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Relationship between Vestibular System, Vision, Anxiety, and Chronic Motion Sensitivity

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Relationship between Vestibular System, Vision, Anxiety, and Chronic Motion Sensitivity

by

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A Dissertation submitted in partial satisfaction of
the requirements for the degree
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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

CMS	Chronic Motion Sensitivity
MSSQ-SF	Motion Sensitivity Susceptibility Questionnaire-Short Form
CDP-IVR	Computerized Dynamic Posturography with Immersion Virtual Reality
CNS	Central Nervous System
SOT	Sensory Organization Test
ES	Equilibrium Score
SD	Standard Deviation
BMI	Body Mass Index
MSQ	Motion Sickness Questionnaire
taMAX	theta maximum
taMIN	theta minimum
ICCs	Intra-class correlation coefficients
STAI	State and Trait Anxiety Inventory
S-Anxiety	State Anxiety
T-Anxiety	Trait Anxiety

ABSTRACT OF THE DISSERTATION

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Dr. Eric Johnson, Chairperson

BACKGROUND: Chronic motion sensitivity (CMS) has been defined as a feeling of un-wellness elicited by either actual or perceived motion. CMS is a common condition and is more prevalent in females than in males. In addition to a variety of symptoms, young adults with CMS have less postural stability than those without CMS.

OBJECTIVE: To determine whether vestibular system integrity, dependence on visual cues for postural stability, and the anxiety level are different between young adults with and without CMS, and whether it differs by gender within each group.

METHODS: Sixty young adults (30 females and 30 males) were assigned to one of two groups (CMS or non-CMS) using the Motion Sickness Susceptibility Questionnaire-Short Form (MSSQ-SF). Postural stability was measured for all participants using the Bertec Balance Advantage–Computerized Dynamic Posturography with Immersion Virtual Reality (CDP-IVR). State and trait anxiety inventory (STAI) used to measure the presence and severity of current state and general trait of anxiety.

RESULTS: There was no significant difference in mean postural stability during eyes closed and unstable platform between the CMS and non-CMS groups ($p=0.57$). However, A significant difference was found in mean postural stability scores during

immersion virtual reality (IVR) between the CMS and non-CMS groups ($p<0.001$). Also, A significant difference was found in mean state and trait anxiety scores between young adults with and without CMS (state anxiety: $p=0.024$; trait anxiety: $p=0.016$)

CONCLUSION: The results suggest that young adults with CMS have normal vestibular system integrity, are over-reliant on visual cues for postural stability, and are more anxious compared to those without CMS

Keywords: motion sensitivity, vestibular system integrity, visual input, Anxiety, postural stability

CHAPTER ONE

INTRODUCTION AND REVIEW OF THE LITERATURE

Motion Sensitivity

Chronic motion sensitivity (CMS), also referred to as motion sickness, is defined as a feeling of un-wellness elicited by either actual or perceived motion [1,2]. It is a common condition with 28.4% of travelers experiencing motion sensitivity [3]. In addition to a variety of symptoms, such as dizziness, vomiting, cold sweats, pallor and nausea, young adults with CMS have less postural stability than those without CMS [2,4,5]. Furman et al. [6] reported that CMS could have a negative effect on a person's quality of life, particularly when it interferes with the ability to work, travel, or practice leisure activities.

Females are reportedly more susceptible to CMS than males; however, the cause is unknown [7,8,9,10,11]. Dobie et al. [12] suggested the cause might be related to males being less inclined to admit illness. In addition, Flanagan et al. [13] reported that optokinetic stimuli increased symptoms of motion sensitivity in females more than in males. However, Park and Hu [11] found that gender differences did not affect the intensity of motion sensitivity symptoms that occurred while viewing a rotating optokinetic drum.

Although the origin and precise neurobiological mechanism of CMS is unknown, the sensory conflict theory, which states that CMS results when sensory information that is transmitted to the CNS by one sensory system does not match the expected information transmitted from another sensory system [14], is the most widely accepted explanation [15]. Reason and Brand [14] classified CMS provoking sensory conflict into two

categories: 1) conflict between sensory inputs (visual, vestibular, and somatosensory) and 2) conflict between canal and otolith signals. The neural pathway that may be responsible for motion sensitivity symptoms includes the following structures: postrema of the medulla oblongata, vestibular apparatus, vestibulocochlear nerve, vestibular nuclei in the brainstem, nodulus and uvula of the cerebellum, reticular formation, and hypothalamus [16,17].

Conflicts among sensory input systems, particularly between the visual and vestibular systems, cause disturbances of balance, which lead to disequilibrium and motion sensitivity [18,19]. Akiduki et al. [18] concluded that visual-vestibular conflict using virtual reality induced motion sickness symptoms and postural instability. They also found a time lag between subjective symptoms of motion sensitivity and objective postural instability, which led the authors to suggest that symptoms of motion sensitivity are the cause of postural instability [18].

Vestibular System Integrity

Vestibular system consists of three main components: a peripheral sensory apparatus, which lies within the labyrinth of the inner ear; a central processing system, which is located in the vestibular nuclear complex in the brain stem and the cerebellum; and a motor output system mediated through the vestibulo-ocular reflex (VOR) and the vestibulospinal reflex (VSR) [19].

The peripheral sensory apparatus detects head angular velocity and linear acceleration coupled with an orientation of the head with respect to gravity; as a result, it provides the central processing system with information about the movement of the head

and its position with respect to gravity and other inertial forces [19].

The central processing system integrates input from the peripheral sensory apparatus with other sensory inputs, somatosensory and visual, to provide accurate information about position and movement of the head in space. Considerable connections among the vestibular nuclear complex, cerebellum, ocular motion nuclei, and brainstem reticular activating systems are needed to originate appropriately oriented and timed signals to the motor output system [19].

The vestibular system is both a sensory and motor system[1]. During functional tasks, motor outputs are determined and altered by information transmitted to the central nervous system (CNS) from vestibular sensory organs. The output of the central vestibular system goes to the ocular muscles serving the VOR and to the spinal cord serving the VSRs. The VOR is responsible for generating compensatory eye movements to maintain gaze stability, and the VSRs are responsible for generating compensatory body movements to maintain postural stability during head movements, posture, and locomotion [19].

Visual and Somatosensory Systems

The visual system provides the CNS with information about the position and movement of the head with respect to surrounding environment. Also, it can determine if a signal from the otoliths corresponds to a tilt with respect to gravity or a linear translation of the head. Contrary to the visual system, the somatosensory system signals the position and motion of the body with respect to its support surface and about the position and motion of body segments with respect to each other. Hence, this system can

determine if a head rotation signals from the vertical canals, the anterior and posterior semicircular canals, is an outcome of motion of the head on the neck or because of falling. Moreover, the somatosensory system gives information about how body segments are aligned with respect to each other and the support surface using information imported from muscle stretch and joint position [19].

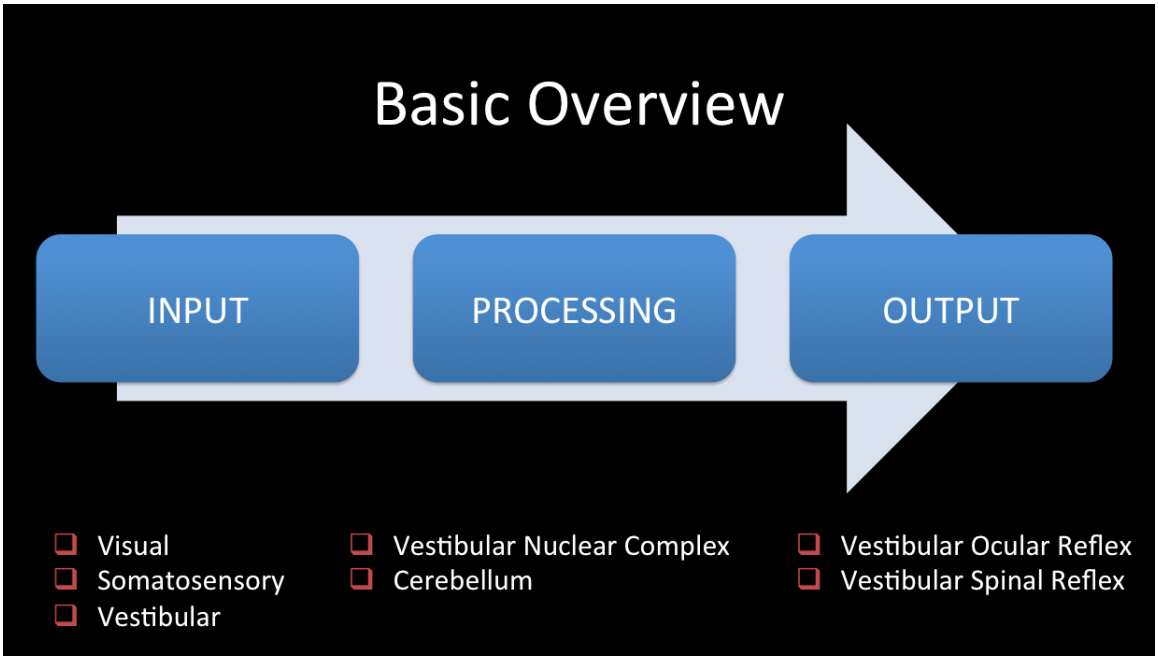

Figure 1. Basic Overview of Vestibular System

Postural Stability

Postural control or balance has been defined as "the ability to maintain equilibrium in a gravitational field by keeping or returning the center of body mass over its base of support" [21]. Postural stability is a complex process that requires central processing of peripheral sensory inputs (vestibular, visual, and somatosensory inputs) [22]. Coherent interaction of sensory inputs and afferent outputs maintains postural stability [19]. However, conflicts among sensory input systems, particularly between the visual and vestibular systems, cause disturbance of balance leading to motion sickness and postural stability [18].

The sensory reweighting process, in which the vestibular system relies primarily on information from visual and/or somatosensory inputs, is one way to compensate for a vestibular deficit [23–25]. The collection of visual and somatosensory information may be facilitated to compensate for a vestibular deficit [19]. Patients with vestibular deficit tend to be over-reliant on visual [26] and somatosensory [27] information for postural stability.

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

The computerized dynamic posturography-with immersion virtual reality (CDP-IVR) including sensory organization test (SOT) is a tool helping clinicians and researchers to determine the affected sensory systems that contribute to postural stability. SOT with IVR is used for this research. SOT is consisted of six sensory conditions: (1) normal vision with fixed support; (2) absent vision with fixed support; (3) swayed-reference vision with fixed support; (4) normal vision with swayed-referenced support;

(5) swayed-reference support with absent vision; and (6) swayed-referenced vision with swayed-referenced support. In this study, investigators assessed subjects' postural stability in three conditions, condition 1, 3 and 5. CDP-IVR calculates the participant's center of gravity displacement and postural sway to provide an overall equilibrium score. The Bertec Balance Advantage CDP-IVR calculates postural stability and generates an equilibrium score in the following manner: Signals from the participants' effort to maintain balance are sampled and analyzed at 1,000 Hertz and the sway path is computed. The testing protocol calculates the sway path with equilibrium scores that are quantified by how well the participant's sway remains within the expected angular limits of stability during each testing condition. The following formula was used to calculate the equilibrium score: Equilibrium Score (ES) = ([12.5 degrees – (taMAX – taMIN)]/12.5 degrees) *100 [20].

The ES uses 12.5° as the normal limit of the anterior-posterior sway angle range; taMAX is the theta maximum, and taMIN is the theta minimum. Theta is a Greek symbol often used to represent angles in two different planes. In the case of computerized dynamic posturography, angle theta is used to describe the maximum and minimum anterior and posterior sway angles in degrees. The sway angle was calculated as follows: Sway Angle = arcsin (COGy/(.55*h)), where y = anterior-posterior sway axis, and h = the subject's height (in centimeters or inches). The inverse sine of the center of gravity was divided by 55% of the participant's height. Participants exhibiting little sway achieve equilibrium scores near 100, while participants whose sway approaches their limits of stability achieve scores near zero [20].

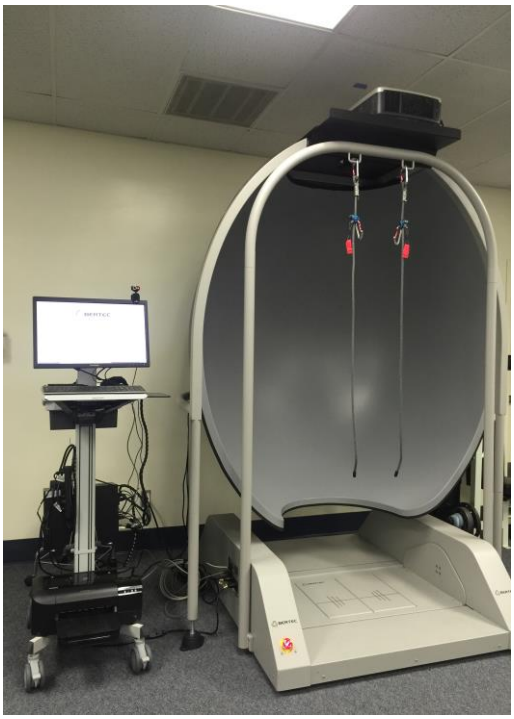

Figure 2. Bertec Balance Advantage Computerized Dynamic Posturography with Immersion Virtual Reality (CDP-IVR)

Anxiety and Vestibular System

Paillard et al. [10] report that the vestibular system is heavily involved in CMS. According to Eager et al., [28], the vestibular system's involvement in CMS makes sufferers susceptible to anxiety. Various studies suggest [28-30] that anxiety is related to vestibular dysfunction. Clinical anxiety disorders are prevalent among patients with vestibular dysfunction [28-35], and reciprocally, vestibular dysfunction has been found to be more prevalent in those with certain anxiety disorders, particularly panic disorder with agoraphobia [36-38].

Anxiety, Chronic Motion Sensitivity, and Postural Stability

According to Paillard et al. [10], there is a weak relationship between anxiety and CMS scores, with women having higher CMS and trait-anxiety scores than men. After comparing state and trait anxiety scores between individuals with extreme scores on the motion sickness questionnaire (MSQ) and individuals that had never experienced motion sensitivity, Collins and Lentz [39] found levels of higher trait-anxiety in CMS participants but not higher state-anxiety before rotatory vestibular stimulation. Tucker and Reinhardt [40] found that individuals with airsickness have higher levels of state-anxiety than those without airsickness.

Furthermore, motion sensitivity is an anomaly that has been associated with activity in the vestibular system as well as anxiety [41]. Reported history of motion sensitivity has been correlated with anxiety [39] and postural instability [42].

Owen et al., [43] appraised the role of anxiety in the relationship between reported motion sensitivity susceptibility and responses to disorienting perceptual-motor

conditions and showed that although postural sway and anxiety were correlated, none of the correlations reached significance. In contrast, in every condition, postural sway was significantly correlated with motion sensitivity and its reported symptoms in disorienting environments, with the correlation being strongest under conditions of inaccurate somatosensory and visual information.

Space and motion discomfort (SMD) [30] experienced by some patients with anxiety disorders is parallel to that experienced by people with CMS who do not suffer from anxiety disorders. Potentially disorienting motion environments in which the perceptual systems involved in orientation provide ambiguous information about self-motion induce both CMS and SMD [44,45]. Jacob [46] assessed postural sway in response to optic flow in the visual field of patients with anxiety disorders and SMD, with results showing significant differences between patients and controls in the degree of sway induced by the moving scenes.

State and Trait Anxiety Inventory

The State and Trait Anxiety Inventory (STAI) was used to measure the presence and severity of current state and general trait anxiety. The STAI includes two subscales: the State Anxiety Scale (S-Anxiety) evaluates the current state of anxiety by asking participants how they feel "right now," using 20 statements that measure their subjective feelings of apprehension, tension, nervousness, worry, and activation/arousal of the autonomic nervous system. The Trait Anxiety Scale (T-Anxiety) evaluates general aspects of participants' anxiety proneness using 20 general statements that measure their calmness, confidence, and security. The range of scores for each subscale is 20–80, with

higher scores indicating greater anxiety. A score of 39 or higher has been suggested to detect clinically significant symptoms for the S-Anxiety scale [47, 48].

Summary

In summary, the origin and precise neurobiological mechanism of CMS is unknown, the sensory conflict theory, which states that CMS results when sensory information that is transmitted to the CNS by one sensory system does not match the expected information transmitted from another sensory system [14], is the most widely accepted explanation [15]. Akiduki et al. [18] reported that that visual-vestibular conflict using virtual reality induced motion sickness symptoms and postural instability. According to Paillard et al. [10], there is a weak relationship between anxiety and CMS scores. Collins and Lentz [39] found levels of higher trait-anxiety in CMS participants but not higher state-anxiety using the old version of the STAI before rotatory vestibular stimulation. Tucker and Reinhardt [40] found that individuals with airsickness have higher levels of state-anxiety than those without airsickness. Relationship between Vestibular system, vision, anxiety and chronic motion sensitivity is not well understood.

References

1. Evans, R. W., Marcus, D., & Furman, J. M. (2007). Motion sickness and migraine. *Headache: The Journal of Head and Face Pain*, *47*(4), 607-610.

2. Oman, C. M. (1990). Motion sickness: a synthesis and evaluation of the sensory conflict theory. *Canadian journal of physiology and pharmacology*, *68*(2), 294-303.

3. Turner, M. (1999). Motion sickness in public road transport: passenger behaviour and susceptibility. *Ergonomics*, *42*(3), 444-461.

4. Alyahya, D., Johnson, E. G., Daher, N. S., Gaikwad, S. B., & Deshpande, S. (2016). Postural control in healthy young adults with and without chronic motion sensitivity, *3*(1), 1-4.

5. Lackner, J. R. (2014). Motion sickness: more than nausea and vomiting. *Experimental brain research*, *232*(8), 2493-2510.

6. Furman, J. M., Marcus, D. A., & Balaban, C. D. (2011). Rizatriptan reduces vestibular-induced motion sickness in migraineurs. *The journal of headache and pain*, *12*(1), 81-88.

7. Golding, J. F. (2006). Motion sickness susceptibility. *Autonomic Neuroscience, 129*(1), 67-76.

8. Golding, J. F., Kadzere, P., & Gresty, M. A. (2005). Motion sickness susceptibility fluctuates through the menstrual cycle. *Aviation, space, and Environmental medicine*, *76*(10), 970-973.

9. Jokerst, M. D., Gatto, M., Fazio, R., Gianaros, P. J., Stern, R. M., & Koch, K. L. (1999). Effects of gender of subjects and experimenter on susceptibility to motion sickness. *Aviation, space, and environmental medicine*, *70*(10), 962-965.

10. Paillard, A. C., Quarck, G., Paolino, F., Denise, P., Paolino, M., Golding, J. F., & Ghulyan-Bedikian, V. (2013). Motion sickness susceptibility in healthy subjects and vestibular patients: effects of gender, age and trait-anxiety. *Journal of Vestibular Research*, *23*(4, 5), 203-209.

11. Park, A. H., & Hu, S. (1999). Gender differences in motion sickness history and susceptibility to optokinetic rotation-induced motion sickness. *Aviation, space, and environmental medicine*, *70*(11), 1077-1080.

12. Dobie, T., McBride, D., Dobie Jr, T., & May, J. (2001). The effects of age and sex on susceptibility to motion sickness. *Aviation, space, and environmental medicine*, *72*(1), 13-20.

13. Flanagan, M. B., May, J. G., & Dobie, T. G. (2005). Sex differences in tolerance to visually-induced motion sickness. *Aviation, space, and environmental medicine*, *76*(7), 642-646.

14. Reason, J. T., & Brand, J. J. (1975). *Motion sickness*. Academic press.

15. Zhang, L. L., Wang, J. Q., Qi, R. R., Pan, L. L., Li, M., & Cai, Y. L. (2016). Motion sickness: current knowledge and recent advance. *CNS neuroscience & therapeutics*, *22*(1), 15-24.

16. Pitman, J. R., & Yolton, R. L. (1983). Etiology and treatment of motion sickness: a review. *Journal of the American Optometric Association*, *54*(1), 31-38.

17. Yates, B. J., Catanzaro, M. F., Miller, D. J., & McCall, A. A. (2014). Integration of vestibular and emetic gastrointestinal signals that produce nausea and vomiting: potential contributions to motion sickness. *Experimental brain research*, *232*(8), 2455-2469.

18. Akiduki, H., Nishiike, S., Watanabe, H., Matsuoka, K., Kubo, T., & Takeda, N. (2003). Visual-vestibular conflict induced by virtual reality in humans. *Neuroscience letters*, *340*(3), 197-200.

19. Herdman, S. J., & Clendaniel, R. (2014). *Vestibular rehabilitation*. FA Davis. Pennsylvania, pp. 2–79.

20. Bertec balance advantage user manual (2016, April 15). Retrieved from http://bertec.com/bertecbalance/our-products/dynamic/

21. Horak FB: Clinical Measurement of Postural Control in Adults. Phys Ther. 1987, 67: 1881-5.

22. Hassan BS, Mockett S, Doherty M: Static postural sway, proprioception, and maximal voluntary quadriceps contraction in patients with knee osteoarthritis and normal control subjects. Ann Rheum Dis. 2001, 60: 612-8.

23. Darlington CL, Smith PF. Molecular mechanisms of recovery from vestibular damage in mammals: recent advances. *Prog Neurobiol.* 2000; 62:313–325.

24. Horak FB, Henry SM, Shumway-Cook A. Postural perturbations: new insights for treatment of balance disorders. *Phys Ther.* 1997;77:517–533.

25. Redfern MS, Yardley L, Bronstein AM. Visual influences on balance. *J Anxiety Disord.* 2001;15:81–94.

26. Redfern, M. S., & Furman, J. M. (1994). Postural sway of patients with vestibular disorders during optic flow. Journal of Vestibular Research, 4, 221±230.

27. Hamid, M., Hughes, G., & Kinney, S. (1991). Specificity and sensitivity of dynamic posturography. Acta Otolaryngologica (Stockholm), 481 (Suppl.), 596±600.

28. Eagger, S., Luxon, L.M., Davies, R.A., Coelho, A., & Ron, M.A. (1992). Psychiatric morbidity in patients with peripheral vestibular disorder. A clinical and neuro-otological study. *Journal of Neurology, Neurosurgery, and Psychiatry*, *55*, 383–387.

29. Jacob, R. G. (1988). Panic disorder and the vestibular system. *Psychiatric Clinics of North America*.

30. Clark, D. B., Hirsch, B. E., Smith, M. G., Furman, J. M., & Jacob, R. G. (1994). Panic in otolaryngology patients presenting with dizziness or hearing loss. *American Journal of Psychiatry*, *151*(8), 1223–1225.

31. Clark, D.B., Leslie, M.I., & Jacob, R.G. (1992). Balance complaints and panic disorder – A clinical-study of panic symptoms in members of a self-help group for balance disorders. *Journal of Anxiety Disorders*, *6*, 47–53.

32. Godemann, F., Schabowska, A., Naetebusch, B., Heinz, A., & Strohle, A. (2006). The impact of cognitions on the development of panic and somatoform disorders: A prospective study in patients with vestibular neuritis. *Psychological Medicine*, *36*, 99–108.

33. Godemann, F., Linden, M., Neu, P., Heipp, E., & Dorr, P. (2004). A prospective study on the course of anxiety after vestibular neuronitis. *Journal of Psychosomatic Research*, *56*, 351–354.

34. Jacob, R.G., Brandt, T., & Furman, J.M. (2004). Psychiatric aspects of dizziness and imbalance. In Bronstein, A., Brandt, T., Woollacott, M., & Nutt, J.G. (Eds.), *Clinical Disorders of Balance, Posture and Gait*, (245–285). Arnold, London.

35. Staab, J.P., & Ruckenstein, M.J. (2003). Which comes first? Psychogenic dizziness versus otogenic anxiety. *Laryngoscope*, *113*, 1714–1718.

36. Perna, G., Dario, A., Caldirola, D., Stefania, B., Cesarani, A., & Bellodi, L. (2001). Panic disorder: The role of the balance system. *Journal of Psychiatric Research*, *35*, 279–286.

37. Yardley, L., Britton, J., Lear, S., Bird, J., & Luxon, L.M. (1995). Relationship between balance system function and agoraphobic avoidance. *Behavioral Research Therapy*, *33*, 435–439.

38. Tecer, A., Tukel, R., Erdamar, B., & Sunay, T. (2004). Audiovestibular functioning in patients with panic disorder. *Journal of Psychosomatic Research*, *57*, 177–182.

39. Collins, W.E., & Lentz, J.M. (1977). Some psychological correlates of motion sickness susceptibility. *Aviation, Space, and Environmental Medicine*, *48*, 587–594.

40. Tucker, G.J., & Reinhardt, R.F. (1967). Airsickness and anxiety. *Aerospace Medicine*, *38*, 855–858.

41. Tice, A.N. et al. (2017). Reliability and validity of Bertec computerized dynamic posturography. *Audiology Now*. Indianapolis: The American Academy of Audiology. 1. Print.

42. Maki, B. E., & McIlroy, W. E. (1996). Influence of arousal and attention on the control of postural sway. *Journal of Vestibular Research*, *6*, 53–59.

43. Owen, N., Leadbetter, A. G., & Yardley, L. (1998). Relationship between postural control and motion sickness in healthy subjects. *Brain Research Bulletin*, *47*, 471–474.

44. Jacob, R. G., Lilienfeld, S. O., Furman, J. M. R., Durrant, J. D., & Turner, S. M. (1989). Panic disorder with vestibular dysfunction: Further clinical observations and description of space and motion phobic stimuli. *Journal of Anxiety Disorders*, *3*, 117–130.

45. Yardley, L. (1992). Motion sickness and perception: a reappraisal of the sensory conflict approach. *British Journal of Psychology*, *83*, 449–473.

46. Jacob R. G, Redfern M.S., & Furman J.M. (1995). Optic-flow induced sway in anxiety disorders associated with space and movement discomfort. *Journal of Anxiety Disorders*, *9*, 411–425.

47. Knight, R.G., Waal-Manning, H.J., & Spears, G.F. (1983). Some norms and reliability data for the State-Trait Anxiety Inventory and the Zung Self-Rating Depression scale. *British Journal of Clinical Psychology*, *22*(Pt 4), 245–249. [PubMed: 6640176]

48. Addolorato, G., Ancona, C., Capristo, E., Graziosetto, R., Di Rienzo, L., Maurizi, M., et al. (1999). State and trait anxiety in women affected by allergic and vasomotor rhinitis. *Journal of Psychosomatic Research*, *46*, 283–289. [PubMed: 10193919]

CHAPTER TWO

EFFECT OF VISUAL INPUT ON POSTURAL STABILITY IN YOUNG ADULTS WITH CHRONIC MOTION SENSITIVITY: A CONTROLLED CROSS-SECTIONAL STUDY

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Abstract

BACKGROUND: Chronic motion sensitivity (CMS) has been defined as a feeling of un-wellness elicited by either actual or perceived motion. CMS is a common condition and is more prevalent in females than in males. In addition to a variety of symptoms, young adults with CMS have less postural stability than those without CMS.

OBJECTIVE: To determine whether dependence on visual cues for postural stability is different between young adults with and without CMS, and whether it differs by gender within each group.

METHODS: Sixty young adults (30 females and 30 males) were assigned to one of two groups (CMS or non-CMS) using the Motion Sickness Susceptibility Questionnaire-Short Form (MSSQ-SF). Postural stability was measured for all participants using the Bertec Balance Advantage–Computerized Dynamic Posturography with Immersion Virtual Reality (CDP-IVR).

RESULTS: A significant difference was found in mean postural stability scores during immersion virtual reality (IVR) between the CMS and non-CMS groups ($p<0.001$); however, no significant difference was shown in mean postural stability between males and females within the CMS and non-CMS groups ($p=0.10$ and $p=0.97$, respectively).

CONCLUSION: The results suggest that young adults with CMS are over-reliant on visual cues for postural stability, and that visual dependence may not be influenced by gender.

Keywords: motion sensitivity, vestibular system integrity, visual input, postural stability

Introduction

Chronic motion sensitivity (CMS), also referred to as motion sickness, is defined as a feeling of un-wellness elicited by either actual or perceived motion [9, 20]. It is a common condition with 28.4% of travelers experiencing motion sensitivity [28]. In addition to a variety of symptoms, such as dizziness, vomiting, cold sweats, pallor and nausea, young adults with CMS have less postural stability than those without CMS [2, 19, 20]. Furman et al. [12] reported that CMS could have a negative effect on a person's quality of life, particularly when it interferes with the ability to work, travel, or practice leisure activities. Females are reportedly more susceptible to CMS than males; however, the cause is unknown [13, 15, 18, 21, 22]. Dobie et al. [8] suggested the cause might be related to males being less inclined to admit illness. In addition, Flanagan et al. [10] reported that optokinetic stimuli increased symptoms of motion sensitivity in females more than in males. However, Park and Hu [22] found that gender differences did not affect the intensity of motion sensitivity symptoms that occurred while viewing a rotating optokinetic drum.

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medulla oblongata, vestibular apparatus, vestibulocochlear nerve, vestibular nuclei in the brainstem, nodulus and uvula of the cerebellum, reticular formation, and hypothalamus [23, 31].

Conflicts among sensory input systems, particularly between the visual and vestibular systems, cause disturbances of balance, which lead to disequilibrium and motion sensitivity [1, 16]. Akiduki et al. [1] concluded that visual-vestibular conflict using virtual reality induced motion sickness symptoms and postural instability. They also found a time lag between subjective symptoms of motion sensitivity and objective postural instability, which led the authors to suggest that symptoms of motion sensitivity are the cause of postural instability [1].

Whitney et al. [29] reported that there is growing evidence regarding the CNS's ability to compensate for vestibular dysfunction and re-weight sensory inputs in order to improve function. Previous studies [5, 25, 26] showed greater postural sway during visually moving environments in patients with vestibular disorders, visual vertigo and in those with anxiety and space and motion discomfort and suggested that these patients may be visually dependent for postural stability. Paillard et al. [21] reported that the vestibular system is heavily involved in CMS. Visual input is suggested to be a provocative stimulus for CMS [20]. The results of a pilot study by Alyahya et al. [2] theorized that participants with CMS have difficulty in maintaining their balance because of an over-reliance on their visual system. However, the role of visual cues remains unclear in CMS. Therefore, the aims of this study were 1) to determine whether dependence on visual cues for postural stability is different between young adults both with and without CMS and 2) to determine whether dependence on visual cues for

postural stability differs by gender within each group. The authors hypothesized that young adults with CMS would be more visually dependent than those without CMS, and visual dependency would be greater in females than in males among participants with CMS.

Methods

Participants

Sixty young adult participants from Loma Linda University and the local community (30 males and 30 females with a mean age of 26.8 ± 4.3 years and a body mass index (BMI) of 24.9 ± 4.6 kg/m^2) were recruited for this study via flyers, email, and word of mouth. Participants were divided into two groups: 30 participants (17 males and 13 females) had CMS, and 30 participants (13 males and 17 females) did not. Participants were excluded if they had a history of neurological disorders, musculoskeletal disorders, vestibular impairments, diabetic peripheral neuropathy, or were taking any medications that cause dizziness or imbalance. All participants signed the informed consent before beginning the study. This informed consent was approved by the academic, ethics committee to guarantee the participants' rights according to the Declaration of Helsinki.

Group Assignment

Participants were assigned to one of two groups, CMS or non-CMS, using the Motion Sickness Susceptibility Questionnaire-Short Form (MSSQ-SF). The MSSQ-SF is a valid and reliable tool used to predict individual differences in CMS caused by different types of motion [14]. The MSSQ-SF showed high internal consistency (Cronbrach's

alpha = 0.87); test-retest reliability (r around 0.9); significant correlation between Section A (child) and Section B (adult) (r=0.68); and predictive validity for motion susceptibility (r=0.51) [14]. The MSSQ-SF does not have cut-offs; therefore, the current investigators had previously contacted the author of the MSSQ-SF who advised the investigators to make cut-offs based on "practical or theoretical grounds". A previous study of CMS participants conducted in the same laboratory found the lowest MSSQ-SF score to be the 30th percentile. As a result, the authors decided that participants who scored in the 30th percentile or higher on the MSSQ-SF comprised the CMS group, whereas those who scored in the 25th percentile or lower were in the non-CMS group. Additionally, participants whose scores ranged from the 26th to the 29th percentile were excluded in order to create a "gap" between the two groups.

Apparatus

Postural stability was measured using the Bertec Balance Advantage–Computerized Dynamic Posturography with Immersion Virtual Reality (CDP-IVR) (Bertec Corporation; Columbus, OH). CDP-IVR calculates the participant's center of gravity displacement and postural sway to provide an overall equilibrium score. The Bertec Balance Advantage CDP-IVR calculates postural stability and generates an equilibrium score in the following manner: Signals from the participants' effort to maintain balance are sampled and analyzed at 1,000 Hertz and the sway path is computed. The testing protocol calculates the sway path with equilibrium scores that are quantified by how well the participant's sway remains within the expected angular limits of stability during each testing condition. The following formula was used to calculate the

equilibrium score: Equilibrium Score (ES) = ([12.5 degrees – (taMAX – taMIN)]/12.5 degrees) *100 [3].

The ES uses 12.5° as the normal limit of the anterior-posterior sway angle range; taMAX is the theta maximum, and taMIN is the theta minimum. Theta is a Greek symbol often used to represent angles in two different planes. In the case of computerized dynamic posturography, angle theta is used to describe the maximum and minimum anterior and posterior sway angles in degrees. The sway angle was calculated as follows: Sway Angle = arcsin (COGy/(.55*h)), where y = anterior-posterior sway axis, and h = the subject's height (in centimeters or inches). The inverse sine of the center of gravity was divided by 55% of the participant's height. Participants exhibiting little sway achieve equilibrium scores near 100, while participants whose sway approaches their limits of stability achieve scores near zero [3].

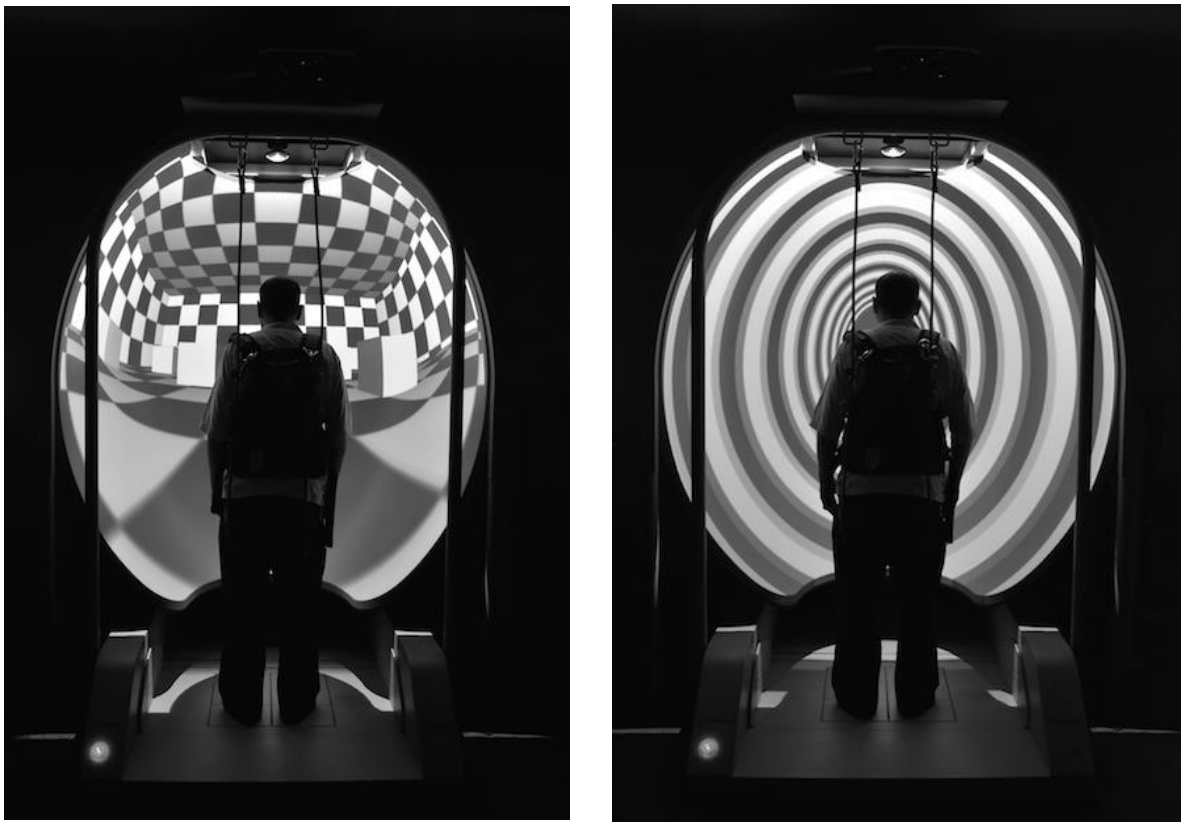

Fig 1. Participant was fitted with a safety harness, placed on a platform, and exposed to Computerized Dynamic Posturography with Immersion Virtual Reality. Condition 1: stable platform, eyes open, and stable visual scene (left); Condition 2: stable platform, eyes open, and infinite tunnel visual flow (right).

Procedures

Prior to testing, each participant removed his or her footwear and was fitted with a safety harness before measurement of his/her postural stability. Postural stability was measured under two conditions that were completed in the same order for all participants: condition 1 measured the baseline postural stability on a stable platform with the participant's eyes open looking at a stable visual scene (see Fig. 1), followed by condition 2, which measured postural stability on a stable platform with the participant's eyes open while they focused on a virtual reality infinite tunnel visual flow (see Fig. 1). Each condition lasted 20 seconds and was performed three times. The infinite tunnel was used to give the participants the perception that they were moving toward the tunnel in an anterior direction. During testing, the investigators monitored the position of the feet, and participants were instructed to stand quietly with their arms at their sides.

Data analysis

Sixty young adults completed the study. The sample size was estimated using a medium effect size of 0.50, power of 0.80, and a level of significance (α) of 0.05. Data were analyzed using the statistical package SPSS for Windows version 22.0 (SPSS, Inc., Chicago, IL). To summarize the data, descriptive statistics were used. Data were reported as the mean ± standard deviation (SD) for quantitative variables and as frequency and percent (%) for categorical variables. The association between gender and physical activity by group (with or without CMS) was assessed using the Chi-square test of independence. The Kolmogorov Smirnov test and box plots were performed to examine the normality of the quantitative variables. An independent t-test was conducted to

compare the means of height (m), weight (kg), and BMI (kg/m^2) between the two groups. Because the distributions of age as well as conditions 1 and 2 were not normal, differences in their mean by group type were examined using the Mann-Whitney test. The level of statistical significance was set at $p \leq 0.05$.

Results

There were no significant differences between the participants with CMS ($n_1=30$) and those without CMS ($n_2=30$) in terms of mean height (m), weight (kg), BMI (kg/m^2) at baseline, or baseline postural stability scores ($p>0.05$, see Table 1). However, there was a significant difference in mean age between the two groups ($p=0.04$, see Table 1). Results showed that there was no significant relationship between gender and physical activity by group (see Table 1). There was a significant difference in mean postural stability for condition 2 between the CMS and non-CMS groups (87.4±7.5 versus 93.1±1.9, $p< 0.001$; Cohen's $d=0.83$) after controlling for age (see Fig. 2). However, there was no significant difference in mean postural stability for condition 2 between males and females either within the CMS group (86.1±8.6 versus 89.2 ± 5.5; Cohen's $d=0.43$, $p=0.10$) or the non-CMS group (93.1±2.1 versus 93.2 ± 1.9; Cohen's $d=0.05$, $p=0.97$, see Table 2).

Table 1.

Mean (SD) of general characteristics by group type (N=60)

Characteristic	CMS (n_1=30)	Non-CMS (n_2=30)	p–value
Female [b]; n (%)	13 (43.3)	17 (56.7)	0.22
Age[c] (years)	27.9 (4.5)	25.6 (3.8)	0.04*
Height[a] (m)	1.7 (0.1)	1.7 (0.1)	0.67
Weight[a] (kg)	75.1 (20.6)	68.7 (14.6)	0.17
BMI[a] (kg/m^2)	25.8 (5.6)	24.1 (3.2)	0.14
Physical Activity [b]; n (%)			0.29
Often	11 (36.7)	14 (46.7)	
Sometimes	16 (53.3)	15 (50.0)	
Never	3 (10.0)	1 (3.3)	
Condition 1 [c]	93.8 (2.7)	94.9 (1.3)	0.25

*p<0.05

Abbreviations: CMS = chronic motion sensitivity; BMI = body mass index; SD = standard deviation

Condition 1 = stable platform, eyes open, and stable visual scene

[a] Independent t-test; [b] Chi square test of independence; [c] Mann-Whitney U test

Table 2

Mean (SD) of equilibrium score for condition 2 (eyes open, infinite tunnel visual flow, and stable platform) by group type and gender

	Female (n_1=30)	Male (n_2=30)	p–value[a]
Non-CMS	93.2 (1.9)	93.1 (2.1)	0.97
CMS	89.2 (5.5)	86.1 (8.6)	0.10

Abbreviations: CMS = Chronic motion sensitivity; SD = Standard Deviation

[a] Mann-Whitney test

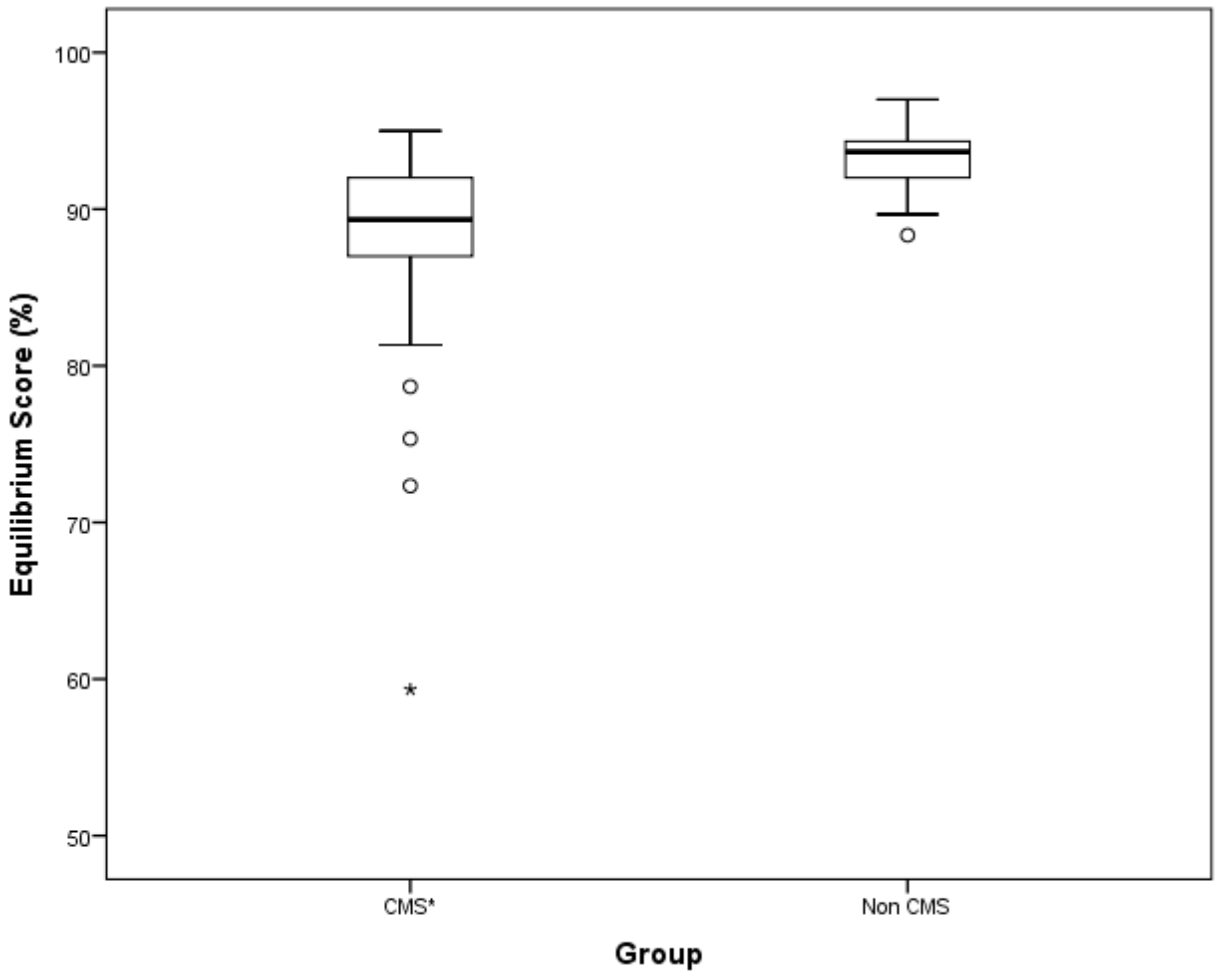

Fig 2. Box and Whisker Plot of Equilibrium Score (%) for Condition 2: stable platform, eyes open, and infinite tunnel visual flow by group type (N=60)
Abbreviation: CMS = Chronic Motion Sensitivity; *p<0.001

Discussion

In the present study, dependence on visual cues for postural stability was examined in young adults with and without CMS. The results demonstrated that postural stability was worse in the CMS group compared to the non-CMS group. The effect of gender on dependence on visual cues for maintaining postural stability was also examined, and there was no significant difference in mean postural stability between females and males within each group.

The infinite tunnel was used to give the participants the perception that they were moving toward the tunnel in an anterior direction. In other words, the participants' visual system received signals of false movement, which challenged their CNS to determine if motion was actually occurring. Young adults with CMS swayed more than those without CMS suggesting that the postural stability of young adults with CMS changes in response to false visual input. Conversely, young adults without CMS demonstrated a better ability to counter misleading visual input. Furman [11] reported that computerized dynamic posturography could provide important information regarding how a patient's balance disturbance affects activities of daily living. In the present study, the balance disturbance was visual input. Whitney et al. [30] indicated that sensitivity to visual perturbations and visual dependency are developed if preference is given to visual inputs. It is likely that the CNS relies on visual information, even when vision is providing inaccurate information about body sway in individuals with CMS. This response reflects that postural stability in young adults with CMS is reliant on the visual system. Therefore, the finding of this study supports the previous suggestion from Alyahya et al. [2].

Shahal et al. [27] reported that people with seasickness have relative vestibular dysfunction and are less dependent on vestibular input for postural stability. Paillard et al. [21] found that patients with vestibular loss had less CMS compared to vestibular patients without vestibular loss (benign paroxysmal positional vertigo, vestibular migraine, or Meniere's disease). In addition, vestibular patients without vestibular loss had more CMS than healthy participants. These findings led Paillard et al. [21] to suggest that the vestibular system is heavily involved in CMS. Black and Nashner [4] reported that some vestibular patients appear to be more reliant on visual cues for postural stability. Relying primarily on information from non-vestibular input is one way to compensate for a vestibular deficit [7, 17, 30]. Therefore, vestibular system involvement in CMS may explain a tendency towards over-reliance on the visual system.

Previous studies [13, 18, 21, 22] have shown gender differences in reports on CMS. However, the theory that the severity of motion sensitivity's symptoms increases by manipulating visual input in females more than males remains controversial [10, 22]. The findings of this study showed no significant difference by gender for postural stability with immersion virtual reality exposure. The lack of statistical significance may be attributed to an insufficient sample size. Although males swayed more than females, the result was not statistically significant. Caillet et al. [6] reported that physical and sports activities can produce a rearrangement process that improves CMS. In this study, 46% of the females were practicing physical and sports activities often versus 29% of the males. This may explain the slight difference between males and females regarding postural stability.

Limitations

There were limitations in this study. First, the study sample included young adult men and women between 20–40 years of age; hence, the findings cannot be generalized to individuals outside of this age range. Second, a valid and reliable physical activity questionnaire was not used; instead, participants reported the frequency of their workouts (never, sometimes, and often). Further research should include different age ranges and a valid physical activity questionnaire should be used. Also, the relationship between anxiety and CMS should be considered.

Conclusion

The results suggest that young adults with CMS are over-reliant on their visual system for maintaining postural stability, and that visual dependence does not differ by gender.

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References

1. Akiduki, H., Nishiike, S., Watanabe, H., Matsuoka, K., Kubo, T., & Takeda, N. (2003). Visual-vestibular conflict induced by virtual reality in humans. *Neuroscience letters*, *340*(3), 197-200.

2. Alyahya, D., Johnson, E. G., Daher, N. S., Gaikwad, S. B., & Deshpande, S. (2016). Postural control in healthy young adults with and without chronic motion sensitivity, International journal of physiotherapy, *3*(1), 1-4.

3. Bertec balance advantage user manual (2016, April 15). Retrieved from http://bertec.com/bertecbalance/our-products/dynamic/

4. Black, F. O., & Nashner, L. M. (1983). Vestibulo-spinal control differs in patients with reduced versus distorted vestibular function. *Acta Oto-Laryngologica*, *96*(sup406), 110-114.

5. Bronstein, A. M. (2004). Vision and vertigo. *Journal of neurology*, *251*(4), 381-387.

6. Caillet, G., Bosser, G., Gauchard, G. C., Chau, N., Benamghar, L., & Perrin, P. P. (2006). Effect of sporting activity practice on susceptibility to motion sickness. *Brain research bulletin*, *69*(3), 288-293.

7. Darlington, C. L., & Smith, P. F. (2000). Molecular mechanisms of recovery from vestibular damage in mammals: recent advances. *Progress in neurobiology*, *62*(3), 313-325.

8. Dobie, T., McBride, D., Dobie Jr, T., & May, J. (2001). The effects of age and sex on susceptibility to motion sickness. *Aviation, space, and environmental medicine*, *72*(1), 13-20.

9. Evans, R. W., Marcus, D., & Furman, J. M. (2007). Motion sickness and migraine. *Headache: The Journal of Head and Face Pain*, *47*(4), 607-610.

10. Flanagan, M. B., May, J. G., & Dobie, T. G. (2005). Sex differences in tolerance to visually-induced motion sickness. *Aviation, space, and environmental medicine*, *76*(7), 642-646.

11. Furman, J. M. (1994). Posturography: uses and limitations. *Bailliere's clinical neurology*, *3*(3), 501-513.

12. Furman, J. M., Marcus, D. A., & Balaban, C. D. (2011). Rizatriptan reduces vestibular-induced motion sickness in migraineurs. *The journal of headache and pain*, *12*(1), 81-88.

13. Golding, J. F. (2006). Motion sickness susceptibility. *Autonomic Neuroscience*, *129*(1), 67-76.

14. Golding, J. F. (2006). Predicting individual differences in motion sickness susceptibility by questionnaire. *Personality and Individual differences*, *41*(2), 237-248.

15. Golding, J. F., Kadzere, P., & Gresty, M. A. (2005). Motion sickness susceptibility fluctuates through the menstrual cycle. *Aviation, space, and Environmental medicine*, *76*(10), 970-973.

16. Herdman, S. J., & Clendaniel, R. (2014). *Vestibular rehabilitation*. FA Davis.

17. Horak, F. B., Henry, S. M., & Shumway-Cook, A. (1997). Postural perturbations: new insights for treatment of balance disorders. *Physical therapy*, *77*(5), 517.

18. Jokerst, M. D., Gatto, M., Fazio, R., Gianaros, P. J., Stern, R. M., & Koch, K. L. (1999). Effects of gender of subjects and experimenter on susceptibility to motion sickness. *Aviation, space, and environmental medicine*, *70*(10), 962-965.

19. Lackner, J. R. (2014). Motion sickness: more than nausea and vomiting. *Experimental brain research*, *232*(8), 2493-2510.

20. Oman, C. M. (1990). Motion sickness: a synthesis and evaluation of the sensory conflict theory. *Canadian journal of physiology and pharmacology*, *68*(2), 294-303.

21. Paillard, A. C., Quarck, G., Paolino, F., Denise, P., Paolino, M., Golding, J. F., & Ghulyan-Bedikian, V. (2013). Motion sickness susceptibility in healthy subjects and vestibular patients: effects of gender, age and trait-anxiety. *Journal of Vestibular Research*, *23*(4, 5), 203-209.

22. Park, A. H., & Hu, S. (1999). Gender differences in motion sickness history and susceptibility to optokinetic rotation-induced motion sickness. *Aviation, space, and environmental medicine*, *70*(11), 1077-1080.

23. Pitman, J. R., & Yolton, R. L. (1983). Etiology and treatment of motion sickness: a review. *Journal of the American Optometric Association*, *54*(1), 31-38.

24. Reason, J. T., & Brand, J. J. (1975). *Motion sickness*. Academic press.

25. Redfern, M., & Furman, J. (1994). Postural sway in response to optic flow stimuli in vestibular patients. *J. Vestib. Res.*, *4*(3), 221-230.

26. Redfern, M. S., Furman, J. M., & Jacob, R. G. (2007). Visually induced postural sway in anxiety disorders. *Journal of anxiety disorders*, *21*(5), 704-716.

27. Shahal, B., Nachum, Z., Spitzer, O., Ben-David, J., Duchman, H., Podoshin, L., & Shupak, A. (1999). Computerized dynamic posturography and seasickness susceptibility. *The Laryngoscope*, *109*(12), 1996-2000.

28. Turner, M. (1999). Motion sickness in public road transport: passenger behaviour and susceptibility. *Ergonomics*, *42*(3), 444-461.

29. Whitney, S. L., Alghadir, A. H., & Anwer, S. (2016). Recent evidence about the effectiveness of vestibular rehabilitation. *Current treatment options in neurology*, *18*(3), 1-15.

30. Whitney, S. L., Jacob, R. G., Sparto, P. J., Olshansky, E. F., Detweiler-Shostak, G., Brown, E. L., & Furman, J. M. (2005). Acrophobia and pathological height vertigo: indications for vestibular physical therapy?. *Physical Therapy*, *85*(5), 443-458.

31. Yates, B. J., Catanzaro, M. F., Miller, D. J., & McCall, A. A. (2014). Integration of vestibular and emetic gastrointestinal signals that produce nausea and vomiting: potential contributions to motion sickness. *Experimental brain research*, *232*(8), 2455-2469.

32. Zhang, L. L., Wang, J. Q., Qi, R. R., Pan, L. L., Li, M., & Cai, Y. L. (2016). Motion sickness: current knowledge and recent advance. *CNS neuroscience & therapeutics*, *22*(1), 15-24.

CHAPTER THREE

RELATIONSHIP BETWEEN VESTIBULAR SYSTEM INTEGRITY AND CHRONIC MOTION SENSITIVITY

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Abstract

Background: Conflict among sensory inputs is the most commonly accepted explanation of chronic motion sensitivity (CMS), or motion sickness. Some vestibular patients have trouble resolving this conflict and as a result, have reduced postural stability. Females are more susceptible to CMS than males. The aims of this study were to evaluate whether the integrity of the vestibular system is diminished in young adults with CMS compared with that in young adults without CMS; to evaluate whether it is diminished in males or females with CMS compared with that in their counterparts without CMS; and to compare the severity of CMS in males and females.

Methods: Sixty healthy adults aged 20–40 years were assigned to two groups with and without CMS using the Motion Sickness Susceptibility Questionnaire—Short Form. Postural stability was measured with Bertec Balance Advantage™ computerized dynamic posturography under two conditions: condition 1 (eyes open, participant on a stable platform with a stable visual scene) and condition 2 (eyes closed, participant on an unstable platform).

Results: Mean postural stability did not differ significantly between the CMS and non-CMS groups under condition 2 (55.9 ± 3.3 versus 58.6 ± 3.3, respectively; $F_{1,57}$ = 0.33. p = 0.57; η^2 = 0.01). When the data for males and females were analyzed separately, there was a significant difference in the mean postural stability of the males in the CMS and non-CMS groups under condition 2 (47.4 ± 4.2 versus 58.9 ± 4.8, respectively; $F_{1,27}$ = 3.20, p = 0.04; η^2 = 0.2). In females, this difference was not significant (66.4 ± 4.9 versus 58.7 ± 4.3, respectively; $F_{1,27}$ = 1.31, p = 0.26; η^2 = 0.05). There was also no

significant difference in the median (min, max) MSSQ-SF percentiles of males and females (86.1 [49.2, 100.7] versus 91.7 [49.8, 100.6]; p = 0.87).

Discussion: Although the severity of CMS is not influenced by sex, young adult males with CMS may have diminished vestibular system integrity.

Keywords: Motion sickness, sex, postural stability

Introduction

Approximately 42% of the adult population reports episodes of dizziness or vertigo to their physicians annually, and vestibular dysfunction is the cause in 85% of these cases [15, 38]. Postural stability is affected by motion-provoked dizziness [2].

Chronic motion sensitivity (CMS), also referred to as 'motion sickness', has been defined as "a feeling of un-wellness caused by motion, especially during travelling and virtual reality immersion" [40]. CMS induces a wide range of symptoms, including cold sweating, varying degrees of pallor, increased salivation, drowsiness, nausea, and vomiting [23, 28, 40].

Several studies have suggested that females are more susceptible to CMS than males and have a greater incidence of vomiting on all major forms of transport and in all motion situations [9, 16, 22, 24, 25, 29, 30]. However, Dobie et al. [11] argue that the greater susceptibility of females to motion sickness cannot be explained by differences in their exposure to motion or physical activity. Instead, it may be attributable to the reluctance of males to admit illness. Furthermore, several studies have detected no significant difference between males and females in terms of CMS rate or the incidence of different symptoms [26, 36].

Several theories have been proposed to explain the neurobiological mechanism of CMS, but the precise etiology is unknown [40]. One of the most widely accepted theories is the sensory conflict theory [28, 40], which states that CMS occurs when signals from various sensory systems (visual, vestibular, or somatosensory) are mismatched [31]. This mismatch commonly occurs between the vestibular and visual systems [15]. Akiduki et al. reported that conflicts among sensory input systems, particularly between the visual

and vestibular systems, induce motion sickness symptoms, leading to postural instability [1]. Alyahya et al. [3] concluded that individuals with CMS have less postural stability than those who do not.

The accurate integration of sensory inputs (visual, somatosensory, and vestibular) provides the information necessary for maintaining postural stability [19]. Each sensory input provides the central nervous system with a different kind of information about the head and body position, the motion experienced, and the surrounding environment [19]. The central nervous system receives signals from these systems and analyzes them to estimate the position and movement of an individual, and provides an output that travels to the spinal cord, allowing the vestibulospinal reflex to maintain postural stability [15, 19].

The sensory reweighting process, in which the vestibular system relies primarily on information from the visual and/or somatosensory inputs, is one way that the body compensates for a vestibular deficit [10, 21, 34]. The combination of visual and somatosensory information may also compensate for a vestibular deficit [19]. Patients with a vestibular deficit tend to be over-reliant on visual [33] and somatosensory [18] information for postural stability.

Alyahya et al. [3] suggested that individuals with CMS are over-reliant on the visual system. In addition, individuals who were susceptible to seasickness, who were tested with computerized dynamic posturography (CDP), were more dependent on the somatosensory and visual inputs than on vestibular input [35]. Studies have suggested that the vestibular system is involved, either directly or indirectly, in CMS [29, 31].

Furman reported that CDP is a useful functional measurement that provides information on a patient's ability to properly use vestibular information [13].

The relationship between the integrity of the vestibular system and CMS in young adults is not completely understood. Some patients with peripheral or central vestibular disorders have trouble resolving conflicts among sensory inputs [34]. Therefore, the objectives of this study were 1) to investigate whether the integrity of the vestibular system is diminished in young adults with CMS compared with that in young adults without CMS; 2) to investigate whether the integrity of the vestibular system is diminished in males or females with CMS compared with that of their counterparts without CMS; and 3) to compare the severity of CMS in males and females. The hypotheses tested were that young adults with chronic CMS have diminished vestibular system function compared with young adults without CMS; that the difference in the integrity of the vestibular system between females with and without CMS is greater than the difference between males with and without CMS; and that CMS is more severe in females than in males.

Methods

Sixty healthy adults (30 males and 30 females) aged 20–40 years (mean, 26.8 ± 4.3 years), with a mean body mass index (BMI) of 24.9 ± 4.6 kg/m^2, participated in this study. They were recruited with flyers, emails, and word of mouth. The participants were divided into two groups: 30 participants (17 males and 13 females) had CMS, and 30 participants (13 males and 17 females) did not. Before participating in the study, the participants read and signed an informed consent agreement that was approved by the Institutional Review Board of Loma Linda University.

The exclusion criteria included: 1) history of neurological disorder, musculoskeletal disorder, vestibular impairment, or diabetic peripheral neuropathy; 2) use of any medication that causes dizziness or imbalance; 3) a result on the Motion Sensitivity Susceptibility Questionnaire—Short Form (MSSQ-SF) between the 30th and 25th percentiles.

The MSSQ-SF was developed to measure susceptibility to CMS and the kinds of motion that most effectively cause motion sensitivity [17]. The MSSQ-SF is a valid and reliable tool used to predict individual differences in CMS caused by different types of motion [17]. The MSSQ-SF showed high internal consistency (Cronbrach's alpha = 0.87); test–retest reliability (r around 0.9); significant correlation between Section A (child) MSA and Section B (adult) MSB (r = 0.68); and predictive validity for motion susceptibility (r = 0.51) [17]. To evaluate CMS, the participants reported how often they felt sick and nauseated within two age ranges: during childhood MSA score and during adulthood MSB score. The MSSQ-SF percentile was calculated to assign each participant to a group and to compare the severity of CMS between males and females. Participants who scored in the 30th percentile or higher on the MSSQ-SF were assigned to the CMS group, whereas those who scored in the 25th percentile or lower were assigned to the non-CMS group.

In this study, 30 participants were assigned to the CMS group and 30 to the non-CMS group. Before any data were collected, the participants removed their footwear, and the investigators made anthropometric measurements (weight and height). The participants were then fitted with a safety harness before the postural stability measurements were made.

Postural stability was measured in all the participants using Bertec Balance Advantage™ computerized dynamic posturography with immersion virtual reality (CDP-IVR) [5] under two conditions (in the following order): condition 1 measured baseline postural stability on a stable platform with a stable visual scene; followed by condition 2 measured postural stability on an unstable platform with the participant's eyes closed. Condition 2 investigated each participant's ability to use the vestibular system. Each condition included three 20 s trials, and the average results of those three trials was calculated for each condition. During testing, the investigators monitored the participants' feet positions and instructed them to keep their eyes closed under condition 2.

CDP can suggest the presence of vestibular system deficits, regardless of localization, and measures a person's ability to properly use vestibular system information in combination with the information from other sensory systems [13]. CDP-IVR calculates postural stability and generates an equilibrium score in the following manner. Signals from the participant's efforts to maintain his/her balance are sampled and analyzed at 1,000 Hz, and the sway path is computed. The testing protocol calculates the sway path from the equilibrium scores, quantifying how well the participant's sway remains within the expected angular limits of stability under each testing condition. The following formula was used to calculate the equilibrium score (ES):
12.5° − (taMAX − taMIN)]/12.5°) × 100. ES uses 12.5° as the normal limit of the anterior–posterior sway angle range; taMAX is the theta maximum and taMIN is the theta minimum. The sway angle was calculated with the following formula: sway angle = arcsin(COGy/[0.55 × h]), where y = anterior–posterior sway axis and h = participant's height in centimeters or inches. The inverse sine of the center of gravity (COG) was

divided by 55% of each person's height. Participants showing little sway will have equilibrium scores near 100, whereas subjects whose sway approaches their limits of stability will have scores near zero [5].

Statistical Analysis

Data were analyzed with the statistical package SPSS for Windows, version 22.0 (SPSS, Inc., Chicago, IL, USA). The sample size required for this study was estimated from a medium effect size of 0.50, a power of 0.80, and a level of significance (α) of 0.05. Means ± standard deviations were computed for quantitative variables, and frequencies (percentages) were calculated for categorical variables. The relationship between sex and physical activity by study group (with or without CMS) was examined using a χ^2 test of independence. The Shapiro–Wilk test and box-and-whisker plots were used to assess the normality of the quantitative variables. To compare the mean heights (m), weights (kg), and BMIs (kg/m^2) of the CMS and non-CMS groups, an independent *t* test was used. Differences in mean age and postural stability under condition 1 by group type were examined with the Mann–Whitney test. Analysis of covariance was used to compare the mean stability scores under condition 2 between adults with CMS and those without CMS, after controlling for age. When the males and females were analyzed separately, the mean integrity of the vestibular system was compared under conditions 1 and 2 by study group, using the Mann–Whitney *U* test. The difference in CMS severity between the male and female adults was examined using an independent *t* test. Differences were deemed statistically significant at $p \leq 0.05$.

Results

There were no significant differences in mean heights (m), weight (kg), or BMI (kg/m^2) at baseline, or in the baseline postural stability scores under condition 1 for participants with CMS ($n_1 = 30$) and those without CMS ($n_2 = 30$) ($p > 0.05$; Table 1). However, there was a significant difference in the mean ages of the two groups ($p = 0.04$; Table 1). There was no significant relationship between sex and physical activity between the two groups (Table 1). There was also no significant difference in mean postural stability between the CMS and non-CMS groups under condition 2 (55.9 ± 3.3 versus 58.6 ± 3.3, respectively; $F_{1,57} = 0.33$, $p = 0.57$; $\eta^2 = 0.01$) after controlling for age.

When the data for males and females were analyzed separately, there was a significant difference in mean postural stability under condition 2 between the males in the CMS and non-CMS groups (47.4 ± 4.2 versus 58.9 ± 4.8, respectively; $F_{1,27} = 3.20$, $p = 0.04$; $\eta^2 = 0.2$; Figure 2). However, the effect of age was not significant ($F_{1,27} = 1.30$, $p = 0.26$; $\eta^2 = 0.05$). In females, this difference was not significant (66.4 ± 4.9 versus 58.7 ± 4.3, respectively; $F_{1,27} = 1.31$, $p = 0.26$; $\eta^2 = 0.05$; Table 2). When the median postural stability under condition 2 was compared between participants with CMS and those without CMS in the male and female groups (separately), the results were similar ($p = 0.03$ and $p = 0.66$, respectively; Table 2). There was also no significant difference in the median (min, max) MSSQ-SF percentiles of the males and females (86.1 [49.2, 100.7] versus 91.7 [49.8, 100.6], respectively; $p = 0.87$).

Table 1.

General baseline characteristics (mean ± SD) of the participants by group (N = 60)

Characteristic	CMS (n_1 = 30)	Non-CMS (n_2 = 30)	p value[a]
Female[b]; n (%)	13 (43.3)	17 (56.7)	0.22
Age[c]* (years)	27.9 (4.5)	25.6 (3.8)	0.04
Height (m)	1.7 (0.1)	1.7 (0.1)	0.67
Weight (kg)	75.1 (20.6)	68.7 (14.6)	0.17
BMI (kg/m^2)	25.8 (5.6)	24.1 (3.2)	0.14
Physical activity[b]; n (%)			0.29
Often	11 (36.7)	14 (46.7)	
Sometimes	16 (53.3)	15 (50.0)	
Never	3 (10.0)	1 (3.3)	
Condition 1[c] (%)	93.8 (2.7)	94.9 (1.3)	0.25

Abbreviations: CMS, chronic motion sensitivity; BMI, body mass index; SD, standard deviation

Condition 1 = baseline postural stability

[a]Independent *t* test; [b]χ^2 test of independence; [c]Mann–Whitney *U* test

*$p < 0.05$

Table 2.

Median (min, max) values under conditions 1 and 2 by study group and gender (N = 60)

Sex	Males (N_1 = 30)			Females (N_2 = 30)		
Variable	CMS (n_1 = 17)	Non-CMS (n_2 = 13)	p value[a]	CMS (n_1 = 13)	Non-CMS (n_2 = 17)	p value[a]
Condition 1	94.7 (85, 97)	95.0 (92, 96)	0.44	95.0 (91, 97)	95.0 (93, 98)	0.41
Condition 2	49.3 (10, 78)	62.0 (36, 78)	0.03	69.0 (22, 77)	68.0 (21, 80)	0.60

Abbreviations: CMS, chronic motion sensitivity

[a]Mann–Whitney *U* test

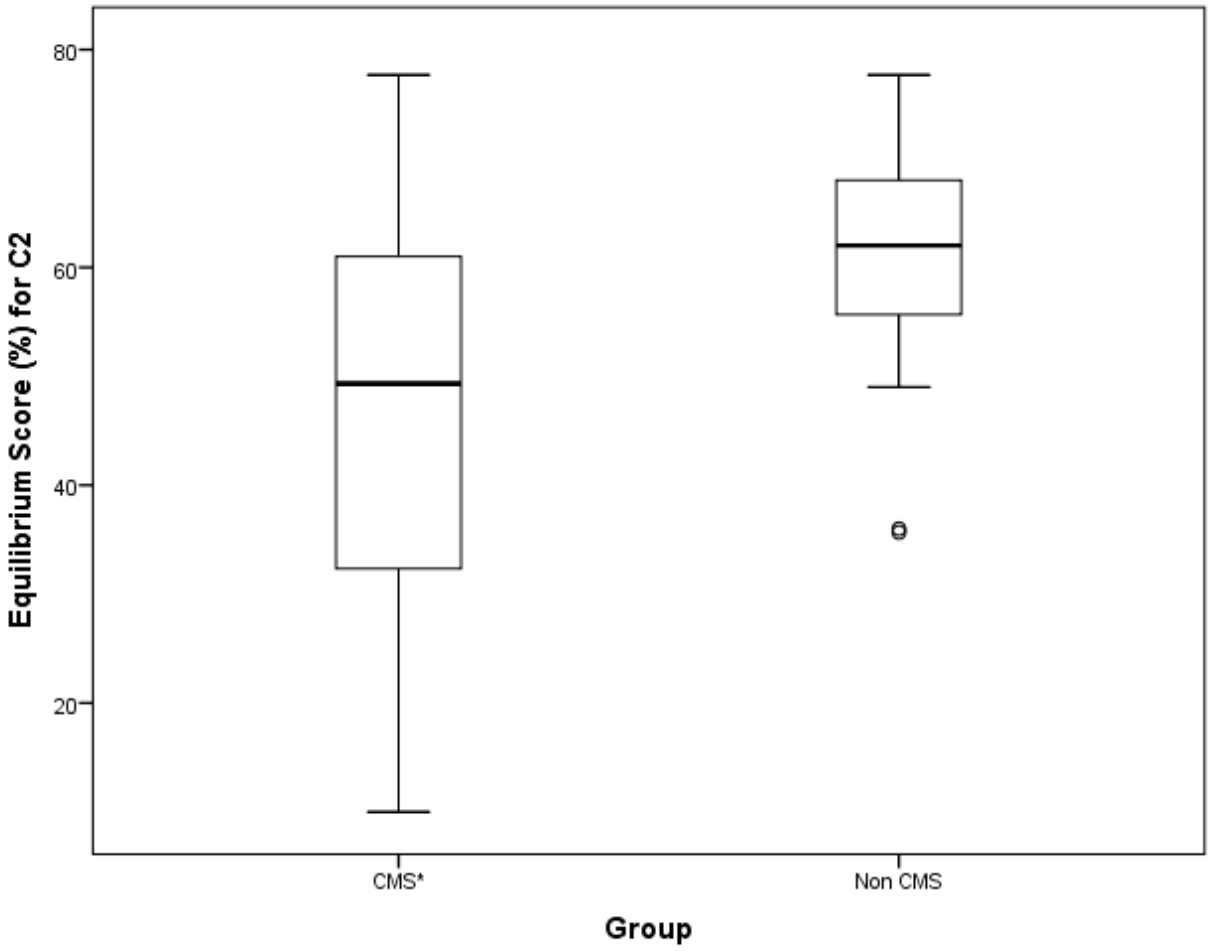

Figure 2. Postural stability (%) by study group among males (N=30)

Discussion

The objective of this study was to investigate whether the integrity of the vestibular system is diminished in young adults with CMS, using CDP. The severity of CMS in the male and female populations of the CMS group was also compared. The results of this study demonstrate that the participants with CMS did not sway more than those without CMS. However, males with CMS swayed more than males without CMS, whereas no difference was observed between the females with and without CMS. These results also show that males and females do not differ in reporting the severity of CMS.

In this study, the young adults (males and females) had the same ability to use their vestibular sensory information, regardless of CMS. This finding suggests that there is no vestibular diminishment in young adults with CMS. Buyuklu et al. [7] used caloric tests and vestibular-evoked myogenic potentials to examine superior and inferior vestibular systems, and found no vestibular deficits in the participants with CMS. There are two possible explanations for the results of this study. First, CMS onset begins around 6–7 years of age [32], reaching peak severity at around 9–10 years of age [37], and declining in severity from adolescence to adulthood [16]. The decline in CMS severity with increasing age may be attributable to continuous habituation to CMS [29]. In the present study, the target age range was young adults, aged 20–40 years, and these subjects may have been able to use vestibular information properly as a result of their habituation to CMS, which improved the integrity of the vestibular system. This would support previous studies [16, 29] that have suggested that the severity of CMS continues to decline with advancing age. Second, the participants with CMS reported more frequent practice of sports and physical activity (46.7% [CMS] versus 36.7% [non-CMS]). Caillet

et al. [8] reported that participation in physical and sporting activities improves CMS by producing a rearrangement process, in which an individual becomes less dependent on visual input and uses vestibular information more effectively.

When the data for males and females were analyzed separately, the results showed that the integrity of the vestibular system is diminished in males with CMS compared with males without CMS. However, vestibular integrity was not diminished in females with CMS. Shahal et al. [35] suggested that males aged 18–25 years who suffer seasickness have relative vestibular dysfunction or an overreliance on the visual and/or somatosensory systems. Reason [31] and Paillard et al. [29] also suggested that the vestibular system is involved directly or indirectly in CMS.

In this study, the severity of CMS in young adults did not differ between males and females based on the rating severity (in terms of MSSQ-SF), consistent with several studies [26, 36], although other studies have reported that females had more-severe CMS than males [24, 25]. Although there was no statistically significant difference between the males and females in the present study, the females scored higher on MSSQ than males. The findings that males had diminished vestibular integrity and lower MSSQ scores are consistent with the suggestion of Dobie et al. [11] that the difference in CMS between males and females may be related to the reluctance of males to admit illness. Another possible explanation is that 46% of the females reported that they often practice sports and physical activity, whereas only 29% of males did so, and Gauchard et al. [14] reported that regular physical activity improves the integrity of the vestibular system.

There were several limitations to this study. Only young adults aged 20–40 years were included, so the findings cannot be generalized to individuals outside this age range.

Furthermore, a valid and reliable physical activity questionnaire was not used. Instead, the participants reported how often they exercised (never, sometimes, or often). A previous study has shown that inactivity can affect postural stability [20], and that participation in sports and other physical activities may improve postural stability and CMS [6, 8, 27, 39].

Conclusion

The results of this study suggest that although the severity of CMS is not influenced by sex, young adult males with CMS may have diminished vestibular system integrity.

References

1. Akiduki, H., Nishiike, S., Watanabe, H., Matsuoka, K., Kubo, T., & Takeda, N. (2003). Visual-vestibular conflict induced by virtual reality in humans. *Neuroscience letters*, *340*(3), 197-200.

2. Akin, F. W., & Davenport, M. J. (2003). Validity and reliability of the Motion Sensitivity Test. *Journal of rehabilitation research and development*, *40*(5), 415.

3. Alyahya, D., Johnson, E. G., Daher, N. S., Gaikwad, S. B., & Deshpande, S. (2016). Postural control in healthy young adults with and without chronic motion sensitivity, International Journal of physiotherapy, *3*(1), 1-4.

4. Badke, M. B., Miedaner, J. A., Grove, C. R., Shea, T. A., & Pyle, G. M. (2005). Effects of vestibular and balance rehabilitation on sensory organization and dizziness handicap. *Annals of Otology, Rhinology & Laryngology*, *114*(1), 48-54.

5. Bertec Balance Advantage user manual. 2013. http://bertec.com/bertecbalance/ (accessed 18.03.2016).

6. Buchner, D. M., Cress, M. E., De Lateur, B. J., Esselman, P. C., Margherita, A. J., Price, R., & Wagner, E. H. (1997). A comparison of the effects of three types of endurance training on balance and other fall risk factors in older adults. *Aging clinical and experimental research*, *9*(1-2), 112-119.

7. Buyuklu, F., Tarhan, E., & Ozluoglu, L. (2009). Vestibular functions in motion sickness susceptible individuals. *European Archives of Oto-Rhino-Laryngology*, *266*(9), 1365.

8. Caillet, G., Bosser, G., Gauchard, G. C., Chau, N., Benamghar, L., & Perrin, P. P. (2006). Effect of sporting activity practice on susceptibility to motion sickness. *Brain research bulletin*, *69*(3), 288-293.

9. Cheung, B., Heskin, R., Hofer, K., & Gagnon, M. (2001). The menstrual cycle and susceptibility to coriolis-induced sickness. *Journal of Vestibular Research*, *11*(2), 129-136.

10. Darlington, C. L., & Smith, P. F. (2000). Molecular mechanisms of recovery from vestibular damage in mammals: recent advances. *Progress in neurobiology*, *62*(3), 313-325.

11. Dobie, T., McBride, D., Dobie Jr, T., & May, J. (2001). The effects of age and sex on susceptibility to motion sickness. *Aviation, space, and environmental medicine*, *72*(1), 13-20.

12. Macefield, V. G., & Walton, D. K. (2015). Susceptibility to motion sickness is not increased following spinal cord injury. *Journal of Vestibular Research*, *25*(1), 35-39.

13. Furman, J. M. (1995). Role of posturography in the management of vestibular patients. *Otolaryngology—Head and Neck Surgery*, *112*(1), 8-15.

14. Gauchard, G. C., Gangloff, P., Jeandel, C., & Perrin, P. P. (2003). Physical activity improves gaze and posture control in the elderly. *Neuroscience research*, *45*(4), 409-417.

15. Gill-Body, K. M. (2001). Current concepts in the management of patients with vestibular dysfunction. *PT-ALEXANDRIA-*, *9*(12), 40-57.

16. Golding, J. F. (2006). Motion sickness susceptibility. *Autonomic Neuroscience*, *129*(1), 67-76.

17. Golding, J. F. (2006). Predicting individual differences in motion sickness susceptibility by questionnaire. *Personality and Individual differences*, *41*(2), 237-248.

18. Golding, J. F. (2006). Predicting individual differences in motion sickness susceptibility by questionnaire. *Personality and Individual differences*, *41*(2), 237-248.

19. Herdman, S. J., & Clendaniel, R. (2014). *Vestibular rehabilitation*. FA Davis.

20. Hindmarsh, J. J., & Estes, E. H. (1989). Falls in older persons: causes and interventions. *Archives of Internal Medicine*, *149*(10), 2217-2222.

21. Horak, F. B., Henry, S. M., & Shumway-Cook, A. (1997). Postural perturbations: new insights for treatment of balance disorders. *Physical therapy*, *77*(5), 517.

22. Jokerst, M. D., Gatto, M., Fazio, R., Gianaros, P. J., Stern, R. M., & Koch, K. L. (1999). Effects of gender of subjects and experimenter on susceptibility to motion sickness. *Aviation, space, and environmental medicine*, *70*(10), 962-965.

23. Lackner, J. R. (2014). Motion sickness: more than nausea and vomiting. *Experimental brain research*, *232*(8), 2493-2510.

24. Lawther, A., & Griffin, M. J. (1988). A survey of the occurrence of motion sickness amongst passengers at sea. *Aviation, space, and environmental medicine*, *59*(5), 399-406.

25. Lentz, J. M. (1977). Motion sickness susceptibility and related behavioral characteristics in men and women. *THREE STUDIES OF MOTION SICKNESS SUSCEPTIBILITY 6. Performing Organization Code*, 1.

26. Levy, G. D., & Rapaport, M. H. (1985). Transderm scopolamine efficacy related to time of application prior to the onset of motion. *Aviation, space, and environmental medicine*, *56*(6), 591-593.

27. Lord, S., & Castell, S. (1994). Effect of exercise on balance, strength and reaction time in older people. *Australian Journal of Physiotherapy*, *40*(2), 83-88.

28. Oman, C. M. (1990). Motion sickness: a synthesis and evaluation of the sensory conflict theory. *Canadian journal of physiology and pharmacology*, *68*(2), 294-303.

29. Paillard, A. C., Quarck, G., Paolino, F., Denise, P., Paolino, M., Golding, J. F., & Ghulyan-Bedikian, V. (2013). Motion sickness susceptibility in healthy subjects and vestibular patients: effects of gender, age and trait-anxiety. *Journal of Vestibular Research*, *23*(4, 5), 203-209.

30. Park, A. H., & Hu, S. (1999). Gender differences in motion sickness history and susceptibility to optokinetic rotation-induced motion sickness. *Aviation, space, and environmental medicine*, *70*(11), 1077-1080.

31. Reason, J. T. (1978). Motion sickness adaptation: a neural mismatch model. *Journal of the Royal Society of Medicine*, *71*(11), 819.

32. Reason, J. T., & Brand, J. J. (1975). *Motion sickness*. Academic press.

33. Redfern, M. S., & Furman, J. M. (1993). Postural sway of patients with vestibular disorders during optic flow. *Journal of vestibular research: equilibrium & orientation*, *4*(3), 221-230.

34. Redfern, M. S., Yardley, L., & Bronstein, A. M. (2001). Visual influences on balance. *Journal of anxiety disorders*, *15*(1), 81-94.

35. Shahal, B., Nachum, Z., Spitzer, O., Ben-David, J., Duchman, H., Podoshin, L., & Shupak, A. (1999). Computerized dynamic posturography and seasickness susceptibility. *The Laryngoscope*, *109*(12), 1996-2000.

36. Turner, M. (1993, September). A survey of motion sickness in road coaches. In *Proceedings of United Kingdom informal meeting on human response to vibration at APRE. Ministry of Defence. Farnborough (Hampshire, UK)*.

37. Turner, M. (1999). Motion sickness in public road transport: passenger behaviour and susceptibility. *Ergonomics*, *42*(3), 444-461.

38. Watson, M. A. M. A. W., & Sinclair, H. (1992). *Balancing actfor people with dizziness and balance disorders* (No. F/616.841 W3).

39. Wolfson, L., Whipple, R., Derby, C., Judge, J., King, M., Amerman, P., ... & Smyers, D. (1996). Balance and strength training in older adults: intervention gains and Tai Chi maintenance. *Journal of the American Geriatrics Society*, *44*(5), 498-506.

40. Zhang, L. L., Wang, J. Q., Qi, R. R., Pan, L. L., Li, M., & Cai, Y. L. (2016). Motion sickness: current knowledge and recent advance. *CNS neuroscience & therapeutics*, *22*(1), 15-24.

CHAPTER FOUR

ROLE OF ANXIETY IN CHRONIC MOTION SENSITIVITY

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Abstract

Background: Chronic motion sensitivity (CMS)—or motion sickness—is defined as a combination of autonomic symptoms and signs provoked by exposure to certain types of motion. Studies have shown that there is a correlation between anxiety and CMS. However, the role of anxiety in CMS is not yet well understood.

Objectives: The purposes of present study were to compare anxiety levels between young adults with and without CMS, to examine the effect of anxiety on postural stability with immersion virtual reality, and to compare anxiety levels between males and females within a CMS group.

Methods: Sixty healthy adults aged 20–40 years were assigned to one of two groups (with or without CMS) using the Motion Sickness Susceptibility Questionnaire—Short Form. The State and Trait Anxiety Inventory (STAI) was used to determine current and general anxiety levels. Postural stability was measured with Bertec Balance Advantage™ computerized dynamic posturography with immersion virtual reality (CDP-IVR).

Results: There was a significant difference in median (minimum and maximum) state anxiety scores between participants with CMS and those without CMS (26.0 [20, 47] versus 21.5 [20, 48]; Z=-2.3, p=.024; refer to Figure 2). In addition, there was a significant difference in trait anxiety scores between the two study groups (33.5 [20, 49] versus 28.5 [21, 62]; Z=-2.4, p=.016). Among adults with CMS, there was no significant difference in median state anxiety scores between males and females (25.0 [20, 47] versus 27.0 (20, 45; Z=-.04, p= .97). Similar findings were observed for trait anxiety scores (37.0 [20, 49] versus 31.0 [23, 45; Z= 1.23, p=.21; refer to Figure 3]).

In terms of the effect of anxiety level on postural stability, there was a significant inverse relationship between state and trait anxiety scores and postural stability (ρ =-.28, p=.03; and ρ=-.32, p=.01, respectively).

Conclusion: The results of this study suggest that young adults with CMS are more anxious than those without CMS; however, this anxiety does not mediate postural instability. In addition, anxiety levels do not appear to be influenced by gender among young adults with CMS.

Key Words: Motion sickness, anxiety, postural stability

Introduction

Chronic motion sensitivity (CMS)—or motion sickness—is defined as a combination of autonomic symptoms and signs provoked by exposure to certain types of motion [1], such as passive motions—like riding in cars, boats, trains, planes, and funfair rides—or illusions, such as those found in movie theaters and virtual reality video games. The signs and symptoms include dizziness, vomiting, cold sweats, pallor, increases in salivation, drowsiness during these activities, nausea, and postural instability [2, 3, 4, 5]. CMS is a common condition, with 28.4% of travelers experiencing motion sensitivity [8]. In addition, Sharma [7] reported that the prevalence of CMS is 28% among Tibetans and Northeast Indians and 26% among Northwest Indians. Studies have shown that the incidence of CMS is greater in women than in men [9, 39, 40]. According to Sharma [7], females (27.3%) are more susceptible than males (16.8%). Paillard et al., [9] report that CMS declines with age and physical activity, including participation in sports activities [7,10]. Furman et al. [6] report that CMS could have a detrimental effect on quality of life, particularly when it interferes with the ability to work, travel, or engage in leisure activities.

The underlying cause of CMS is not yet known; however, a mismatch or sensory conflict is the most commonly accepted theory for explaining CMS [34]. Sensory conflict theory states that sensory inputs (visual, vestibular, and somatosensory) are mismatched [11]. Akiduki et al. [13] examined the most common conflict—which is between visual and vestibular systems—using virtual reality and report that visual-vestibular conflict provoked motion sickness symptoms and postural instability.

Paillard et al. [9] report that the vestibular system is heavily involved in CMS. According to Eager et al., [13], the vestibular system's involvement in CMS makes sufferers susceptible to anxiety. Various studies suggest [13,14,15] that anxiety is related to vestibular dysfunction. Clinical anxiety disorders are prevalent among patients with vestibular dysfunction [13, 15, 16, 17, 18, 19, 20, 25], and reciprocally, vestibular dysfunction has been found to be more prevalent in those with certain anxiety disorders, particularly panic disorder with agoraphobia [21, 22, 23].

According to Paillard et al. [9], there is a weak relationship between anxiety and CMS scores, with women having higher CMS and trait-anxiety scores than men. After comparing state and trait anxiety scores between individuals with extreme scores on the motion sickness questionnaire (MSQ) and individuals that had never experienced motion sensitivity, Collins and Lentz [12] found levels of higher trait-anxiety in CMS participants but not higher state-anxiety before rotatory vestibular stimulation. Tucker and Reinhardt [26] found that individuals with airsickness have higher levels of state-anxiety than those without airsickness.

Furthermore, motion sensitivity is an anomaly that has been associated with activity in the vestibular system as well as anxiety [38]. Reported history of motion sensitivity has been correlated with anxiety [27] and postural instability [28].

Owen et al., [29] appraised the role of anxiety in the relationship between reported motion sensitivity susceptibility and responses to disorienting perceptual-motor conditions and showed that although postural sway and anxiety were correlated, none of the correlations reached significance. In contrast, in every condition, postural sway was significantly correlated with motion sensitivity and its reported symptoms in disorienting

environments, with the correlation being strongest under conditions of inaccurate somatosensory and visual information.

Space and motion discomfort (SMD) [30] experienced by some patients with anxiety disorders is parallel to that experienced by people with CMS who do not suffer from anxiety disorders. Potentially disorienting motion environments in which the perceptual systems involved in orientation provide ambiguous information about self-motion induce both CMS and SMD [31,32]. Jacob [33] assessed postural sway in response to optic flow in the visual field of patients with anxiety disorders and SMD, with results showing significant differences between patients and controls in the degree of sway induced by the moving scenes.

Alharbi et al. [47] suggest that young adults with CMS depend on visual stimuli to maintain postural stability. The role of anxiety levels among individuals with CMS is not well understood. Therefore, the purposes of our study were 1) to compare anxiety levels between young adults with and without CMS, 2) to examine the effect of anxiety on postural stability with immersion virtual reality, and 3) to compare anxiety levels between males and females within the CMS group.

Methods

Participants

A total of 60 young adult participants aged from 20–40 years old from Loma Linda University and the local community (30 males and 30 females with a mean age of 26.8 ± 4.3 years and a body mass index [BMI] of 24.9 ± 4.6 kg/m^2) were recruited for this study via email, word of mouth, and flyers posted around the campus. Participants

who had a history of neurological or musculoskeletal disorders, vestibular impairments, diabetic peripheral neuropathy, or were taking any medications that affect balance were excluded. All participants signed informed consent prior to participation in the study. The study protocol was approved by the local Ethics Committee of the Loma Linda University and complied with the ethical standards of the Declaration of Helsinki.

Group Assignment

The Motion Sickness Susceptibility Questionnaire-Short Form (MSSQ-SF) was used to assign participants into one of two groups. The MSSQ-SF is a valid and reliable tool used to predict individual differences in CMS caused by different types of motion [36]. The MSSQ-SF showed the following: a Cronbrach's alpha reliability of 0.87, a test-retest reliability around r=0.9, Section A (child) with Section B (adult) r=0.68, and predictive validity for motion susceptibility r=0.51 [36]. The MSSQ-SF does not have cut-offs; therefore, the authors contacted the author of the MSSQ-SF, who recommended that the current authors make cut-offs based on "practical or theoretical grounds." The lowest MSSQ-SF score found in a previous study of CMS participants conducted in the same laboratory is the 30^{th} percentile. As a result, the authors decided that participants who scored in the 30^{th} percentile or higher on the MSSQ-SF would be assigned to the CMS group, whereas those who scored in the 25^{th} percentile or lower would be assigned to the non-CMS group. In addition, participants whose scores ranged from the 26^{th} to the 29^{th} percentile were excluded to create a "gap" between the two groups. Thirty participants (17 males and 13 females) had CMS, and 30 participants (13 males and 17 females) did not.

Questionnaire

The State and Trait Anxiety Inventory (STAI) was used to measure the presence and severity of current state and general trait anxiety. The STAI includes two subscales: the State Anxiety Scale (S-Anxiety) evaluates the current state of anxiety by asking participants how they feel "right now," using 20 statements that measure their subjective feelings of apprehension, tension, nervousness, worry, and activation/arousal of the autonomic nervous system. The Trait Anxiety Scale (T-Anxiety) evaluates general aspects of participants' anxiety proneness using 20 general statements that measure their calmness, confidence, and security. The range of scores for each subscale is 20–80, with higher scores indicating greater anxiety. A score of 39 or higher has been suggested to detect clinically significant symptoms for the S-Anxiety scale [45, 46].

Apparatus

Bertec Balance Advantage–Computerized Dynamic Posturography with Immersion Virtual Reality (CDP-IVR) (Bertec Corporation; Columbus, OH) was used to measure postural stability. The Bertec test-retest reliability composite score is 0.92, and the validity composite score is 0.84 [35]. CDP-IVR calculates the participant's center of gravity displacement and postural sway to provide an overall equilibrium score. The Bertec Balance Advantage CDP-IVR calculates postural stability and generates an equilibrium score in the following manner: Signals from the participants' efforts to maintain balance are sampled and analyzed at 1,000 Hertz, and the sway path is computed. The testing protocol calculates the sway path with equilibrium scores that are quantified by how well the participant's sway remains within the expected angular limits

of stability during each testing condition. The following formula was used to calculate the equilibrium score:

Equilibrium Score (ES)=([12.5 degrees – (the taMAX–the taMIN)]/12.5 degrees)*100 [37].

The ES uses 12.5° as the normal limit of the anterior-posterior sway angle range; taMAX is the theta maximum, and taMIN is the theta minimum. Theta is a Greek symbol often used to represent angles in two different planes. In the case of computerized dynamic posturography, angle theta is used to describe the maximum and minimum anterior and posterior sway angles in degrees. The sway angle was calculated as follows: Sway Angle=arcsin (COGy/(.55*h)), where y=anterior-posterior sway axis, and h=the subject's height (in centimeters or inches). The inverse sine of the center of gravity was divided by 55% of the participant's height. Participants exhibiting little sway achieve equilibrium scores near 100, whereas participants whose sway approaches their limits of stability achieve scores near zero [37].

Procedures

Before measuring postural stability, each participant took off his or her footwear and was fitted with a safety harness. Postural stability was measured on a stable platform with the participant's eyes open while they focused on a virtual reality infinite tunnel visual flow (see Fig. 3). Postural stability was measured three times, with each measurement duration lasting for 20 seconds. During testing, the positions of the participants' feet were monitored. In addition, the participants were instructed to stand with their arms at their sides.

Statistical Analysis

Data analysis was conducted using the Statistical Package for the Social Sciences (SPSS) for Windows, version 22.0 (SPSS, Inc., Chicago, IL). The sample size needed for this study was estimated using a medium effect size of 0.50, a power of 0.80, and a level of significance (α) of 0.05. Mean±standard deviation (SD) was computed for quantitative variables and frequency (percentage) for categorical variables. To assess the normality of the quantitative variables, Shapiro-Wilk tests and box and whisker plots were performed. To compare the means of height (m), weight (kg), and BMI (kg/m^2) between the CMS and non-CMS groups, an independent t-test was used. Differences in mean age and State and Trait Anxiety Inventory (STAI) scores by group type were examined using the Mann-Whitney test. Among adults with CMS, we examined differences in STAI scores between males and females using the Mann-Whitney U test. To examine the effect of anxiety on postural stability, Spearman's correlation was conducted. The level of statistical significance was set at $p \leq 0.05$.

Results

There were no significant differences in mean height (m), weight (kg), or BMI (kg/m^2) at baseline between participants with CMS ($n_1=30$) and those without CMS ($n_2=30$) ($p>0.05$, see Table 1). However, there was a significant difference in mean age between the two groups ($p=0.04$, see Table 1).

There was a significant difference in median (min, max) state anxiety scores between participants with CMS and those without CMS (26.0 [20, 47] versus 21.5 [20, 48]; $Z=-2.3$, $p=.024$; refer to Figure 2). In addition, there was a significant difference in

trait anxiety scores between the two study groups (33.5 [20, 49] versus 28.5 [21, 62]; Z=-2.4, p=.016). Among adults with CMS, there was no significant difference in median state anxiety scores between males and females (25.0 (20, 47) versus 27.0 (20, 45; Z=-.04, p= .97). Similar findings were observed for trait anxiety scores (37.0 [20, 49] versus 31.0 [23, 45; Z= 1.23, p=.21; refer to Figure 3]).

In terms of the effect of anxiety level on postural stability, there was a significant inverse relationship between state and trait anxiety scores and postural stability (ρ =-.28, p=.03; and ρ=-.32, p=.01, respectively).

Table 1.

Mean (SD) of general characteristics by group type at baseline (N=60)

Characteristic	CMS (n_1=30)	Non-CMS (n_2=30)	p-value[a]
Female [b]; n (%)	13 (43.3)	17 (56.7)	0.22
Age[c]* (years)	27.9 (4.5)	25.6 (3.8)	0.04
Height (m)	1.7 (0.1)	1.7 (0.1)	0.67
Weight (kg)	75.1 (20.6)	68.7 (14.6)	0.17
BMI (kg/m^2)	25.8 (5.6)	24.1 (3.2)	0.14

*p<0.05

Abbreviations: CMS=chronic motion sensitivity; BMI=body mass index; SD=standard deviation

[a] Independent t-test; [b] Chi-square test of independence; [c] Mann-Whitney U test

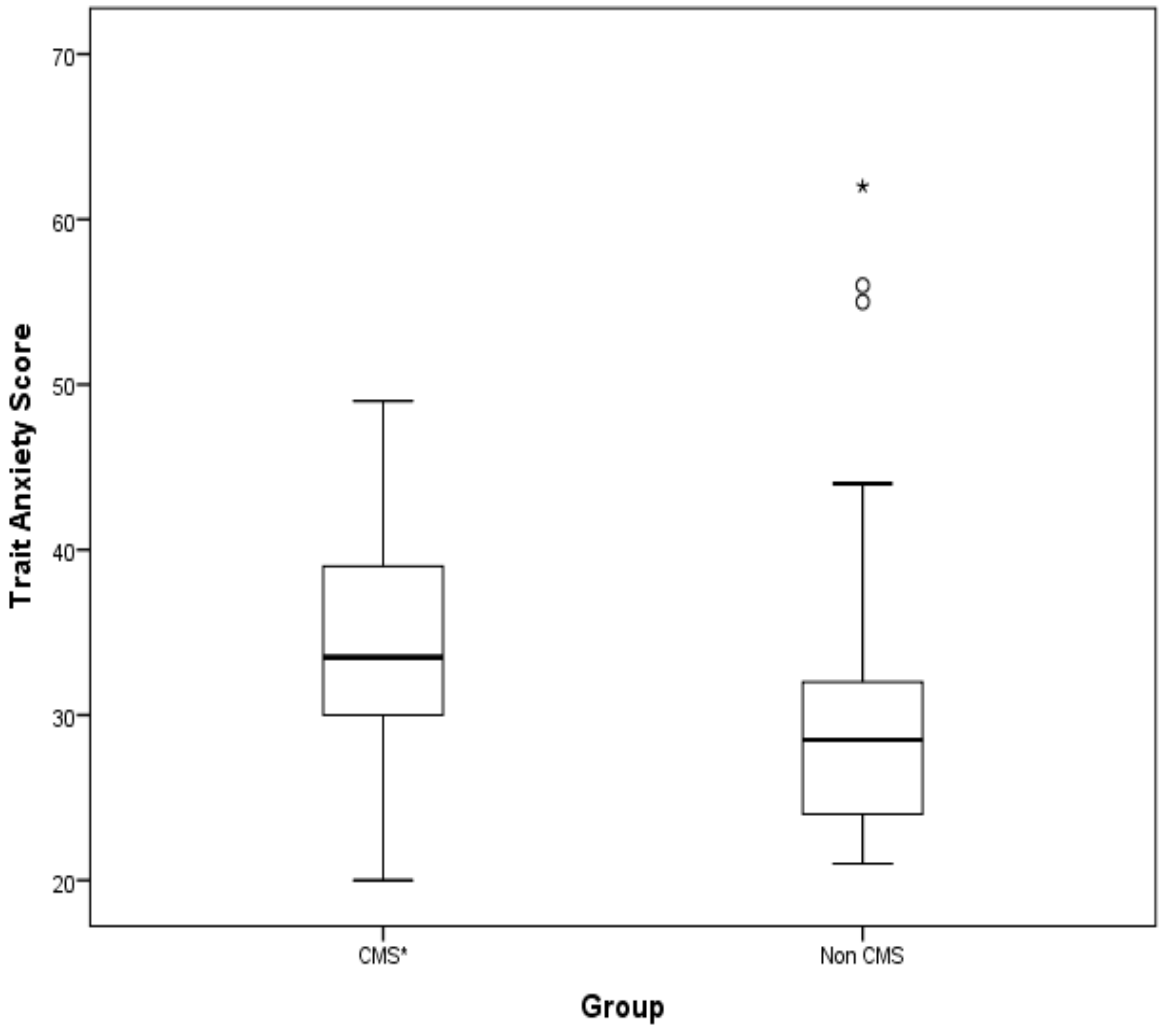

Figure 1. Box and Whisker plot of trait anxiety score by group (N=60)

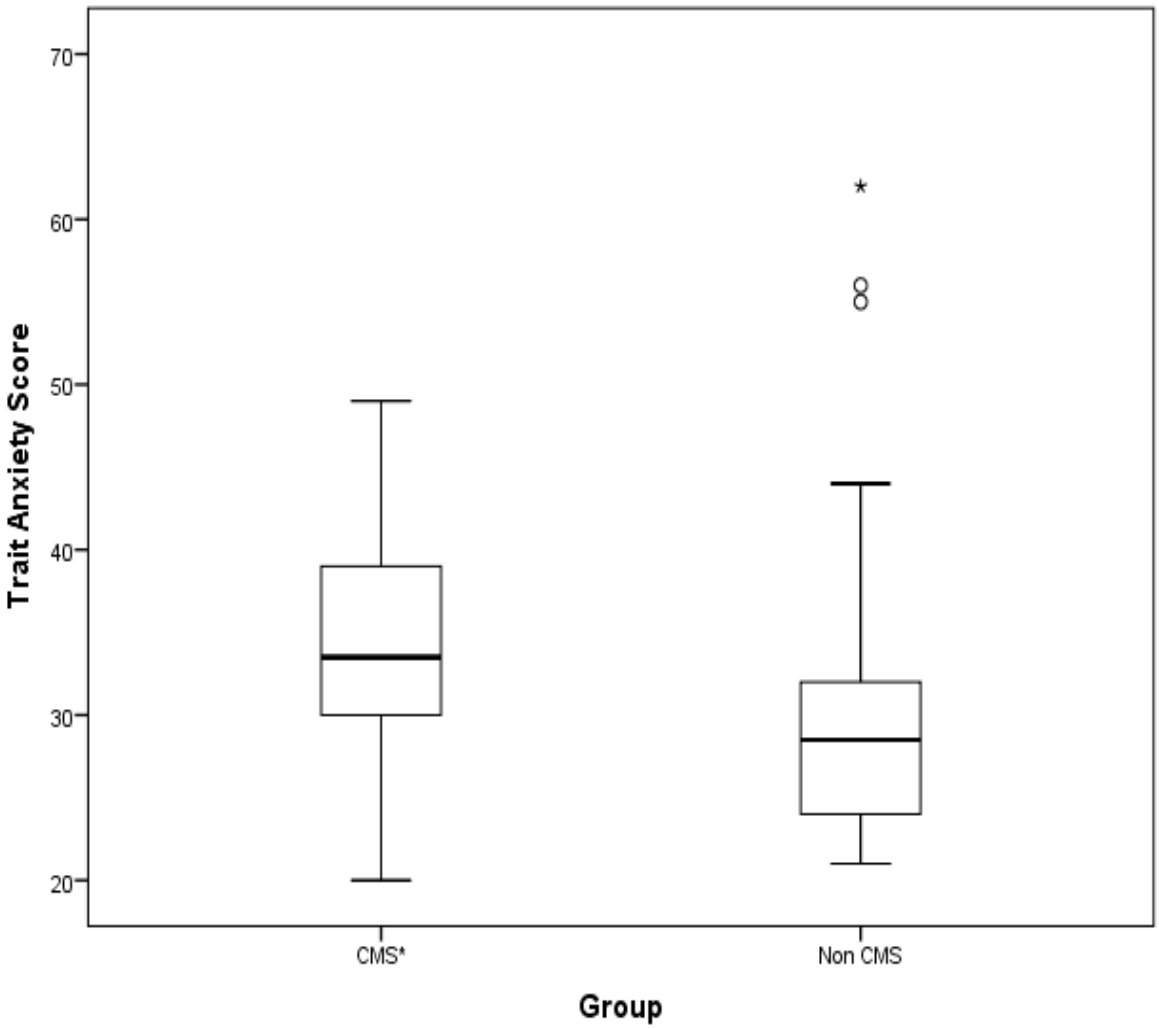

Figure 1. Box and Whisker plot of trait anxiety score by group (N=60)

Fig 3. Participants were fitted with a safety harness, placed on a stable platform, and exposed to computerized dynamic posturography with immersion virtual reality.

Discussion

In the present study, the state and trait anxiety scores were compared between young adults with and without CMS; the results demonstrated that young adults with CMS had higher scores than those without CMS. These results suggest that young adults with CMS are more anxious than those without CMS. For S-Anxiety, the findings of this study are consistent with those of Tucker and Reinhardt [26], who compared the state anxiety level between individuals with and without airsickness. However, the results of this study contradict the findings of Collins and Lentz [12], who used STAI- X. STAI-X was revised in 1983 to become STAI-Y, which was used in the present study. The revised version may have facilitated detection of the difference between the two groups despite the tool used for assigning the groups. Moreover, the S-Anxiety measures the anxiety level "right now;" the lab environment, including the CDP-IVR, may play a role in increasing the state anxiety level because the participants may feel that the CDP-IVR could provoke sickness, which was mentioned in the informed consent. Examining S-Anxiety is important in this situation because it mimics the real situations that individuals with CMS experience. T-Anxiety, the result of the present study is in agreement with studies showing [27, 29] that there is a correlation between anxiety and CMS and with the study [12] that reported that individuals with CMS are more anxious compared to those without CMS. These findings suggest that young adults with CMS are generally more anxious than those without CMS. Most of the activities causing motion sensitivity are entertainment activities; by avoiding these activities, individuals with CMS may become less active, leading to social restrictions, which may contribute to anxiety. However, even though the participants with CMS had significantly higher scores than

those without CMS, the median score did not reach the cut off of the questionnaire. The median score for participants with CMS was 33.5, but only a score of 39 or higher indicates a need for medical attention.

Postural instability was shown to be correlated with CMS, especially when the visual and somatosensory inputs are misleading [29]. Alharbi et al. [47] found that participants with CMS depend on visual stimuli to maintain postural stability. The infinite tunnel was used in the present study to examine the correlation between anxiety and postural stability when the visual information was misleading. Although there was a correlation between anxiety and postural stability, anxiety did not mediate the responses to misleading visual information. This finding is consistent with those of Owen et al., [29] who had similar results regarding the role of anxiety in postural stability. However, the results obtained by Owen et al. differ from the results of the present study in terms of the relationship found between anxiety levels and postural stability. The findings of the present study suggest that anxiety does not play a role in postural stability among individual with CMS

Females are reportedly more susceptible to CMS than males; however, the cause of this difference is unknown [9, 39, 40]. Paillard et al. [9] report that females have higher trait anxiety scores than males. However, the results of this study show that there is no difference in mean state and trait anxiety scores between males and females among participants with CMS. The lack of statistical significance may be attributed to an insufficient sample size. The results suggest that anxiety levels are not influenced by gender among adults with CMS.

Limitations of the present study include a narrow age range of adults aged 20–40 years; consequently, the findings cannot be generalized to individuals outside of this range. Another limitation is that the authors used simple self-reports about how often the participants work out (never, sometimes, or often). Several studies have demonstrated that physical and sports activities may improve postural stability and reduce anxiety levels (state and trait) [41–44]. Further research should include different age ranges and a valid activity questionnaire.

Conclusion

The results of this study suggest that young adults with CMS are more anxious than those without CMS; although this anxiety level was higher among individuals with CMS, it did not reach the level of requiring medical attention. Moreover, this anxiety does not mediate postural instability. In addition, anxiety levels are not influenced by gender among adults with CMS.

References

1. Irwin, J.A. (1881). The pathology of sea-sickness. *Lancet, 2*, 907–909.

2. Oman., C.M. (1990). Motion sickness: A synthesis and evaluation of the sensory conflict theory. *Canadian Journal of Physiology and Pharmacology*, *68*, 294–303.

3. Alyahya, D., Johnson, E.G., Gaikwad, S.B., Daher, N.S., & Deshpande, S. (2016). Postural control in healthy young adults with and without chronic motion sensitivity. *Journal of Physiotherapy and Physical Rehabilitation, 3*, 1–4.

4. Lackner, J.R. (2014). Motion sickness: More than nausea and vomiting. *Experimental Brain Research, 232*, 2493–2510.

5. Zhang, L.L., Wang, J.Q., Qi, R.R., Pan, L.L., Li, M., & Cai, Y.L. Motion sickness: Current knowledge and recent advance. (2016). *CNS Neuroscience & Therapeutics*, *22*, 15–24.

6. Furman, J.M. (1994). Posturography: Uses and limitations. *Bailliere's Clinical Neurology*, *3*, 501–513.

7. Sharma, K. (1997). Prevalence and correlates of susceptibility to motion sickness. *Acta geneticae medicae et gemellologiae: Twin research*, *46*(2), 105–121.

8. Turner, M. (1999). Motion sickness in public road transport: Passenger behavior and susceptibility. *Ergonomics*, *42*, 444–461.

9. Paillard, A., Quarck, G., Paolino, F., Denise, P., Paolino, M., Golding, J.F., & Ghulyan-Bedikian, V. (2013). Motion sickness susceptibility in healthy subjects and vestibular patients: Effects of gender, age, and trait-anxiety. *Journal of Vestibular Research, 23*, 203–209.

10. Caillet, G., Bosser, G., Gauchard, G.C., Chau, N., Benamghar, L., & Perring, P.P. (2006). Effect of sporting activity practice on susceptibility to motion sickness. *Brain Research Bulletin, 69*, 288–293.

11. Reason, J.T., & Brand, J.J. (1975). *Motion sickness*. London: Academic Press.

12. Collins, W.E., & Lentz, J.M. (1977). Some psychological correlates of motion sickness susceptibility. *Aviation, Space, and Environmental Medicine*, *48*, 587–594.

13. Eagger, S., Luxon, L.M., Davies, R.A., Coelho, A., & Ron, M.A. (1992). Psychiatric morbidity in patients with peripheral vestibular disorder. A clinical and neuro-otological study. *Journal of Neurology, Neurosurgery, and Psychiatry*, *55*, 383–387.

14. Jacob, R. G. (1988). Panic disorder and the vestibular system. *Psychiatric Clinics of North America*.

15. Clark, D. B., Hirsch, B. E., Smith, M. G., Furman, J. M., & Jacob, R. G. (1994). Panic in otolaryngology patients presenting with dizziness or hearing loss. *American Journal of Psychiatry*, *151*(8), 1223–1225.

16. Clark, D.B., Leslie, M.I., & Jacob, R.G. (1992). Balance complaints and panic disorder – A clinical-study of panic symptoms in members of a self-help group for balance disorders. *Journal of Anxiety Disorders*, *6*, 47–53.

17. Godemann, F., Schabowska, A., Naetebusch, B., Heinz, A., & Strohle, A. (2006). The impact of cognitions on the development of panic and somatoform disorders: A prospective study in patients with vestibular neuritis. *Psychological Medicine*, *36*, 99–108.

18. Godemann, F., Linden, M., Neu, P., Heipp, E., & Dorr, P. (2004). A prospective study on the course of anxiety after vestibular neuronitis. *Journal of Psychosomatic Research*, *56*, 351–354.

19. Jacob, R.G., Brandt, T., & Furman, J.M. (2004). Psychiatric aspects of dizziness and imbalance. In Bronstein, A., Brandt, T., Woollacott, M., & Nutt, J.G. (Eds.), *Clinical Disorders of Balance, Posture and Gait*, (245–285). Arnold, London.

20. Staab, J.P., & Ruckenstein, M.J. (2003). Which comes first? Psychogenic dizziness versus otogenic anxiety. *Laryngoscope*, *113*, 1714–1718.

21. Perna, G., Dario, A., Caldirola, D., Stefania, B., Cesarani, A., & Bellodi, L. (2001). Panic disorder: The role of the balance system. *Journal of Psychiatric Research*, *35*, 279–286.

22. Yardley, L., Britton, J., Lear, S., Bird, J., & Luxon, L.M. (1995). Relationship between balance system function and agoraphobic avoidance. *Behavioral Research Therapy*, *33*, 435–439.

23. Tecer, A., Tukel, R., Erdamar, B., & Sunay, T. (2004). Audiovestibular functioning in patients with panic disorder. *Journal of Psychosomatic Research*, *57*, 177–182.

24. Jacob, R.G., Furman, J.M., Durrant, J.D., & Turner, S.M. (1996). Panic, agoraphobia, and vestibular dysfunction. *American Journal of Psychiatry*, *153*, 503–512.

25. Stein, M.B., Asmundson, G.J., Ireland, D., & Walker, J.R. (1994). Panic disorder in patients attending a clinic for vestibular disorders. *American Journal of Psychiatry*, *151*, 1697–1700.

26. Tucker, G.J., & Reinhardt, R.F. (1967). Airsickness and anxiety. *Aerospace Medicine*, *38*, 855–858.

27. Collins, W.E., & Lentz, J.M. (1977). Some psychological correlates of motion sickness susceptibility. *Aviation, Space, and Environmental Medicine*, 48, 587–594.

28. Maki, B. E., & McIlroy, W. E. (1996). Influence of arousal and attention on the control of postural sway. *Journal of Vestibular Research, 6,* 53–59.

29. Owen, N., Leadbetter, A. G., & Yardley, L. (1998). Relationship between postural control and motion sickness in healthy subjects. *Brain Research Bulletin, 47*, 471–474.

30. Jacob, R. G., Woody, S. R., Clark, D. B., Lilienfeld, S. O., Hirsch, B. E., Kucera, G. D., . . . & Durrant, J. D. (1993). Discomfort with space and motion: a possible marker of vestibular dysfunction assessed by the Situational Characteristics Questionnaire. *Journal of Psychopathology and Behavioral Assessment, 15*, 299–324.

31. Jacob, R. G., Lilienfeld, S. O., Furman, J. M. R., Durrant, J. D., & Turner, S. M. (1989). Panic disorder with vestibular dysfunction: Further clinical observations and description of space and motion phobic stimuli. *Journal of Anxiety Disorders, 3*, 117–130.

32. Yardley, L. (1992). Motion sickness and perception: a reappraisal of the sensory conflict approach. *British Journal of Psychology, 83*, 449–473.

33. Jacob R. G, Redfern M.S., & Furman J.M. (1995). Optic-flow induced sway in anxiety disorders associated with space and movement discomfort. *Journal of Anxiety Disorders, 9,* 411–425.

34. Zhang, L.L., Wang, J.Q., Qi, R.R., Pan, L.L., Li, M., & Cai, Y.L. (2016). Motion sickness: Current knowledge and recent advance. *CNS Neuroscience & Therapeutics, 22,* 15–24.

35. Tice, A.N. et al. (2017). Reliability and validity of Bertec computerized dynamic posturography. *Audiology Now*. Indianapolis: The American Academy of Audiology. 1. Print.

36. Golding, J.F. (2006). Predicting individual differences in motion sickness susceptibility by questionnaire. *Personality and Individual Differences, 41*, 237–248.

37. Bertec balance advantage user manual (2016, April 15). Retrieved from http://bertec.com/bertecbalance/our-products/dynamic/

38. Mark S., Redfern, L.Y., & Adolfo M.B. (2001). Visual influences on balance. *Journal of Anxiety Disorders, 15,* 81–94.

39. Golding, J.F. Motion sickness susceptibility. (2006a). *Autonomic Neuroscience, 129,* 67–76.

40. Park, A.H., & Hu, S. (1999). Gender differences in motion sickness history and susceptibility to optokinetic rotation-induced motion sickness. *Aviation, Space, and Environmental Medicine, 70,* 1077–1080

41. Petruzzello, S. J., Landers, D. M., Hatfield, B. D., Kubitz, K. A., & Salazar, W. (1991). A meta-analysis on the anxiety-reducing effects of acute and chronic exercise. *Sports Medicine, 11*(3), 143–182.

42. Lord, S., & Castell, S. (1994). Effect of exercise on balance, strength and reaction time in older people. *Australian Journal of Physiotherapy*, *40*(2) 83–88.

43. Wolfson, L., Whipple, R., Derby, C., Judge, J., King, M., Amerman, P., et al. (1996). Balance and strength training in older adults: Intervention gains and Tai Chi maintenance. *Journal of the American Geriatrics Society*, *44*(5) 498–506.

44. Buchner, D.M., Cress, M.E., De Lateur, B.J., Esselman, P.C., Margherita, A.J., Price, R., et al. (1997). A comparison of the effects of three types of endurance training on balance and other fall risk factors in older adults. *Aging Clinical and Experimental Research*, *9*(1–2), 112–119.

45. Knight, R.G., Waal-Manning, H.J., & Spears, G.F. (1983). Some norms and reliability data for the State-Trait Anxiety Inventory and the Zung Self-Rating Depression scale. *British Journal of Clinical Psychology*, *22*(Pt 4), 245–249. [PubMed: 6640176]

46. Addolorato, G., Ancona, C., Capristo, E., Graziosetto, R., Di Rienzo, L., Maurizi, M., et al. (1999). State and trait anxiety in women affected by allergic and vasomotor rhinitis. *Journal of Psychosomatic Research, 46*, 283–289. [PubMed: 10193919]

47. Ahmad, A., Alharbi, E.G., Johnson, A.A., Albalwi, N.S., Daher, T.K., Cordett, O.I.A, & Fahad, H.A. (2017). Effect of visual input on postural stability in young adults with chronic motion sensitivity: A controlled cross-sectional study. *Journal of Vestibular Research*.

CHAPTER FIVE

DISCUSSION

The origin and precise neurobiological mechanism of CMS is unknown. The purposes of the present study were to investigate whether young adults with CMS are visually dependent for postural stability, to examine whether young adults with CMS have diminished vestibular system integrity, and to compare whether they are more anxious compared to those without CMS.

The infinite tunnel was used to give the participants the perception that they were moving toward the tunnel in an anterior direction. In other words, the participants' visual system received signals of false movement, which challenged their CNS to determine if motion was actually occurring. Young adults with CMS swayed more than those without CMS suggesting that the postural stability of young adults with CMS changes in response to false visual input. Conversely, young adults without CMS demonstrated a better ability to counter misleading visual input. Furman [1] reported that computerized dynamic posturography could provide important information regarding how a patient's balance disturbance affects activities of daily living. In the present study, the balance disturbance was visual input. Whitney et al. [2] indicated that sensitivity to visual perturbations and visual dependency are developed if preference is given to visual inputs. It is likely that the CNS relies on visual information, even when vision is providing inaccurate information about body sway in individuals with CMS. This response reflects that postural stability in young adults with CMS is reliant on the visual system. Therefore, the finding of this study supports the previous suggestion from Alyahya et al. [3].

In this study, the young adults had the same ability to use their vestibular sensory information, regardless of CMS. This finding suggests that there is no vestibular diminishment in young adults with CMS. Buyuklu et al. [4] used caloric tests and vestibular-evoked myogenic potentials to examine superior and inferior vestibular systems, and found no vestibular deficits in the participants with CMS. There are two possible explanations for the results of this study. First, CMS onset begins around 6–7 years of age [5], reaching peak severity at around 9–10 years of age [6], and declining in severity from adolescence to adulthood [7]. The decline in CMS severity with increasing age may be attributable to continuous habituation to CMS [8]. In the present study, the target age range was a young adult, aged 20–40 years, and these subjects may have been able to use vestibular information properly as a result of their habituation to CMS, which improved the integrity of the vestibular system. This would support previous studies [7,8] that have suggested that the severity of CMS continues to decline with advancing age. Second, the participants with CMS reported more frequent practice of sports and physical activity (46.7% [CMS] versus 36.7% [non-CMS]). Caillet et al. [9] reported that participation in physical and sporting activities improves CMS by producing a rearrangement process, in which an individual becomes less dependent on visual input and uses vestibular information more effectively.

The results demonstrated that young adults with CMS had higher scores than those without CMS. These results suggest that young adults with CMS are more anxious than those without CMS. For S-Anxiety, the findings of this study are consistent with those of Tucker and Reinhardt [10], who compared the state anxiety level between individuals with and without airsickness. However, the results of this study contradict the

findings of Collins and Lentz [12], who used STAI- X. STAI-X was revised in 1983 to become STAI-Y, which was used in the present study. The revised version may have facilitated detection of the difference between the two groups despite the tool used for assigning the groups. Moreover, the S-Anxiety measures the anxiety level "right now;" the lab environment, including the CDP-IVR, may play a role in increasing the state anxiety level because the participants may feel that the CDP-IVR could provoke sickness, which was mentioned in the informed consent. Examining S-Anxiety is important in this situation because it mimics the real situations that individuals with CMS experience. T-Anxiety, the result of the present study is in agreement with studies showing [12] that there is a correlation between anxiety and CMS and with the study [11] that reported that individuals with CMS are more anxious compared to those without CMS. These findings suggest that young adults with CMS are generally more anxious than those without CMS. Most of the activities causing motion sensitivity are entertainment activities; by avoiding these activities, individuals with CMS may become less active, leading to social restrictions, which may contribute to anxiety. However, even though the participants with CMS had significantly higher scores than those without CMS, the median score did not reach the cut off of the questionnaire. The median score for participants with CMS was 33.5, but only a score of 39 or higher indicates a need for medical attention.

References

1. Furman, J. M. (1994). Posturography: uses and limitations. *Bailliere's clinical neurology*, *3*(3), 501-513.

2. Whitney, S. L., Jacob, R. G., Sparto, P. J., Olshansky, E. F., Detweiler-Shostak, G., Brown, E. L., & Furman, J. M. (2005). Acrophobia and pathological height vertigo: indications for vestibular physical therapy?. *Physical Therapy*, *85*(5), 443-458.

3. Alyahya, D., Johnson, E. G., Daher, N. S., Gaikwad, S. B., & Deshpande, S. (2016). Postural control in healthy young adults with and without chronic motion sensitivity, international physiotherapy, *3*(1), 1-4.

4. Buyuklu, F., Tarhan, E., & Ozluoglu, L. (2009). Vestibular functions in motion sickness susceptible individuals. *European Archives of Oto-Rhino-Laryngology*, *266*(9), 1365.

5. Reason, J. T., & Brand, J. J. (1975). *Motion sickness*. Academic press.

6. Turner, M. (1999). Motion sickness in public road transport: passenger behaviour and susceptibility. *Ergonomics*, *42*(3), 444-461.

7. Golding, J. F. (2006). Motion sickness susceptibility. *Autonomic Neuroscience*, *129*(1), 67-76.

8. Paillard, A. C., Quarck, G., Paolino, F., Denise, P., Paolino, M., Golding, J. F., & Ghulyan-Bedikian, V. (2013). Motion sickness susceptibility in healthy subjects and vestibular patients: effects of gender, age and trait-anxiety. *Journal of Vestibular Research*, *23*(4, 5), 203-209.

9. Caillet, G., Bosser, G., Gauchard, G. C., Chau, N., Benamghar, L., & Perrin, P. P. (2006). Effect of sporting activity practice on susceptibility to motion sickness. *Brain research bulletin*, *69*(3), 288-293.

10. Tucker, G.J., & Reinhardt, R.F. (1967). Airsickness and anxiety. *Aerospace Medicine, 38*, 855–858.

11. Collins, W.E., & Lentz, J.M. (1977). Some psychological correlates of motion sickness susceptibility. *Aviation, Space, and Environmental Medicine*, 48, 587–594.

12. Owen, N., Leadbetter, A. G., & Yardley, L. (1998). Relationship between postural control and motion sickness in healthy subjects. *Brain Research Bulletin*, *47*, 471–474.

APPENDIX A

HEALTH HISTORY SCREENING FORM

Relationship Between Vestibular System, Vision, Anxiety, and Chronic Motion Sensitivity

Health History Screening Form

Date: _____
Subject's ID Code: _____
Subject's Age: _____

Please indicate if you have any of the following:

• Past or current cervical spinal orthopedic impairments	No	Yes
• Current lower extremity injuries	No	Yes
• Past or current vestibular impairments	No	Yes
• Past or current neurological pathology	No	Yes
• Current medications causing dizziness or imbalance	No	Yes

APPENDIX B

PARTICIPANT'S INFORMATION

Participant's Information

Name:

Date of Birth:

Weight:

Height:

How often do you work out? Never Sometimes Often

Email:

Contact Number:

APPENDIX C

INFORMED CONSENT FORM

INFORMED CONSENT

TITLE:	**RELATIONSHIP BETWEEN VESTIBULAR SYSTEM, VISION, ANXIETY, AND CHRONIC MOTION SENSITIVITY**
SPONSOR:	**Department of Allied Health Studies, 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 this graduate students research study is to investigate the effects of chronic motion sensitivity on anxiety level and the balance systems. Specifically, we aim to examine whether young adults with or without chronic motion sensitivity have differences in vestibular system integrity and/or differences in vision reliance for maintaining balance. You are invited to participate in this research study because you are a healthy adult between 20-40 years of age with or without chronic motion sensitivity.

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

Approximately 60 subjects will be recruited to participate in this study.

3. HOW LONG WILL THE STUDY GO ON?

The study requires one session at Loma Linda University.

4. HOW WILL I BE INVOLVED?

You will be asked several questions to determine your eligibility to participate in this study. If you are eligible and willing to participate, you will be responsible for your own travel to and from the research lab.
Your date of birth, height and weight will be recorded followed by these activities:

- You will complete a survey about motion sensitivity for group assignment.
- You will complete survey about anxiety.
- You will stand on a device to measure your balance in several exercises.

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

There is risk of falling and/or mild dizziness during data collection conditions of performing virtual reality immersion, and/or eyes closed. To prevent falling, you will be wearing a safety harness and two researchers will be standing beside you at all times during balance testing. There is also a minimal risk of breach of confidentiality.

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

There are no expected benefits to the subjects without chronic motion sensitivity; however, subjects with chronic motion sensitivity will be provided with home exercises that may relieve their symptoms. The expected benefit to humanity is to improve our understanding of balance and the effect of chronic motion sensitivity. This knowledge may lead to improved treatments as future research is guided by our findings.

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 or if your safety and welfare are at risk.

9. HOW WILL INFORMATION ABOUT ME BE KEPT CONFIDENTIAL?

Efforts will be made to keep your personal information confidential, but we cannot guarantee absolute confidentiality. We will use a pseudonym throughout the study for all recorded data so your actual name will not be used. You will not be identified by name in any publications describing the results of this study. Data in hard copy will be kept in a locked file cabinet in a locked office and electronic data will be password protected.

10. WHAT COSTS ARE INVOLVED?

There is no cost to you for your participation in this study.

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

You will receive a $40 gift card after completing 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.

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.

13. 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	

14. 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

AUTHORIZATION FOR USE OF 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:	Relationship Between Vestibular System, Vision, Anxiety, and 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 graduate student research 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 not 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

APPENDIX E

FLYER FOR RECRUITING PARTICIPANTS

LOMA LINDA UNIVERSITY
School of Allied Health Professions

Research Opportunity

"**Relationship Between Vestibular System, Vision, Anxiety, and Chronic Motion Sensitivity**"

The Department of Physical Therapy of the School of Allied Health Profession, Loma Linda University is conducting a research study examining whether young adults with chronic motion sensitivity have diminished vestibular system integrity, are visually dependent for postural stability, and are anxious compared to those without chronic motion sensitivity.

PARTICIPANTS ARE NEEDED

You may qualify to participate in this study if:

- You are healthy adults with or without history of chronic motion sensitivity.
- Your age is between 20-40

You are eligible to participate if you do not have past or current cervical spine orthopedic impairments, vestibular impairments, neurological pathology, or current medications causing dizziness or imbalance. Then, your balance will be measured using a non-invasive computerized machine.
Neither you nor your health insurance provider will be charged for the cost of any evaluation or treatment provided for the purposes of this study. After completing the assessment, you will receive a gift card as an expression of our thanks for your participation

If you are interested to participate or would like to know more about the study, please contact **Ahmad Alharbi** at **909-272-6706** or email at aalharbi@llu.edu
Principle investigator: **Dr. Eric Johnson,** email at ejohnson@llu.edu

APPENDIX F

MOTION SICKNESS SUSCEPTIBILITY QUESTIONNAIRE-SHORT FORM

Motion Sickness Susceptibility Questionnaire Short-form (MSSQ-Short)

1. Please State Your **Age** ..... Years. *2.* Please State Your Sex (tick box) **Male** [1] **Female** [2]

This questionnaire is designed to find out how susceptible to motion sickness you are, and what sorts of motion are most effective in causing that sickness. Sickness here means feeling queasy or nauseated or actually vomiting.

Your CHILDHOOD Experience Only (before 12 years of age), for each of the following types of transport or entertainment please indicate:

3. **As a CHILD (before age 12),** how often you **Felt Sick or Nauseated** (tick boxes):

	Not Applicable - Never Travelled	**Never Felt Sick**	**Rarely Felt Sick**	**Sometimes Felt Sick**	**Frequently Felt Sick**
Cars					
Buses or Coaches					
Trains					
Aircraft					
Small Boats					
Ships, e.g. Channel Ferries					
Swings in playgrounds					
Roundabouts in playgrounds					
Big Dippers, Funfair Rides					
	1	0	1	2	3

Your Experience over the LAST 10 YEARS (approximately), for each of the following types of transport or entertainment please indicate:

4. **Over the LAST 10 YEARS,** how often you **Felt Sick or Nauseated** (tick boxes):

	Not Applicable - Never Travelled	**Never Felt Sick**	**Rarely Felt Sick**	**Sometimes Felt Sick**	**Frequently Felt Sick**
Cars					
Buses or Coaches					
Trains					
Aircraft					
Small Boats					
Ships, e.g. Channel Ferries					
Swings in playgrounds					
Roundabouts in playgrounds					
Big Dippers, Funfair Rides					
	1	0	1	2	3

Scoring the MSSQ- Short

Section A (Child) (Question 3)

Score the number of types of transportation not experienced (i.e., total the number of ticks in the 't' column, maximum is 9).

Total the sickness scores for each mode of transportation, i.e. the nine types from 'cars' to 'big dippers' (use the 0-3 number score key at bottom, those scores in the 't' column count as zeroes).

MSA = (total sickness score child) x (9) / (9 - number of types not experienced as a child)

Note 1. Where a subject has not experienced any forms of transport a division by zero error occurs. It is not possible to estimate this subject's motion sickness susceptibility in the absence of any relevant motion exposure.
Note 2. The Section A (Child) score can be used as a pre-morbid indicator of motion sickness susceptibility in patients with vestibular disease.

Section B (Adult) (Question 4)

Repeat as for section A but using the data from section B.

MSB = (total sickness score adult) x (9) / (9 - number of types not experienced as an adult)

Raw Score MSSQ-Short

Total the section A (Child) MSA score and the section B (Adult) MSB score to give the MSSQ-Short raw score (possible range from minimum 0 to maximum 54, the maximum being unlikely)

MSSQ raw score = MSA + MSB

Percentile Score MSSQ-Short

The raw to percentile conversions are given below in the Table 1 of Statistics & Figure 1. Use interpolation where necessary.

Alternatively a close approximation is given by the fitted polynomial where y is percentile; x is raw score

$y = a.x + b.x^2 + c.x^3 + d.x^4$

a = 5.1160923 b = -0.055169904
c = -0.00067784495 d = 1.0714752e-005

Table 1. Means and Percentile Conversion Statistics for the MSSQ-Short (n=257)

Percentiles Conversion	Raw Scores MSSQ-Short		
	Child Section A	Adult Section B	Total A+B
0	0	0	0
10	.0	.0	.8
20	2.0	1.0	3.0
30	4.0	1.3	7.0
40	5.6	2.6	9.0
50	7.0	3.7	11.3
60	9.0	6.0	14.1
70	11.0	7.0	17.9
80	13.0	9.0	21.6
90	16.0	12.0	25.9
95	20.0	15.0	30.4
100	23.6	21.0	44.6
Mean	7.75	5.11	12.90
Std. Deviation	5.94	4.84	9.90

Table note: numbers are rounded

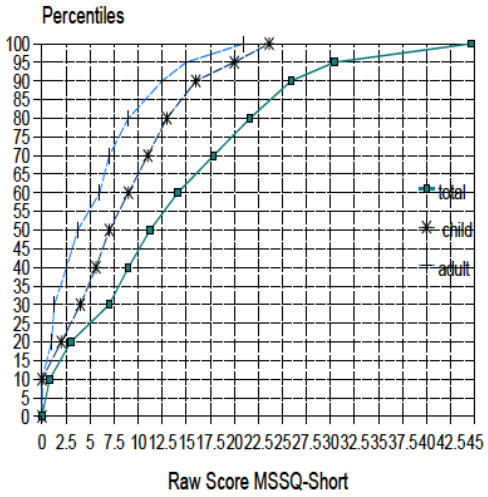

Figure 1. Cumulative distribution Percentiles of the Raw Scores of the MSSQ-Short (n=257 subjects).

APPENDIX G

STATE AND TRAIT ANXIETY INVENTORY

SELF-EVALUATION QUESTIONNAIRE STAI Form Y-1

Please provide the following information:

Name_____ Date_____ S_____

Age_____ Gender (*Circle*) **M** **F** T_____

DIRECTIONS:

A number of statements which people have used to describe themselves are given below. Read each statement and then circle the appropriate number to the right of the statement to indicate how you feel *right* now, that is, *at this moment*. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

	NOT AT ALL	SOMEWHAT	MODERATELY SO	VERY MUCH SO
1. I feel calm	1	2	3	4
2. I feel secure	1	2	3	4
3. I am tense	1	2	3	4
4. I feel strained	1	2	3	4
5. I feel at ease	1	2	3	4
6. I feel upset	1	2	3	4
7. I am presently worrying over possible misfortunes	1	2	3	4
8. I feel satisfied	1	2	3	4
9. I feel frightened	1	2	3	4
10. I feel comfortable	1	2	3	4
11. I feel self-confident	1	2	3	4
12. I feel nervous	1	2	3	4
13. I am jittery	1	2	3	4
14. I feel indecisive	1	2	3	4
15. I am relaxed	1	2	3	4
16. I feel content	1	2	3	4
17. I am worried	1	2	3	4
18. I feel confused	1	2	3	4
19. I feel steady	1	2	3	4
20. I feel pleasant	1	2	3	4

STAI-AD Test Form Y
www.mindgarden.com

SELF-EVALUATION QUESTIONNAIRE

STAI Form Y-2

Name_____ Date_____

DIRECTIONS

A number of statements which people have used to describe themselves are given below. Read each statement and then circle the appropriate number to the right of the statement to indicate how you generally feel. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe how you generally feel.

	ALMOST NEVER	SOMETIMES	OFTEN	ALMOST ALWAYS
21. I feel pleasant	1	2	3	4
22. I feel nervous and restless	1	2	3	4
23. I feel satisfied with myself	1	2	3	4
24. I wish I could be as happy as others seem to be	1	2	3	4
25. I feel like a failure	1	2	3	4
26. I feel rested	1	2	3	4
27. I am "calm, cool, and collected"	1	2	3	4
28. I feel that difficulties are piling up so that I cannot overcome them	1	2	3	4
29. I worry too much over something that really doesn't matter	1	2	3	4
30. I am happy	1	2	3	4
31. I have disturbing thoughts	1	2	3	4
32. I lack self-confidence	1	2	3	4
33. I feel secure	1	2	3	4
34. I make decisions easily	1	2	3	4
35. I feel inadequate	1	2	3	4
36. I am content	1	2	3	4
37. Some unimportant thought runs through my mind and bothers me	1	2	3	4
38. I take disappointments so keenly that I can't put them out of my mind	1	2	3	4
39. I am a steady person	1	2	3	4
40. I get in a state of tension or turmoil as I think over my recent concerns and interests	1	2	3	4

STAIP-AD Test Form Y
www.mindgarden.com

State-Trait Anxiety Inventory for Adults Scoring Key (Form Y-1, Y-2)

Developed by Charles D. Spielberger in collaboration with R.L. Gorsuch, R. Lushene, P.R. Vagg, and G.A. Jacobs

To use this stencil, fold this sheet in half and line up with the appropriate test side, either Form Y-1 or Form Y-2. Simply total the scoring **weights** shown on the stencil for each response category. For example, for question # 1, if the respondent marked 3, then the **weight** would be **2**. Refer to the manual for appropriate normative data.

Form Y-1	NOT AT ALL	SOMEWHAT	MODERATELY SO	VERY MUCH SO
1.	4	3	2	1
2.	4	3	2	1
3.	1	2	3	4
4.	1	2	3	4
5.	4	3	2	1
6.	1	2	3	4
7.	1	2	3	4
8.	4	3	2	1
9.	1	2	3	4
10.	4	3	2	1
11.	4	3	2	1
12.	1	2	3	4
13.	1	2	3	4
14.	1	2	3	4
15.	4	3	2	1
16.	4	3	2	1
17.	1	2	3	4
18.	1	2	3	4
19.	4	3	2	1
20.	4	3	2	1

Form Y-2	ALMOST NEVER	SOMETIMES	OFTEN	ALMOST ALWAYS
21.	4	3	2	1
22.	1	2	3	4
23.	4	3	2	1
24.	1	2	3	4
25.	1	2	3	4
26.	4	3	2	1
27.	4	3	2	1
28.	1	2	3	4
29.	1	2	3	4
30.	4	3	2	1
31.	1	2	3	4
32.	1	2	3	4
33.	4	3	2	1
34.	4	3	2	1
35.	1	2	3	4
36.	4	3	2	1
37.	1	2	3	4
38.	1	2	3	4
39.	4	3	2	1
40.	1	2	3	4

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STAI-AD Scoring Key
www.mindgarden.com