyes * Touch * Delta * Group	0.093	0.912

Table 3.42. Tests of Between-Subjects Effects for 4-way mixed ANOVA for Delta

Tests of Between-Subjects Effects		
Source	**F**	**p**
Group	0.892	0.425

Table 3.43. Descriptive Statistics for the Delta of 5th, 6th, 7th, 8th Trials

		1st Fall				2nd Fall			
Trial	Cond.	Group	Delta	Mean	S.D.	Delta	Mean	S.D.	N
5th	EOTC	Handball	1st	-23.1657	12.9158	2nd	-24.4834	7.4645	8
		Sedentary		-42.4139	24.9571		-38.0540	28.9894	8
		Swimmer		-30.9334	6.5604		-31.0878	8.7285	8
		Total		-32.1710	17.8512		-31.2084	18.1094	24
6th	ECTC	Handball	1st	-35.6752	18.2619	2nd	-27.8083	8.2648	8
		Sedentary		-46.2651	30.4654		-35.4730	22.8148	8
		Swimmer		-42.9192	16.7880		-38.2279	15.2671	8
		Total		-41.6198	22.1390		-33.8364	16.4446	24
7th	EOTO	Handball	1st	-22.3940	5.8754	2nd	-18.4511	4.1763	8
		Sedentary		-23.2607	10.3126		-18.0955	13.5967	8
		Swimmer		-21.6843	5.8965		-16.5735	6.1086	8
		Total		-22.4463	7.3409		-17.7067	8.5803	24
8th	ECTO	Handball	1st	-24.8984	8.9932	2nd	-20.9585	5.2535	8
		Sedentary		-28.6618	13.9786		-29.4509	18.8892	8
		Swimmer		-28.8808	10.9506		-26.9296	13.6625	8
		Total		-27.4803	11.1386		-25.7796	13.6760	24

According to the P eyes = 0.0000; independent from touch conditions, deltas and the groups, the effect of ATV on the backward body tilt (fall) response at adapting to EO condition is significantly different with respect to EC condition. Therefore, during vibration, independent from touch conditions, deltas and the groups, existence / deprivation of visual information significantly changes the backward body tilt (fall) response.

According to the P eyes * group = 0.170; independent from touch conditions and deltas, between the groups, trends of changes in the effect of ATV on the backward body tilt (fall) response between adapting to different eyes conditions (EO and EC) are not significantly different. This indicates that independent from touch conditions and deltas, evaluations of eyes information are not significantly different between the groups.

According to the P touch = 0.003; independent from eyes conditions, deltas and the groups, the effect of ATV on the backward body tilt (fall) response at adapting to TO condition is significantly different with respect to TC condition. Therefore, during vibration, independent from eyes conditions, deltas and the groups, existence / deprivation of touch information significantly changes the backward body tilt (fall) response.

According to the P touch * group = 0.555; independent from eyes conditions and deltas, between the groups, trends of changes in the effect of ATV on the backward body tilt (fall) response between adapting to different touch conditions (TO and TC) are similar. This indicates that independent from eyes conditions and deltas, evaluations of touch information show similarities between the groups.

According to the P delta = 0.001; independent from the groups, touch and eyes conditions, the effect of ATV on the backward body tilt (fall) response is significantly different between 1^{st} and 2^{nd} deltas. Therefore, independent from the groups, touch and eyes conditions, adaptation / learning / anticipation to the ATV significantly changes the backward body tilt (fall) response in between 1^{st} and 2^{nd} falls.

According to the P delta * group = 0.719; independent from touch and eyes conditions, between the groups, trends of changes in the effect of ATV on the backward body tilt (fall) response between 1^{st} and 2^{nd} deltas are similar. This indicates that independent from touch and eyes conditions, the effect of adaptation / learning / anticipation to the ATV on the backward body tilt (fall) response shows similarities between the groups.

According to the P eyes * touch = 0.854; independent from deltas and the groups, trends of changes in the effect of ATV on the backward body tilt (fall) response between adapting to EOTO and EOTC conditions (or between adapting to EOTC and ECTC conditions) and between adapting to ECTO and ECTC conditions (or between adapting to EOTO and ECTO) are similar. This indicates that independent from deltas and the groups, evaluations of touch information (or eyes information) show similarities in between EO and EC conditions (or in between TO and TC).

According to the P eyes * delta = 0.635; independent from touch conditions and the groups, between 1st and 2nd deltas, trends of changes in the effect of ATV on the backward body tilt (fall) response between adapting to different eyes conditions (EO and EC) are similar. This indicates that independent from touch conditions and the groups, evaluations of eyes information show similarity in between 1st and 2nd falls.

According to the P touch * delta = 0.413; independent from eyes conditions and the groups, between deltas, trends of changes in the effect of ATV on the backward body tilt (fall) response between adapting to different touch conditions (TO and TC) are similar. This indicates that independent from eyes conditions and the groups, evaluations of touch information show similarity in between the falls.

According to the P group = 0,425; independent from deltas and sensory conditions, the effect of ATV on the backward body tilt (fall) response is not significantly different between the groups.

Later comparisons are insignificant.

These results indicate that during vibration, independent from the groups, the effect of ATV on the backward body tilt (fall) response changes both at adapting to the different sensory conditions and adapting to the ATV. Moreover, effect of adaptation to the ATV and evaluation of both touch and eyes information show similarities between the groups.

3.2.1.1. Delta (Δ) Results for Anticipation Effect

As stated in Section 3.2.1, independent from the groups and different sensory conditions (trials), adaptation / learning / anticipation to the ATV significantly changes the backward body tilt (fall) response in between 1st and 2nd falls. Moreover, independent from different sensory conditions (trials) effect of adaptation / learning /

anticipation to the ATV on the backward body tilt (fall) response shows similarities between the groups.

Here, to analyze the effect of adaptation / learning / anticipation to the ATV on the backward body tilt (fall) response at adapting to different sensory conditions (trials) respectively, the 2-way mixed ANOVAs were formed by one within-subjects factor (independent variables / repeated measures) as delta (Δ_1, Δ_2) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).

These statistical analyses were conducted with delta metrics of 1st and 2nd falls of 5th, 6th, 7th and 8th trials for each group, respectively. The results of these analyses are stated below

3.2.1.1.a. Delta (Δ) Results for Anticipation Effect in 5th Trial (Δ_1 vs Δ_2)

Tests of within-subjects effects for 2-way mixed ANOVA for Delta of 5th trial data are shown in Table 3.44. Tests of between-subjects effects for 2-way mixed ANOVA for Delta of 5th trial data are shown in Table 3.45. Also, descriptive statistics for Delta of 5th trial are shown in Table 3.46.

Table 3.44. Tests of Within-Subjects Effects for 2-way mixed ANOVA for Delta of 5th Trial

Tests of Within-Subjects Effects		
Source	**F**	**p**
Delta	0.298	0.591
Delta * Group	0.965	0.397

Table 3.45. Tests of Between-Subjects Effects for 2-way mixed ANOVA for Delta of 5th Trial

Tests of Between-Subjects Effects		
Source	**F**	**p**
Group	1.918	0.172

Table 3.46. Descriptive Statistics for the Delta of 5^{th} Trial

Trial	Cond.	Fall	Delta	Group	Mean	S.D.	N
5^{th}	EOTC	1^{st}	1^{st}	Handball	-23,1657	12,9158	8
				Sedentary	-42,4139	24,9571	8
				Swimmer	-30,9334	6,5604	8
				Total	-32,1710	17,8512	24
5^{th}	EOTC	2^{nd}	2^{nd}	Handball	-24,4834	7,4645	8
				Sedentary	-38,0540	28,9894	8
				Swimmer	-31,0878	8,7285	8
				Total	-31,2084	18,1094	24

According to the P delta = 0.591; in EOTC condition (5^{th} trial), independent from the groups, the effect of ATV on the backward body tilt (fall) response is similar between 1^{st} and 2^{nd} deltas. Therefore, independent from the groups, adaptation / learning / anticipation to the ATV in 5^{th} trial does not significantly change the backward body tilt (fall) response in between 1^{st} and 2^{nd} falls (see in Table 3.46).

According to the P delta * group = 0.397; in EOTC condition (5^{th} trial), between the groups, trends of changes in the effect of ATV on the backward body tilt (fall) response between 1^{st} and 2^{nd} deltas are not significantly different. This indicates that effect of adaptation / learning / anticipation to the ATV on the backward body tilt (fall) response in 5^{th} trial is not significantly different between the groups.

According to the P group = 0,172; in EOTC condition (5^{th} trial), independent from deltas, the effect of ATV on the backward body tilt (fall) response is not significantly different between the groups.

However, as denoted in Table 3.46, in EOTC condition, there are some differences between the means of the groups for both 1^{st} and 2^{nd} falls.

3.2.1.1.b. Delta (Δ) Results for Anticipation Effect in 6th Trial (Δ_1 vs Δ_2)

Tests of within-subjects effects for 2-way mixed ANOVA for Delta of 6th trial data are shown in Table 3.47. Tests of between-subjects effects for 2-way mixed ANOVA for Delta of 6th trial data are shown in Table 3.48. Also, descriptive statistics for Delta of 6th trial are shown in Table 3.49.

Table 3.47. Tests of Within-Subjects Effects for 2-way mixed ANOVA for Delta of 6th Trial

Tests of Within-Subjects Effects		
Source	**F**	**p**
Delta	7.511	0.012
Delta * Group	0.385	0.685

Table 3.48. Tests of Between-Subjects Effects for 2-way mixed ANOVA for Delta of 6th Trial

Tests of Between-Subjects Effects		
Source	**F**	**p**
Group	0.622	0.546

Table 3.49. Descriptive Statistics for the Delta of 6th Trial.

Trial	Cond.	Fall	Delta	Group	Mean	S.D.	N
6th	ECTC	1st	1st	Handball	-35,6752	18,2619	8
				Sedentary	-46,2651	30,4654	8
				Swimmer	-42,9192	16,7880	8
				Total	-41,6198	22,1390	24
6th	ECTC	2nd	2nd	Handball	-27,8083	8,2648	8
				Sedentary	-35,4730	22,8148	8
				Swimmer	-38,2279	15,2671	8
				Total	-33,8364	16,4446	24

According to the P delta = 0.012; in ECTC condition (6th trial), independent from the groups, the effect of ATV on the backward body tilt (fall) response is significantly different between 1st and 2nd deltas. Therefore, independent from the groups, adaptation / learning / anticipation to the ATV in 6th trial significantly decreased the backward body tilt (fall) response in 2nd fall with respect to 1st fall. (see in Table 3.49).

According to the P delta * group = 0.685; in ECTC condition (6th trial), between the groups, trends of changes in the effect of ATV on the backward body tilt (fall) response between 1st and 2nd deltas are similar. This indicates that effect of adaptation / learning / anticipation to the ATV on the backward body tilt (fall) response in 6th trial show similarities between the groups.

According to the P group = 0,546; in ECTC condition (6th trial), independent from deltas, the effect of ATV on the backward body tilt (fall) response is similar between the groups.

As denoted in Table 3.49, in ECTC condition, there are some differences between the means of the groups for both 1st and 2nd falls. Adaptation / learning / anticipation to the ATV does not change the mean distribution of groups and the inter-group differences in 2nd fall.

3.2.1.1.c. Delta (Δ) Results for Anticipation Effect in 7th Trial (Δ_1 vs Δ_2)

Tests of within-subjects effects for 2-way mixed ANOVA for Delta of 7th trial data are shown in Table 3.50. Tests of between-subjects effects for 2-way mixed ANOVA for Delta of 7th trial data are shown in Table 3.51. Also, descriptive statistics for Delta of 7th trial are shown in Table 3.52.

Table 3.50. Tests of Within-Subjects Effects for 2-way mixed ANOVA for Delta of 7th Trial

Tests of Within-Subjects Effects		
Source	**F**	**p**
Delta	13.624	0.001
Delta * Group	0.096	0.909

Table 3.51. Tests of Between-Subjects Effects for 2-way mixed ANOVA for Delta of 7th Trial

Tests of Between-Subjects Effects		
Source	**F**	**p**
Group	0.093	0.912

Table 3.52. Descriptive Statistics for the Delta of 7th Trial.

Trial	Cond.	Fall	Delta	Group	Mean	S.D.	N
7th	EOTO	1st	1st	Handball	-22,3940	5,8754	8
				Sedentary	-23,2607	10,3126	8
				Swimmer	-21,6843	5,8965	8
				Total	-22,4463	7,3409	24
7th	EOTO	2nd	2nd	Handball	-18,4511	4,1763	8
				Sedentary	-18,0955	13,5967	8
				Swimmer	-16,5735	6,1086	8
				Total	-17,7067	8,5803	24

According to the P delta = 0.001; in EOTO condition (7th trial), independent from the groups, the effect of ATV on the backward body tilt (fall) response is significantly different between 1st and 2nd deltas. Therefore, independent from the groups, adaptation / learning / anticipation to the ATV in 7th trial significantly decreases the backward body tilt (fall) response in between 1st and 2nd falls (see in Table 3.52).

According to the P delta * group = 0.909; in EOTO condition (7th trial), between the groups, trends of changes in the effect of ATV on the backward body tilt (fall) response between 1st and 2nd deltas are similar. This indicates that the effect of adaptation / learning / anticipation to the ATV on the backward body tilt (fall) response in 7th trial is similar between the groups.

According to the P group = 0,912; in EOTO condition (7th trial), independent from deltas, the effect of ATV on the backward body tilt (fall) response is similar between the groups.

Therefore, as denoted in Table 3.52, in EOTO condition, the means of the groups are almost the same.

3.2.1.1.d. Delta (Δ) Results for Anticipation Effect in 8th Trial (Δ_1 vs Δ_2)

Tests of within-subjects effects for 2-way mixed ANOVA for Delta of 8th trial data are shown in Table 3.53. Tests of between-subjects effects for 2-way mixed ANOVA for Delta of 8th trial data are shown in Table 3.54. Also, descriptive statistics for Delta of 8th trial are shown in Table 3.55.

Table 3.53. Tests of Within-Subjects Effects for 2-way mixed ANOVA for Delta of 8th Trial

Tests of Within-Subjects Effects		
Source	**F**	**p**
Delta	0.432	0.518
Delta * Group	0.281	0.758

Table 3.54. Tests of Between-Subjects Effects for 2-way mixed ANOVA for Delta of 8th Trial

Tests of Between-Subjects Effects		
Source	**F**	**p**
Group	0.701	0.507

Table 3.55. Descriptive Statistics for the Delta of 8th Trial.

Trial	Cond.	Fall	Delta	Group	Mean	S.D.	N
8th	ECTO	1st	1st	Handball	-24,8984	8,9932	8
				Sedentary	-28,6618	13,9786	8
				Swimmer	-28,8808	10,9506	8
				Total	-27,4803	11,1386	24
8th	ECTO	2nd	2nd	Handball	-20,9585	5,2535	8
				Sedentary	-29,4509	18,8892	8
				Swimmer	-26,9296	13,6625	8
				Total	-25,7796	13,6760	24

According to the P delta = 0.518; in ECTO condition (8^{th} trial), independent from the groups, the effect of ATV on the backward body tilt (fall) response is similar between 1^{st} and 2^{nd} deltas. Therefore, independent from the groups, adaptation / learning / anticipation to the ATV in 8^{th} trial des not significantly change the backward body tilt (fall) response in between 1^{st} and 2^{nd} falls (see in Table 3.55).

According to the P delta * group = 0.758; in ECTO condition (8^{th} trial), between the groups, trends of changes in the effect of ATV on the backward body tilt (fall) response between 1^{st} and 2^{nd} deltas are similar. This indicates that the effect of adaptation / learning / anticipation to the ATV on the backward body tilt (fall) response in 8^{th} trial shows similarities between the groups.

According to the P group = 0,507; in ECTO condition (8^{th} trial), independent from deltas, the effect of ATV on the backward body tilt (fall) response is not significantly different between the groups.

Therefore, as denoted in Table 3.55, in ECTO condition, the means of the groups are close to each other; however, not close as in EOTO condition.

3.2.1.2. Delta (Δ) Results for Touch Effect

As stated in Section 3.2.1,

- During vibration, independent from eyes conditions, deltas and the groups, existence / deprivation of touch information significantly changes the backward body tilt (fall) response.
- Independent from deltas and the groups, evaluations of touch information show similarities in between different eyes conditions.
- Independent from eyes conditions and the groups, evaluations of touch information show similarity in between the falls.
- Independent from eyes conditions and deltas, evaluation of touch information show similarities between the groups.

Here, to analyze the effect of ATV on backward body tilt (fall) response between adapting to different touch conditions for both eyes conditions respectively, the 3-way mixed ANOVAs were formed by two within-subjects factors (independent variables / repeated measures) as touch conditions (TC, TO) and delta (Δ_1, Δ_2) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).

These statistical analyses were conducted with delta metrics of 1st and 2nd falls of 5th and 7th trials for in EO condition and 1st and 2nd falls of 6th and 8th trials for EC condition for each group, respectively. The results of these analyses are stated below.

3.2.1.2.a. Delta (Δ) Results for Touch Effect in EO Condition (5th vs 7th Trials)

Delta (Δ) Results for Touch Effect between 5th & 7th Trials (1st & 2nd falls integrated analysis)

Here, to analyze the effect of ATV on the backward body tilt (fall) response between adapting to different touch conditions for EO condition, the 3-way mixed ANOVA was formed by two within-subjects factors (independent variables / repeated measures) as touch conditions (TC, TO) and delta (Δ_1, Δ_2) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).

This statistical analysis was conducted with delta metrics of 1st and 2nd falls of 5th and 7th trials for in EO condition for each group, respectively. Figure 3.12. shows Delta data for 1st & 2nd falls of 5th and 7th trials. Tests of within-subjects effects for 3-way mixed ANOVA for Delta of 5th and 7th trials data are shown in Table 3.56. Tests of between-subjects effects for 3-way mixed ANOVA for Delta of 5th and 7th trials data are shown in Table 3.57. Also, descriptive statistics for Delta of 5th and 7th trials are shown in Table 3.58. The results of this analysis are stated below.

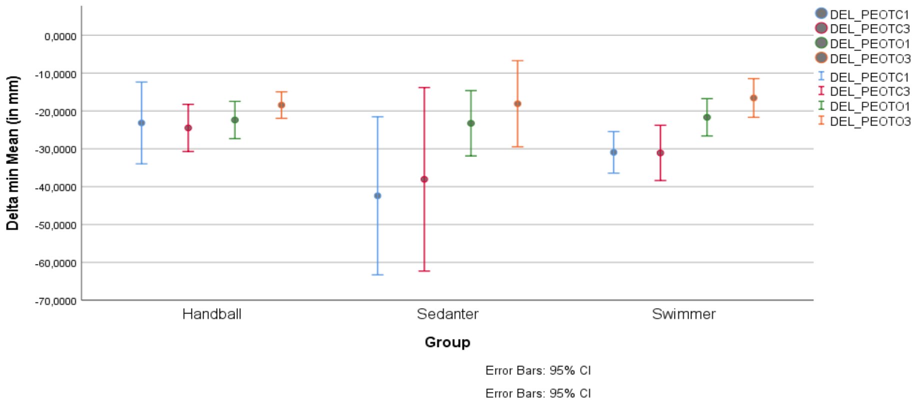

Figure 3.12. Delta Data for 1st & 2nd falls of 5th & 7th Trials

Table 3.56. Tests of Within-Subjects Effects for 3-way mixed ANOVA for Delta of 5th & 7th Trials

Tests of Within-Subjects Effects		
Source	**F**	**p**
Touch	19.629	0.0002
Touch * Group	3.168	0.063
Delta	10.566	0.004
Delta * Group	1.334	0.285
Touch * Delta	2.217	0.151
Touch * Delta * Group	0.343	0.713

Table 3.57. Tests of Between-Subjects Effects for 3-way mixed ANOVA for Delta of 5th & 7th Trials

Tests of Between-Subjects Effects		
Source	**F**	**p**
Group	1.103	0.350

Table 3.58. Descriptive Statistics for Delta of 1st & 2nd falls of 5th & 7th Trials

		1st Fall				2nd Fall			
Trial	Cond.	Group	Delta	Mean	S.D.	Delta	Mean	S.D.	N
5th	EOTC	Handball	1st	-23,1657	12,9158	2nd	-24,4834	7,4645	8
		Sedentary		-42,4139	24,9571		-38,0540	28,9894	8
		Swimmer		-30,9334	6,5604		-31,0878	8,7285	8
		Total		-32,1710	17,8512		-31,2084	18,1094	24
7th	EOTO	Handball	1st	-22,3940	5,8754	2nd	-18,4511	4,1763	8
		Sedentary		-23,2607	10,3126		-18,0955	13,5967	8
		Swimmer		-21,6843	5,8965		-16,5735	6,1086	8
		Total		-22,4463	7,3409		-17,7067	8,5803	24

According to the P touch = 0.0002; in EO condition, independent from deltas and the groups, the effect of ATV on the backward body tilt (fall) response at adapting to TO condition (7th trial) is significantly different with respect to TC condition (5th trial). Therefore, during vibration, independent from deltas and the groups, existence of touch information in EO condition significantly decrease the backward body tilt (fall) response (see total mean values in Table 3.58).

According to the P touch * group = 0.063; in EO condition, independent from deltas, between the groups, trends of changes in the effect of ATV on the backward body tilt (fall) response between adapting to TO (7th trial) and TC (5th trial) conditions are marginally significant different. This indicates that independent from deltas, evaluations of touch information in EO condition are marginally significantly different between the groups.

According to the P delta = 0.004; in EO condition, independent from the groups and touch conditions, the effect of ATV on the backward body tilt (fall) response is significantly different between 1st and 2nd deltas. Therefore, independent from the groups and touch conditions, adaptation / learning / anticipation to the ATV in EO condition significantly changes the backward body tilt (fall) response in between 1st and 2nd falls (This result originated from the anticipation effect on the backward body tilt (fall) response in 7th trial).

According to the P delta * group = 0.285; in EO condition, independent from touch conditions, between the groups, trends of changes in the effect of ATV on the backward body tilt (fall) response between 1st and 2nd deltas are not significantly different. This indicates that in EO condition, independent from touch conditions, the effect of adaptation / learning / anticipation to the ATV on the backward body tilt (fall) response are not significantly different between the groups (As it is known, especially from 7th trial, similar anticipation effect on the backward body tilt (fall) response is observed between the groups rather than 5th trial).

According to the P touch * delta = 0.151; in EO condition, independent from the groups, between 1st and 2nd deltas, trends of changes in the effect of ATV on the backward body tilt (fall) response between adapting to TO (7th trial) and TC (5th trial) conditions are not significantly different. This indicates that in EO condition, independent from the groups, evaluation of touch information is not significantly different in between 1st and 2nd falls.

According to the P group = 0,350; independent from deltas and touch conditions, the effect of ATV on the backward body tilt (fall) response in EO conditions is not significantly different between the groups.

Touch * Delta * Group comparison is insignificant.

<u>Delta (Δ) Results for Touch Effect between 5th & 7th Trials (1st & 2nd falls individual analysis)</u>

Here, to analyze the effect of ATV on the backward body tilt (fall) response between adapting to different touch conditions in EO condition for each fall respectively, the 2-way mixed ANOVAs were formed by one within-subjects factor (independent variables / repeated measures) as touch conditions (TC, TO) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).

These statistical analyses were conducted with delta metrics of 1st and 2nd falls of 5th and 7th trials for in EO condition for each group, respectively. Tests of within-subjects effects for 2-way mixed ANOVA for Delta of 5th and 7th trials data are shown in Table 3.59. Tests of between-subjects effects for 2-way mixed ANOVA for Delta of 5th and 7th trials data are shown in Table 3.60. Descriptive statistics for 1st & 2nd falls of 5th & 7th trials were demonstrated in Table 3.58. above. The results of these analyses are stated below.

Table 3.59. Tests of Within-Subjects Effects for 2-way mixed ANOVA for Delta

Tests of Within-Subjects Effects				
	Δ_1 (1st fall)		**Δ_2 (2nd fall)**	
Source	**F**	**p**	**F**	**p**
Touch	10.048	0.005	24.153	0.0001
Touch * Group	2.998	0.072	2.175	0.138

Table 3.60. Tests of Between-Subjects Effects for 2-way mixed ANOVA for Delta

Tests of Between-Subjects Effects				
	Δ_1 (1st fall)		**Δ_2 (2nd fall)**	
Source	**F**	**p**	**F**	**p**
Group	1.867	0.179	0.572	0.573

According to the P touch $_{(1st\ fall)}$ = 0.005 and P touch $_{(2nd\ fall)}$ = 0.0001; in EO condition, independent from the groups, the effect of ATV on the backward body tilt (fall) response between adapting to TO condition (7th trial) and TC condition (5th trial) is significantly different for both 1st and 2nd deltas. Therefore, during vibration, independent from the groups, existence of touch information in EO condition significantly decrease the backward body tilt (fall) in both 1st and 2nd falls (see in Table

3.58). P touch values of 1st and 2nd falls are different. Because, independent from the groups, adaptation / learning / anticipation to the ATV in 7th trial significantly decreases the backward body tilt (fall) in 2nd fall with respect to 1st fall, the significant difference in between 2nd falls of 5th and 7th trials increases with respect to 1st falls. However, it is stated in integrated analysis of Section 3.2.1.2.a as P touch * delta = 0.151; independent from the groups, between 1st and 2nd deltas / falls, trends of change between TC (5th trial) and TO (7th trial) conditions are not significantly different.

Figure 3.13. demonstrates the statistical effects of anticipation and touch information on fall response for EO condition.

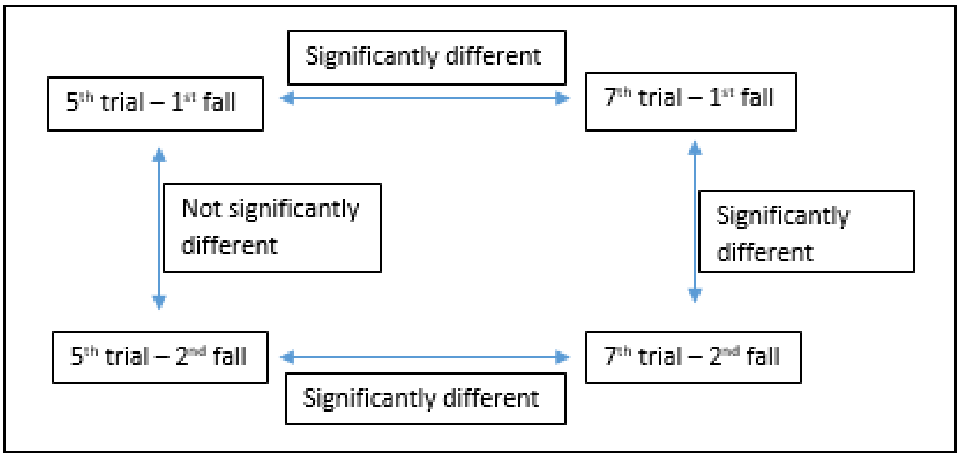

Figure 3.13. Statistical effects of anticipation and touch information on fall response for EO condition

According to the P touch * group $_{(1st\ fall)}$ = 0.072 and P touch * group $_{(2nd\ fall)}$ = 0.138; in EO condition, between the groups, trends of changes in the effect of ATV on the backward body tilt (fall) response between adapting to TO (7th trial) and TC (5th trial) conditions are not significantly different in 2nd fall; however, marginally significantly different in 1st fall. This indicates that evaluations of touch information in EO condition are not significantly different between the groups in 2nd fall; however, are marginally significantly different between the groups in 1st fall (It is also stated in integrated analysis of Section 3.2.1.2.a as P touch * group = 0.063; independent from deltas / falls, between the groups, trends of change between TC (5th trial) and TO (7th trial) conditions are marginally significant different). However, as it is seen in Table 3.58 and Figure 3.12, in both of two falls, sedentary group benefits from evaluation of touch information more than athletes group does and swimmers benefit more than handball players do.

In here, the thing worthy to notice is that in EO condition, independent from the groups belong to athletes or sedentary, in consequence of the existence of touch information, all groups' absolute mean and S.D. values of the backward body tilt (fall) both decrease and become almost the same (see in Table 3.58). The decrease in S.D. values states that existence of touch information decreases in-group differences. On the other hand, almost the same mean and S.D. values state that existence of touch information in EO condition, vanish inter-group differences and unites them in terms of the backward body tilt (fall) response.

According to the $P_{group\ (1st\ fall)} = 0,179$ and $P_{group\ (2nd\ fall)} = 0.573$; independent from touch conditions, the effect of ATV on the backward body tilt (fall) response in EO conditions is not significantly different between the groups in both 1st and 2nd falls (It is also stated in integrated analysis of Section 3.2.1.2.a as $P_{group} = 0.350$; independent from deltas / falls and touch conditions, between the groups, the effect of ATV is not significantly different).

Therefore, as denoted in Table 3.58, in EOTO condition, inter-group backward body tilt (fall) differences, which are observed in EOTC condition, are vanished by the existence of touch information.

3.2.1.2.b. Delta (Δ) Results for Touch Effect in EC Condition (6th vs 8th Trials)

Delta (Δ) Results for Touch Effect between 6th & 8th Trials (1st & 2nd falls integrated analysis)

Here, to analyze the effect of ATV on the backward body tilt (fall) response between adapting to different touch conditions for EC condition, the 3-way mixed ANOVA was formed by two within-subjects factors (independent variables / repeated measures) as touch conditions (TC, TO) and delta (Δ_1, Δ_2) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).

This statistical analysis was conducted with delta metrics of 1st and 2nd falls of 6th and 8th trials for in EC condition for each group, respectively. Figure 3.14. shows Delta data for 1st & 2nd falls of 6th and 8th trials. Tests of within-subjects effects for 3-way mixed ANOVA for Delta of 6th and 8th trials data are shown in Table 3.61. Tests of between-subjects effects for 3-way mixed ANOVA for Delta of 6th and 8th trials data are shown in Table 3.62. Also, descriptive statistics for Delta of 6th and 8th trials are shown in Table 3.63. The results of this analysis are stated below.

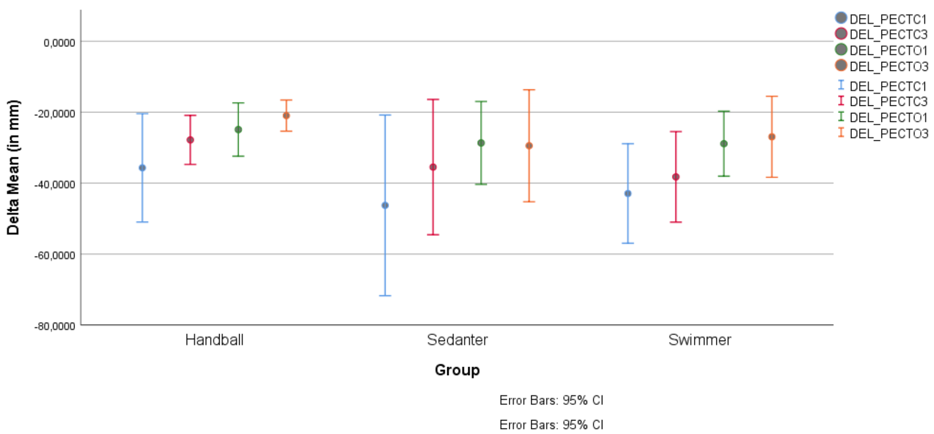

Figure 3.14. Delta Data for 1st & 2nd falls of 6th & 8th Trials

Table 3.61. Tests of Within-Subjects Effects for 3-way mixed ANOVA for Delta of 6th & 8th Trials

Tests of Within-Subjects Effects		
Source	**F**	**p**
Touch	24.165	0.0001
Touch * Group	0.268	0.767
Delta	5.906	0.024
Delta * Group	0.150	0.861
Touch * Delta	2.588	0.123
Touch * Delta * Group	0.537	0.592

Table 3.62. Tests of Between-Subjects Effects for 3-way mixed ANOVA for Delta of 6th & 8th Trials

Tests of Between-Subjects Effects		
Source	**F**	**p**
Group	0.699	0.508

Table 3.63. Descriptive Statistics for Delta of 1st & 2nd falls of 6th & 8th Trials

		1st Fall				2nd Fall			
Trial	Cond.	Group	Delta	Mean	S.D.	Delta	Mean	S.D.	N
6th	ECTC	Handball	1st	-35,6752	18,2619	2nd	-27,8083	8,2648	8
		Sedentary		-46,2651	30,4654		-35,4730	22,8148	8
		Swimmer		-42,9192	16,7880		-38,2279	15,2671	8
		Total		-41,6198	22,1390		-33,8364	16,4446	24
8th	ECTO	Handball	1st	-24,8984	8,9932	2nd	-20,9585	5,2535	8
		Sedentary		-28,6618	13,9786		-29,4509	18,8892	8
		Swimmer		-28,8808	10,9506		-26,9296	13,6625	8
		Total		-27,4803	11,1386		-25,7796	13,6760	24

According to the P touch = 0.0001; in EC condition, independent from deltas and the groups, the effect of ATV on the backward body tilt (fall) response at adapting to TO condition (8th trial) is significantly different with respect to TC condition (6th trial). Therefore, during vibration, independent from deltas and the groups, existence of touch information in EC condition significantly decrease the backward body tilt (fall) response (see total mean values in Table 3.63).

According to the P touch * group = 0.767; in EC condition, independent from deltas, between the groups, trends of changes in the effect of ATV on the backward body tilt (fall) response between adapting to TO (8^{th} trial) and TC (6^{th} trial) conditions are similar. This indicates that independent from deltas, evaluations of touch information in EC condition are similar between the groups.

According to the P delta = 0.024; in EC condition, independent from the groups and touch conditions, the effect of ATV on the backward body tilt (fall) response is significantly different between 1^{st} and 2^{nd} deltas. Therefore, independent from the groups and touch conditions, adaptation / learning / anticipation to the ATV in EC condition significantly changes the backward body tilt (fall) response in between 1^{st} and 2^{nd} falls (This result originated from the anticipation effect on the backward body tilt (fall) response in 6^{th} trial).

According to the P delta * group = 0.861; in EC condition, independent from touch conditions, between the groups, trends of changes in the effect of ATV on the backward body tilt (fall) response between 1^{st} and 2^{nd} deltas are similar. This indicates that in EC condition, independent from touch conditions, the effect of adaptation / learning / anticipation to the ATV on the backward body tilt (fall) response is similar between the groups (As it is known, from both 6^{th} and 8^{th} trials, similar anticipation effect on the backward body tilt (fall) response is observed between the groups).

According to the P touch * delta = 0.123; in EC condition, independent from the groups, between 1^{st} and 2^{nd} deltas, trends of changes in the effect of ATV on the backward body tilt (fall) response between adapting to TO (8^{th} trial) and TC (6^{th} trial) conditions are not significantly different. This indicates that in EC condition, independent from the groups, evaluation of touch information is not significantly different in between 1^{st} and 2^{nd} falls.

According to the P group = 0.508; independent from deltas and touch conditions, the effect of ATV on the backward body tilt (fall) response in EC conditions is similar between the groups.

Touch * Delta * Group comparison is insignificant.

Delta (Δ) Results for Touch Effect between 6th & 8th Trials (1st & 2nd falls individual analysis)

Here, to analyze the effect of ATV on the backward body tilt (fall) response between adapting to different touch conditions in EC condition for the each fall respectively, the 2-way mixed ANOVAs were formed by one within-subjects factor (independent variables / repeated measures) as touch conditions (TC, TO) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).

These statistical analyses were conducted with delta metrics of 1st and 2nd falls of 6th and 8th trials for in EC condition for each group, respectively. Tests of within-subjects effects for 2-way mixed ANOVA for Delta of 6th and 8th trials data are shown in Table 3.64. Tests of between-subjects effects for 2-way mixed ANOVA for Delta of 6th and 8th trials data are shown in Table 3.65. Descriptive statistics for 1st & 2nd falls of 6th & 8th trials were demonstrated in Table 3.63. above. The results of these analyses are stated below.

Table 3.64. Tests of Within-Subjects Effects for 2-way mixed ANOVA for Delta of 6th & 8th Trials

Tests of Within-Subjects Effects				
	Δ_1 (1st fall)		**Δ_2 (2nd fall)**	
Source	**F**	**p**	**F**	**p**
Touch	20.095	0.0002	8.779	0.007
Touch * Group	0.391	0.681	0.363	0.7

Table 3.65. Tests of Between-Subjects Effects for 2-way mixed ANOVA for Delta of 6th & 8th Trials

Tests of Between-Subjects Effects				
	Δ_1 (1st fall)		**Δ_2 (2nd fall)**	
Source	**F**	**p**	**F**	**p**
Group	0.432	0.655	0.940	0.406

According to the P touch $_{(1st\ fall)}$ = 0.0002 and P touch $_{(2nd\ fall)}$ = 0.007; in EC condition, independent from the groups, the effect of ATV on the backward body tilt (fall) response between adapting to TO condition (8th trial) and TC condition (6th trial) is significantly different for both 1st and 2nd deltas. Therefore, during vibration, independent from the groups, existence of touch information in EC condition significantly decrease the backward body tilt (fall) in both 1st and 2nd falls (see in Table 3.63). P touch values of 1st and 2nd falls are different. Because, independent from the groups, adaptation / learning / anticipation to the ATV in 6th trial significantly decreases the backward body tilt (fall) in 2nd fall with respect to 1st fall, the significant difference in between 2nd falls of 6th and 8th trials decrease with respect to 1st falls. However, it is stated in integrated analysis of Section 3.2.1.2.b as P touch * delta = 0.123; independent from the groups, between 1st and 2nd deltas / falls, trends of change between TC (6th trial) and TO (8th trial) conditions are not significantly different.

Figure 3.15. demonstrates the statistical effects of anticipation and touch information on fall response for EC condition.

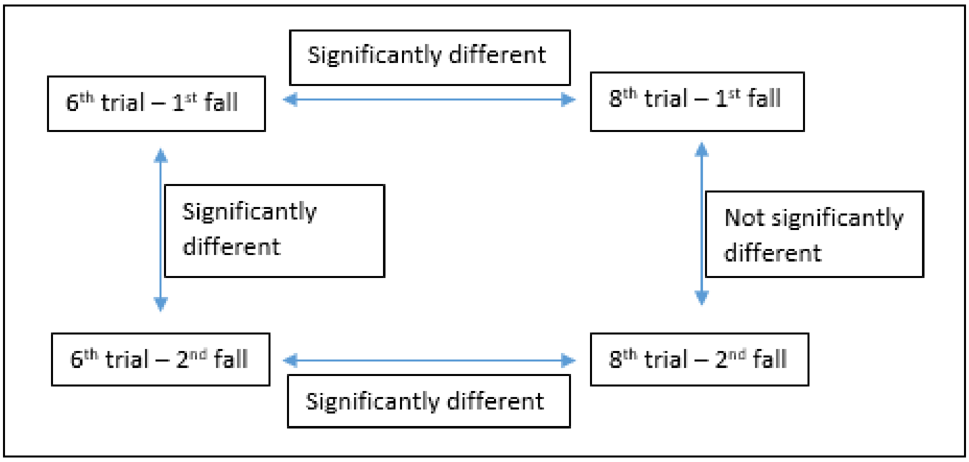

Figure 3.15. Statistical effects of anticipation and touch information on fall response for EC condition

According to the P touch * group $_{(1st\ fall)}$ = 0.681 and P touch * group $_{(2nd\ fall)}$ = 0.7; in EC condition, between the groups, trends of changes in the effect of ATV on the backward body tilt (fall) response between adapting to TO (8th trial) and TC (6th trial) conditions are similar in both 1st and 2nd deltas (It is also stated in integrated analysis of Section 3.2.1.2.b as P touch * group = 0.767; independent from deltas / falls, between the groups, trends of change between TC (6th trial) and TO (8th trial) conditions are similar). This indicates that evaluations of touch information in EC condition are similar between the groups in both 1st and 2nd falls.

In here, the thing worthy to notice is that in EC condition, independent from the groups belong to athletes or sedentary, in consequence of the existence of touch information, all groups' absolute mean and S.D. values of the backward body tilt (fall) decrease. The decrease in S.D. values states that the existence of touch information decreases in-group differences. On the other hand, the existence of touch information in EC condition did not change the mean distributions of groups, did not change inter-group differences, did not vanish inter-group differences and did not unites them in terms of the backward body tilt (fall) as in EO condition (see in Figure 3.14; for the both falls, the slopes between the groups' mean points in 6th trial are almost the same in 8th trial).

According to the P group $_{(1st\ fall)}$ = 0,655 and P group $_{(2nd\ fall)}$ = 0.406; independent from touch conditions, the effect of ATV on the backward body tilt (fall) response in EC conditions is similar between the groups in both 1st and 2nd falls (It is also stated in integrated analysis of Section 3.2.1.2.b as P group = 0.508; independent from deltas / falls and touch conditions, between the groups, the effect of ATV is similar.)

Therefore, as denoted in Table 3.63, in ECTO condition, inter-group backward body tilt (fall) differences, which are observed in ECTC condition, are not vanished by the existence of touch information as in EOTO condition.

3.2.1.3. Delta (Δ) Results for Eyes Effect

As stated in Section 3.2.1,

- During vibration, independent from touch conditions, deltas and the groups, existence / deprivation of visual information significantly changes the backward body tilt (fall) response.
- Independent from deltas and the groups, evaluations of eyes information show similarities in between different eyes conditions.
- Independent from touch conditions and the groups, evaluations of eyes information show similarity in between 1st and 2nd falls.
- Independent from touch conditions and deltas, evaluations of eyes information are not significantly different between the groups.

Here, to analyze the effect of ATV on backward body tilt (fall) response between adapting to different eyes conditions for both touch conditions respectively, the 3-way mixed ANOVAs were formed by two within-subjects factors (independent variables / repeated measures) as eyes conditions (EO, EC) and delta (Δ_1, Δ_2) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).

These statistical analyses were conducted with delta metrics of 1^{st} and 2^{nd} falls of 5^{th} and 6^{th} trials for in TC condition and 1^{st} and 2^{nd} falls of 7^{th} and 8^{th} trials for TO condition for each group, respectively. The results of these analyses are stated below.

3.2.1.3.a. Delta (Δ) Results for Eyes Effect in TC Condition (5^{th} vs 6^{th} Trials)

Delta (Δ) Results for Eyes Effect between 5^{th} & 6^{th} Trials (1^{st} & 2^{nd} falls integrated analysis)

Here, to analyze the effect of ATV on the backward body tilt (fall) response between adapting to different eyes conditions for TC condition, the 3-way mixed ANOVA was formed by two within-subjects factors (independent variables / repeated measures) as eyes conditions (EO, EC) and delta (Δ_1, Δ_2) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).

This statistical analysis was conducted with delta metrics of 1^{st} and 2^{nd} falls of 5^{th} and 6^{th} trials for in TC condition for each group, respectively. Figure 3.16. shows Delta data for 1^{st} & 2^{nd} falls of 5^{th} and 6^{th} trials. Tests of within-subjects effects for 3-way mixed ANOVA for Delta of 5^{th} and 6^{th} trials data are shown in Table 3.66. Tests of between-subjects effects for 3-way mixed ANOVA for Delta of 5^{th} and 6^{th} trials data are shown in Table 3.67. Also, descriptive statistics for Delta of 1^{st} and 2^{nd} falls of 5^{th} and 6^{th} trials are shown in Table 3.68. The results of this analysis are stated below.

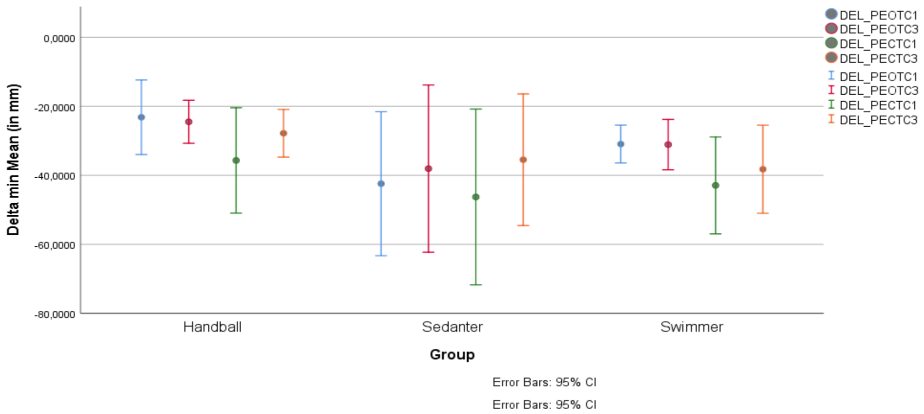

Figure 3.16. Delta Data for 1st & 2nd falls of 5th & 6th Trials

Table 3.66. Tests of Within-Subjects Effects for 3-way mixed ANOVA for Delta of 5th & 6th Trials

Tests of Within-Subjects Effects		
Source	**F**	**p**
Eyes	4.766	0.041
Eyes * Group	0.983	0.391
Delta	7.585	0.012
Delta * Group	1.051	0.367
Eyes * Delta	3.794	0.065
Eyes * Delta * Group	0.131	0.878

Table 3.67. Tests of Between-Subjects Effects for 3-way mixed ANOVA for Delta of 5th & 6th Trials

Tests of Between-Subjects Effects		
Source	**F**	**p**
Group	1.242	0.309

Table 3.68. Descriptive Statistics for Delta of 1st & 2nd falls of 5th & 6th Trials

		1st Fall				2nd Fall			
Trial	Cond.	Group	Delta	Mean	S.D.	Delta	Mean	S.D.	N
5th	EOTC	Handball	1st	-23,1657	12,9158	2nd	-24,4834	7,4645	8
		Sedentary		-42,4139	24,9571		-38,0540	28,9894	8
		Swimmer		-30,9334	6,5604		-31,0878	8,7285	8
		Total		-32,1710	17,8512		-31,2084	18,1094	24
6th	ECTC	Handball	1st	-35,6752	18,2619	2nd	-27,8083	8,2648	8
		Sedentary		-46,2651	30,4654		-35,4730	22,8148	8
		Swimmer		-42,9192	16,7880		-38,2279	15,2671	8
		Total		-41,6198	22,1390		-33,8364	16,4446	24

According to the P eyes = 0.041; in TC condition, independent from deltas and the groups, the effect of ATV on the backward body tilt (fall) response at adapting to EC condition (6th trial) is significantly different with respect to EO condition (5th trial). Therefore, during vibration, independent from deltas and the groups, deprivation of eyes information in TC condition significantly increases the backward body tilt (fall) (see total mean values in Table 3.68).

According to the P eyes * group = 0.391; in TC condition, independent from deltas, between the groups, trends of changes in the effect of ATV on the backward body tilt (fall) response between adapting to EC (6th trial) and EO (5th trial) conditions are similar. This indicates that independent from deltas, evaluations of eyes information in TC condition show similarities between the groups.

According to the P delta = 0.012; in TC condition, independent from the groups and eyes conditions, the effect of ATV on the backward body tilt (fall) response is significantly different between 1st and 2nd deltas. Therefore, independent from the groups and eyes conditions, adaptation / learning / anticipation to the ATV in TC condition significantly changes the backward body tilt (fall) response in between 1st and 2nd falls (This result originated from the anticipation effect on the backward body tilt (fall) response in 6th trial).

According to the P delta * group = 0.367; in TC condition, independent from eyes conditions, between the groups, trends of changes in the effect of ATV on the backward body tilt (fall) response between 1^{st} and 2^{nd} deltas are similar. This indicates that in TC condition, independent from eyes conditions, the effect of adaptation / learning / anticipation to the ATV on the backward body tilt (fall) response shows similarities between the groups (As it is known, especially in 6^{th} trial, similar anticipation effect on the backward body tilt (fall) response is observed between the groups rather than 5^{th} trial).

According to the P eyes * delta = 0.065; in TC condition, independent from the groups, between 1^{st} and 2^{nd} deltas, trends of changes in the effect of ATV on the backward body tilt (fall) response between adapting to EC (6^{th} trial) and EO (5^{th} trial) conditions are marginally significantly different. This indicates that in TC condition, independent from the groups, evaluations of eyes information are marginally significantly different in between 1^{st} and 2^{nd} falls (This result originated from the anticipation effect on the backward body tilt (fall) response in 6^{th} trial. As in discussed in following subtopic individual analysis, due to the compensation of the deprivation of eyes information by the anticipation, mean and S.D. values of 2^{nd} falls of 5^{th} and 6^{th} trials became similar. Therefore, trend of change in 2^{nd} delta became significantly different with respect to 1^{st} delta. For this reason, evaluation of eyes information is actually not significantly different in between 1^{st} and 2^{nd} falls.)

According to the P group = 0,309; independent from deltas and eyes conditions, the effect of ATV on the backward body tilt (fall) response in TC conditions is not significantly different between the groups.

Eyes * Delta * Group comparison is insignificant.

Delta (Δ) Results for Eyes Effect between 5th & 6th Trials (1st & 2nd falls individual analysis)

Here, to analyze the effect of ATV on the backward body tilt (fall) response between adapting to different eyes conditions in TC condition for the each fall respectively, the 2-way mixed ANOVAs were formed by one within-subjects factor (independent variables / repeated measures) as eyes conditions (EO, EC) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).

These statistical analyses were conducted with delta metrics of 1st and 2nd falls of 5th and 6th trials for in TC condition for each group, respectively. Tests of within-subjects effects for 2-way mixed ANOVA for Delta of 5th and 6th trials data are shown in Table 3.69. Tests of between-subjects effects for 2-way mixed ANOVA for Delta of 5th and 6th trials data are shown in Table 3.70. Descriptive statistics for 1st & 2nd falls of 5th & 6th trials were demonstrated in Table 3.68. above. The results of these analyses are stated below.

Table 3.69. Tests of Within-Subjects Effects for 2-way mixed ANOVA for Delta

Tests of Within-Subjects Effects				
	Δ_1 (1st fall)		**Δ_2 (2nd fall)**	
Source	**F**	**p**	**F**	**p**
Eyes	6.898	0.016	0.813	0.377
Eyes * Group	0.607	0.554	0.942	0.406

Table 3.70. Tests of Between-Subjects Effects for 2-way mixed ANOVA for Delta

Tests of Between-Subjects Effects				
	Δ_1 (1st fall)		**Δ_2 (2nd fall)**	
Source	**F**	**p**	**F**	**p**
Group	1.398	0.269	1.019	0.378

According to the P eyes $_{(1st\ fall)}$ = 0.016 and P eyes $_{(2nd\ fall)}$ = 0.377; in TC condition, independent from the groups, the effect of ATV on the backward body tilt (fall) response between adapting to EC (6^{th} trial) and EO condition (5^{th} trial) is significantly different for 1^{st} delta; however, are similar for 2^{nd} delta. Therefore, during vibration, independent from the groups, deprivation of eyes information in TC condition significantly increased the backward body tilt (fall) in 1^{st} fall; however, did not significantly change the backward body tilt (fall) in 2^{nd} fall (see in Table 3.68). The difference between P eyes values of 1^{st} and 2^{nd} falls are also stated in integrated analysis of Section 3.2.1.3.a as P eyes * delta = 0.065; independent from the groups, between 1^{st} and 2^{nd} deltas / falls, trends of change between EO (5^{th} trial) and EC (6^{th} trial) conditions are marginally significantly different. Because, independent from the groups, adaptation / learning / anticipation to the ATV in 6^{th} trial significantly decreases the backward body tilt (fall) in 2^{nd} fall with respect to 1^{st} fall, the significant difference in between 1^{st} falls of 5^{th} and 6^{th} trials vanishes in between 2^{nd} falls.

Figure 3.17. demonstrates the statistical effects of anticipation and eyes information on fall response for TC condition.

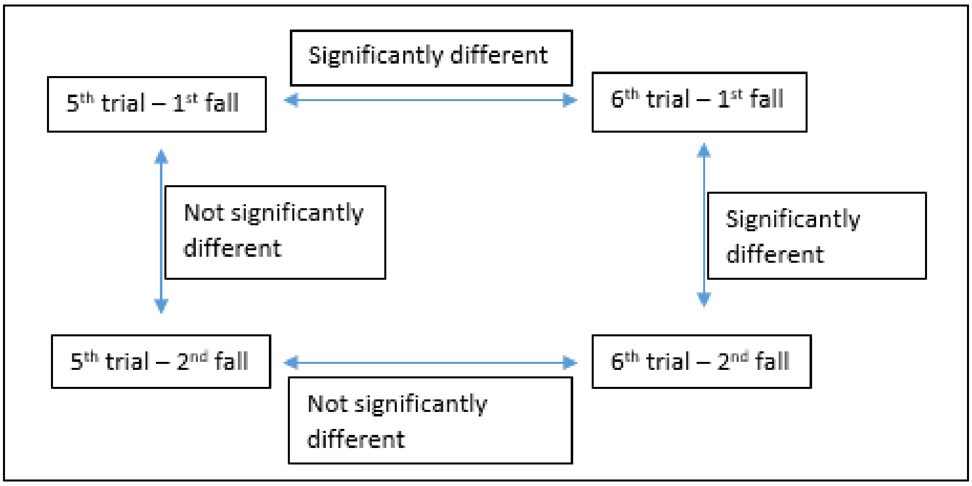

Figure 3.17. Statistical effects of anticipation and eyes information on fall response for TC condition

According to the P eyes * group $_{(1st\ fall)}$ = 0.554 and P eyes * group $_{(2nd\ fall)}$ = 0.406; in TC condition, between the groups, trends of changes in the effect of ATV on the backward body tilt (fall) response between adapting to EC (6^{th} trial) and EO (5^{th} trial) conditions are similar in both 1^{st} and 2^{nd} deltas (It is also stated in integrated analysis of Section 3.2.1.3.a as P eyes * group = 0.391; independent from deltas / falls, between the groups, trends of change between EO (5^{th} trial) and EC (6^{th} trial) conditions are similar). This indicates that evaluations of eyes information in TC condition are similar between the groups in both 1^{st} and 2^{nd} falls.

In here, the thing worthy to notice is that in TC condition, independent from the groups belong to athletes or sedentary, in consequence of the deprivation of eyes information, all groups' absolute mean and S.D. values of the backward body tilt (fall) increase in 1^{st} fall. Increase in S.D. values states that deprivation of eyes information increase in-group differences. However, in TC condition, in consequence of the deprivation of eyes information, the mean distributions of groups and so inter-group differences do not change (see in Figure 3.16; for the 1^{st} fall, the slopes between the groups' mean points in 5^{th} trial are similar in 6^{th} trial). On the other hand, adaptation / learning / anticipation to the ATV compensated the deprivation of eyes information and so, mean and S.D. values of the backward body tilt (fall) of each group in 2^{nd} falls of 6^{th} trial become similar with 2^{nd} falls of 5^{th} trial (It is stated in Table 3.68.).

According to the P group $_{(1st\ fall)}$ = 0,269 and P group $_{(2nd\ fall)}$ = 0.378; independent from eyes conditions, the effect of ATV on the backward body tilt (fall) response in TC condition is not significantly different between the groups in both 1^{st} and 2^{nd} falls (It is also stated in integrated analysis of Section 3.2.1.3.a as P group = 0.309; independent from deltas / falls and eyes conditions, between the groups, the effect of ATV is not significantly different).

Therefore, as denoted in Table 3.68, for the 1^{st} fall, in EOTC condition, inter-group postural sway differences, which are observed in ECTC condition, are not vanished by the existence of eyes information as in EOTO condition.

3.2.1.3.b. Delta (Δ) Results for Eyes Effect in TO Condition (7th vs 8th Trials)

Delta (Δ) Results for Eyes Effect between 7th & 8th Trials (1st & 2nd falls integrated analysis)

Here, to analyze the effect of ATV on the backward body tilt (fall) response between adapting to different eyes conditions for TO condition, the 3-way mixed ANOVA was formed by two within-subjects factors (independent variables / repeated measures) as eyes conditions (EO, EC) and delta (Δ_1, Δ_2) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).

This statistical analysis was conducted with delta metrics of 1st and 2nd falls of 7th and 8th trials for in TO condition for each group, respectively. Figure 3.18 shows Delta min data for 1st & 2nd falls of 7th & 8th trials. Tests of within-subjects effects for 3-way mixed ANOVA for Delta of 7th and 8th trials data are shown in Table 3.71. Tests of between-subjects effects for 3-way mixed ANOVA for Delta of 7th and 8th trials data are shown in Table 3.72. Also, descriptive statistics for 1st & 2nd falls of 7th and 8th trials were demonstrated in Table 3.73. The results of this analysis are stated below.

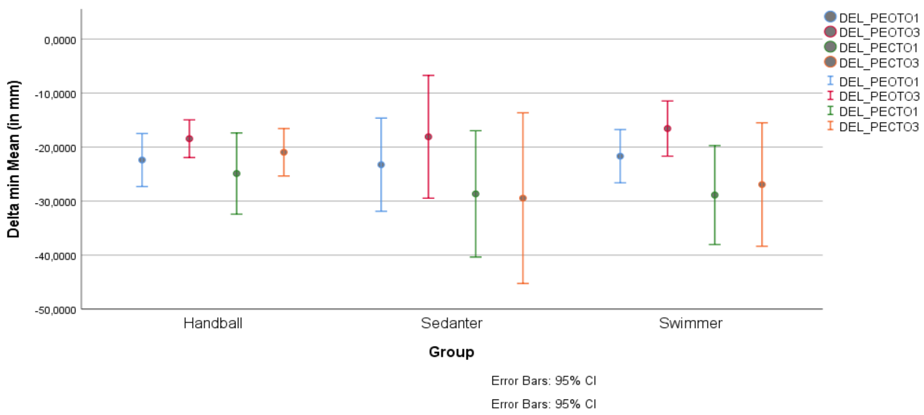

Figure 3.18. Delta Data for 1st & 2nd falls of 7th & 8th Trials.

Table 3.71. Tests of Within-Subjects Effects for 3-way mixed ANOVA for Delta of 7th & 8th Trials

Tests of Within-Subjects Effects		
Source	**F**	**p**
Eyes	13.687	0.001
Eyes * Group	1.309	0.291
Delta	4.399	0.048
Delta * Group	0.119	0.888
Eyes * Delta	1.271	0.272
Eyes * Delta * Group	0.407	0.671

Table 3.72. Tests of Between-Subjects Effects for 3-way mixed ANOVA for Delta of 7th & 8th Trials

Tests of Between-Subjects Effects		
Source	**F**	**p**
Group	0.288	0.753

Table 3.73. Descriptive Statistics for Delta of 1st & 2nd falls of 7th & 8th Trials

		1st Fall				2nd Fall			
Trial	Cond.	Group	Epoch	Mean	S.D.	Epoch	Mean	S.D.	N
7th	EOTO	Handball	1st	-22,3940	5,8754	3rd	-18,4511	4,1763	8
		Sedentary		-23,2607	10,3126		-18,0955	13,5967	8
		Swimmer		-21,6843	5,8965		-16,5735	6,1086	8
		Total		-22,4463	7,3409		-17,7067	8,5803	24
8th	ECTO	Handball	1st	-24,8984	8,9932	3rd	-20,9585	5,2535	8
		Sedentary		-28,6618	13,9786		-29,4509	18,8892	8
		Swimmer		-28,8808	10,9506		-26,9296	13,6625	8
		Total		-27,4803	11,1386		-25,7796	13,6760	24

According to the P eyes = 0.001; in TO condition, independent from deltas and the groups, the effect of ATV on the backward body tilt (fall) response at adapting to EC condition (8th trial) is significantly different with respect to EO condition (7th trial).

Therefore, during vibration, independent from deltas and the groups, deprivation of eyes information in TO condition significantly increases the backward body tilt (fall) (see total mean values in Table 3.73).

According to the P eyes * group = 0.291; in TO condition, independent from deltas, between the groups, trends of changes in the effect of ATV on the backward body tilt (fall) response between adapting to EC (8^{th} trial) and EO (7^{th} trial) conditions are not significantly different. This indicates that independent from deltas, evaluations of eyes information in TO condition show similarities between the groups.

According to the P delta = 0.048; in TO condition, independent from the groups and eyes conditions, the effect of ATV on the backward body tilt (fall) response is significantly different between 1^{st} and 2^{nd} deltas. Therefore, independent from the groups and eyes conditions, adaptation / learning / anticipation to the ATV in TO condition is significantly change the backward body tilt (fall) response in between 1^{st} and 2^{nd} falls (This result originated from the anticipation effect on the backward body tilt (fall) response in 7^{th} trial).

According to the P delta * group = 0.888; in TO condition, independent from eyes conditions, between the groups, trends of changes in the effect of ATV on the backward body tilt (fall) response between 1^{st} and 2^{nd} deltas are similar. This indicates that in TO condition, independent from eyes conditions, the effect of adaptation / learning / anticipation to the ATV on the backward body tilt (fall) response shows similarities between the groups (As it is known, from both 7^{th} and 8^{th} trials, similar anticipation effect on the backward body tilt (fall) response is observed between the groups).

According to the P eyes * delta = 0.272; in TO condition, independent from the groups, between 1^{st} and 2^{nd} deltas, trends of changes in the effect of ATV on the backward body tilt (fall) response between adapting to EC (8^{th} trial) and EO (7^{th} trial) conditions are not significant different. This indicates that in TO condition, independent from the groups, evaluations of eyes information are not significant different in between 1st and 2nd falls.

According to the P group = 0.753; independent from deltas and eyes conditions, the effect of ATV on the backward body tilt (fall) response in TO condition is similar between the groups.

Eyes * Delta * Group comparison is insignificant.

Delta (Δ) Results for Eyes Effect between 7th & 8th Trials (1st & 2nd falls individual analysis)

Here, to analyze the effect of ATV on the backward body tilt (fall) response between adapting to different eyes conditions in TO condition of the each fall respectively, the 2-way mixed ANOVAs were formed by one within-subjects factor (independent variables / repeated measures) as eyes conditions (EO, EC) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players).

These statistical analyses were conducted with delta metrics of 1st and 2nd falls of 7th and 8th trials for in TO condition for each group, respectively. Tests of within-subjects effects for 2-way mixed ANOVA for Delta of 7th and 8th trials data are shown in Table 3.74. Tests of between-subjects effects for 2-way mixed ANOVA for Delta of 7th and 8th trials data are shown in Table 3.75. The results of these analyses are stated below.

Table 3.74. Tests of Within-Subjects Effects for 2-way mixed ANOVA for Delta of 7th & 8th Trials

Tests of Within-Subjects Effects				
	Δ_1 (1st fall)		**Δ_2 (2nd fall)**	
Source	**F**	**p**	**F**	**p**
Eyes	8.293	0.009	9.512	0.006
Eyes * Group	0.611	0.552	1.142	0.338

Table 3.75. Tests of Between-Subjects Effects for 2-way mixed ANOVA for Delta of 7th & 8th Trials

Tests of Between-Subjects Effects				
	Δ_1 (1st fall)		**Δ_2 (2nd fall)**	
Source	**F**	**p**	**F**	**p**
Group	0.147	0.864	0.352	0.707

According to the P eyes $_{(1st\ fall)}$ = 0.009 and P eyes $_{(2nd\ fall)}$ = 0.006; in TO condition, independent from the groups, the effect of ATV on the backward body tilt (fall) response between adapting to EC (8th trial) and EO condition (7th trial) is significantly different for both 1st and 2nd deltas. Therefore, during vibration, independent from the groups, deprivation of eyes information in TO condition significantly increased the backward body tilt (fall) in both 1st and 2nd fall (see in Table 3.73.). Although independent from the groups, adaptation / learning / anticipation to the ATV in 7th trial significantly decreases the backward body tilt (fall) in 2nd fall with respect to 1st fall, the significant difference in between 2nd falls of 7th and 8th trials slightly increases with respect to 1st falls. This slightly change between P eyes values of 1st and 2nd falls are also stated in integrated analysis of Section 3.2.1.3.b as P eyes * delta = 0.272; independent from the groups, between 1st and 2nd deltas / falls, trends of change between EO (7th trial) and EC (8th trial) conditions are similar.

Figure 3.19. demonstrates the statistical effects of anticipation and eyes information on fall response for TO condition.

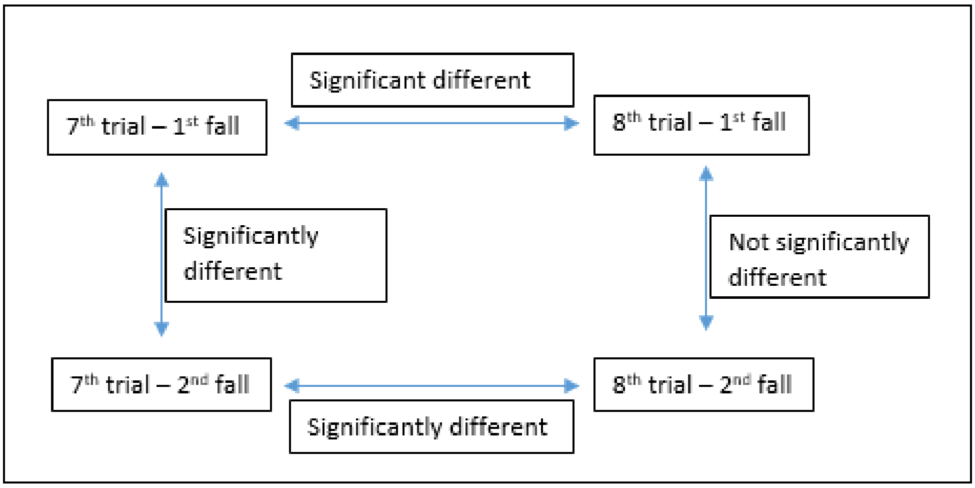

Figure 3.19. Statistical effects of anticipation and eyes information on fall response for TO condition

According to the P eyes * group $_{(1st\ fall)}$ = 0.552 and P eyes * group $_{(2nd\ fall)}$ = 0.338; in TO condition, between the groups, trends of changes in the effect of ATV on the backward body tilt (fall) response between adapting to EC (8^{th} trial) and EO (7^{th} trial) conditions are similar in both 1^{st} and 2^{nd} deltas (It is also stated in integrated analysis of Section 3.2.1.3.b as P eyes * group = 0.291; independent from deltas / falls, between the groups, trends of change between EO (7^{th} trial) and EC (8^{th} trial) conditions are similar). This indicates that evaluations of eyes information in TO condition are similar between the groups for both 1^{st} and 2^{nd} falls.

In here, the thing worthy to notice is that in TO condition, independent from the groups belong to athletes or sedentary, in the existence of eyes information, all groups' mean and S.D. values of the backward body tilt (fall) are almost the same. Therefore, inter-group differences vanished and the groups united in terms of the backward body tilt (fall) response. On the other hand, in consequence of the deprivation of eyes information in TO condition, all groups' mean and S.D. values of the backward body tilt (fall) increase in 1^{st} and 2^{nd} falls. Thus, with deprivation of eyes information in TO condition, inter-group differences formed and in-group differences increased.

However, existence of touch information prevents to grow in-group and inter-group differences as much as in TC condition.

According to the P group $_{(1st\ fall)}$ = 0,864 and P group $_{(2nd\ fall)}$ = 0.707; independent from eyes conditions, the effect of ATV on the backward body tilt (fall) response in TO conditions is similar between the groups in both 1st and 2nd falls (It is also stated in integrated analysis of Section 3.2.1.3.b as P group = 0.753; independent from deltas / falls and eyes conditions, between the groups, the effect of ATV is similar).

Therefore, as denoted in Table 3.73, in EOTO condition, inter-group backward body tilt (fall) differences, which are observed in ECTO condition, are vanished by the existence of touch information.

3.2.1.4. Delta (Δ) Results for Touch Vs Eyes Effect

Here, to compare the contributions of bodily somatosensory (touch) and visual information to the sensory negative feedback mechanism to control the maintenance of upright stance during ATV, trends of change in the effect of ATV on the backward body tilt (fall) response between adapting to ECTO (8th trial) and ECTC (6th trial) conditions, EOTC (5th trial) and ECTC (6th trial) conditions, EOTO (7th trial) and EOTC (5th trial) conditions, EOTO (7th trial) and ECTO (8th trial) conditions are analyzed. Tests of within-subjects effects for 3-way mixed ANOVA for Delta data are shown in Table 3.76. Also, descriptive statistics for Delta of 1st and 2nd falls of 5th, 6th, 7th and 8th trials are shown in Table 3.77. These tables were formed by the data under previous topics.

Table 3.76. Tests of Within-Subjects Effects for 3-way mixed ANOVA for Delta

Tests of Within-Subjects Effects			
ANOVA Between	**Source**	**F**	**p**
EOTC (5^{th}) and ECTC (6^{th})	Eyes	4.766	0.041
ECTC (6^{th}) and ECTO (8^{th})	Touch	24.165	0.0001
EOTO (7^{th}) and ECTO (8^{th})	Eyes	13.687	0.001
EOTC (5^{th}) and EOTO (7^{th})	Touch	19.629	0.0002

Table 3.77. Descriptive Statistics for 1^{st} & 2^{nd} falls of 5^{th}, 6^{th}, 7^{th} & 8^{th} Trials for Delta

			1^{st} Fall			2^{nd} Fall			
Trial	Cond.	Group	Delta	Mean	S.D.	Delta	Mean	S.D.	N
5^{th}	EOTC	Total	1^{st}	-32.1710	17.8512	2^{nd}	-31.2084	18.1094	24
6^{th}	ECTC	Total	1^{st}	-41.6198	22.1390	2^{nd}	-33.8364	16.4446	24
7^{th}	EOTO	Total	1^{st}	-22.4463	7.3409	2^{nd}	-17.7067	8.5803	24
8^{th}	ECTO	Total	1^{st}	-27.4803	11.1386	2^{nd}	-25.7796	13.6760	24

According to P touch = 0.0001 and P eyes = 0.041, supplying touch information (ECTO) or visual information (EOTC) as a first sensorial information source to the sensory negative feedback mechanism, which is deprived of visual and touch information (ECTC), cause a significant decrease in the backward body tilt (fall). However, the difference between P touch = 0.0001 and P eyes = 0.041 values indicates that contribution of touch information to sensory negative feedback mechanism to control the backward body tilt (fall) response is more than visual information (see in Table 3.77, the backward body tilt (fall) in 8^{th} trial is lower than 5^{th} trial, $6^{th} > 5^{th} > 8^{th}$). Moreover, p = 0.066 value (which is obtained from 3-way mixed ANOVA was formed by two within-subjects factors as sensory condition (EOTC and ECTO) and delta (1^{st}, 2^{nd}) and one between-subjects factor as the subject groups (sedentary, swimmers, handball players)) indicates that independent from deltas and the groups, the effect of ATV on the backward body tilt (fall) response at adapting to ECTO condition (8^{th} trial) is marginally significant lower with respect to EOTC condition (5^{th} trial). Therefore, during vibration, the backward body tilt (fall) in ECTO condition

(8^{th} trial) is marginally significant lower than EOTC condition (5^{th} trial) and so, contribution of touch information to sensory negative feedback mechanism to control the backward body tilt (fall) response is statistically significantly more than visual information.

Supplying touch information (EOTO) or visual information (EOTO) as a second sensorial information source to the sensory negative feedback mechanism, which has either visual (EOTC) or touch (ECTO) information, cause a significant decrease in the backward body tilt (fall) (P touch = 0.0002 and P eyes = 0.001, respectively). As in first sensorial information source, supplying touch information as a second sensorial information source contribute to sensory negative feedback mechanism statistically significantly more than visual information to control the backward body tilt (fall) response (see in Table 3.77, $6^{th} > 5^{th} > 8^{th} > 7^{th}$ in terms of absolute mean and S.D. values of the backward body tilt (fall)).

As it is shown in Table 3.43, Figure 3.14 and Figure 3.16, supplying visual or touch information as a first sensorial information source to the sensory negative feedback mechanism did not change the mean distribution and inter-group differences. However, as it is shown in Table 3.43, Figure 3.12 and Figure 3.18, supplying visual or touch information as a second sensorial information source to the sensory feedback mechanism aggregate means, vanished inter-group differences and unified them.

3.2.1.5. Overall Delta (Δ) Results

This part includes the overall Delta results and their relations with hypotheses.

1. For each group, at adapting to the different sensory conditions (EOTC, ECTC, EOTO, ECTO), ATV causes the backward body tilt (fall) response. Therefore, 1^{st} hypothesis is confirmed.

2. Independent from the groups, due to the effect of adaptation / learning / anticipation to the ATV, effect of ATV on the backward body tilt (fall) response and so the

backward body tilt (fall) significantly decreases in 2nd fall with respect to 1st fall in both 6th trial (ECTC) and 7th trial (EOTO); however, the backward body tilt (fall) response is not significantly change in between 1st and 2nd falls of 5th (EOTC) and 8th (ECTO) trials. Therefore, 2nd hypothesis is denied. On the other hand, anticipation could not resist to the backward body tilt (fall) response during ATV.

3. Effect of adaptation / learning / anticipation to the ATV on the backward body tilt (fall) response shows similarities between the groups in 5th (EOTC), 6th (ECTC), 7th (EOTO) and 8th (ECTO) trials.

4. Independent from 1st and 2nd falls, between the groups, the effect of ATV on the backward body tilt (fall) response and so the backward body tilt (fall) is similar in 5th (EOTC), 6th (ECTC) and 8th (ECTO) trials and is almost the same in 7th trial (EOTO). Therefore, hypotheses 4.2.II, 4.3.II and 5 are denied.

5. For both EO and EC conditions, independent from 1st and 2nd falls and the groups, the effect of ATV on the backward body tilt (fall) response at adapting to TO condition is significantly lower with respect to TC condition. Therefore, during vibration, independent from 1st and 2nd falls and the groups, existence of touch information in EO and EC conditions significantly decreases the backward body tilt (fall). Therefore, hypothesis 3.1 is confirmed.

6. Independent from 1st and 2nd falls, between the groups, trends of changes in the effect of ATV on the backward body tilt (fall) response between adapting to TO and TC conditions are similar for EC condition and marginally significant different for EO condition. As it is seen in Table 3.58 and Figure 3.12, in EO condition, sedentary group has the maximum trends of change. Swimmers and handball players' groups are follow them. Therefore, hypothesis 3.2 is denied.

7. For both TC and TO conditions, independent from 1st and 2nd falls and the groups, the effect of ATV on the backward body tilt (fall) response at adapting to EC condition is significantly higher with respect to EO condition. Therefore, during vibration, independent from 1st and 2nd falls and the groups, deprivation of eyes information in

TC and TO conditions significantly increases the backward body tilt (fall). Therefore, hypothesis 4.1 is confirmed.

8. In TC condition, independent from 1st and 2nd falls, between the groups, trends of changes in the effect of ATV on the backward body tilt (fall) response between adapting to EC and EO conditions are similar. Therefore, hypothesis 4.2.I is denied.

9. In TO condition, independent from 1st and 2nd falls, between the groups, trends of changes in the effect of ATV on the backward body tilt (fall) response between adapting to EC (8th trial) and EO (7th trial) conditions are similar. Therefore, hypothesis 4.3.I is denied.

10. In TC condition, adaptation / learning / anticipation to the ATV compensates the deprivation of eyes information in terms of the backward body tilt (fall) response.

11. Contribution of touch information to sensory negative feedback mechanism to control the backward body tilt (fall) response is significantly more than visual information.

12. Supplying visual or touch information as a first sensorial information source to the sensory negative feedback mechanism is not change mean distribution and inter-group differences. However, supplying visual or touch information as a second sensorial information source to the sensory feedback mechanism aggregate means, vanish inter-group differences and unify them.

CHAPTER 4

DISCUSSION AND CONCLUSION

4.1. Discussion

In this study, it was expected and found that ATV alters proprioceptive information and causes increase in the postural sway and the backward body tilt (fall) at adapting to all designed sensory environments. Because, proprioceptive information is the reference information about one's self. Evaluation of the other sensorial information takes the proprioceptive information as a reference. So, if human is represented as an inverted pendulum placed upright on ankles, upright stance of this pendulum is maintained by Achilles tendon of the ankle. Therefore, alteration in proprioceptive information by ATV causes destabilization of the whole pendulum. This destabilization is controlled by sensory negative feedback mechanism. It is found that contribution of touch information to sensory negative feedback mechanism is more than visual information. However, in QS, it is found that while visual information significantly changed the postural sway, touch information is ineffective.

It was expected that anticipation effect decreased the postural sway and the backward body tilt (fall) during vibration. However, its effect is not observed in each trial. The first fall of the 5^{th} trial was the naive one for all subjects. Because, no one knows that the experiments include tendon vibration. This is also verbally verified by the subjects. Therefore, significant anticipation effect is not observed in 1^{st} fall of 5^{th} trial. After the first vibration in 5^{th} trial, according to the interview, although subjects did not know that the experiments include more than one tendon vibration, many of subjects had been anticipating the other vibration without any prediction about starting time of the vibration. Not having any prediction may be the explanation of why 2^{nd} vibration response is similar the naive one. Hence, the anticipation effect is not observed in 5^{th}

trials. Nevertheless, according to the interview, in 5th trial, subjects had been counting the seconds between the first and the second vibrations. Moreover, they figured out that the tendon vibration experiments include two vibrations. The experiment was designed to break the anticipation effect in the first vibration. Therefore, data recording was started after a random time in each experiment; thus, subjects could not specify when the vibration starts. However, the time between the first and the second vibration was kept constant to motivate the constant anticipation effect. Therefore, subjects guessed the second vibration time approximately right after they experienced in 5th trial. This differences in anticipation between the first and the second vibrations should be the reason of the significant difference between the first and the second fall in terms of postural sway and backward body tilt (fall). Presumably because of the similarity of the anticipation, 7th trial is similar with 6th trial in terms of postural sway. Until 8th trial, subjects probably figured out that the first vibration is started in a random time and so, anticipation differences between the first and the second vibrations diminish during 8th trial.

It is probable that by knowing that tendon vibration will cause postural perturbation, subjects may adjust the tension of their muscle spindles during pre-vibration period to prevent effect of illusion by the activation of muscle groups that compensates the backward body tilt (fall). Therefore, subjects struggle with the perturbation as soon as the vibration starts. In this way, during vibration, postural sway and backward body tilt (fall) decreases.

In addition to them, it is founded that anticipation is strong as to compensate the deprivation of eyes information. However, it is not strong as to prevent the postural sway increase and backward body tilt (fall) during ATV. However, the power of anticipation effect should be studied in detail.

In this study, it was expected that in TC condition handball players, in TO condition swimmers would be affected the least from eyes information changes. However, neither of these two expectations are confirmed. On the other hand, in both EO and

EC conditions, it was expected that with the existence of touch information, the biggest trends of change would be observed in swimmer group. For EC condition, all groups show similar trends; however, for EO condition, sedentary group has the biggest trends of change. Swimmers and handball players' groups are follow them. This is an unexpected result and should be analyzed in detail.

Probably the most interesting result is that when the visual and bodily somatosensory information are supplied together to the sensory negative feedback mechanism, inter-group differences vanished.

4.2. Conclusion and Future Study

In this study, effect of Achilles tendon vibration on postural sway behavior and backward body tilt (fall) response at adapting to different eyes and touch conditions were examined between three different groups. Contributions of visual and somatosensorial information to the sensory negative feedback mechanism were also analyzed.

In this study, we observed from CoPx plots that there are differences in reaching time to the maximum backward body tilt (fall) between both different sensory conditions and groups. In addition, there are differences in recovery after the vibration ends. It is looking that there are group behavior differences in terms of overcorrection and undercorrection of their position after the vibration ends. Of course, the effect of adaptation to the different sensory condition on recovery behavior should be evaluated in details.

The other observation from CoPx plots is that while the falling is proceeding to its maximum in vibration period, postural correction starts in the middle of vibration period.

This kind of studies not only light the way of understanding the mechanism of the posture control, but also open a new door for future studies to go deeper.

In further studies, question of “Can illusion be defeated by anticipation?” may be answered. Number of participant in experiments of future studies may be higher in order to analyze the differences in person scale, as well. And also, the increase in the number of subjects certainly increases the power of the statistical analyses.

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APPENDICES

A. CoPx PLOTS OF THE HANDBALL PLAYERS GROUP

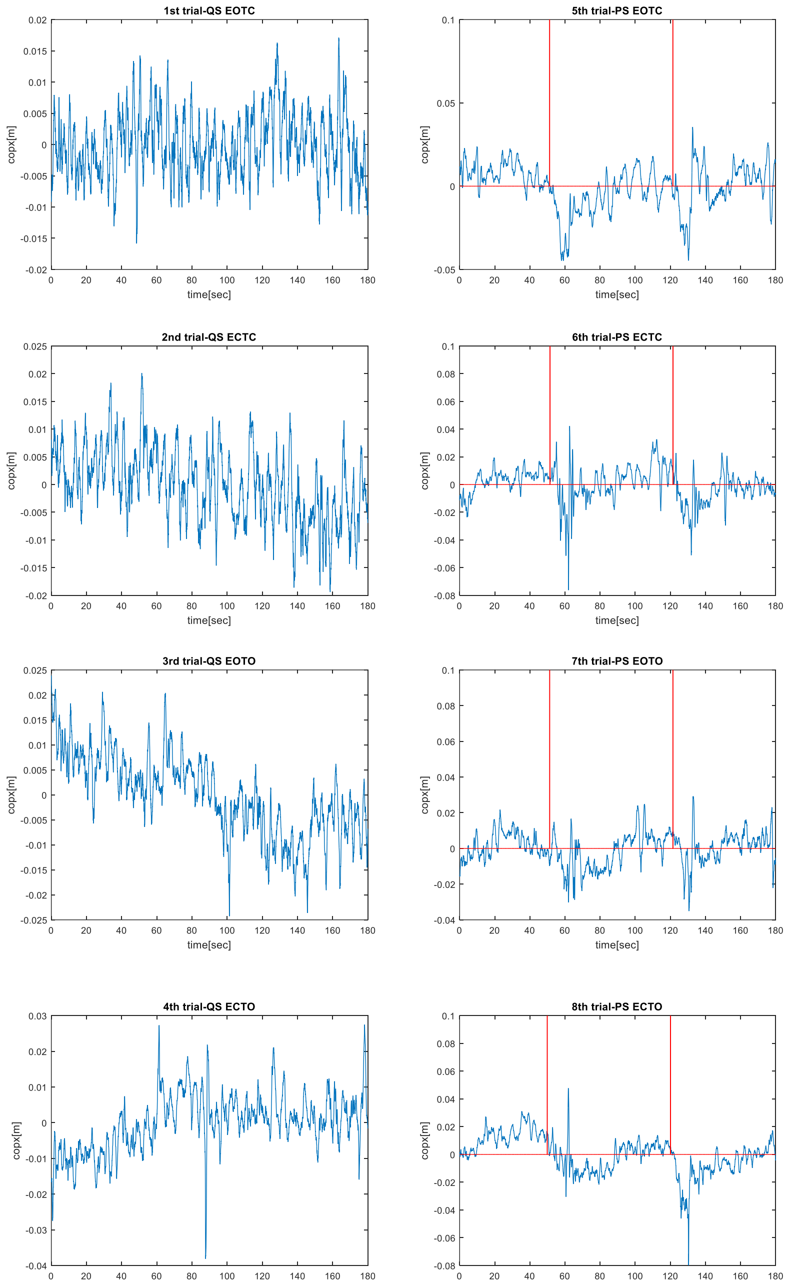

Figure A.1. CoPx Plots of the 1st Subject of the Handball Players Group

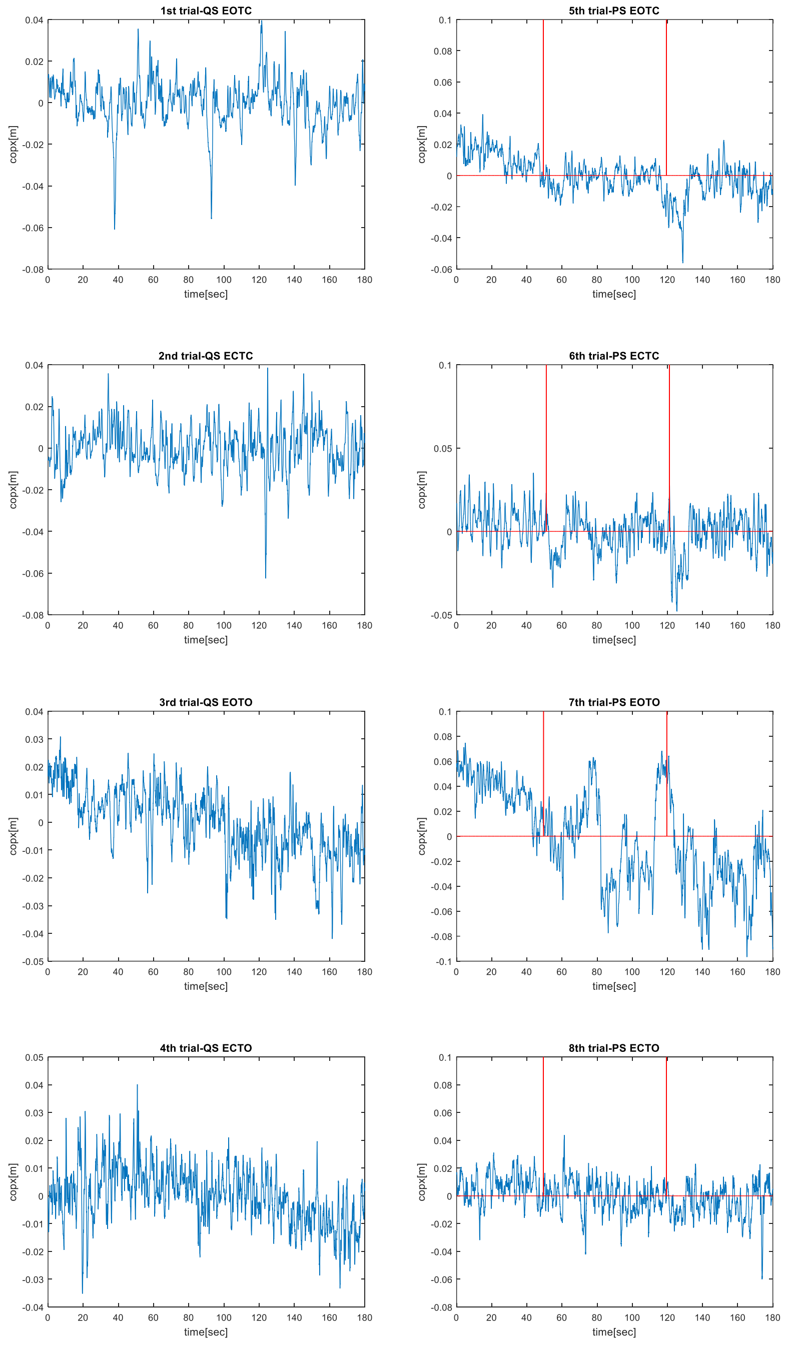

Figure A.2. CoPx Plots of the 2nd Subject of the Handball Players Group

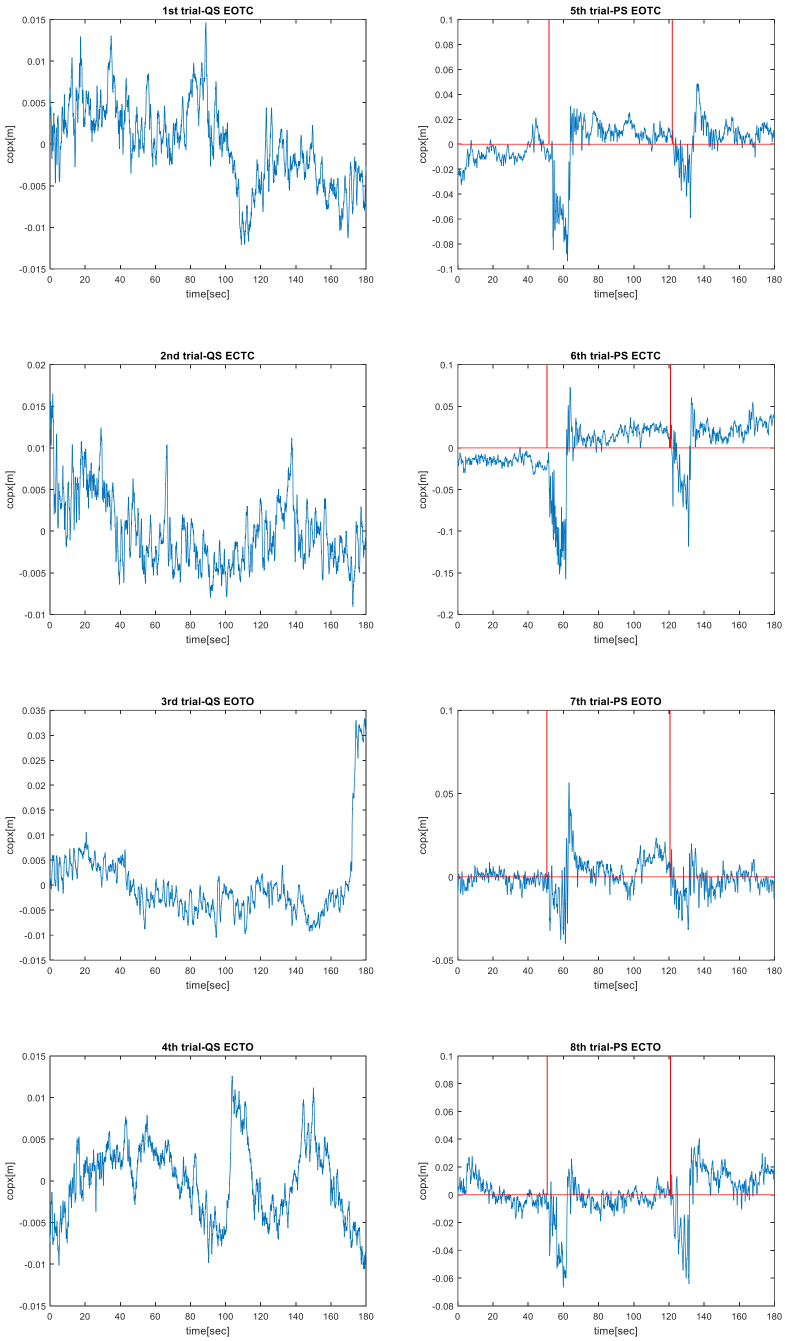

Figure A.3. CoPx Plots of the 3rd Subject of the Handball Players Group

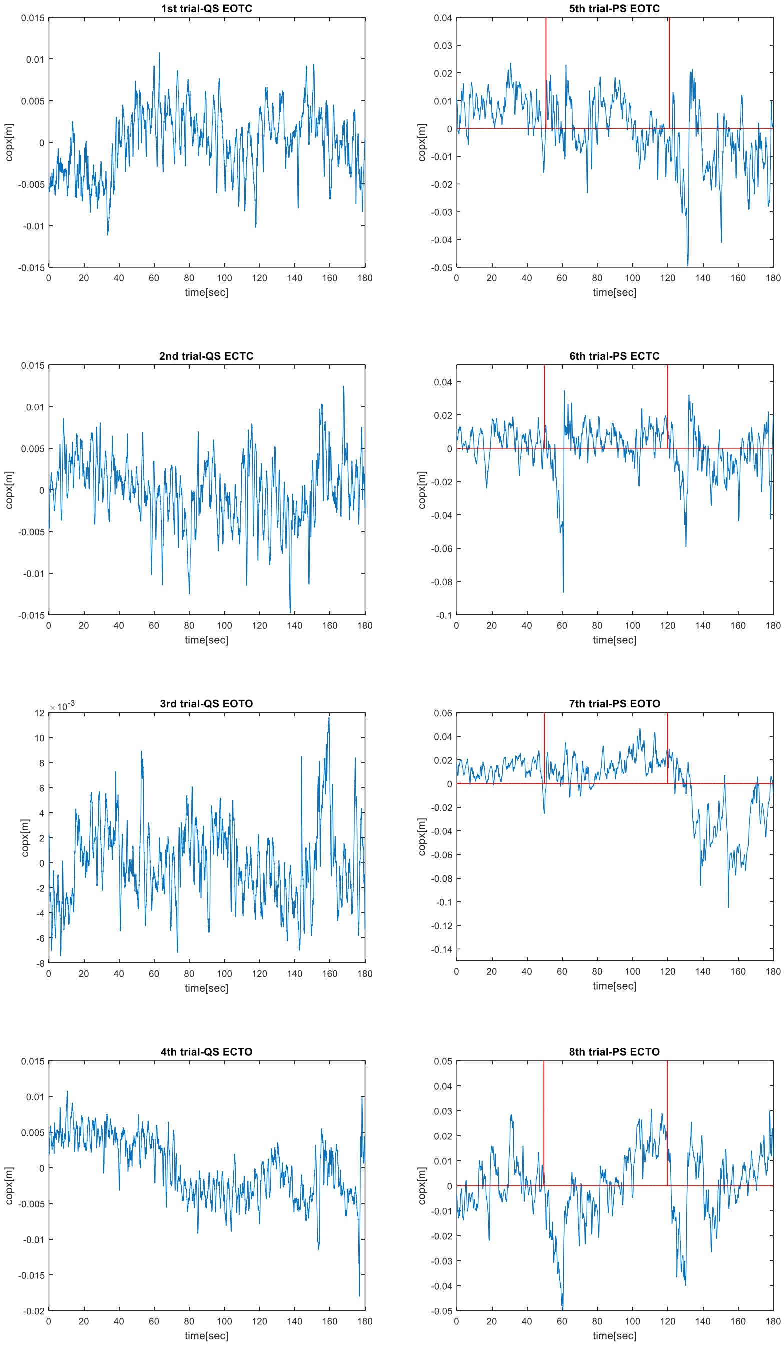

Figure A.4. CoPx Plots of the 4th Subject of the Handball Players Group

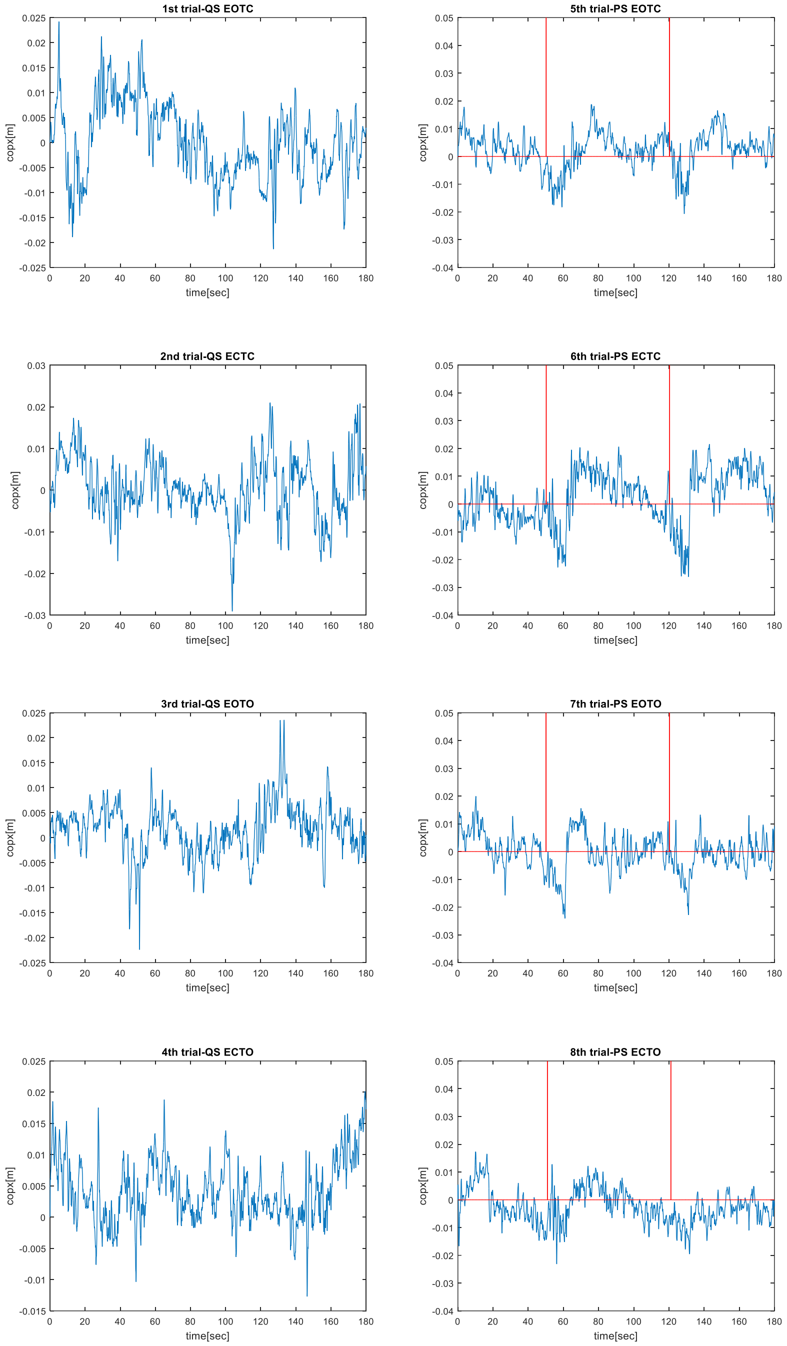

Figure A.5. CoPx Plots of the 5th Subject of the Handball Players Group

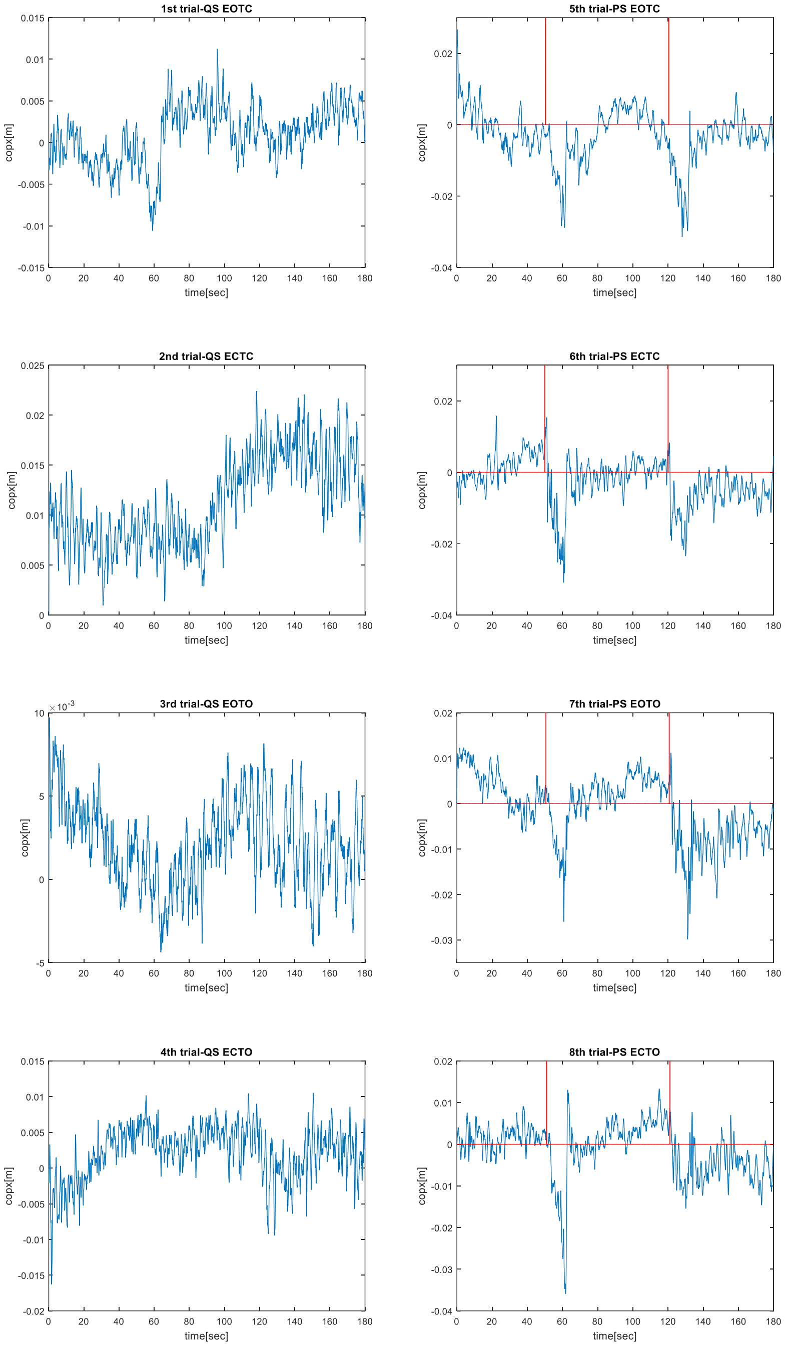

Figure A.6. CoPx Plots of the 6th Subject of the Handball Players Group

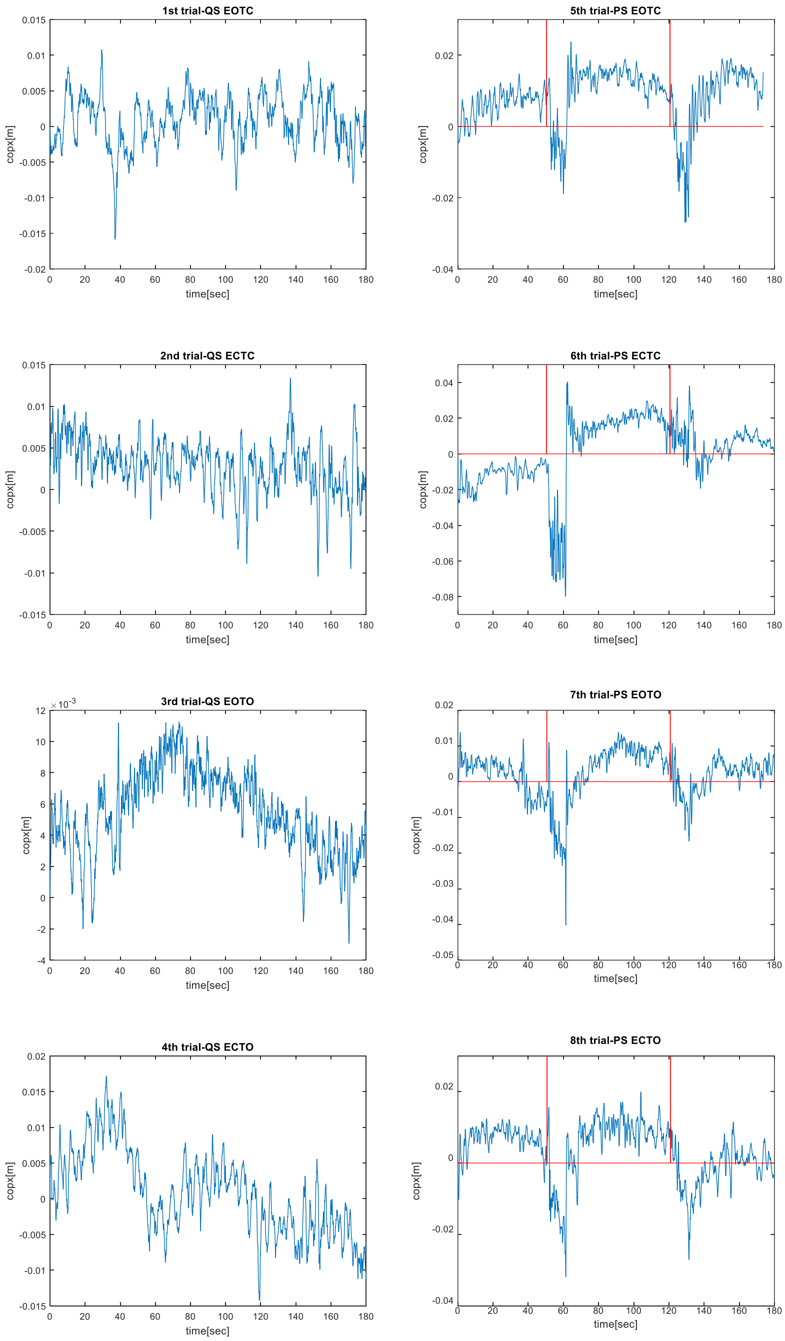

Figure A.7. CoPx Plots of the 7th Subject of the Handball Players Group

Figure A.8. CoPx Plots of the 8th Subject of the Handball Players Group

B. CoPx PLOTS OF THE SWIMMERS GROUP

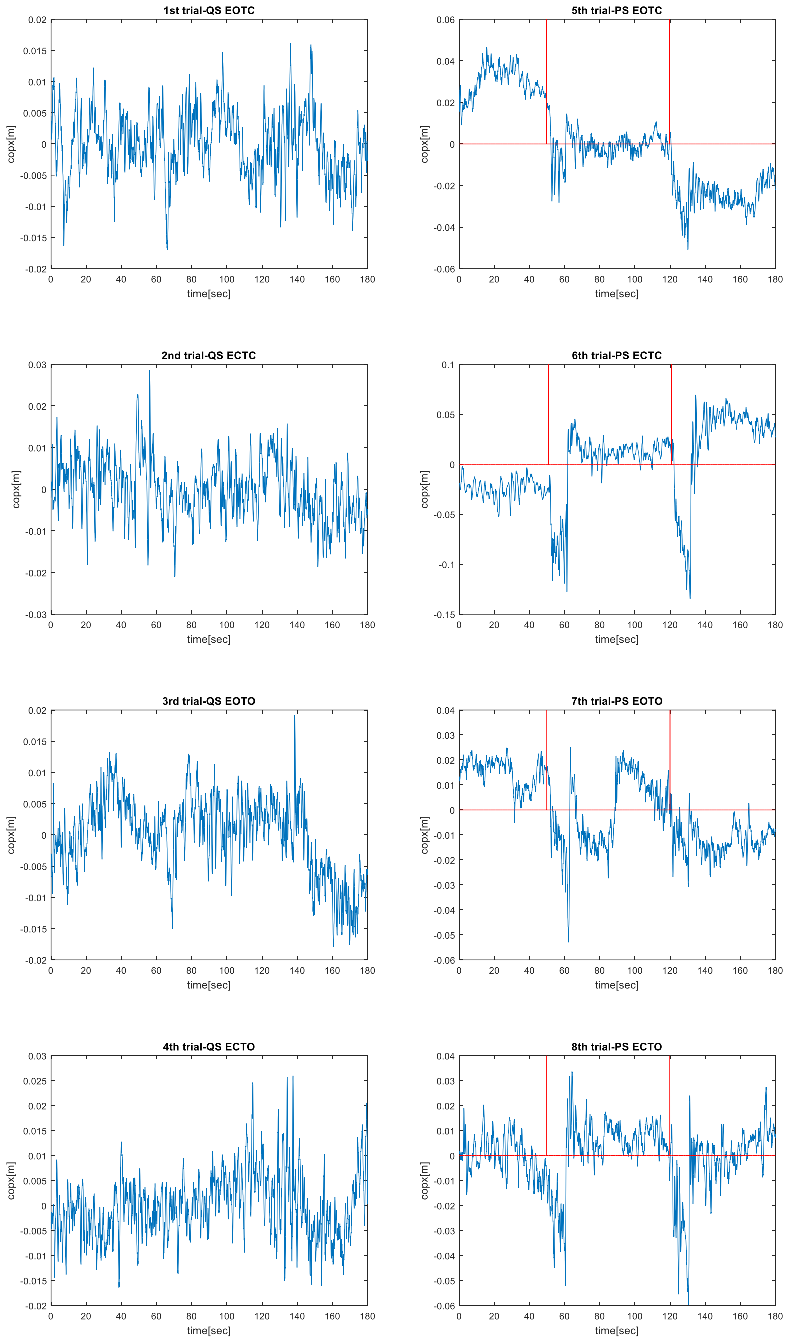

Figure B.9. CoPx Plots of the 1st Subject of the Swimmers Group

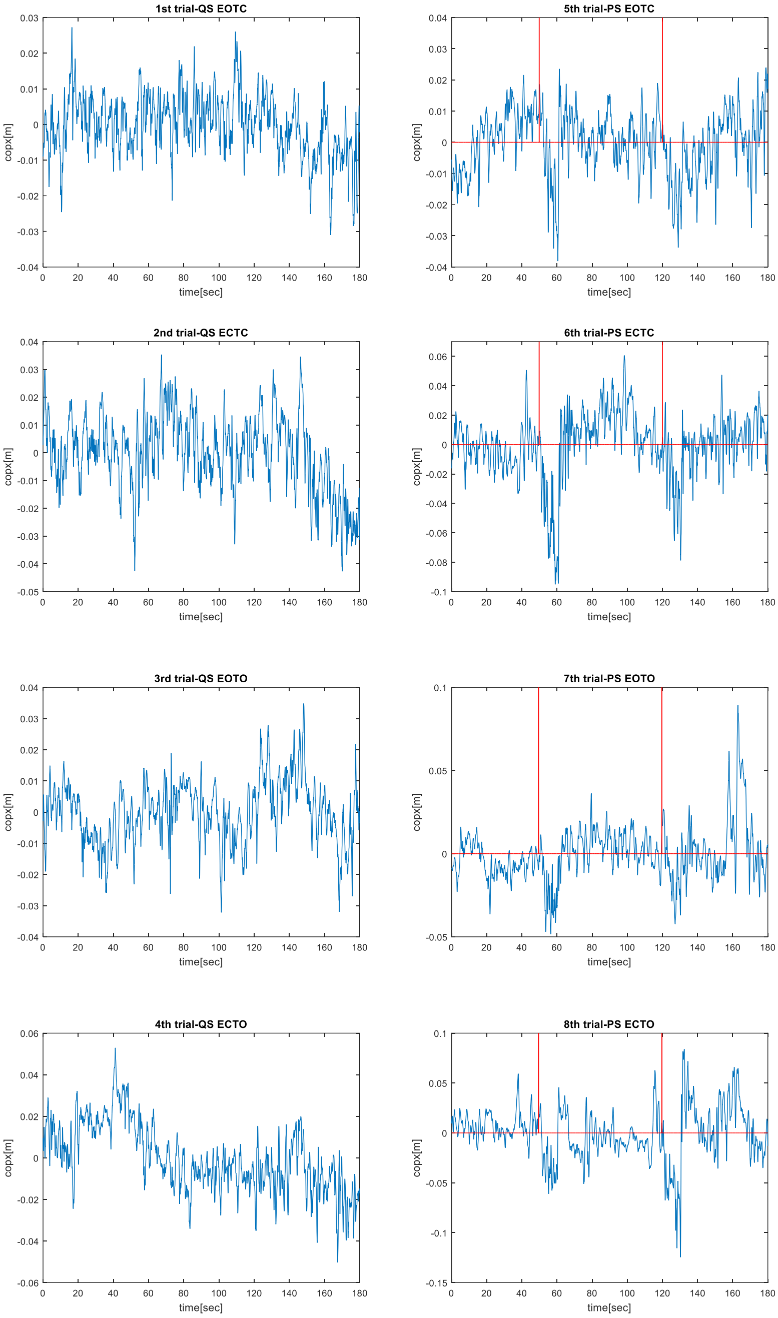

Figure B.10. CoPx Plots of the 2nd Subject of the Swimmers Group

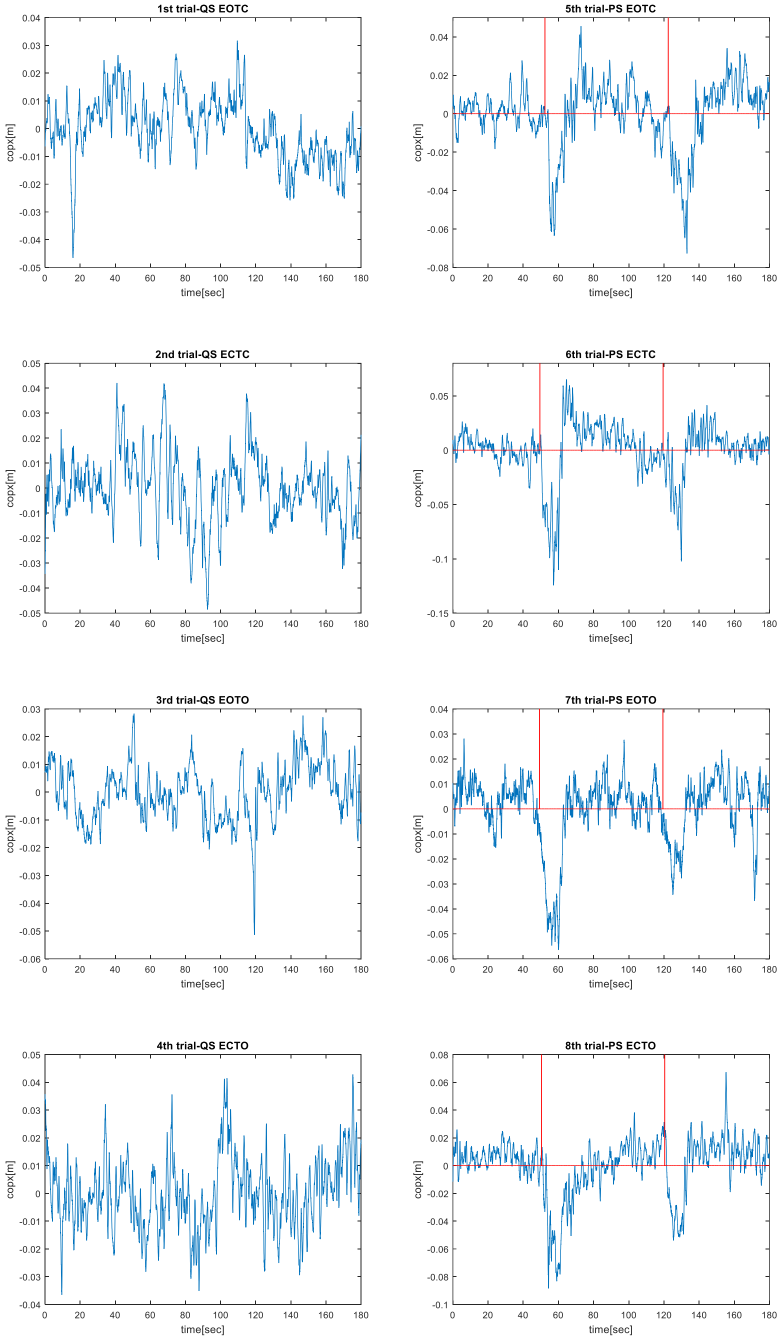

Figure B.11. CoPx Plots of the 3rd Subject of the Swimmers Group

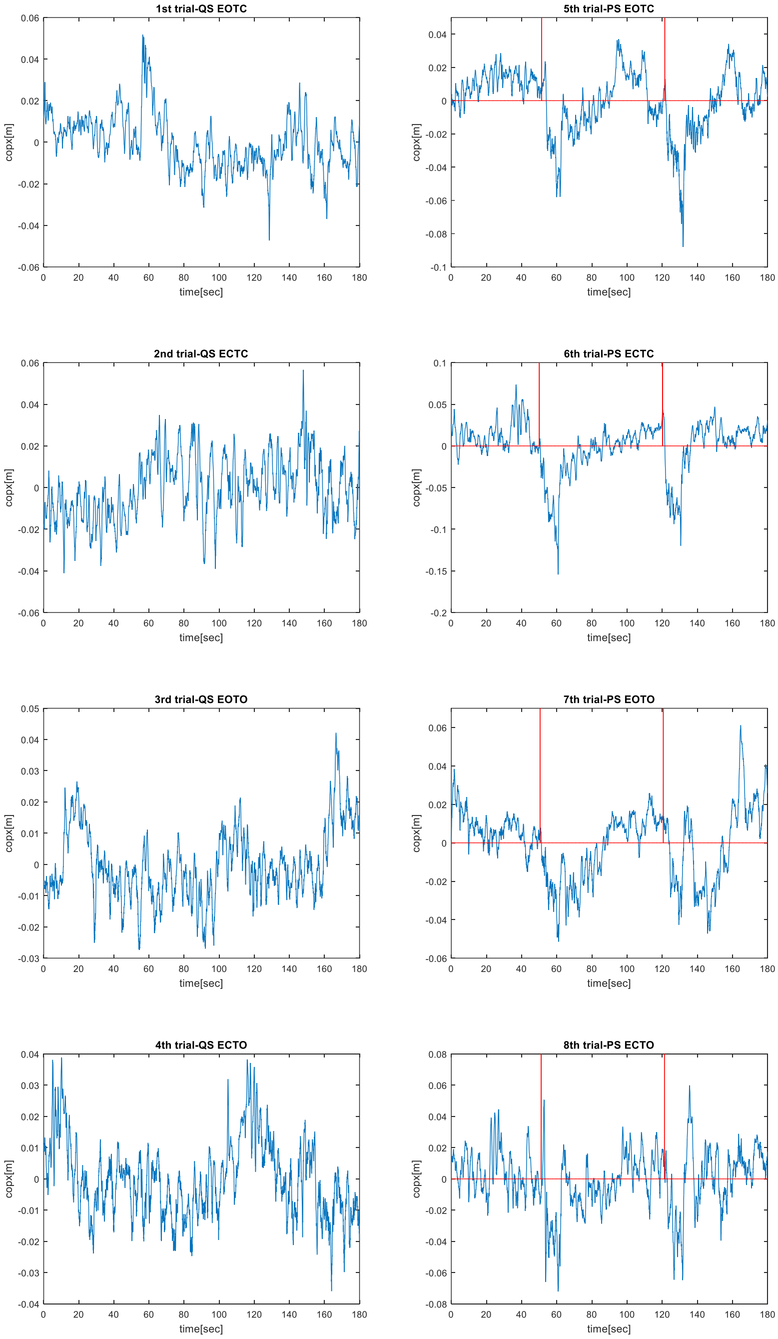

Figure B.12. CoPx Plots of the 4th Subject of the Swimmers Group

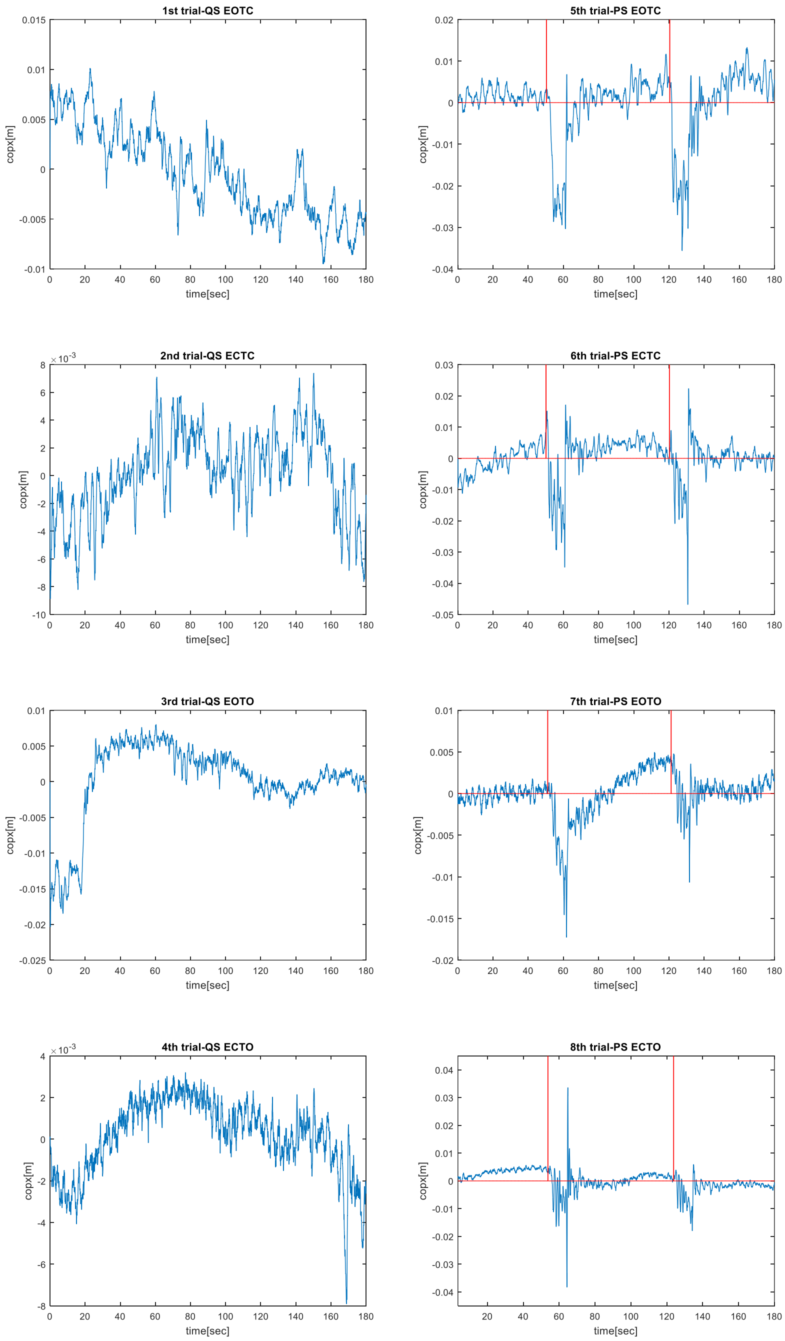

Figure B.13. CoPx Plots of the 5th Subject of the Swimmers Group

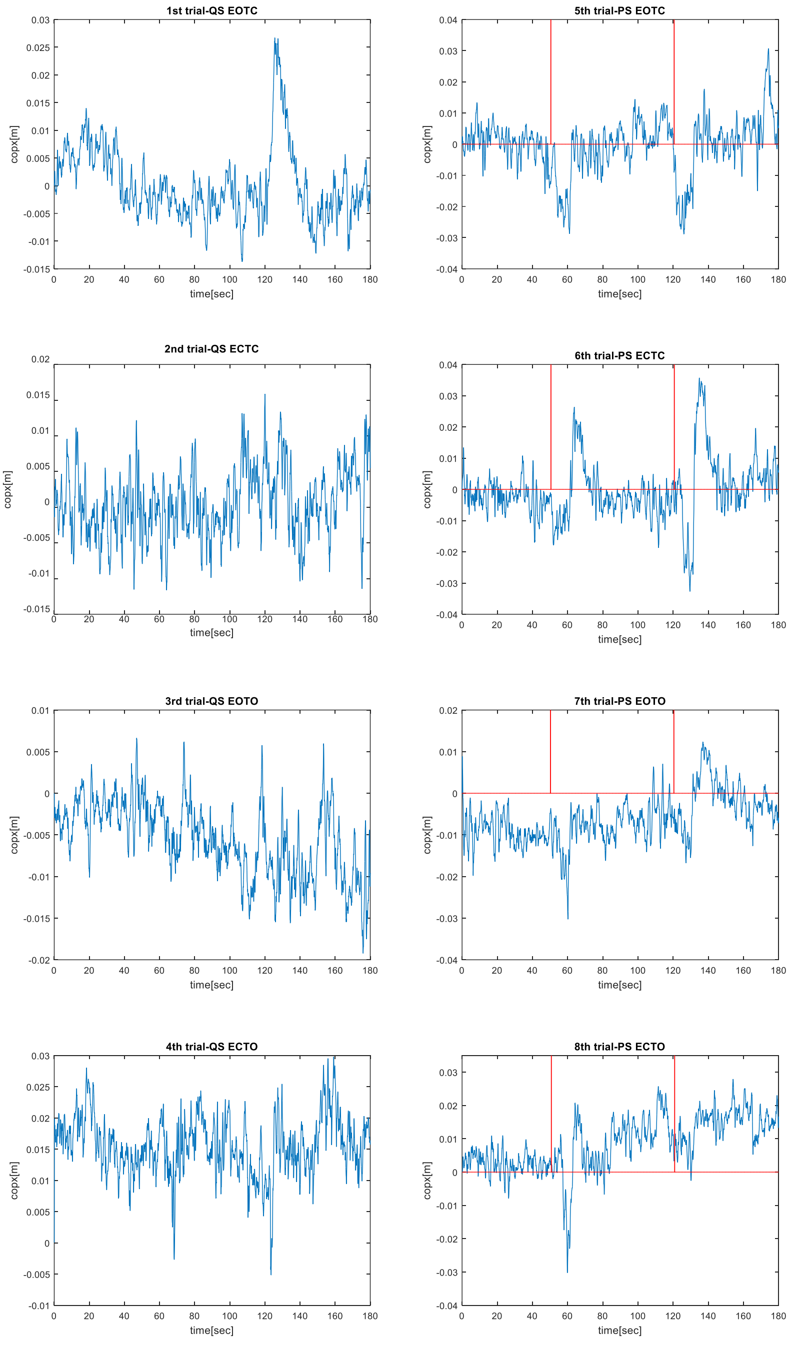

Figure B.14. CoPx Plots of the 6th Subject of the Swimmers Group

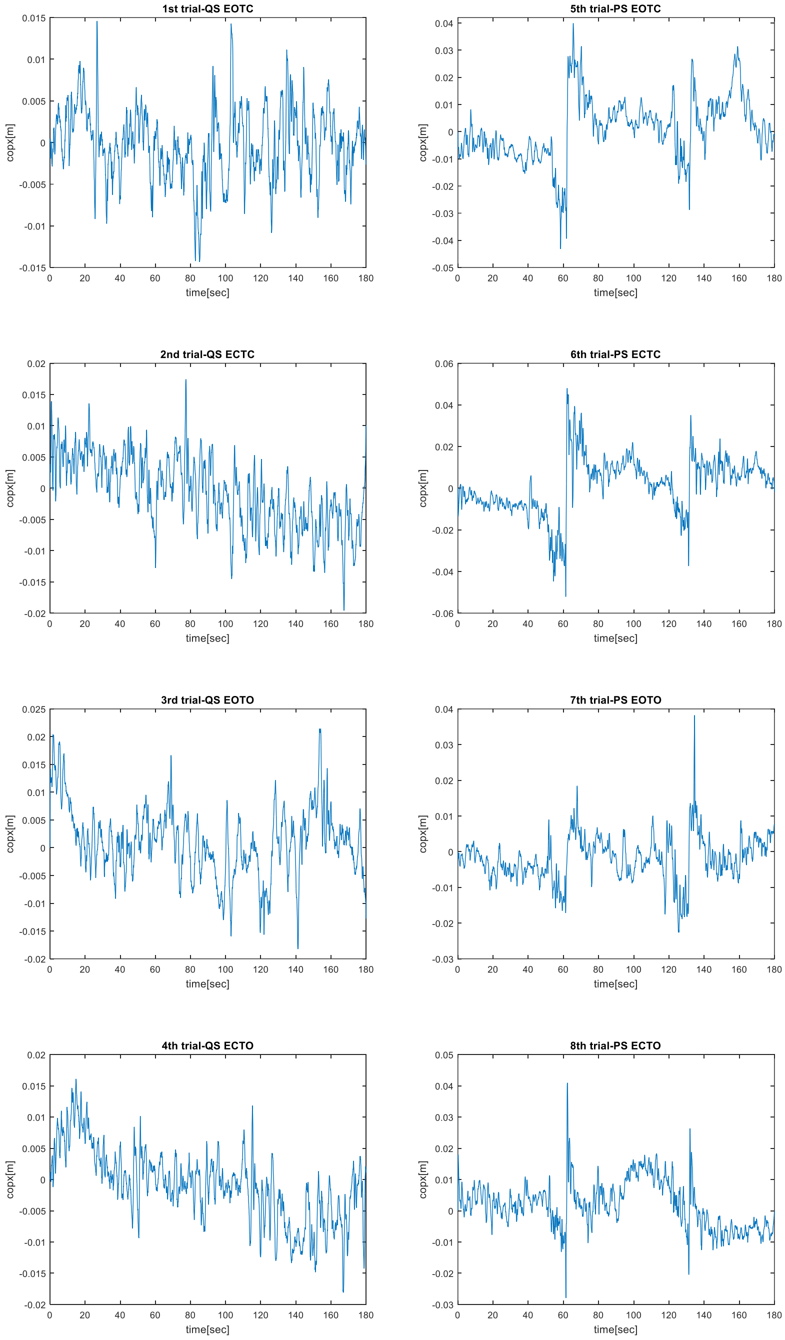

Figure B.15. CoPx Plots of the 7th Subject of the Swimmers Group

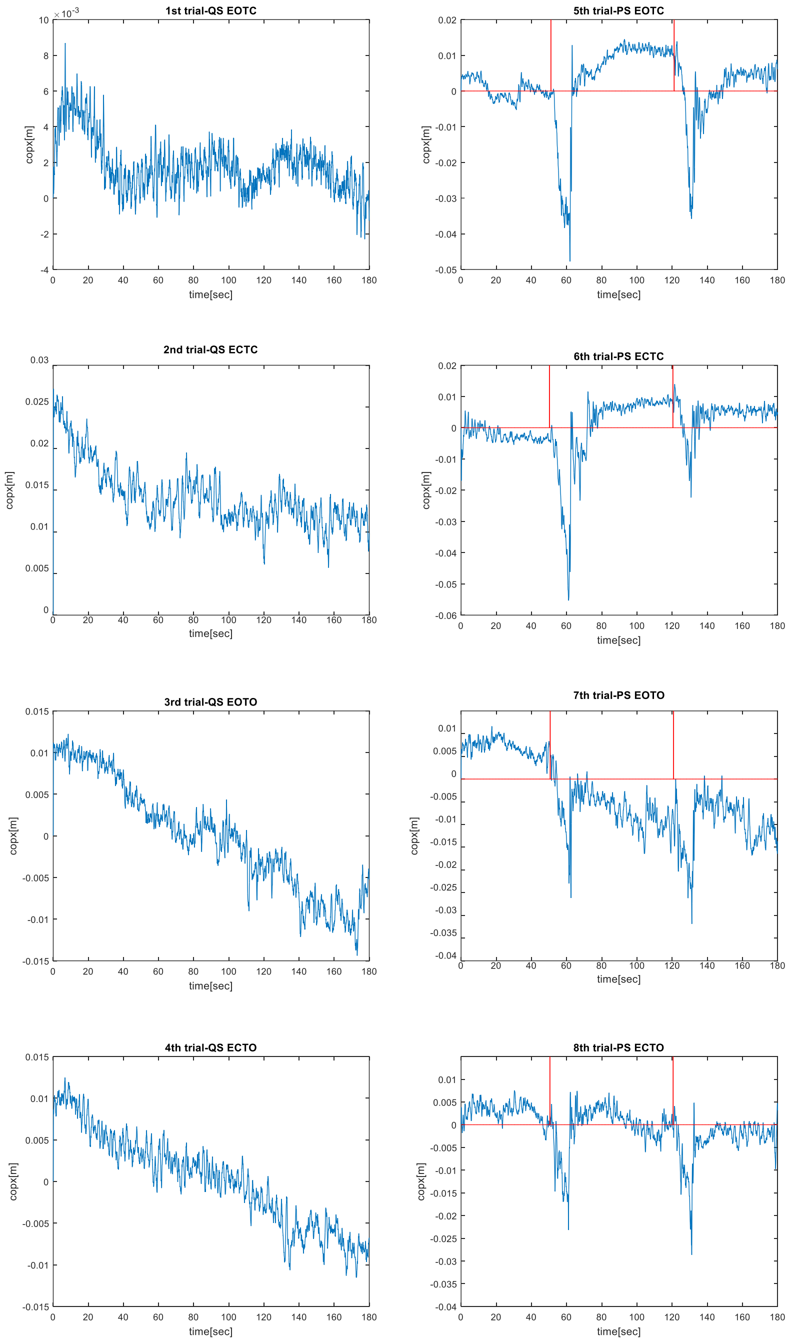

Figure B.16. CoPx Plots of the 8th Subject of the Swimmers Group

C. CoPx PLOTS OF THE SEDENTARY GROUP

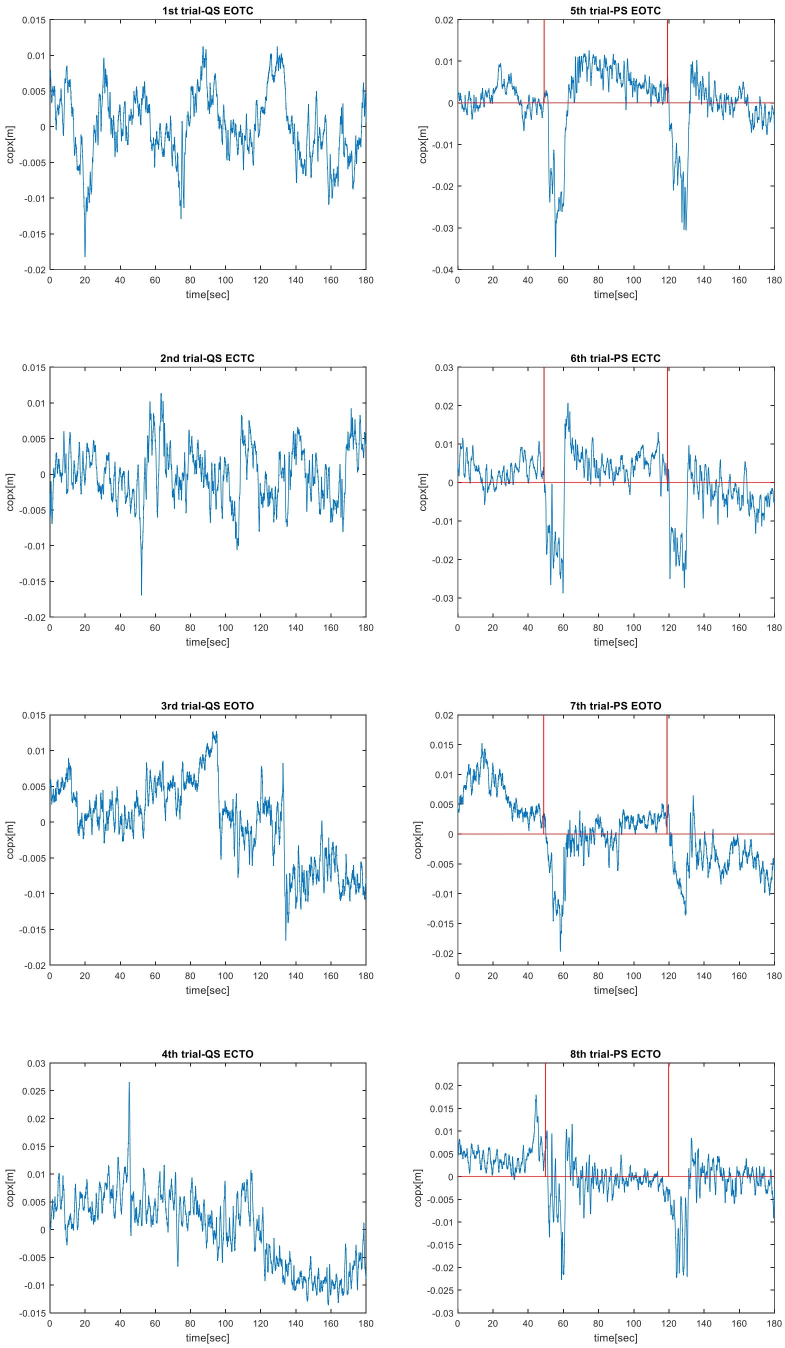

Figure C.17. CoPx Plots of the 1st Subject of the Sedentary Group

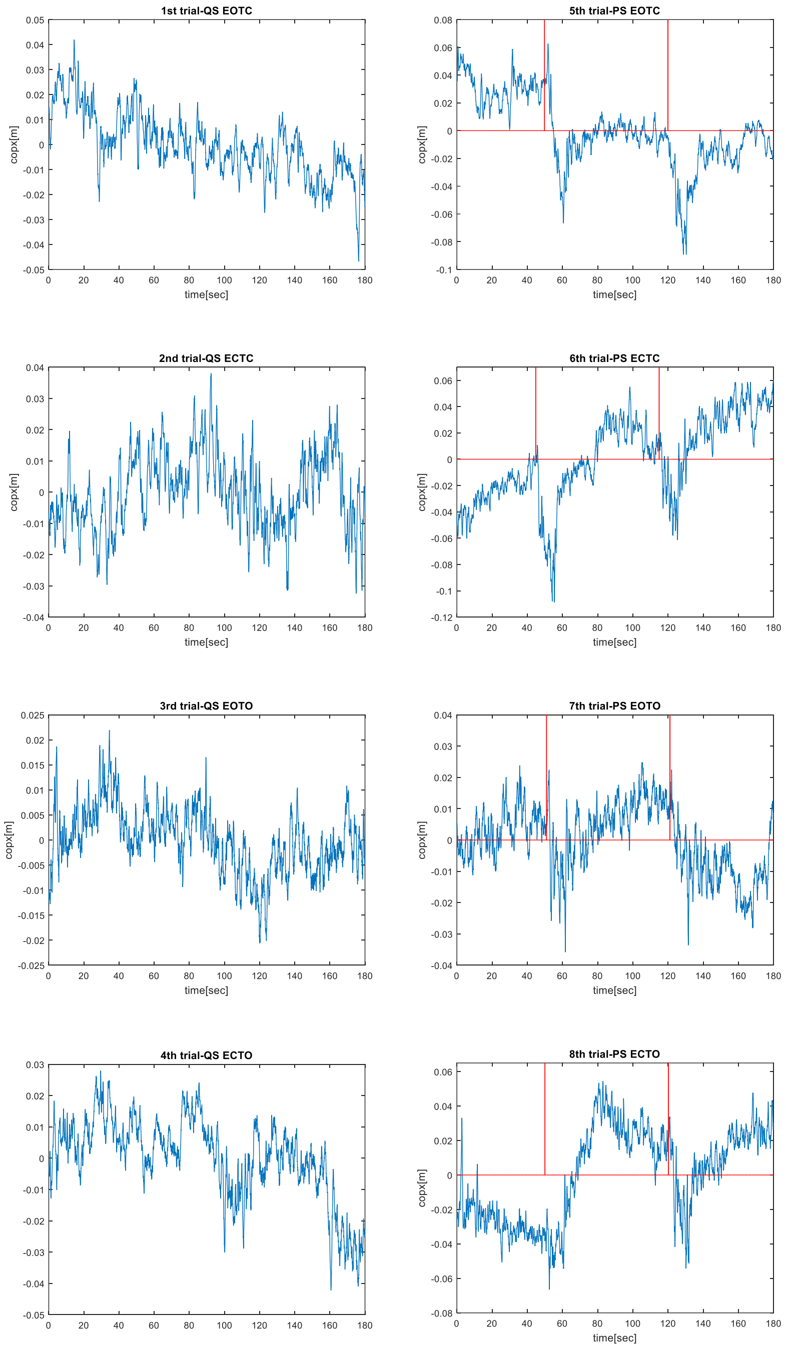

Figure C.18. CoPx Plots of the 2nd Subject of the Sedentary Group

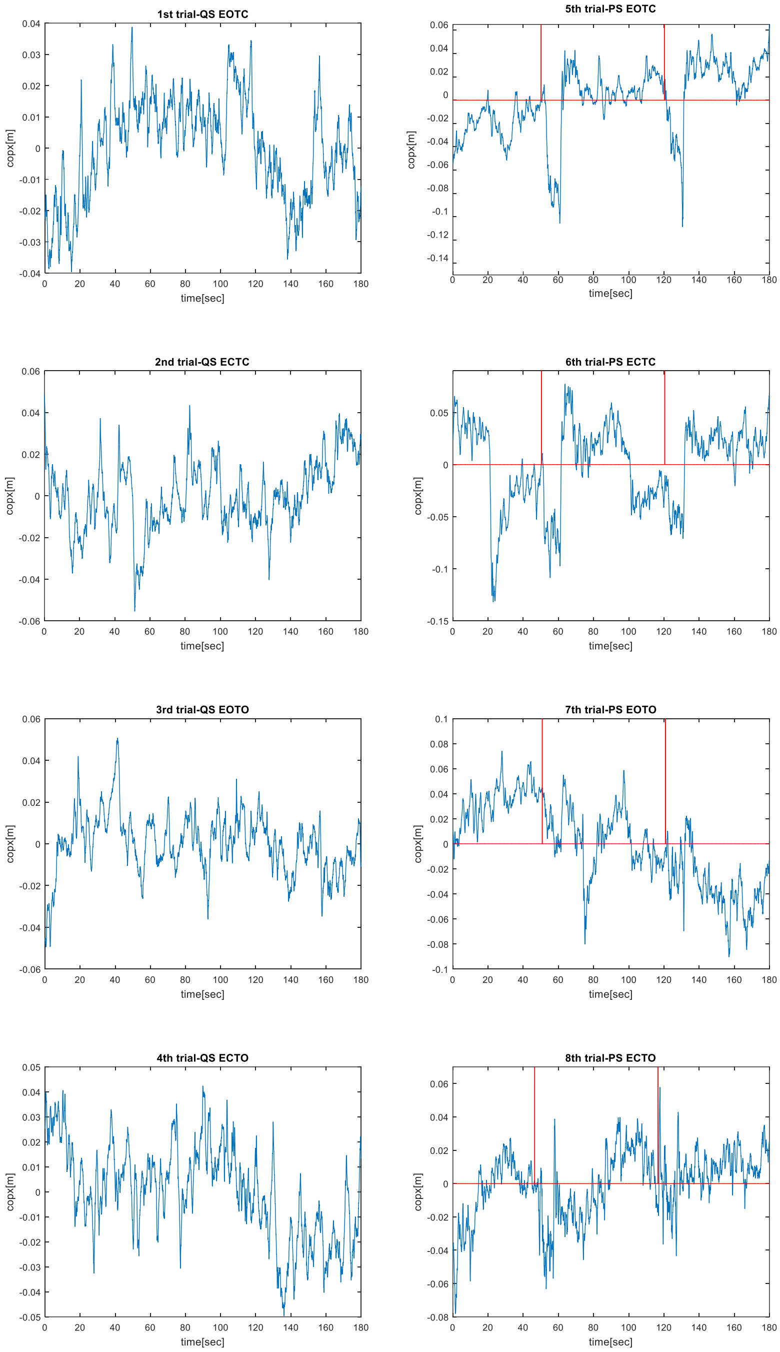

Figure C.19. CoPx Plots of the 3rd Subject of the Sedentary Group

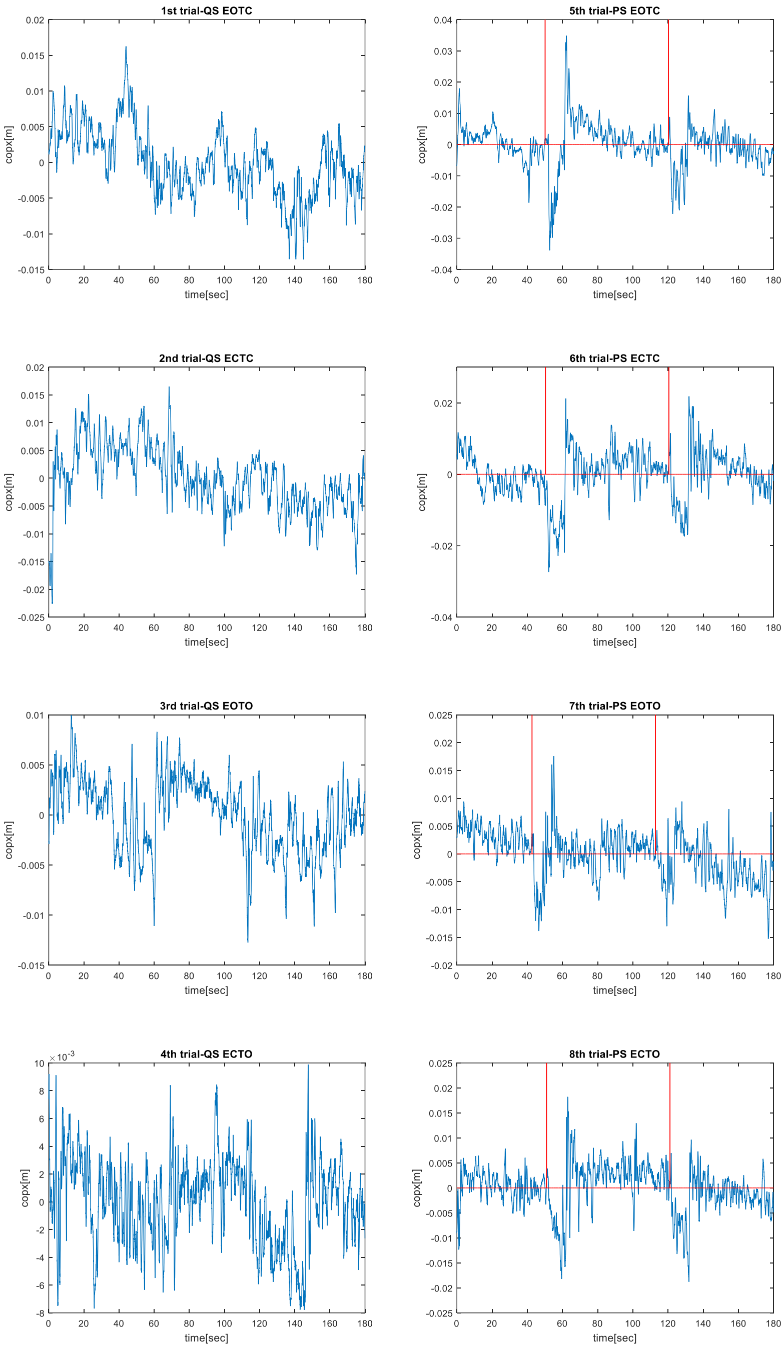

Figure C.20. CoPx Plots of the 4th Subject of the Sedentary Group

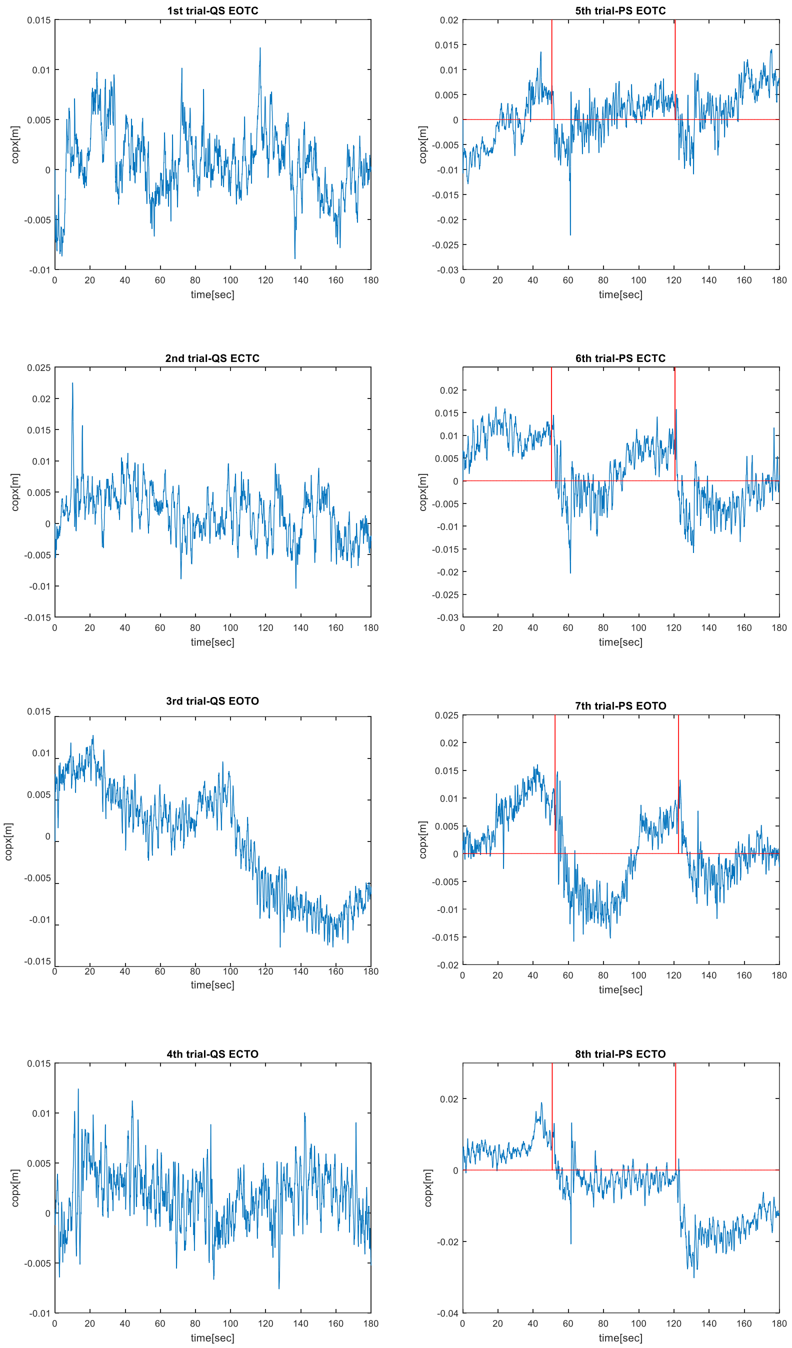

Figure C.21. CoPx Plots of the 5^{th} Subject of the Sedentary Group

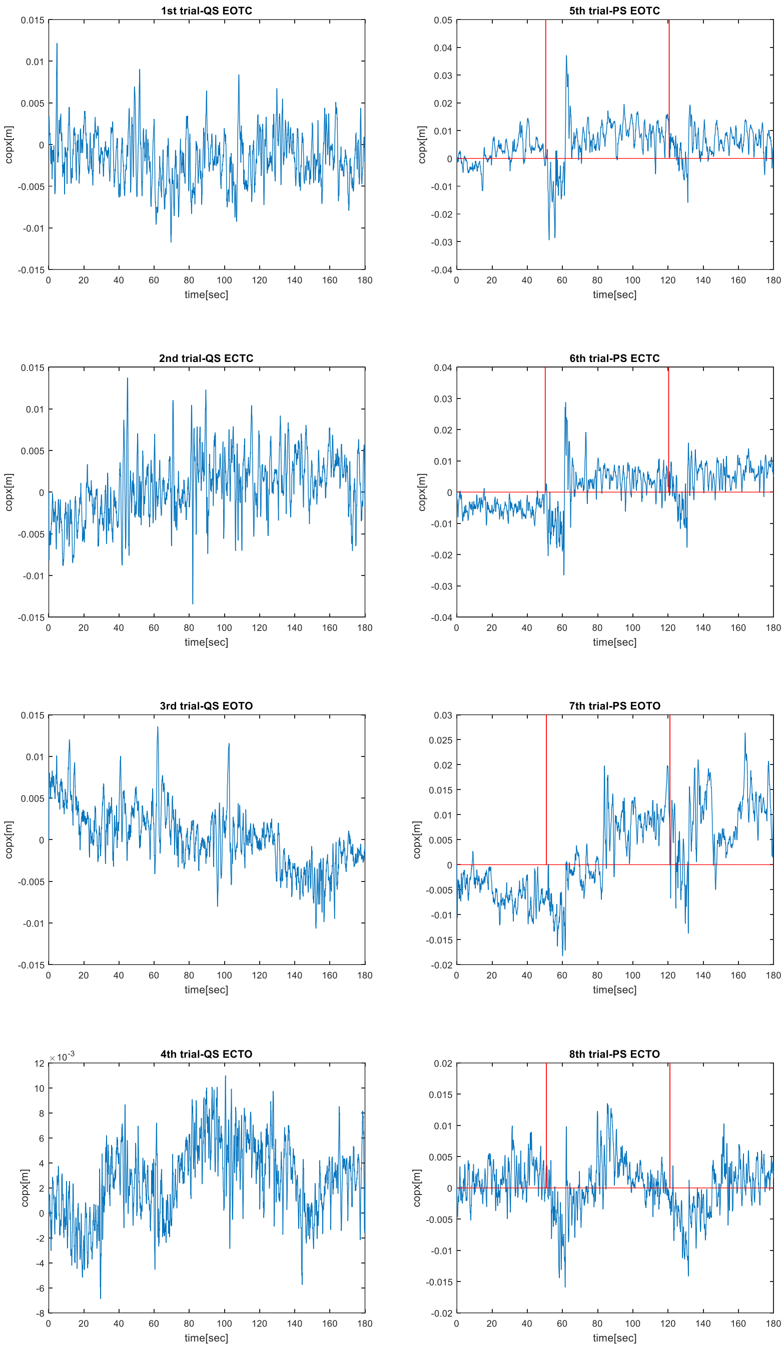

Figure C.22. CoPx Plots of the 6th Subject of the Sedentary Group

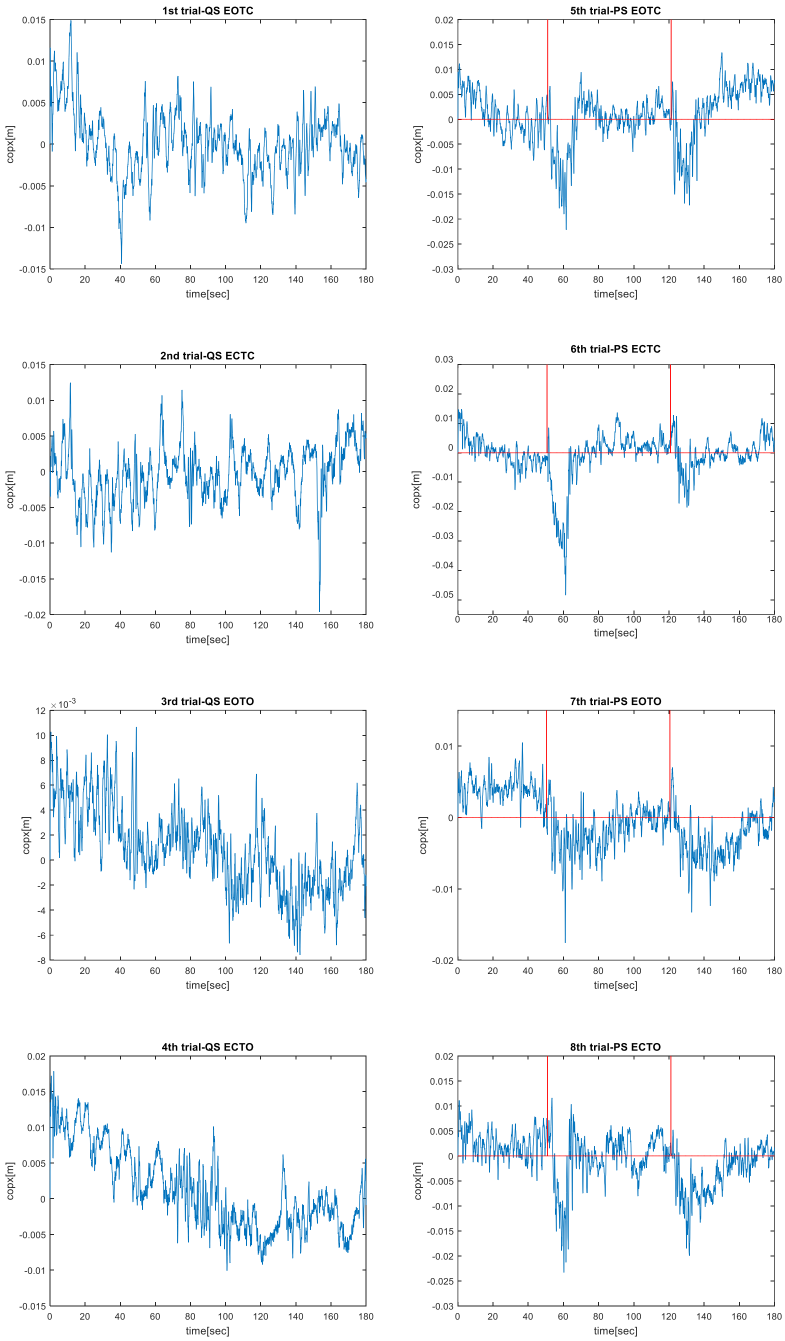

Figure C.23. CoPx Plots of the 7th Subject of the Sedentary Group

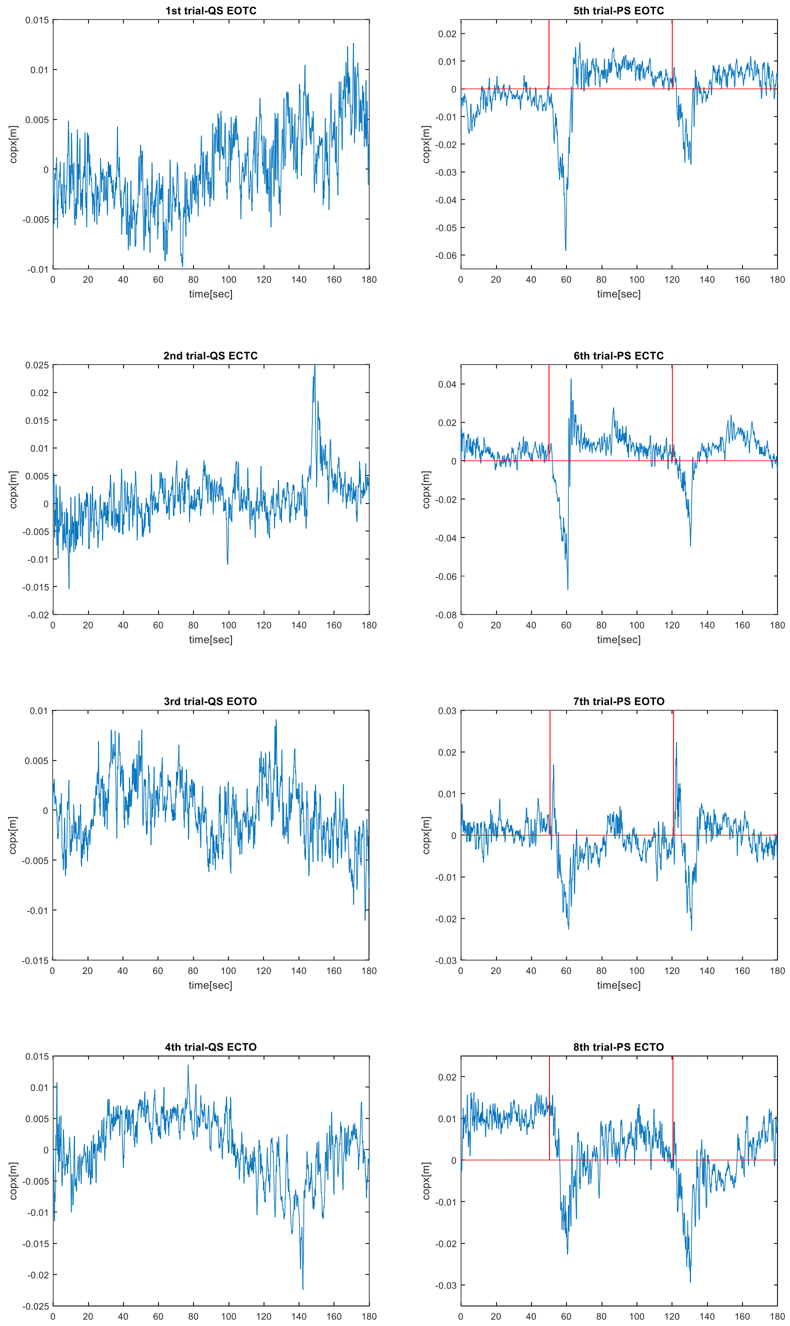

Figure C.24. CoPx Plots of the 8th Subject of the Sedentary Group

D. SUBJECT INFORMATION

Table D.1. *Subject Information*

Group	Subject Number	Weight (kg)	Height (cm)	Age (years)	Sportive Experience (years)	Right (R) - Left (L) Handed
Handball Players	1	68	179	19	11	R
	2	82	192	21	8	R
	3	76	179	19	9	R
	4	70	178	19	12	R
	5	95.5	186	20	10	R
	6	91.5	x	20	11	R
	7	83	182	21	11	R
	8	80	179	23	13	L
	Mean	80.75	182.14	20.25	10.63	
	S.D.	9.57	5.15	1.39	1.60	
Swimmers	1	57	167	15	10	R
	2	101	194	25	20	R
	3	84	185	20	11	R
	4	87	179	21	14	R
	5	69	x	x	x	x
	6	69	x	20	10	R
	7	71	172	19	13	R
	8	67	179	20	15	R
	Mean	75.63	179.33	20.00	13.29	
	S.D.	14.01	9.52	2.94	3.55	
Sedentary	1	63	160	30	4.5	R
	2	98	187	34	13	R
	3	74	176	22	3	R
	4	70	170	32	0	R
	5	77	170	32	0	R
	6	62	161	27	2	R
	7	70	x	24	0	R
	8	78.5	170	28	0	R
	Mean	74.06	170.57	28.63	2.81	
	S.D.	11.35	9.16	4.17	4.46	