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Effect of Vestibular Adaptation Exercises on Chronic Motion Sensitivity

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Effect of Vestibular Adaptation Exercises on Chronic Motion Sensitivity

by

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Each person whose signature appears below certifies that this dissertation in his/her opinion is adequate, in scope and quality, as a dissertation for the degree Doctor of Science.

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ABBREVIATIONS

VOR	Vestibular Ocular Reflex
VSR	Vestibular Spinal Reflex
VVC	Visual–Vestibular Conflict
VR	Virtual Reality
VE	Virtual Environment
IVR	Immersion Virtual Reality
UVD	Unilateral Vestibular Hypofunction
SSC	Semicircular Canals
HIT	Head Impulse Test
BVH	Bilateral Vestibular Hypofunction
HSN	Head Shaking-Induced Nystagmus Test
cDVA	Computerized Dynamic Visual Acuity
CDP-IVR	Computerized Dynamic Posturography with Immersion Virtual Reality
SD	Standard Deviation
SE	Standard Error
BMI	Body Mass Index

ABSTRACT OF THE DISSERTATION

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by

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Doctor of Science, Graduate Program in Physical Therapy
Loma Linda University, December 2015
Dr. Eric Johnson, Chairperson

Dizziness is one of the most common complaints reported to primary care physicians. It is often associated with vestibular dysfunction and typically impacts postural stability. Motion sickness, or motion sensitivity, is stimulated by abnormal spatial orientation and is a common symptom related to dizziness and postural instability. The main cause of the motion sensitivity is aberrant sensory input from the visual, vestibular and somatosensory systems. The aim of this study was to measure the effect of vestibular adaptation exercises on postural stability in young healthy adults with subjective awareness of chronic motion sensitivity.

Methods: Fifty healthy male and female participants between 20 to 40 years of age with chronic motion sensitivity were randomly assigned to either an experimental or control group. Postural stability measurements were taken at baseline and after 6 weeks using computerized dynamic posturography with immersion virtual reality. The experimental group performed daily vestibular adaptation exercises for 6 weeks.

Results. There was no significant difference between the two groups at baseline in terms of mean age, height, weight, BMI or baseline postural stability scores ($p>0.05$). Significant differences in mean postural stability scores were observed post intervention

in both groups but larger improvements were detected in the experimental group ($p=0.002$).

Conclusions: Minimal dosage of vestibular adaptation exercises improved postural stability in younger adults with chronic motion sensitivity. Additionally, familiarity of the testing environment during post-test measurements may have contributed to improvements in the control group over time; however, changes were greater in the experimental group.

CHAPTER ONE

INTRODUCTION AND REVIEW OF THE LITERTURE

Postural Stability

The ability to maintain balance is essential for everyday life. Simple definition of postural stability is the ability to maintain equilibrium and orientation of our body in a gravitational environment [(1)]. It involves the stability of body's position in space in order to obtain stability and orientation [(2)]. Postural stability is a complex process requiring central processing of peripheral sensory inputs [(3)].

There are three sensory inputs (visual, somatosensory and vestibular) works together to delivered output systems [(4)]. The afferent input from these systems is processed in the vestibular nuclear complex and cerebellum driving in two primary reflexes for visual and postural stability, the vestibulo-ocular reflex (VOR) and vestibulo-spinal reflex (VSR), respectively (Figure 1) [(5)]. The VOR maintains stability of the image on the fovea of the retina (where visual acuity is best) during head motions by producing compensatory eye movements (Figure 2) [(6-9)]. The VSR maintains postural stability through the musculoskeletal system during quiet and dynamic activities [(10,11)]. Sensory input and processing conflicts, particularly between the visual and vestibular systems, can result in disturbance of postural stability leading to disequilibrium and motion sickness [(4)].

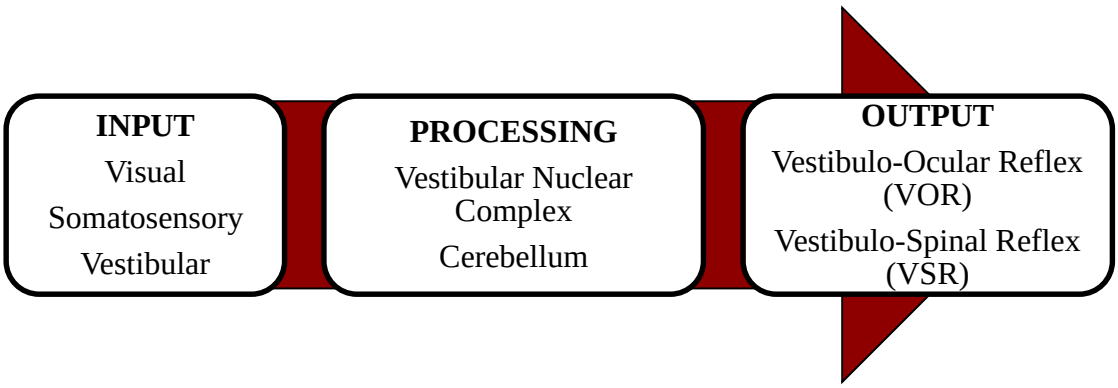

Figure 1. Postural control

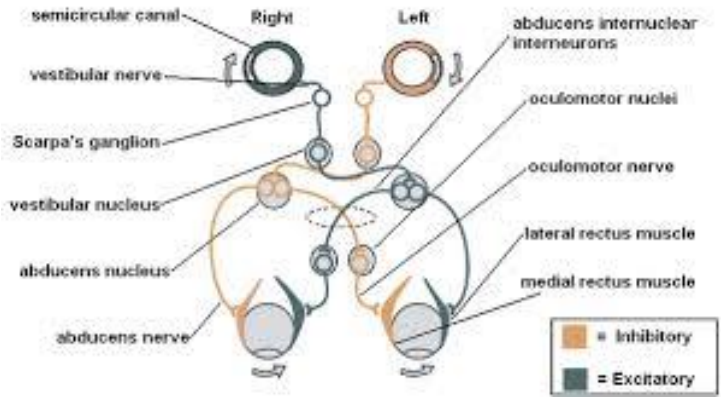

Figure 2. Vestibulo-ocular reflex

Healthy people commonly experience postural instability when exploring their surrounding visual environment while standing on unstable surfaces or when in virtual reality (VR) environments [(12)]. Therefore, posture instability had a major rule to promote the symptom motion sensitivity [(13)].

Motion Sensitivity

Akin and Davenport described motion sensitivity as "a disturbing sense of vertigo or dizziness associated with head movement" and is often caused by vestibular

dysfunction [5,14]. Moreover, motion sickness, or motion sensitivity, is stimulated by abnormal spatial orientation and is a common symptom related to dizziness and postural instability [15]. Additional symptoms associated with motion sensitivity include nausea, vomiting and cold sweating [12]. Motion sensitivity and postural stability can be influenced by gender, age, psychological status and the environment [16]. Many otherwise healthy people experience motion sensitivity during activities including riding roller coasters, boat rides, and/or reading in moving vehicles. As a result, they often avoid these activities because it produces motion sensitivity symptoms including dizziness, nausea, imbalance, and/or blurry vision [12,16].

Researchers found that motion sickness and postural instability might be caused by VR, which induced the visual–vestibular conflict (VVC) [15] and supported by sensory conflict theory. Conflicting of three sensory inputs information evoked the cause of the motion sickness and postural instability more than each specific individual input [4].

In healthy people literature found that there was a relation between motion sickness and motion discomfort [12]. People with postural instability have more capability to self-report history of motion sensitivity symptoms [12].

The motion sensitivity symptoms are different between each individual. Further more, each person has different intensity and duration of the symptoms that ranged from low to sever symptoms. However, by the repetitions of being exposures to the motion, motion adaptation will lead to decrease the symptom of the motion sensitivity [17].

Virtual Reality

Variety of visual scene was created through computer graphics technology called

VR that makes people feels immersed in the VR. However, there are different interactions of the head movements and the display of the VR scene between the VR in the real world and technology world. And based on the interaction a results of VVC. More over, the VVC enhance the individual to adapt to the new scene. Therefore, motion sensitivity and postural instability might produce [18].

In the VR literature, instability of the posture might produce by a virtual environment (VE), which could interfere with the safety of some activities [4].

Simulated VR and related technologies have been used to demonstrate the relationship between motion sensitivity and postural stability [19]. Akiduki et al reported that motion sensitivity and postural instability are caused by a VVC that can be reproduced in VR environments [15].

Hoffman et al reported that immersion virtual reality (IVR) is a false reality created in the mentality of the VR user with the help of advanced computer technology [20]. The VE creates a false of entering the computer-generated world by converging the various multisensory inputs [20]. Motion sensitivity and decreased postural stability can be exacerbated in VR environments [12,18,21].

Vestibular Adaptation

Dizziness is considered as one of the most common medical complaints in the United States, which might cause by vestibular dysfunctions [22]. Dizziness is defined as a sensation of light-headedness, imbalance, disequilibrium, vertigo, and oscillopsia [6,23,24].

Vestibular rehabilitation has been shown in the literature to decrease complaints of dizziness in patients with vestibular dysfunction [25,26]. Furthermore, with the scientific

development in the medical field, the use of the vestibular rehabilitation increased in demand as major treatment for vestibular dysfunction [27].

The vestibular system is located in the inner ear and is comprised of three semicircular canals, the utricle and saccule [5]. The vestibular system along with the visual and somatosensory systems, are the primary systems contributing to motion and postural stability [5].

Several investigators have reported on the relationship between vestibular dysfunction and the effect of vestibular adaptation exercises on postural stability and dizziness [28-30]. Giray et al reported significant improvements after performing vestibular adaptation exercises in patients with chronic unilateral vestibular dysfunction (UVD) [28]. Hall et al reported that patients with UVD had decreased fall risk after performing vestibular adaptation exercises [29]. Additionally, Morimoto et al reported that vestibular adaptation exercises improved the gaze stability and postural stability after three weeks in healthy young adults [30].

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CHAPTER TWO

VESTIBULAR ADAPATATION EXERCISE PRESCRIPTION:

A REVIEW OF THE LITERATURE

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Abstract

Dizziness is considered to one of the most common medical complaints in the United States, which might cause by Vestibular dysfunctions. Vestibular rehabilitation has been shown in the literature to decrease complaints of dizziness in patients with vestibular dysfunction. By clinical assessment of vestibular system will determine the vestibular dysfunction by taken appropriate history and evaluation of eye movements and balance. The vestibular system consists of three important components that work together to provide visual acuity and postural stability during head movement. Vestibular adaptation exercise aimed to improve the function of the VOR through visual fixation on a target during head movement. The purpose of this paper was to review the literature of vestibular adaptation exercise prescription.

Key Words: Vestibular system, vestibular dysfunction, vestibular rehabilitation

Vestibular Dysfunction

Vestibular dysfunctions are classified as either peripheral or central vestibular disorders. Peripheral vestibular disorders affect the peripheral sensory apparatus or the vestibular nerve while central vestibular disorders affect the vestibular nuclear complex, central protrusion that distributed to the vestibular ocular reflex (VOR) and vestibular spinal reflex (VSR), brainstem, or cerebellum [1]. Vestibular dysfunction can cause dizziness, which is considered to one of the most common medical complaints in the United States [2]. Dizziness is defined as a sensation of light headedness, imbalance, disequilibrium, vertigo, and oscillopsia [3-5]. Patients with dizziness have increased risk for falls and lower quality of life [6-8]. Vestibular rehabilitation has been shown in the literature to decrease complaints of dizziness in patients with vestibular dysfunction [9,10]. Furthermore, with the scientific development in the medical field, the use of the vestibular rehabilitation increased in demand as major treatment for vestibular dysfunction [11].

Vestibular Anatomy and Physiology

The vestibular system consists of three important components that work together to provide visual acuity and postural stability during head movement [1]. These components include:

1) Peripheral sensory apparatus (located in the inner ear), which is responsible for, identify and deliver information of head angular and linear velocity in addition to direction of the head with respect to gravity to the central processing system [1,5,12].

2) Central processing system (located in the vestibular nuclear complex in the brain

stem and the cerebellum), which operate vestibular system input with other sensory inputs (somatosensory and visual) and produce accurate information of the head position and movement [1,5,12].

3) Motor output system that interferes through the VOR and VSR and cause compensatory eye movements and body movements for gaze stability and postural stability respectively during head movements, posture, and locomotion [1,5,12].

Acceleration of head movement is detected by neural structures located in the membranous vestibular labyrinth [1,5]. The anterior, posterior, and horizontal semicircular canals (SCC) detect angular acceleration and are orthogonal with respect to each other [5,12]. Each SCC has a contralateral coplanar pair. The horizontal SSC's form a coplanar pair while the vertical (posterior and contralateral anterior) SCC's form coplanar pairs. Each of the SSC's responds best to motion in its own plane, with coplanar pairs exhibiting a push-pull dynamic [1,5,12]. In response to the direction and acceleration of the angular head movement, endolymph, which contains a high concentration of potassium and lower concentration of sodium, moves freely within each SCC [5].

The SSC's enlarge at one end to form the ampulla, and within the ampulla lies the cupula, which is a gelatinous obstacle that contains the sensory hair cells [5]. The depolarization of the hair cells in the horizontal SCC occurs when the endolymph moves toward the ampulla, while depolarization occurs when endolymph moves away from the ampulla in the vertical SSC's (posterior and anterior) [5]. The otolith organs of the membranous labyrinth consist of saccule and utricle. Hair cells of the otolith project into a gelatinous article that has calcium carbonate crystals called otoconia [5].

When the head moves, the hair cells of the SSC's and otoliths transform the

mechanical energy to neural discharges, which controlled by brainstem and the cerebellum. The SSC's and otolith organs are able to react to head movement in special order by the reaction of their orientation. "The SSC's respond to angular velocity, and the otoliths to linear acceleration due to differences in their fluid mechanics" [12].

Vestibular Hypofunction Physical Examination

Clinical assessment of vestibular system will determine the vestibular dysfunction by taken appropriate history and evaluation of eye movements and balance.

Head Impulse Test (HIT)

The HIT [13] is performed with the patient sitting and positioning their head into 30 degrees of cervical flexion. The patient is asked to focus on the clinician's chin while unpredictable small amplitude and high velocity passive rotation movements are performed. The clinician observes for corrective saccades at the conclusion of each movement then slowly returns the patient's head to center. The test is repeated several times in each direction. Schubert et al reported that the sensitivity of the HIT for identifying vestibular hypofunction was 71% for unilateral vestibular hypofunction (UVH) and 84% for bilateral vestibular hypofunction (BVH); specificity was 82% [14].

Head Shaking-induced Nystagmus Test (HSN)

The HSN [13] is performed with the patient sitting while the clinician positions their head into 30 degrees of cervical flexion. The patient is asked to close their eyes while the clinician passively rotates the patient's head at a speed of approximately 2 Hz

for 20 repetitions. The clinician observes for nystagmus after the patient's open their eyes [5]. Pérez et al reported the sensitivity of the HSN for peripheral vestibular dysfunction was 48.8% and specificity was 95% [15].

Computerized Dynamic Visual Acuity (cDVA)

The cDVA [13] is performed with the patient sitting in front of a monitor and fitted with a velocity sensor on their head. The computer will display an optotype (letter E) in four different directions (up, down, left, right). The patient is instructed to actively rotate their head between 120 degrees/second and 180 degrees/second. The differences between static and dynamic cDVA scores are calculated. Herdman et al reported that sensitivity of the cDVA was 94.5% and specificity was 95.2% [16].

Adaptation Exercises Prescription

The main purpose of vestibular adaptation exercises is to improve the function of the VOR through visual fixation on a target during head movement "head–eye coordination" [17]. The two primary vestibular adaptation exercises are visual fixation on a fixed target and visual fixation on a moving target. Patients should begin adaptation exercises without visual distractions (plain background) with tolerable speed, repetitions, and frequency and progressed as able [18,19]. Vestibular adaption exercises are ideally performed 3-5 times daily for up to two minutes. Physical therapists are required to develop, monitor, and evaluate the progression of the adaptation exercises taking in to consideration the stage of vestibular dysfunction of the patients [20,21]. To maximize the benefits of adaptation exercises, they should be designed to reflect the patient-specific

function and environment [11].

Improving the functionality of the patients through vestibular adaptation exercises is dependent on the duration of the dysfunction and may take more than the generally expected recovery time of 6 weeks [22]. The average duration of vestibular rehabilitation therapy programs range from 4 to 10 weeks [11].

The vestibular system modifies the stimulation of VOR slowly over a period of several hours or days in the most experimental models, however, because of the vertigo, nausea, and vomiting that can be induced by head movement, "prolonged stimulation is not clear in the acute stage after UVH in human beings" [10].

It has been reported in the literature that "short-term periods of unidirectional optokinetic stimulation (30 seconds, 10 times daily for 10 days) can produce VOR gain changes after UVH in human beings compared with non-treated patients". Therefore, it has been hypothesized that even brief periods of stimulation can produce recovery of vestibular function. Moreover, "73% of the subjects who performed the vestibular adaptation exercises had a normal VOR on clinical examination" [10,23].

According to a systematic review of vestibular rehabilitation for UVH, "the dosage (frequency, intensity, and timing) and specifics of vestibular rehabilitation (e.g. compensatory, adaptation, substitution, task-specific) is not clear from the largely heterogeneous studies. However, it appears even a minimalist approach of education, demonstration and home exercises may be effective" [24].

Giray et al found in randomized control trail, that short term (4 week) of customized vestibular rehabilitation, which includes adaptation, substitution, visual desensitization and balance exercises affects in the chronic UVH patients. Patients who

went to the experimental group had significant improvement in the postural stability and balance with decreased symptoms comparing to the patients who went to the control group as measured by unsteadiness Visual Analog Scale, Dizziness Handicap Inventory, Berg Balance Scale and computerized dynamic posturography. Customized vestibular rehabilitation was prescribed to the patients by a physical therapist based on the patient's history, physical assessments and diagnosis [25].

Herdman et al found in prospective randomized, double blind trial, that vestibular exercises enhance the vestibulo-ocular reflex and facilitates recovery of visual acuity during head movement in patients with UVH and BVH. Both groups underwent to the measurements of predictable / unpredictable DVA head movement by the computer test and oscillopsia by visual analog scale (VAS). Experimental group performed adaptation exercise, eye head exercise to targets to improve gaze stability, gait and balance exercise. While placebo exercise perform saccadic eye movement exercise without moving the head, gait and balance exercise that not includes head movements, then they switch to the vestibular exercise after 4 weeks for the UVH and after 6 weeks for the BVH. There was significant improvement in both predictable and unpredictable DVA (P<. 001) in experimental group comparing to the placebo group (p=. 07) [20,21].

Krebs et al found in a double blind, placebo-controlled randomized trial that vestibular rehabilitation for UVH or BVH effects in gait velocity and stability. Patients who went to the vestibular rehabilitation group had gait velocity and stability significantly (P < 0.01) increased after 6 weeks comparing to the strengthening exercise group. However, when both groups had vestibular rehabilitation at 12 weeks, the difference was small (P =0.05). And there were no differences at 1 year between the

groups as measured by locomotor stability, gait speed and base of support. Patients who went under vestibular rehabilitation group performed gaze stability and balance retraining exercises for 6 weeks followed by 6 weeks of home vestibular rehabilitation exercises. While patients who went under placebo group performed 6 weeks of isometric strengthening exercises followed by 6 weeks of vestibular rehabilitation [26].

Pavlou et al found in randomized control trail with chronic peripheral vestibular hypofunction patients that both customized vestibular rehabilitation (gaze control and stability, balance training) and simulator groups (organizing whole-body or visual environment rotators) improved significantly in posturography and subjective scores. However, simulator group showed better statistical improvement for visual vertigo symptom scores $p<0.01$. The difference between groups was significant for posturography scores ($p=0.02$) [27].

Vestibular Adaptation Exercises Physiology

To maintain the stability of the image in the retina of the fovea (where visual acuity is best) and postural control while head is moving to either direction is expose and improved by VOR which produce the compensatory equal eye movement but in the opposite direction of the head movement [5,28-30]. The ability to maintain the stability and whole body equilibrium was produced by VSR. The skeletal extensor muscles assist the head movement acceleration by facilitation and inhibition [23,31].

It has been well established that the VOR gain can be rapidly adapted by producing an imbalance between the visual and vestibular information. The short-term adaptive changes in VOR gain can be induced by moving a visual stimulus on the same

time with the movement of the head [32-35]. The VOR has two components. The angular VOR is mediated by the SSC's and is responsible for gaze stabilization during cervical flexion, extension, and rotation. The linear VOR is mediated by the otoliths during translator movements where the head is moving with high frequency and simultaneously viewing objects [12].

The neurophysiology description of the horizontal SSC VOR is prescribed as following:

1. "When the head turns to the right, endolymphatic flow deflects the cupulae to the left".
2. "The discharge rate from hair cells in the right crista increases in proportion to the velocity of the head motion, while the discharge rate from hair cells in the left horizontal crista decreases".
3. "These changes in firing rate are transmitted along the vestibular nerve and influence the discharge of the neurons of the medial and superior vestibular nuclei and cerebellum".
4. "Excitatory impulses are transmitted through white matter tracts in the brainstem to the oculomotor nuclei, which activate the right (ipsilateral) medial rectus and the left (contralateral) lateral rectus. Inhibitory impulses are also transmitted to their antagonists".
5. "Simultaneous contraction of the left lateral rectus and right medial rectus muscles, and relaxation of the left medial rectus and right lateral rectus occurs, resulting in lateral compensatory eye movements toward the left".
6. "If the eye velocity is not adequate for the given head velocity and retina image

motion is greater than 2 degree per second, the cerebellar projection to the vestibular nuclei will modify the firing rate of the neurons within the vestibular nuclei to reduce the error" [12].

During head movements, the performance of vestibular adaptation increased when different amplitudes of retinal slip applied. Practicing adaptation exercise that progressively increasing retinal slip errors is further useful than the use of sudden, large errors. "The greatest changes in VOR gain occur at the training frequencies". However, it should not be changed suddenly [36].

"During the acute stage following unilateral vestibular dysfunction, the VOR gain is as low as 0.25 and 0.5 for rotation of the head toward and away from the involved side (normal VOR gain is usually between 0.5 and 0.8). The gain of the horizontal VOR recovers quickly and is within normal limits in 1 to 3 months for slow head rotations" [37,38].

The VOR_gain can increase from 10%–35% with exposure to artificial retinal slip during head rotation for minutes to hours. However, "exposure to an adaptation stimulus lasting hours to days produces gain changes of 60% to 100% of the adaptive need". Recent investigation found that long duration of VOR training produce more VOR gain compared to short VOR training times [36].

There are some considerations of the mechanisms behind the adaptation of VOR. Learning takes multiple time scale, with different percentage of both learning and forgetting (seconds, minutes, hours, days, and months), however, relearning on identical function will be take place once forgotten (recall). Training arrangement affects learning

and forgetting, and rest periods between training session affects the retention of learning [36].

The VSR contains more than one reflexes according to the timing (dynamic versus static or tonic) and sensory input (SSC versus otolith). For instance, the sequence in generating a labyrinthine reflex as following [12]:

1. "When the head is tilted to one side, both the SSC's and otoliths are stimulated. Endolymphatic flow deflects the cupula and shear force deflects hair cells within the otoliths"
2. "The vestibular nerve and vestibular nucleus are activated".
3. "Impulses are transmitted via the lateral and medial vestibulospinal tracts to the spinal cord".
4. "Extensor activity is induced on the side to which the head is inclined, and flexor activity is induced on the opposite side. The head movement opposes the movement registered by the vestibular system" [12].

Conclusion

There are three primary inputs that contribute to maintain our balance and to see the image clearly with head movement. These systems will process in the vestibular nuclear complex in the brain stem and the cerebellum. Therefore, it is going to drive to two primary output, which are VOR and VSR. Based on the clinical assessment of vestibular system will determine the vestibular dysfunction by taken appropriate history and evaluation of eye movements and balance. More over, adaptation exercise prescription will be developed to reflect the patient-specific function and environment

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CHAPTER THREE

EFFECT OF VESTIBULAR ADAPTATION EXERCISE ON CHRONIC MOTION SENSITIVITY

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Abstract

Background: Dizziness is one of the most common complaints reported to primary care physicians. It is often associated with vestibular dysfunction and typically impacts postural stability. Motion sickness, or motion sensitivity, is stimulated by abnormal spatial orientation and is a common symptom related to dizziness and postural instability. The main cause of the motion sensitivity is aberrant sensory input from the visual, vestibular and somatosensory systems. The aim of this study was to measure the effect of vestibular adaptation exercises on postural stability in young healthy adults with subjective awareness of chronic motion sensitivity.

Methods: Fifty healthy male and female participants between 20 to 40 years of age with chronic motion sensitivity were randomly assigned to either an experimental or control group. Postural stability measurements were taken at baseline and after 6 weeks using computerized dynamic posturography with immersion virtual reality. The experimental group performed daily vestibular adaptation exercises for 6 weeks.

Results. There was no significant difference between the two groups at baseline in terms of mean age, height, weight, BMI or baseline postural stability scores ($p>0.05$). Significant differences in mean postural stability scores were observed post intervention in both groups but larger improvements were detected in the experimental group ($p=0.002$).

Conclusions: Minimal dosage of vestibular adaptation exercises improved postural stability in younger adults with chronic motion sensitivity. Additionally, familiarity of the testing environment during post-test measurements may have

contributed to improvements in the control group over time; however, changes were greater in the experimental group.

Keywords: Motion sensitivity, postural stability, vestibular rehabilitation

Introduction

Dizziness is one of the most common complaints reported to primary care physicians [1]. It is often associated with vestibular dysfunction and typically impacts postural stability [2]. Motion sickness, or motion sensitivity, is stimulated by abnormal spatial orientation and is a common symptom related to dizziness and postural instability [3]. Motion sensitivity and postural stability can be influenced by gender, age, psychological status and the environment [4]. Many otherwise healthy people experience motion sensitivity during activities including riding roller coasters, boat rides, and/or reading in moving vehicles. As a result, they often avoid these activities because it produces motion sensitivity symptoms including dizziness, nausea, imbalance, and/or blurry vision [4,5]. Additionally, healthy people commonly experience postural instability when exploring their surrounding visual environment while standing on unstable surfaces or when in virtual reality environments [5,6].

Simulated virtual reality and related technologies have been used to demonstrate the relationship between motion sensitivity and postural stability [7]. Akiduki et al reported that motion sensitivity and postural instability are caused by a visual-vestibular conflict that can be reproduced in virtual reality environments [3].

Akin and Davenport describe motion sensitivity as “a disturbing sense of vertigo or dizziness associated with head movement” that is often the result of vestibular dysfunction [8]. The vestibular system is located in the inner ear and is comprised of three

semicircular canals, the utricle and saccule [9]. The vestibular system, along with the visual and somatosensory systems, are the primary systems contributing to motion and postural stability. The afferent input from these systems is processed in the vestibular nuclear complex and coordinates the vestibulo-ocular reflex (VOR) and vestibulo-spinal reflex, respectively [9]. The VOR maintains stability of the image on the retina during head motions by producing compensatory eye movements for gaze stability [10-13]. The vestibulo-spinal reflex maintains postural stability through the musculoskeletal system during functional activities [14,15]. Improvement of the VOR can be achieved through vestibular adaptation exercises [16].

Several investigators have reported on the relationship between vestibular dysfunction and the effect of vestibular adaptation exercises on postural stability and dizziness [17-19]. Giray et al reported significant improvements after performing vestibular adaptation exercises in patients with chronic unilateral vestibular dysfunction [17]. According to Hall et al, patients with unilateral vestibular dysfunction had decreased fall risk after performing vestibular adaptation exercises [18]. Additionally, Morimoto et al used vestibular adaptation exercises to improve gaze stability and postural stability after three weeks in healthy young adults [19]. The purpose of this study was to measure the effects of vestibular adaptation exercises on postural stability in healthy young adults with sub-clinical chronic motion sensitivity.

Methods

Fifty healthy adults between 20 and 40 years of age with sub-clinical chronic motion sensitivity were recruited for this randomized controlled trial. Sub-clinical

chronic motion sensitivity was operationally defined as a history of avoiding activities causing dizziness, nausea, imbalance, and/or blurred vision without having a related medical diagnosis. Participants were included in the study if they reported avoiding activities such as reading while a passenger in a moving vehicle, driving on winding roads, boats, airplanes, horseback riding, roller coaster rides and quick movements due to symptoms consistent with motion sensitivity. Participants were excluded if they were currently taking medications causing dizziness or imbalance or had cervical spine orthopedic impairments, vestibular impairments or any neurological pathology. The Loma Linda University Institutional Review Board approved the study. All participants signed an informed consent prior to their beginning the study.

Participants were randomly assigned to either an experimental or control group using a random number table. The experimental group received vestibular adaptation exercises. Both groups received postural stability measurements at baseline and after six weeks using computerized dynamic posturography with immersion virtual reality (CDP-IVR) [20]. Additionally, the experimental group had a follow-up assessment at three weeks post-baseline to progress their vestibular adaptation exercises as tolerated. Participants in the experimental group received daily-automated e-mails using a Qualtrics on-line survey reminding them to perform their exercises.

The Bertec Balance Advantage CDP-IVR was used to measure postural stability by calculating center of gravity displacements through strain gauges in the forceplate [21-24]. Postural stability was measured under two conditions. Condition 1 measured postural stability on a stable forceplate with eyes open and focusing on a virtual reality infinite tunnel (Figure 1). The infinite tunnel provided the visual illusion that participants were

moving towards the tunnel in an anterior direction. Condition 2 measured postural stability on an unstable forceplate with eyes open focusing on the virtual reality infinite tunnel. Each condition lasted twenty seconds and was repeated three times and an average was calculated.

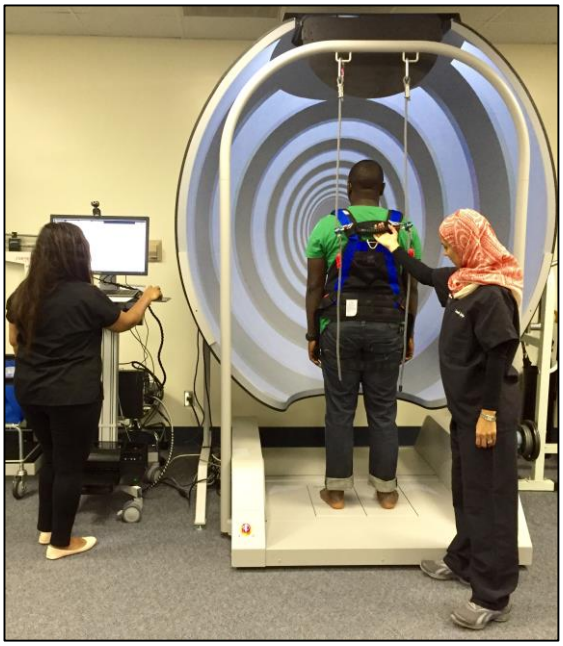

Figure 1. Computerized Dynamic Posturography with Immersion Virtual Reality (CDP-IVR).

Vestibular adaptation exercises have been shown to improve function of the VOR through visual fixation on a target during head movement "head–eye coordination" [16, 25, 26]. Participants in the experimental group performed the vestibular adaptation exercises one time daily for 5 minutes (Figure 2 and Appendix 1).

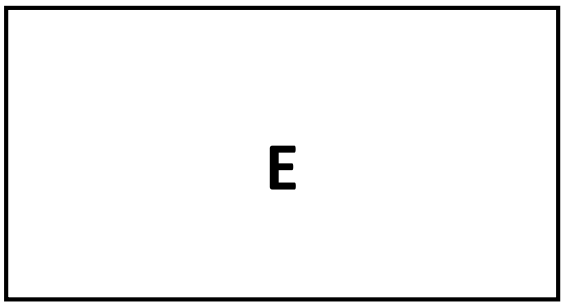

Figure 2. Vestibular Adaptation Exercise Card

Appendix 1. Vestibular adaptation exercises as instructed below:

- Stand in corner with your back to wall and a chair in front for balance as needed
- Hold letter E at eye level
- Keep eyes focused on the letter E
- Rotate head smoothly from side to side for 60 seconds
- Letter E should be relatively focused during exercise
- Rest for 60 seconds, then repeat
- Perform a total of 3 repetitions of 60 seconds 1 time daily as tolerated

Statistical Analysis

Sample size was calculated using a medium effect size of 0.50 between the experimental and control groups, a power of 0.80 and the level of significance was set at 0.05. Data was analyzed using SPSS Statistics Grad Pack 22.0 PREMIUM for windows. Descriptive statistics were used to summarize the data. Data was reported as mean ± standard deviation (SD) for quantitative variables and frequency and percentage for categorical variables. Normality of quantitative variables was examined using

Kolmogorov Smirnov test and box plots. To compare means of height, weight, and body mass index (BMI) between the experimental and control groups at baseline, an independent t-test was conducted. Mean age and CDP-IVR for all conditions (1, 2, and average) by group type were compared using Mann-Whitney U test. The distribution of gender by group was examined using Fisher's Chi-square test. To investigate the effect of the intervention on the outcome measures over time, a 2x2 mixed factorial ANOVA was conducted. The level of significance was set at $p \leq 0.05$.

Results

There was no significant difference between the experimental (N=26) and the control group (N=24) in terms of mean age, height, weight, BMI, the CDP-IVR scores for conditions 1, 2, and average at baseline ($p>0.05$). Seventeen participants (70.8%) in the experimental group were females compared to 17 participants (65.4%) in the control group ($p=0.77$) (Table 1).

In the experimental group, there was a borderline significant difference in mean CDP-IVR score between baseline and six weeks later for condition 1 (90.4±1.2 vs. 87.3±1.7, $p=0.08$) (Figure 3), significant difference in condition 2 (54.2±4.5 vs. 39.9±4.8, $p=0.001$) (Figure 4), and average of the two conditions (72.3±2.5 vs. 63.6±2.9, $p=0.002$) (Figure 5). However, in the control group, there was a significant difference in mean CDP-IVR score post versus pre for condition 2 (51.7±4.3 vs. 43.8±4.6, $p=0.03$), and average of the two conditions (69.3±2.3 vs. 65.4±2.8, $p=0.02$) but not for condition 1 ($p=0.60$) (Table 2).

When comparing the mean CDP-IVR score between the experimental and control groups, there was a significant difference between baseline and six weeks later for condition 1 only (p=0.03) (Table 2). Results indicated the 894 out of 928 responded "yes" on daily exercise reminders through Qualtrics program for assessment of compliance with the home exercise program (96%).

Table 1. Mean (SD) of general characteristics (N= 50)

	Experimental (N_1=26)	Control (N_2=24)	p –value[a]
Female; n (%)[c]	17(70.8)	17(65.4)	0.77
Age (years)[b]	27.3(4.0)	28.4(3.9)	0.22
Height (inches)	65.3(3.6)	65.2(3.9)	0.90
Weight (lb)	146.1(33.8)	143.2(24.9)	0.73
BMI (kg/m^2)	23.9(3.9)	23.7(3.3)	0.83
CDP-IVR condition 1[b]	87.3(9.6)	87.1(6.6)	0.54
CDP-IVR condition 2[b]	39.9(25.7)	43.8(21.6)	0.34
CDP-IVR average[b]	63.6(16.2)	65.4(12.4)	0.28

Abbreviation: SD=Standard deviation; CDP-IVR=Computerized Dynamic Posturography with Immersion Virtual Reality
[a] Independent t-test
[b] Mann-Whitney U test
[c] Fisher's Chi-Square

Table 2. Mean (SE) of the postural stability for both groups by condition over time (N=50).

Group	Experimental			Control			
	Pre	Post	p -value [a]	Pre	Post	p -value [a]	p-value [b]
Condition 1	87.3(1.7)	90.4(1.2)	0.08	87.1(1.6)	86.9(1.2)	0.60	0.03
Condition 2	39.9(4.8)	54.2(4.5)	0.001	43.8(4.6)	51.7(4.3)	0.03	0.51
Condition Av	63.6(2.9)	72.3(2.5)	0.002	65.4(2.8)	69.3(2.3)	0.02	0.29

Abbreviations: SE=Standard error; Av=Average
[a] p- values for the null hypothesis that there is a no significant difference between pre and post
[b] p- values for the null hypothesis that there is a no significant difference between the 2 groups

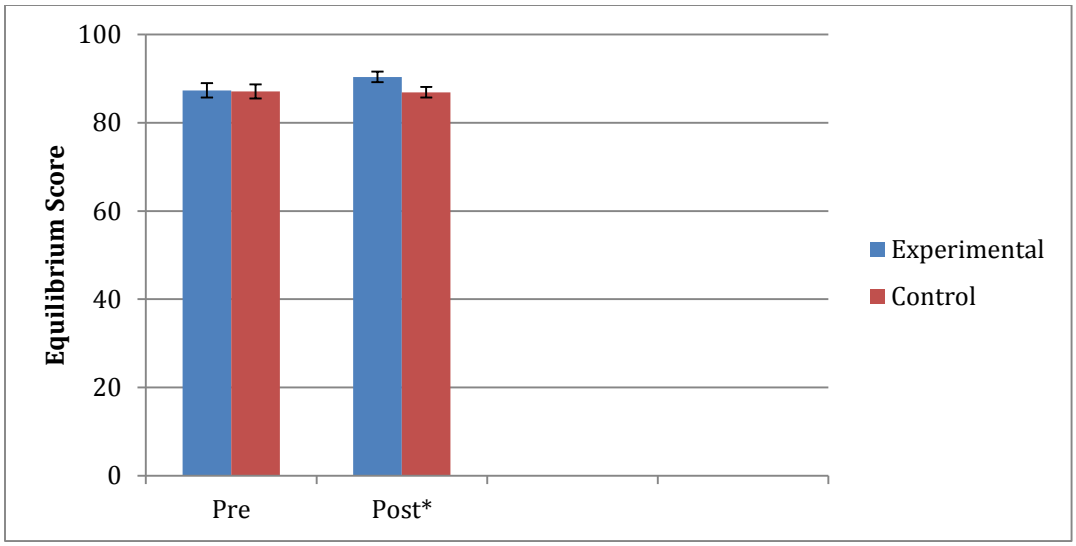

Figure 3. Mean± SE of postural stability of CDP-IVR for condition 1 by group over time (N=50)
*borderline significant for the experimental group (p=0.08); control group (p=0.60)

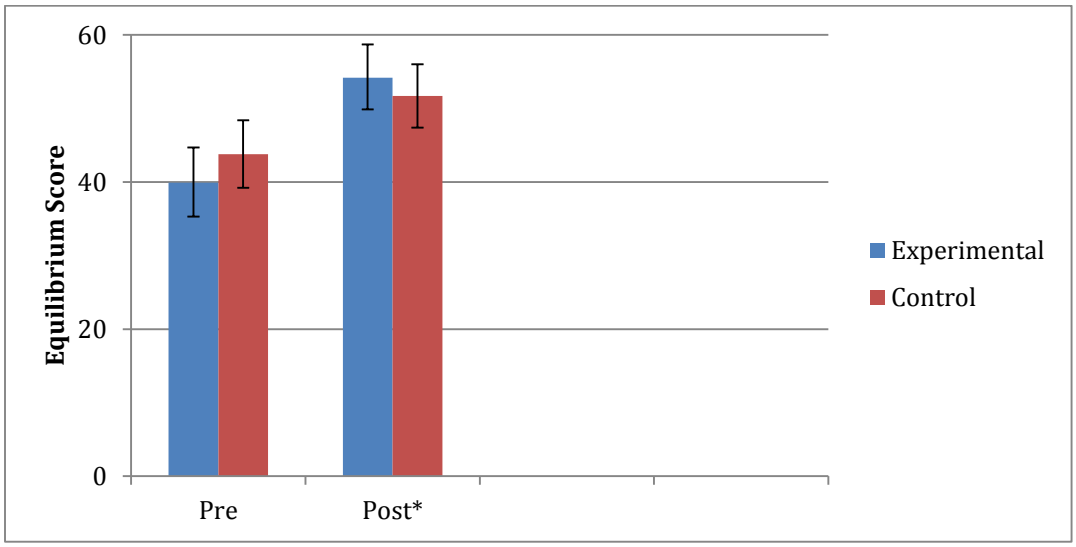

Figure 4. Mean± SE of in postural stability of CDP-IVR for condition 2 by group over time (N=50)
*highly significant for the experimental group (p=0.001); significant for control group (p=0.03)

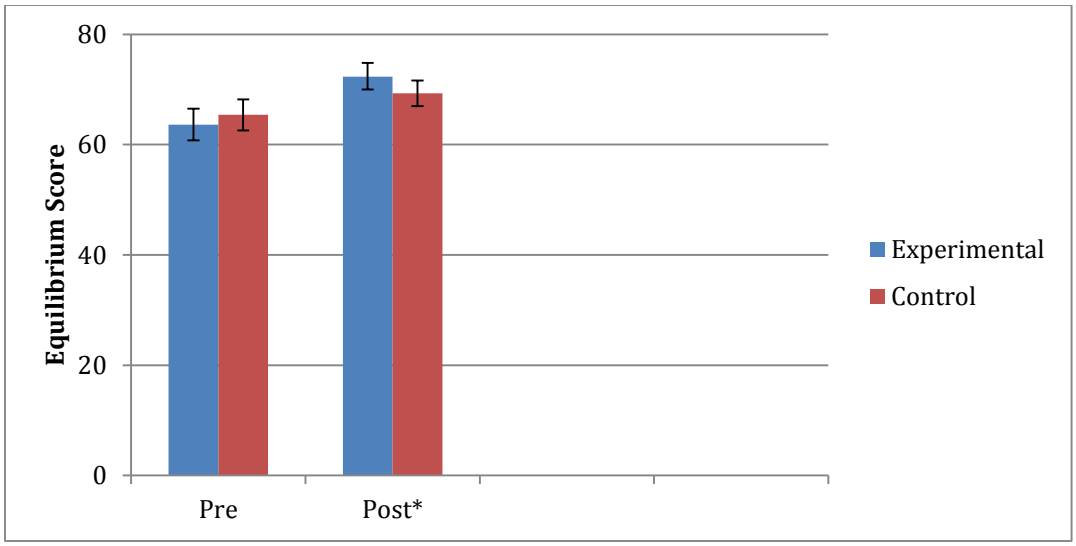

Figure 5. Mean± SE of postural stability of CDP-IVR for condition average by group over time (N=50)
*highly significant for the experimental group (p=0.002); significant for control group (p=0.02)

Discussion

The purpose of this study was to measure the effect of vestibular adaptation exercises on adults with sub-clinical chronic motion sensitivity. Postural stability was measured using CDP-IVR. Results supported the hypothesis that vestibular adaptation exercises would improve postural stability in participants with a history of sub-clinical chronic motion sensitivity.

Motion sensitivity has been defined as "a disturbing sense of vertigo or dizziness associated with head movement" that is often caused by vestibular dysfunction [(8)]. Furthermore, Akiduki et al reported that motion sensitivity and postural instability are caused by a visual-vestibular conflict [(3)]. The authors of the current investigation propose that the visual-vestibular conflict begins in childhood and persists into adulthood resulting in sub-clinical chronic motion sensitivity. Specifically, the authors suggest an

over-reliance on the visual system with a residual deficit of the vestibular system.

Significant improvements have been reported after performing vestibular adaptation exercises in patients with vestibular dysfunction [17,18]. Although the population in the current investigation did not have medically diagnosed vestibular dysfunction, they did report chronic motion sensitivity causing them to avoid certain activities. The authors suggest a sub-clinical vestibular dysfunction exists in some people with undiagnosed chronic motion sensitivity. Given the evidence supporting vestibular adaptation exercises improving vestibular dysfunction, the authors proposed strengthening the vestibular system using adaptation exercises in the experimental group and measuring the effects of postural stability, which is a component of motion sensitivity. The use of CDP-IVR provided a visually challenging sense of moving for study participants with a potential over-reliance on their visual system.

Because of the visually challenging environment caused by the CDP-IVR, familiarization of the testing conditions may explain the improvements observed in both experimental and control groups [27]. However, the averaged results after 6 weeks between both test conditions and between groups was greater in the experimental group.

Future studies should use a validated motion sensitivity subject report to correlate subjective and objective findings in adults with sub-clinical chronic motion sensitivity. Akiduki et al indicated that there was a variance between "subjective reports of motion sickness or balance and objective postural instability" [3]. However, Cobb and Nichols reported a strong correlation between self-reported symptoms of simulator sickness and between postural instability and a self-reported of motion sickness symptoms [5].

The low dosage of the adaptation exercises may have minimized the improvements observed in our study. Studies recommend that patients begin vestibular adaptation exercises with tolerable velocity, repetitions, and frequency then progress the exercises as able [25, 26, 28, 29]. Additionally, to maximize the benefits of vestibular adaptation exercises, it has been suggested they be designed to reflect the patient-specific function and environment [30]. The range of vestibular adaptation exercise programs has been reported as 3 to 10 weeks [9, 19, 30].

Recommendations for future research include the inclusion of a standardized subjective assessment tool to quantify the degree of motion sensitivity. Also, more frequent direct observation of the vestibular adaptation exercise program to improve the quality of the exercise performance. Additionally, vestibular adaptation exercises should be progressed including velocity, amplitude, duration, frequency, and directionality of movements to determine if more gains are possible.

Conclusion

Results of this study suggest that a minimal dosage of vestibular adaptation exercises over a 6-week period improves postural stability in younger adults with sub-clinical chronic motion sensitivity. Further research is warranted to determine if additional exercise progression will result in increased gains. Older adult populations should also be included.

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CHAPTER FOUR

POSTURAL CONTROL IN HEALTHY YOUNG ADULTS WITH AND WITHOUT CHRONIC MOTION SENSITIVITY

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Abstract

Background: Postural control requires complex processing of peripheral sensory inputs from the visual, somatosensory and vestibular systems. Motion sensitivity and decreased postural control are influenced by visual-vestibular conflicts. The purpose of this study was to measure the difference between the postural control of healthy adults with and without history of sub-clinical chronic motion sensitivity using a computerized dynamic posturography in a virtual reality environment.

Methods: Twenty healthy adults between 22 and 33 years of age participated in the study. Eleven subjects had sub-clinical chronic motion sensitivity and 9 subjects did not. Postural control was measured using computerized dynamic posturography with immersion virtual reality on stable (condition 1) and unstable (condition 2) platforms.

Results. There was no significant difference between the two groups in terms of mean age, height, weight, body mass index in kg/m^2 (BMI), postural control scores for conditions 2, and average ($p>0.05$). However, significant differences were observed in mean postural control for condition 1 between groups ($p=0.03$).

Conclusions: Results of this study suggest that healthy young adults without chronic sub-clinical motion sensitivity have better postural control than those with chronic sub-clinical motion sensitivity. Further investigation is warranted.

Keywords: Motion sensitivity, postural control, balance

Introduction

The ability to maintain balance is essential for everyday life. Postural control is the ability to maintain equilibrium and orientation in a gravitational environment [(1)]. It

involves the control of body's position in space in order to obtain stability and orientation [2]. Postural control is a complex process requiring central processing of peripheral sensory inputs [3]. These peripheral sensory inputs include the visual, somatosensory and vestibular systems working together to maintain postural control [4]. Sensory input and processing conflicts, particularly between the visual and vestibular systems, can result in disturbance of postural control leading to disequilibrium and motion sickness [4].

Motion sickness, or motion sensitivity, is defined as disorientation of space and is a common symptom related to dizziness and impaired postural control [5,6]. Additional symptoms associated with motion sensitivity include nausea, vomiting and cold sweating [6]. Motion sensitivity is affected by factors such as gender, age, psychological status, and environmental factors [7]. Motion sensitivity and impaired postural control can occur in healthy adults while exploring visual surroundings, particularly while standing on unstable surfaces [6].

Hoffman et al reported that immersion virtual reality (IVR) is an false reality created in the mentality of the virtual reality (VR) user with the help of advanced computer technology [8]. The virtual environment creates a false sense of movement by entering a computer-generated world with converging various multisensory inputs [8]. Motion sensitivity and decreased postural control can be exacerbated in VR environments [6,9,10].

The purpose of this study was to measure the difference between the postural control of healthy adults with and without any history of sub-clinical chronic motion sensitivity using a VR environment. We operationally defined sub-clinical as a history of

avoiding activities causing dizziness, nausea, imbalance, and/or blurred vision without having a related medical diagnosis.

Methods

Twenty healthy male and female subjects 22 to 33 years of age were recruited for the study. Eleven subjects reported sub-clinical chronic motion sensitivity and 9 subjects did not. Motion sensitivity was determined using an activity avoidance questionnaire because of symptoms including dizziness, nausea, imbalance, and/or blurred vision. Subjects with sub-clinical motion sensitivity were included if they responded "yes" to avoiding at least one of the following activities on the questionnaire: reading in a moving vehicle, traveling on winding roads, boats or ships, airplanes, horseback riding, roller coasters, and/or quick movements. Subjects without sub-clinical chronic motion sensitivity reported “no” to all activities on the same questionnaire. Subjects were excluded if they reported cervical spine orthopedic impairments, vestibular impairments, neurological pathology, or currently being on any medications causing dizziness or imbalance. All subjects signed a Loma Linda University's Institutional Review Board approved informed consent prior to participation in the study.

Procedures

There were two groups in this study, eleven subjects in the sub-clinical chronic motion sensitivity group and 9 subjects in the non-motion sensitivity group. Postural control was measured in both groups using the Bertec Balance Advantage-Dynamic Computerized Dynamic Posturography with Immersion Virtual Reality (CDP-IVR) [(11)]. See Figure 1. The CDP-IVR recorded subjects’ center of gravity displacement and

postural sway velocity in degrees/second while immersed in a virtual reality environment (12-14).

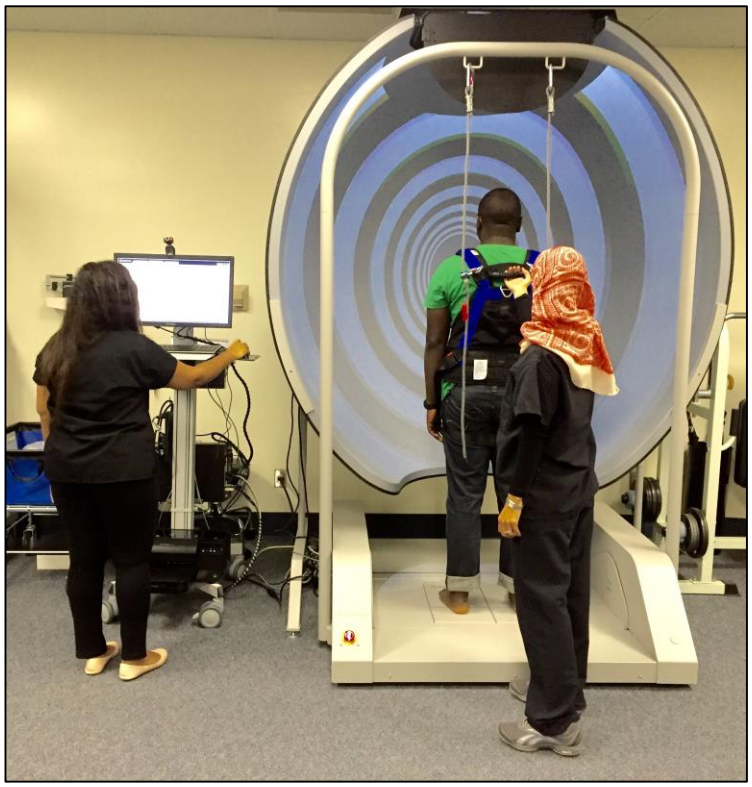

Figure 1: Bertec Balance Advantage-Dynamic Computerized Dynamic Posturography with Immersion Virtual Reality (CDP-IVR)

Postural control was measured under two conditions. Condition 1 measured postural control on a stable forceplate with eyes open while focusing on a virtual reality infinite tunnel visual flow (Figure 1). The infinite tunnel provided the visual illusion that subjects were moving towards the tunnel in an anterior direction. Condition 2 included the additional challenge of an unstable forceplate. Each condition lasted twenty seconds and was repeated three times and an average was calculated.

Statistical Analysis

Data was analyzed using SPSS Statistics Grad Pack 22.0 PREMIUM for windows. Descriptive statistics was used to summarize the data. Data was reported as mean ± standard deviation (SD) for quantitative variables and frequency and percent (%) for categorical variables. Normality of quantitative variables was examined using Kolmogorov Smirnov test and box plots. To compare the means of height, weight, and body mass index (BMI) between the two groups, an independent t-test was conducted. Differences in mean age and postural control scores for all conditions (1, 2, and average) by group type were assessed using Mann-Whitney U test. The distribution of gender by group was examined using Fisher's Chi- square test. The level of significance was set at $p \leq .05$.

Results

There was no significant difference noted between the motion sensitivity ($n_1=11$) and the non-motion sensitivity groups ($n_2=9$) in terms of mean age, height, weight, BMI, the sensory organization test (SOT) scores for conditions 2, and average at baseline ($p>0.05$). Seven subjects (63.68%) in the motion sensitivity group were females compared to 4 female subjects (44.4%) in the non-motion sensitivity group ($p=0.34$). See Table 1.

There was a significant difference in mean SOT for condition 1 between motion sensitivity and non-motion sensitivity group (85.1±10.8 vs 92.1±2.3, $p=0.03$). However, there was no significant difference in mean SOT for condition 2 between the two groups (48.2±21.4 vs.55.3±20.1, $p=0.23$), and for average of the two conditions (66.7±15.0 vs. 73.7±10.6, $p=0.09$). See Table 1.

Table 1. Mean (SD) of general characteristics (n= 20)

	Motion Sensitivity (n_1=11)	Non-Motion Sensitivity (n_2=9)	p –value[a]
Female; n (%)[c]	7(63.6)	4(44.4)	0.34
Age (years)[b]	27.3(4.4)	26.7(3.9)	0.75
Height (inches)	65.1(3.5)	66.3(3.3)	0.43
Weight (lb)	151.5(27.3)	165.5(39.4)	0.36
BMI (kg/m^2)	25.1(3.5)	26.4(6.0)	0.54
SOT condition 1[b]	85.1(10.8)	92.1(2.3)	0.03
SOT condition 2[b]	48.2(21.4)	55.3(20.1)	0.23
SOT average[b]	66.7(15.0)	73.7(10.6)	0.09

Abbreviations: SD=Standard deviation; SOT=Sensory Organization Test
[a] Independent t-test
[b] Mann-Whitney U test
[c] Fisher's Chi-Square

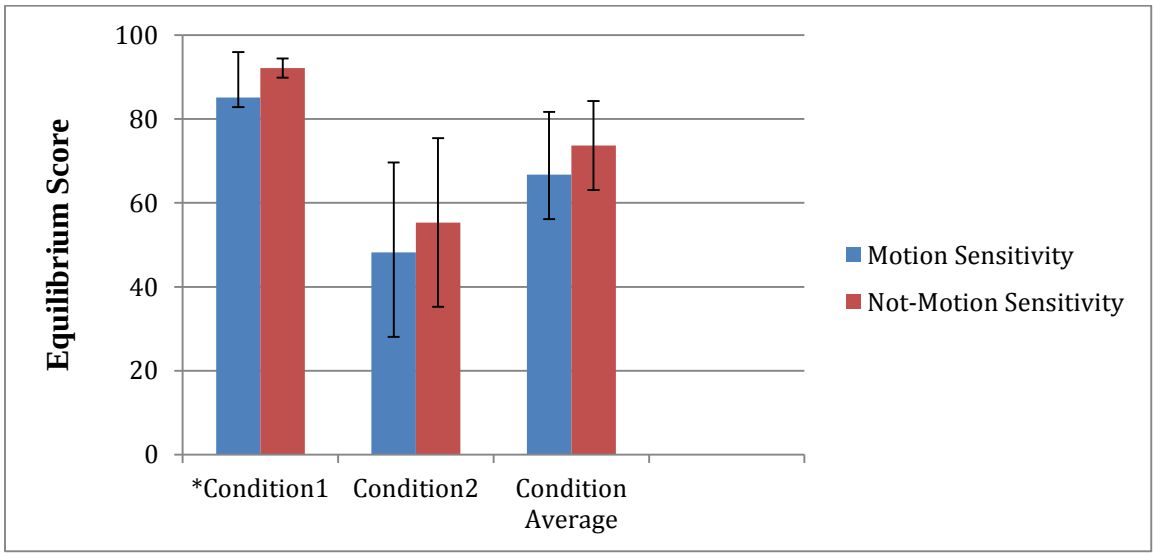

Figure 2. Mean± SE of postural control of sensory organization test for condition 1, condition 2, and condition average by type of group (N=20)
*Significant for the Condition 1 (p=0.03); SE=Standard error

Discussion

The purpose of this study was to measure the difference in postural control between healthy young adults with and without chronic sub-clinical motion sensitivity. Postural control was measured with CDP-IVR. The results suggest that young adults without chronic sub-clinical motion sensitivity have better postural control. The young adults with sub-clinical motion sensitivity had more postural sway during both testing conditions although only the first condition was significant. These results support previous reports that individuals with motion sensitivity have poor postural control making it difficult to disregard misleading visual input [(15)]. Subjects without motion sensitivity could rely on normal sensory integration during the CDP-IVR infinite tunnel visual flow and were better able to maintain their balance. The motion sensitive subjects were likely dealing with an over reliant visual system and the visual-vestibular conflict contributed to increased difficulties in maintaining their balance.

The results of the current investigation suggest that chronic sub-clinical motion sensitivity impairs postural control in healthy young adults. Limitations of this study included using a non-validated self-report activity avoidance questionnaire. Hironori et al reported a variance between "subjective reports of motion sickness or balance and objective decreased postural control" [(5)]. Alternatively, Cobb described a strong correlation between decreased postural control and self-reported symptoms of simulator sickness [(4)].

Conclusion

Results of this study suggest that healthy young adults without chronic sub-clinical motion sensitivity have better postural control than those with chronic sub-clinical motion sensitivity.

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CHAPTER FIVE

DISCUSSION

There are three primary inputs that contribute to maintain our balance and to see the image clearly with head movement [(1)]. These systems will process in the vestibular nuclear complex in the brainstem and the cerebellum. Therefore, it is going to drive to two primary output, which are vestibulo-ocular reflex (VOR) and vestibulo-spinal reflex (VSR) [(2)]. Based on the clinical assessment of vestibular system will determine the vestibular dysfunction by taken appropriate history and evaluation of eye movements and balance. More over, adaptation exercise prescription will be developed to reflect the patient-specific function and environment [(3)].

Therefore, we hypothesized that the vestibular adaptation exercise improved the postural stability on adults with sub-clinical chronic motion sensitivity. Postural stability was measured using Computerized Dynamic Posturography with Immersion Virtual Reality (CDP-IVR). Based on the results our hypothesis was supported that vestibular adaptation exercises would improve postural stability in participants with a history of sub-clinical chronic motion sensitivity. So a minimal dosage of 5 minutes daily of vestibular adaptation exercises over a 6-week period was suggested to improves postural stability in younger adults with sub-clinical chronic motion sensitivity.

However, by measured the postural stability between healthy young adults with and without chronic sub-clinical motion sensitivity using CDP-IVR. Results suggest that healthy young adults without chronic sub-clinical motion sensitivity have better postural stability than those with chronic sub-clinical motion sensitivity

Motion sensitivity has been defined as "a disturbing sense of vertigo or dizziness associated with head movement" that is often caused by vestibular dysfunction [4]. Furthermore, Akiduki et al reported that motion sensitivity and postural instability are caused by a visual-vestibular conflict (VVC) [5]. In the investigation of the effect of adaptation exercise on adult subjects with history of sub-clinical chronic motion sensitivity, we proposed that the VVC begins in childhood and persists into adulthood resulting in sub-clinical chronic motion sensitivity. Specifically, suggest an over-reliance on the visual system with a residual deficit of the vestibular system.

Moreover, individuals with motion sensitivity have poor postural stability making it difficult to disregard misleading visual input [6]. Subjects without motion sensitivity could rely on normal sensory integration during the CDP-IVR infinite tunnel and were better able to maintain their balance. The motion sensitive subjects were likely dealing with an over reliant visual system and the VVC contributed to increased difficulties in maintaining their balance.

Significant improvements have been reported after performing vestibular adaptation exercises in patients with vestibular dysfunction [7,8]. Although the population in the investigation did not have medically diagnosed vestibular dysfunction, they did report chronic motion sensitivity that caused them to avoid certain activities. We suggest a sub-clinical vestibular dysfunction exists in some people with undiagnosed chronic motion sensitivity. Given the evidence supporting vestibular adaptation exercises improving vestibular dysfunction, we proposed strengthening the vestibular system using adaptation exercises in the experimental group and measuring the effects of postural stability, which is a component of motion sensitivity. The use of CDP-IVR provided a

visually challenging sense of moving for study participants with a potential over-reliance on their visual system.

Because of the visually challenging environment caused by the CDP-IVR, familiarization of the testing conditions may explain the improvements observed in both experimental and control group time [9]. However, the averaged results after 6 weeks between both test conditions and between groups was greater in the experimental group.

Future studies should use a validated motion sensitivity subject report to correlate subjective and objective findings in adults with sub-clinical chronic motion sensitivity. Akiduki et al indicated that there was a variance between "subjective reports of motion sickness or balance and objective postural instability" [10]. However, Cobb and Nichols reported a strong correlation between self-reported symptoms of simulator sickness and between postural instability and a self-reported of motion sickness symptoms [11].

The low dosage of the adaptation exercises (five minutes daily) may have minimized the improvements observed in our study. Studies recommend that patients begin vestibular adaptation exercises with tolerable velocity, repetitions, and frequency then progress the exercises as able [12-15]. Additionally, to maximize the benefits of vestibular adaptation exercises, it has been suggested they be designed to reflect the patient-specific function and environment [3]. The range of vestibular adaptation exercise programs has been reported as 6 to 10 weeks [3,16].

Conclusion

Our conclusion indicates that postural stability might be impaired by sub-clinical chronic motion sensitivity in healthy young adults. And 5 minutes of minimal dosage of

vestibular adaptation exercises improved postural stability in younger adults with chronic motion sensitivity.

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APPENDIX A

DATA COLLECTION SHEET

Health History Screening Form

Please indicate if you have any of the following:

- Past or current cervical spine orthopedic impairments YES NO
- Past or current vestibular impairments YES NO
- Past or current neurological pathology YES NO
- Past or current migraine/headache YES NO
- Current medications that cause symptoms YES NO

If "yes" please clarify the name of the medication?

Activity Avoidance Questionnaire

Do you avoid any of the activities below because they produce symptoms of dizziness, nausea, imbalance, and/or blurry vision?

If "Yes" please rate the symptom using the following rating scale:

1= minimally bothersome, 5= moderately bothersome, 10 = severely bothersome

Activity			Symptom	Rating Scale
Reading in moving vehicle	No	Yes	dizziness/nausea/imbalance/blurry vision	1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / 10
Driving any vehicle (car, bicycle, etc)	No	Yes	dizziness/nausea/imbalance/blurry vision	1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / 10
Driver or passenger on a zigzagging road	No	Yes	dizziness/nausea/imbalance/blurry vision	1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / 10
Boat passenger	No	Yes	dizziness/nausea/imbalance/blurry vision	1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / 10
Airplane passenger	No	Yes	dizziness/nausea/imbalance/blurry vision	1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / 10
Horseback riding	No	Yes	dizziness/nausea/imbalance/blurry vision	1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / 10
Riding a roller coaster	No	Yes	dizziness/nausea/imbalance/blurry vision	1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / 10
Quick motions such as picking something up from floor or reaching up to a shelf	No	Yes	dizziness/nausea/imbalance/blurry vision	1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / 10

Adaptation Exercise Prescription

ACTIVITY 1

- stand in corner of room with chair in front for safety
- hold letter E with plain white background at eye level
- keep eyes focused on letter E during exercise
- rotate head smoothly from side to side as quickly as able through a comfortable range of motion for 60 seconds followed by a 60 second rest
- letter E should be relatively focused during exercise
- exercise repeated 3 times once daily

APPENDIX B

QUALTRICS HOME EXERCISE COMPLIANCY REMINDER

Exercise Log Reminder
Danah Alyahya [noreply@qemailserver.com]

Sent: Tuesday, January 13, 2015 7:00 PM
To: Alyahya, Danah (LLU)

Dear Research Participant 001

This is a friendly reminder for your daily exercise log.

Follow this link to the Survey:
Please click here to access the daily log

Or copy and paste the URL below into your internet browser:
https://llu.co1.qualtrics.com/WRQualtricsSurveyEngine/?Q_SS=0NhoeiaJ0M7X6xn_cBDeu9jJKCIDqtf&_=1

Thank you for your participation
Danah Alyahya

Exercise Log Script

Dear Research Participant,

This is Danah Alyahya from the research project

Did you complete your exercises today?

- ○ Yes.
- ○ No

>>

Can you please briefly state the reason why you didn't complete your exercise for today

>>

APPENDIX C

INFORMED CONSENT

TITLE: **EFFECT OF VESTIBULAR ADAPTATION EXERCISES ON CHRONIC MOTION SENSITIVITY**

SPONSOR: **Department of Physical Therapy, Loma Linda University**

PRINCIPAL INVESTIGATOR:

Eric Glenn Johnson, DSc, PT, MS-HPEd, NCS

Professor, Physical Therapy Department

Loma Linda University, Loma Linda CA

School of Allied Health Professions

Nichol Hall Room #A-712

Phone: (909) 558-4632 Extension 47471

Fax: *(909) 558-0459*

Email Address: ejohnson@llu.edu

1. WHY IS THIS STUDY BEING DONE?

The purpose of the study is to determine the effect of adaptation exercises on motion sensitivity.

Adaptation exercises are a Physical Therapy treatment approach often prescribed for patients with dizziness. Although motion sensitivity is a type of dizziness, there have been no research publications describing the effects of adaptation exercises on dizziness. You are invited to participate in this research study because you are an adult between the ages of 20-40 with chronic motion sensitivity.

2. HOW MANY PEOPLE WILL TAKE PART IN THIS STUDY?

Approximately 50 subjects will participate in this study.

3. HOW LONG WILL THE STUDY GO ON?

Your participation in this study will last approximately six weeks. If you are in the group receiving adaptation exercises, you will need to devote 5 minutes daily for the home adaptation exercises as well as a weekly follow-up in Nichol Hall #A-712. Otherwise, your participation will require 60 minutes on the first day of data collection and 60 minutes on the second day of data collection approximately 6-weeks later.

4. HOW WILL I BE INVOLVED?

Participation in this study involves the following:

Your date of birth, height and weight will be recorded. You will then complete a brief health questionnaire and an activity avoidance questionnaire. We will then randomly assign you to either a control group or experimental group. Pre and post motion sensitivity measurements will then be performed using a non-invasive computerized device. This device has a stable platform that records your body sway while you look at a moving picture. Between pre-post measurements, subjects in the experimental group will

perform simple exercises called “adaptation exercises” for 5 minutes daily for approximately 6-weeks lasting. Subjects in the control group will not be given any exercises and will simply return after 6-weeks for the post-test measurements. If you agree to participate in this study, you will be responsible for your own travel to and from the research lab for each day of data collection.

5. WHAT ARE THE REASONABLY FORESEEABLE RISKS OR DISCOMFORTS I MIGHT HAVE?

Participating in this study exposes you to minimal risk because you may lose your balance during the testing procedures. To prevent falling, you will be wearing a safety harness and two researchers will be standing beside you at all times. For subjects in the experimental group, improperly performing the adaptation exercises can result in increased symptoms of dizziness and/or imbalance. The investigators will train all subjects in the experimental group in correct adaptation exercise performance and will monitor the exercise performance during follow-up sessions in Nichol Hall #A-712. There is also a minimal risk of breach of confidentiality.

6. WILL THERE BE ANY BENEFIT TO ME OR OTHERS?

The expected benefit to humanity is the data obtained from this study may identify a home exercise program to improve general motion sensitivity. It is possible that subjects in the experimental group may personally benefit from participation in the study by improving their motion sensitivity. Subjects in the control group will have the opportunity to receive the adaptation exercise training at the conclusion of the study.

7. WHAT ARE MY RIGHTS AS A SUBJECT?

Participation in this study is voluntary. Your decision whether or not to participate or terminate at any time will not affect your present or future relationship with the Loma Linda University Department of Physical Therapy. You do not give up any legal rights by participating in this study.

8. WHAT HAPPENS IF I WANT TO STOP TAKING PART IN THIS STUDY?

You are free to withdraw from this study at any time. If you decide to withdraw from this study you should notify the research team immediately. The research team may also end your participation in this study if you do not follow instructions, miss scheduled visits, or if your safety and welfare are at risk.

9. HOW WILL INFORMATION ABOUT ME BE KEPT CONFIDENTIAL?

Your identity will not be recorded with the research data. We cannot guarantee absolute confidentiality. You will not be identified by name in any publications describing the results of this study. All electronic data will be maintained on an encrypted computer and paper data kept in a locked file cabinet in a locked office.

10. WHAT COSTS ARE INVOLVED?

There is no cost to you for your participation in this study beyond the time involved to participate.

11. WILL I BE PAID TO PARTICIPATE IN THIS STUDY?

You will receive a $10 gift card at the conclusion of each day of data collection.

12. WHO DO I CALL IF I HAVE QUESTIONS?

If you feel you have been injured by taking part in this study, consult with a physician or call 911 if the situation is a medical emergency. No funds have been set aside nor any plans made to compensate you for time lost for work, disability, pain or other discomforts resulting from your participation in this research.

13. SUBJECT'S STATEMENT OF CONSENT

If you wish to contact an impartial third party not associated with this study regarding any question or complaint you may have about the study, you may contact the Office of Patient Relations, Loma Linda University Medical Center, Loma Linda, CA 92354, phone (909) 558-4674, e-mail patientrelations@llu.edu for information and assistance.

14. SUBJECT'S STATEMENT OF CONSENT

I have read the contents of the consent form and have listened to the verbal explanation given by the investigators. My questions concerning this study have been answered to my satisfaction. I hereby give voluntary consent to participate in this study. I have been given a copy of this consent form. Signing this consent document does not waive my rights nor does it release the investigators, institution, or sponsors from their responsibilities. I may call and leave a voice message for Eric Johnson, DSc during routine office hours at this

number (909) 558-4632 ext. 47471 or e-mail him at ejohnson@llu.edu, if I have additional questions and concerns.

I understand I will be given a copy of this consent form after signing it.

Signature of Subject	Printed Name of Subject
Date	

15. INVESTIGATOR'S STATEMENT

I have reviewed the contents of this consent form with the person signing above. I have explained potential risks and benefits of the study.

Signature of Investigator	Printed Name of Investigator
Date	

APPENDIX D

PROTECTED HEALTH INFORMATION

INSTITUTIONAL REVIEW BOARD
Authorization for Use of
Protected Health Information (PHI)
Per 45 CFR §164.508(b)
RESEARCH PROTECTION PROGRAMS
LOMA LINDA UNIVERSITY | Office of the Vice President of Research Affairs
24887 Taylor Street, Suite 202 Loma Linda, CA 92350
(909) 558-4531 (voice) / (909) 558-0131 (fax)/e-mail: irb@llu.edu

TITLE OF STUDY: The Effect of Vestibular Adaptation Exercises on Chronic Motion Sensitivity

PRINCIPAL INVESTIGATOR: Eric G. Johnson, DSc, PT, MS-HPEd, NCS

Others who will use, collect, or share PHI: Authorized Research Personnel

The study named above may be performed only by using personal information relating to your health. National and international data protection regulations give you the right to control the use of your medical information. Therefore, by signing this form, you specifically authorize your medical information to be used or shared as described below**.**

The following personal information, considered "Protected Health Information" (PHI) is needed to conduct this study and may include, but is not limited to name, birth date, phone number, e-mail, and a health questionnaire.

The individual(s) listed above will use or share this PHI in the course of this study with the Institutional Review Board (IRB) and the Office of Research Affairs of Loma Linda University.

The main reason for sharing this information is to be able to conduct the study as described earlier in the consent form. In addition, it is shared to ensure that the study meets legal, institutional, and accreditation standards. Information may also be shared to report adverse events or situations that may help prevent placing other individuals at risk.

All reasonable efforts will be used to protect the confidentiality of your PHI, which may be shared with others to support this study, to carry out their responsibilities, to conduct public health reporting and to comply with the law as applicable. Those who receive the PHI may share with others if they are required by law, and they may share it with others who may not be required to follow national and international "protected health information" (PHI) regulations such as the federal privacy rule.

Subject to any legal limitations, you have the right to access any protected health information created during this study. You may request this information from the Principal Investigator named above but it will only become available after the study analyses are complete.

- This authorization does <u>not</u> expire, and will continue indefinitely unless you notify the researchers that you wish to revoke it.

You may change your mind about this authorization at any time. If this happens, you must withdraw your permission in writing. Beginning on the date you withdraw your permission, no new personal health information will be used for this study. However,

study personnel may continue to use the health information that was provided before you withdrew your permission. If you sign this form and enter the study, but later change your mind and withdraw your permission, you will be removed from the study at that time. To withdraw your permission, please contact the Principal Investigator or study personnel at 909-583-4966.

You may refuse to sign this authorization. Refusing to sign will not affect the present or future care you receive at this institution and will not cause any penalty or loss of benefits to which you are entitled. However, if you do not sign this authorization form, you will not be able to take part in the study for which you are being considered. You will receive a copy of this signed and dated authorization prior to your participation in this study.

I agree that my personal health information may be used for the study purposes described in this form.

Signature of Patient *or* Patient's Legal Representative	Date
Printed Name of Legal Representative (if any)	Representative's Authority to Act for Patient
Signature of Investigator Obtaining Authorization	Date