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Effects of Head Motion on Postural Stability in Participants with Chronic Motion Sensitivity

Abdulaziz A. Albalwi

LOMA LINDA UNIVERSITY
School of Allied Health Professions
in conjunction with the
Faculty of Graduate Studies

Effects of Head Motion on Postural Stability in Participants with Chronic Motion Sensitivity

by

Abdulaziz A. Albalwi

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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.

____, Chairperson
Eric Johnson, Professor of Physical Therapy

____
Tim Cordett, Assistant Professor of Physical Therapy

____
Noha Daher, Professor of Epidemiology and Biostatistics

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ABBREVIATIONS

CMS	Chronic Motion Sensitivity
MSSQ-SF	Motion Sensitivity Susceptibility-Short Form
CDP	Computerized Dynamic Posturography
VOR	Vestibulo-Ocular Reflex
VSR	Vestibulo-Spinal Reflex
COR	Cervico-Ocular Reflex
SOT	Sensory Organization Test
ES	Equilibrium Score
Hz	Hertz
SD	Standard Deviation
BMI	Body Mass Index
MSQ	Motion Sickness Questionnaire
taMAX	theta maximum
taMIN	theta minimum
ICCs	Intra-class correlation coefficients
AAQ	Activity Avoidance Questionnaire

ABSTRACT OF THE DISSERTATION

Effects of Head Motion on Postural Stability in Participants with Chronic Motion Sensitivity

by

Abdulaziz A. Albalwi

Doctor of Science, Graduate Program in Physical Therapy
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Dr. Eric Johnson, Chairperson

Background: Motion sensitivity, or motion sickness, is common among individuals in modern vehicular and visually stimulating environments; notably, people with normal vestibular function are susceptible to this condition. Motion-provoked dizziness often causes postural instability.

Purposes: This study aimed to compare the effects of head motion on postural stability in healthy adults with and without chronic motion sensitivity (CMS) and to determine the effects of head motion direction (horizontal versus vertical) on postural stability.

Methods: Sixty healthy adult males and females aged 20 to 40 years old were assigned to two groups, 30 participants with CMS and 30 participants without CMS. Pre-data collection, all participants were trained on specific parameters of cervical rotation, flexion, and extension. Then, postural stability measurements were taken during three conditions (static, horizontal, and vertical head movements) using the Bertec Balance Advantage Dynamic Computerized Dynamic Posturography (CDP).

Results: There was a significant difference between the CMS and non-CMS groups in mean postural stability during head movement in both horizontal and vertical head motions ($p = 0.005$ and $p = 0.024$, respectively); however, no significant difference was shown in mean postural stability between horizontal and vertical head motions within each group (p = 0.297 in CMS group and p = 0.179 in non-CMS group).

Conclusions: The results indicate that healthy young adults without CMS have better postural stability during head motion than those with CMS, and that head motion direction (horizontal versus vertical) does not influence postural stability within each study group.

CHAPTER ONE

INTRODUCTION AND REVIEW OF THE LITERATURE

Motion Sensitivity

Nearly 2,400 years ago, the Greek physician Hippocrates wrote, "Sailing on the sea proves that motion disorders the body" [1,2]. Motion sensitivity is common among individuals in modern vehicular and visually stimulating environments; notably, people with normal vestibular function are susceptible to this condition [3]. Motion sensitivity, which is also known as motion sickness, is defined as sickness (especially nausea and vomiting) produced by certain types of motion [4]. Another definition of motion sensitivity is "the onset of vomiting or nausea experienced by the land, air, sea, or space traveler that results in impaired function" [5]. According to Sharma, motion sensitivity affects nearly one-third of travelers by air, land, and sea, and females are more susceptible to this condition than males [6]. Modern transportation, such as cars, trains, amusement park rides, airplanes, boats, and entertainment innovations like virtual reality, play a major role in extending the range of motion sensitivity [7], and transportation in general is part of everyday life for most people [8].

Previous studies have identified nausea and vomiting as the major indicators for motion sensitivity [3,9]. Other signs and symptoms include dizziness, visual and postural instability, cold sweats, pallor, repetitive yawning, excess salivation, drowsiness, headache and even severe pain [3,10,11]. Although the pathophysiological mechanisms of motion sensitivity are not fully known [11], several theories address its causation. The most widely accepted theory is the sensory conflict theory, which states that motion sensitivity results from a conflict or mismatch between sensory inputs (commonly between the visual and vestibular systems) [8,12]. Additional theories include the postural instability and subjective vertical conflict theories. The postural instability theory proposed by Riccio and Stoffregen states that motion sensitivity does not occur as a result of sensory conflict, but is caused by an inability to control one's posture [13,14]. However, the subjective vertical conflict theory states "All situations which provoke motion sickness are characterized by a condition in which the sensed vertical as determined on the basis of integrated information from the eyes, the vestibular system and the non-vestibular proprioceptors is at variance with the subjective vertical as expected from previous experience" [15].

Motion Sensitivity Assessment

During World War II, many individuals became susceptible to motion sensitivity during air and ocean transport, prompting researchers to explore this phenomenon [16]. One of the earliest measurements used to assess motion sensitivity was the Pensacola Motion Sickness Questionnaire (MSQ), which included more than 20 symptoms [17]. Wood et al. [18] later developed a shorter version using only seven symptoms. From there, the list was narrowed to what are now considered the four most common symptoms of motion sensitivity: nausea, vomiting, pallor, and cold sweats [17]. Most assessments of motion sensitivity are conducted via reported symptoms in the presence of motion in real or virtual environments [8], and symptom severity subjectivity is obtained via verbal or written reports [19].

Motion sensitivity can reduce work performance [20, 21]. Matsangas, McCauley, and Becker [21] found that mild motion sensitivity reduces cognitive multitask performance. Consequently, it is important to accurately assess motion sensitivity to assist in evaluating the effectiveness of countermeasures and to promote current therapies [19], such as gaze stability exercises [22,23]. In 1968, Reason designed the first form of the Motion Sickness Susceptibility Questionnaire (MSSQ) to assess the types of motion that cause this sickness in children and adults [24]. Reason and Brand fully developed the questionnaire in 1975 [20]. The MSSQ then became commonly used to assess susceptibility to motion sensitivity [20,25]. In 1998, Golding developed the Motion Sickness Susceptibility Questionnaire-Short Form (MSSQ-SF), which included only 18 items instead of the 54 items in the long form [20].

Postural Stability

There are three sensory inputs to maintain our balance. These are vestibular, visual, and proprioceptive, which is also referred to somatosensory. The vestibular system sends signals related to head and body position, and the eyes send visual data [24]. Muscles and joints send signals about body position [24]. These signals go to brain and therefore efferent output goes to the eyes muscles and to the spinal cord to serve the vestibulo-ocular reflex (VOR) and vestibulospinal reflex (VSR) (Figure) [24]. The VOR provides visual stability meaning we can see clearly when head is moving. The VSR provides postural stability through the musculoskeletal system (Figure) [24].

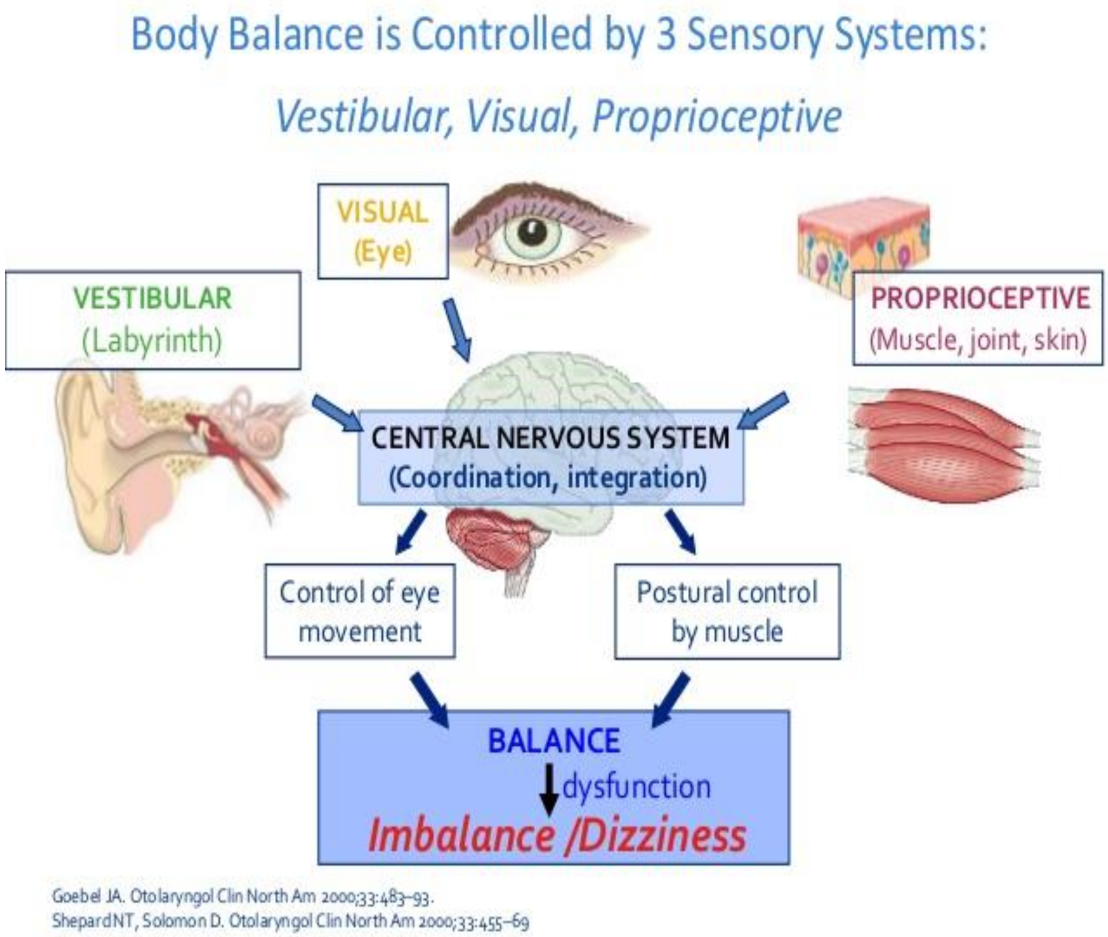

Figure. Sensory Inputs

Postural stability is a complex task that requires proper integration of sensory inputs from the visual, vestibular, and somatosensory systems [25-27]. Therefore, postural stability includes “the coordination of movement strategies to stabilize the center of body mass during both self-initiated and externally triggered disturbances of stability” [27]. A common complaint of individuals with postural instability is motion-provoked dizziness [28]. According to Akin and Davenport, motion-provoked dizziness is “a disturbing sense of vertigo or dizziness associated with head movement” [28]. Several studies [14,29,30] have shown a relationship between motion sensitivity and postural instability. Owen et al. [30] investigated this relationship and found that greater postural instability was correlated with motion sensitivity.

Head Motion

Most functional daily tasks require active range of motion of the cervical spine [31]. However, head movements can sometimes cause nausea and disorientation [32]. Stimulation of the vestibular system activates the VOR and the VSR, while stimulation of the upper neck-joint receptors activates the cervico-ocular reflex (COR) [33]. Consequently, both head and neck rotation contribute to stimulating these reflexes [34]. Furthermore, increased postural instability can be stimulated by either active head rotation or head tilt in patients with vestibular dysfunction [35,36] as well as in healthy people [37,38]. It has been observed that head movements in weightlessness, especially in the pitch direction, are most likely to cause motion sensitivity [39]. Horizontal movements are likely more relevant to routine activities of daily life and comprise a substantial portion of the head movements associated with daily balance activities [35].

Lackner and Graybiel [40] examined the effects of the direction of head movement (i.e., yaw, roll, and pitch) and found that all movements provoked motion sensitivity. Paloski et al. [37] examined the effects of different head movement frequencies on healthy subjects' postural control. Their results showed that postural instability was increased during dynamic head tilts [37].

Computerized Dynamic Posturography (CDP)

CDP is a quantitative method to isolating and assessing how the balance system uses individual sensory and motor components of balance during standing and consists of two components: sensory organization tests (SOTs) and motor coordination tests [41]. Clinicians use CDP to estimate the relative contribution of the three sensory inputs (visual, vestibular, and somatosensory) and neuromuscular systems to postural stability in a given individual [41]. The Sensory Organization Test (SOT) is designed to determine how well the individual uses the vestibular, visual, and somatosensory systems to stabilize posture [41,42]. The Bertec Balance Advantage Computerized Dynamic Posturography (CDP) was used to measure the static and dynamic changes in postural stability performance. In this study, investigators measured subjects' postural stability during three conditions (static, horizontal head motion, and vertical head motion). The CDP calculates postural stability and generates an equilibrium score in the following manner: Signals from the subjects' effort to maintain balance are sampled and analyzed at 1000 Hertz, and the sway path is computed. The testing protocol calculates the sway path with equilibrium scores quantified by how well the subjects' 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. The ES uses 12.5° as the normal limit of the anterior-posterior sway angle range; taMAX is theta maximum; and taMIN is theta minimum. The sway angle was calculated using the following formula: Sway Angle = arcsin (COGy/(.55*h)) where y = anterior-posterior sway axis and h = the subject's height in centimeters or inches. The inverse sin of the center of gravity was divided by 55% of each person's height. Subjects exhibiting little sway will achieve equilibrium scores near 100, while subjects whose sway approaches their limits of stability will achieve scores near zero [43].

Summary

In summary, motion sensitivity is a common problem for individuals in modern vehicular and visually stimulating environments, and people with normal vestibular function are susceptible to this condition [3]. Modern transportation and entertainment innovations play a major role in extending the range of motion sensitivity [7]. A common complaint of individuals with postural instability is motion-provoked dizziness [28]. Several studies [14,29,30] have shown a relationship between motion sensitivity and postural instability. The majority of functional tasks of daily life require active range of motion of the cervical spine [31]. However, head movements sometimes cause nausea and disorientation [32]. The previous investigations indicated that active head movements decrease postural stability in both patients with vestibular dysfunction [35,36] and healthy subjects [37,38].

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CHAPTER TWO

EFFECTS OF HEAD MOTION ON POSTURAL STABILITY IN HEALTHY YOUNG ADULTS WITH AND WITHOUT CHRONIC MOTION SENSITIVITY

Abdulaziz A. Albalwi[1], Eric G. Johnson[1*], Ahmad A. Alharbi[1], Noha S. Daher[2], Tim K. Cordett[1], Oluwaseun I. Ambode[1], Fahad H. Alshehri[1]

[1]Department of Physical Therapy, School of Allied Health Professions, Loma Linda University, Loma Linda, CA, USA

[2]Department of Allied Health Studies, School of Allied Health Professions, Loma Linda University, Loma Linda, CA, USA

* Correspondence: Dr. Eric G. Johnson, *DSc, PT, MS-HPEd, NCS*, 24951 North Circle Drive, Nichol Hall A-712, Loma Linda, California 92350, Phone: (909) 558-4632 ext. 47471, Fax: (909) 558-0459, ejohnson@llu.edu

Abstract

Motion sensitivity, or motion sickness, is common among individuals in modern vehicular and visually stimulating environments; notably, people with normal vestibular function are susceptible to this condition. Motion-provoked dizziness often causes postural instability. This study aimed to compare the effects of head motion on postural stability in healthy adults with and without chronic motion sensitivity (CMS) and to determine the effects of head motion direction (horizontal versus vertical) on postural stability. Sixty healthy adult males and females aged 20 to 40 years old were assigned to two groups, 30 participants with CMS and 30 participants without CMS. Pre-data collection, all participants were trained on specific parameters of cervical rotation, flexion, and extension. Then, postural stability measurements were taken during three conditions (static, horizontal, and vertical head movements) using the Bertec Balance Advantage Dynamic Computerized Dynamic Posturography (CDP). There was a significant difference between the CMS and non-CMS groups in mean postural stability during head movement in both horizontal and vertical head motions ($p = 0.005$ and $p = 0.024$, respectively); however, no significant difference was shown in mean postural stability between horizontal and vertical head motions within each group ($p = 0.297$ in CMS group and $p = 0.179$ in non-CMS group). The results indicate that healthy young adults without CMS have better postural stability during head motion than those with CMS, and that head motion direction (horizontal versus vertical) does not influence postural stability within each study group.

Keywords: motion sensitivity, motion sickness, postural stability, head motion

Introduction

Motion sensitivity, or motion sickness, is common among individuals in modern vehicular and visually stimulating environments; notably, people with normal vestibular function are susceptible to this condition [1]. Motion sensitivity is traditionally defined as "the onset of vomiting or nausea experienced by the land, air, sea, or space traveler that results in impaired function" [2]. According to Turner, 28.4% of travelers experience motion sensitivity [3], and it is more common among females than males [3,4]. Modern transportation, such as cars, trains, amusement park rides, airplanes, boats, and entertainment innovations like virtual reality, play a major role in extending the range of motion sensitivity [5], and transportation in general is part of everyday life for most people [6].

Symptoms of motion sensitivity may include visual and postural instability, pallor, sweating, excess salivation, headaches, drowsiness, malaise, nausea, and vomiting [6,7]. The primary theory concerning the mechanism of motion sensitivity is the sensory conflict theory, which states that "Sensory information provided by one sensory channel does not match the expected input from another channel; commonly, these two inputs originate in the vestibular system and the eyes" [8]. An opposing theory is the postural instability theory, which states that "motion sickness comes about not through sensory conflict but through an inability to control one's posture" [8]. The sensory conflict theory is more widely accepted than the postural instability theory [9].

Postural stability is a complex task that requires proper integration of sensory inputs from the visual, vestibular, and somatosensory systems [10-12]. Therefore, postural stability includes "the coordination of movement strategies to stabilize the center of body mass during both self-initiated and externally triggered disturbances of stability" [12]. A common complaint of individuals with postural instability is motion-provoked dizziness [13]. According to Akin and Davenport, motion-provoked dizziness is "a disturbing sense of vertigo or dizziness associated with head movement" [13]. Several studies [14-16] have shown a relationship between motion sensitivity and postural instability. Owen et al. [16] investigated this relationship and found that greater postural instability was correlated with motion sensitivity. Stimulation of the vestibular system activates the vestibulo-ocular reflex (VOR) and the vestibulospinal reflex (VSR), while stimulation of the upper neck-joint receptors activates the cervico-ocular reflex (COR) [17]. Consequently, both head and neck rotation contribute to stimulating these reflexes [18]. Furthermore, increased postural instability can be stimulated by either active head rotation or head tilt in patients with vestibular dysfunction [19,20] as well as in healthy people [21,22].

Most functional daily tasks require active range of motion of the cervical spine [23]. However, head movements can sometimes cause nausea and disorientation [24]. It has been observed that head movements in weightlessness, especially in the pitch direction, are most likely to cause motion sensitivity [25]. Horizontal movements are likely more relevant to routine activities of daily life and comprise a substantial portion of the head movements associated with daily balance activities [19]. Lackner and Graybiel [26] examined the effects of the direction of head movement (i.e., yaw, roll, and pitch) and found that all movements provoked motion sensitivity. Paloski et al. [21] examined the effects of different head movement frequencies on healthy subjects' postural control. Their results showed that postural instability was increased during dynamic head tilts

[21]. Though, some studies have investigated the relationship between motion sensitivity and postural stability, to our knowledge, none has compared the effects of head motion on postural stability in subjects with and without chronic motion sensitivity (CMS). Therefore, this study aimed to compare the effects of head motion on postural stability in healthy adults with and without CMS as well as the effects of head motion direction (horizontal versus vertical) on postural stability. The primary hypothesis was that postural stability during head motion would be worse in the CMS group compared to the non-CMS group. The secondary hypothesis was that postural stability would be worse during vertical head motion compared to horizontal head motion within groups.

Methods

Design

This study was a cross-sectional design.

Participants

Sixty healthy participants: 30 males and 30 females with mean age of 26.8 ± 4.3 years and mean body mass index (BMI) of 24.9 ± 4.6 (kg/m^2) were recruited for this study using flyers, emails, and by word of mouth. Participants were divided into two groups: 30 participants had a history of CMS and 30 participants did not. Participants with a history of vestibular disorder, neurological pathology, head or cervical trauma, lack of normal cervical spine active range of motion, Motion Sensitivity Susceptibility Questionnaire-Short Form (MSSQ-SF) score between the 30th and 25th percentile, and those who were taking any medications that might affect balance were excluded from the study. This study was conducted at Loma Linda University in the physical therapy neurology research laboratory.

Ethics

All participants reviewed and signed an informed consent form that was approved by the Loma Linda University Institutional Review Board prior to participating in the study.

Procedures

All participants filled out the MSSQ-SF. Those with a self-reported CMS and an MSSQ-SF score in the 30th percentile or more were assigned to the CMS group. Participants who did not report CMS and with an MSSQ-SF score in the 25th percentile or less were assigned to the non-CMS group.

Next, the investigators took anthropometric measurements (weight and height) of the participants. Pre-data collection, all participants were trained on the specific parameters of cervical rotation, flexion, and extension. To prevent falling, participants wore a safety harness, and two investigators stood behind them during all postural stability testing. The participants' postural stability was measured during three conditions (static, horizontal, and vertical head movements) using the Bertec Balance Advantage Dynamic Computerized Dynamic Posturography (CDP) (see Figure 1). Each condition included three twenty-second trials, and the average of those three trials for each condition was calculated. In the static condition, participants stood on the CDP force plate with bare feet and remained still during testing.

The authors in this study considered both the velocity and amplitude of head motions during walking at slow speed. A previous study found that the predominant frequency of head motion during walking was restricted to a range from 1.4 Hz at 0.6 m/s to 2.5 Hz at 2.2 m/s [27]. Based on normal head velocity and amplitude during walking, the authors utilized a velocity of 1.5 Hz [27] and 11° horizontal amplitude and 8° vertical amplitude [28]. The dynamic conditions were measured with the participants performing active head motions (horizontal or vertical) while standing on the CDP force plate with bare feet while moving their heads to the auditory cue of a metronome set at 1.5 Hz. They maintained a range of motion amplitude of approximately 11° in the horizontal plane (5.5° to each side) and 8° in the vertical plane (4° up and 4° down) while guided by a head-mounted laser pointer (SenMoCOR LED/Laser, Orthopedic Physical Therapy Products, USA) (Figure 2). The order of horizontal and vertical head movements was randomized. In previous studies involving head movement, Mishra et al. [19], Honaker et al. [20], and Moussa et al. [29] instructed subjects to perform head movements with their eyes closed during sensory organization testing by holding their hands 15° to each side of their face to control range of motion. In the present study, the investigators utilized a head-mounted laser pointer and instructed the participants to keep their eyes open to guide range of motion amplitude (Figure 3). The investigators developed a grid for participants to track with the laser (Figure 4). Additionally, the investigators provided verbal cueing for proper excursion, a metronome for velocity, and a head-mounted laser pointer for amplitude.

The CDP calculates postural stability and generates an equilibrium score in the following manner: Signals from the subjects' 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 quantified by how well the subjects' 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) = $([12.5° - (\text{the taMAX} - \text{the taMIN})]/12.5°)*100$. The ES uses 12.5° as the normal limit of the anterior-posterior sway angle range; taMAX is theta maximum, and taMIN is theta minimum. The sway angle was calculated using the following formula: Sway Angle = arcsin (COGy/(.55*h)) where y = the anterior-posterior sway axis and h = the subject's height in centimeters or inches. The inverse Sin of the center of gravity was divided by 55% of each person's height. Subjects exhibiting little sway will achieve equilibrium scores near 100, while subjects whose sway approaches their limits of stability will achieve scores near zero [30].

Figure 1. Bertec Balance Advantage Computerized Dynamic Posturography (CDP)

Figure 2. Head-Mounted Laser Pointer

Figure 3. Participant was fitted with a safety harness and performed horizontal and vertical head motions using a head-mounted laser pointer to guide amplitude.

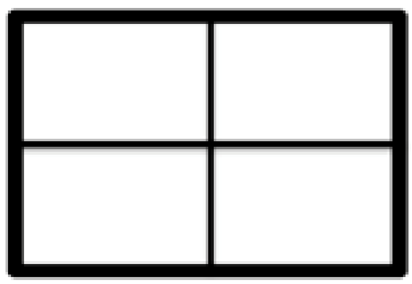

Figure 4. A grid was developed to guide the amplitude of horizontal (11°) and vertical (8°) head motions.

Statistical Analysis

Sixty participants were recruited for this study. The sample size was estimated using a medium effect size of 0.50, a power of 0.80, and a level of significance (α) at 0.05. Data analyses were performed using statistical package SPSS for Windows version 22.0 (SPSS, Inc., Chicago, IL). Descriptive statistics were given as mean and standard deviation for quantitative variables and frequency and percent (%) for categorical variables. The association between gender and physical activity by group (CMS versus non-CMS) was examined using the Chi-square test of independence. Assessment of normality was performed using the Kolmogorov-Smirnov test. Comparisons of the means of height, weight, and body mass index (BMI) between the two groups were performed using the Independent *t*-test. Because the distributions of age and conditions 1 (static), 2, and 3 (horizontal and vertical excursion respectively) were not normal, differences in mean age and postural stability for all conditions by group type were assessed using the Mann-Whitney U test. Differences in mean postural stability by direction of head motion (horizontal versus vertical) in each group were examined using the Wilcoxon Signed-Rank test. The level of significance was set at $p \leq 0.05$.

Results

There was no significant difference in mean height (m), weight (kg), BMI (kg/m^2), and baseline postural stability scores between the CMS ($n_1 = 30$) and non-CMS groups ($n_2 = 30$) ($p > 0.05$, Table 1). However, there was a significant difference in mean age between the two groups ($p = 0.04$, Table 1). Results showed that there was no significant relationship between gender and physical activity by group (Table 1). There was a significant difference between the CMS and non-CMS groups in mean postural stability during head movements in both horizontal and vertical head motions (91.1 ± 4.3 versus 93.6 ± 2.0, $p = 0.005$; Cohen's d = 0.74, and 90.7 ± 4.7 versus 93.1 ± 1.9, $p = 0.024$; Cohen's d = 0.65, respectively, Figures 5 and 6), after controlling for age. However, there was no significant difference in mean postural stability between horizontal and vertical head motions within groups (91.1 ± 4.3 versus 90.7 ± 4.7, $p = 0.297$; Cohen's d = 0.20 in CMS group and 93.6 ± 2.0 versus 93.1 ± 1.9, $p = 0.179$; Cohen's d = 0.25 in non-CMS group, Table 2).

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 (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

* $p < 0.05$
Abbreviations: SD, Standard Deviation; CMS, Chronic motion sensitivity;
BMI, Body Mass Index; Condition 1, Static, without head motion;
[a] Independent *t*-test, [b] Chi-square test of Independence, [c] Mann-Whitney U test

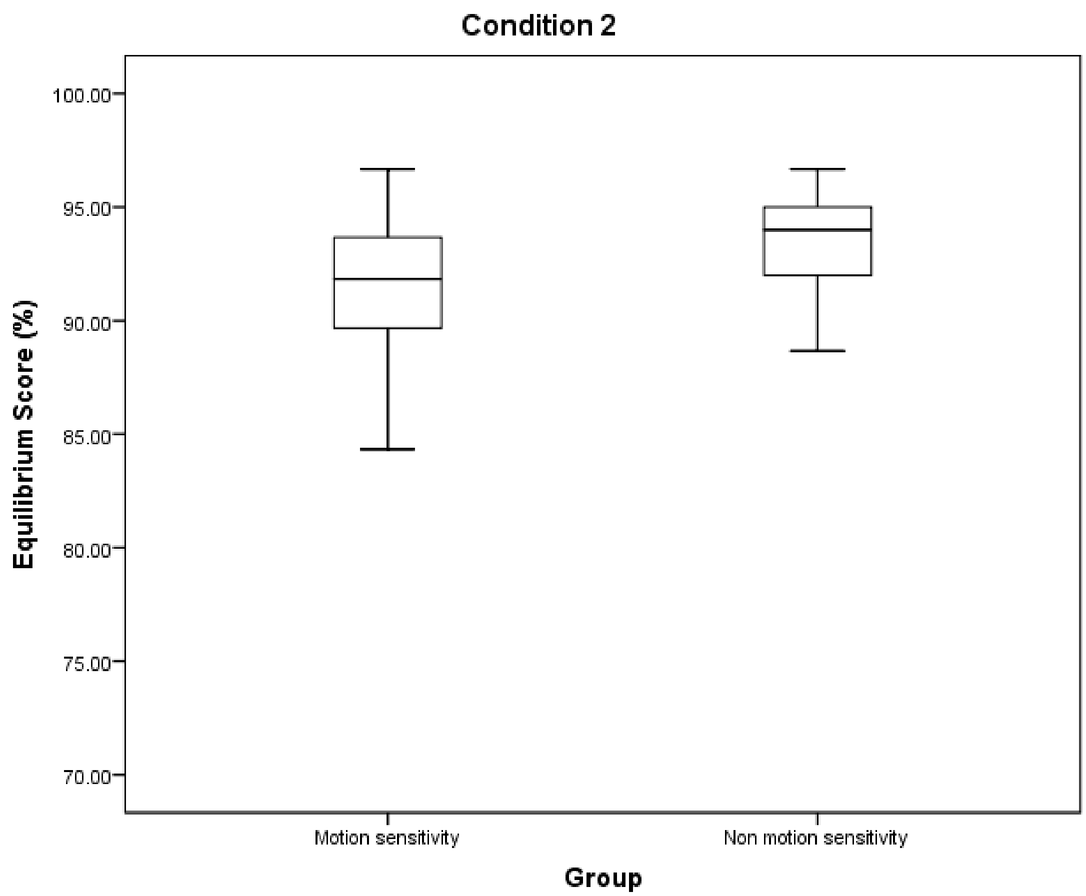

Figure 5. Box and whisker plot of postural stability for condition 2 (horizontal head motion) by group type ($p < 0.01$)

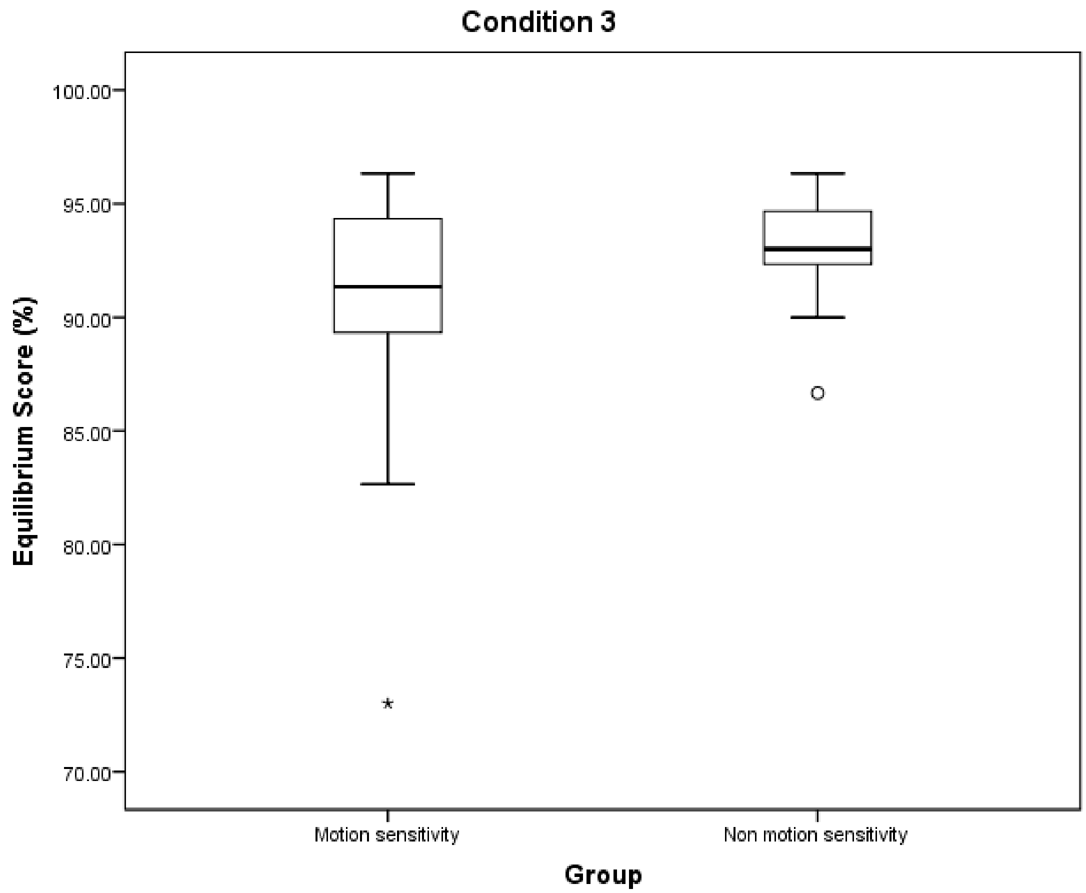

Figure 6. Box and whisker plot of postural stability for condition 3 (vertical head motion) by group type (p = 0.02)

Table 2. Mean (SD) of postural stability during head motion by direction of head motion (N = 60)

Group	C2 Average	C3 Average	p –value[a]
CMS (n_1 = 30)	91.1 (4.3)	90.7 (4.7)	0.297
Non-CMS (n_2 = 30)	93.6 (2.0)	93.1 (1.9)	0.179

Abbreviations: C2, Condition 2 (horizontal head motion);
C3, Condition 3 (vertical head motion);
[a] Wilcoxon Signed-Rank test

Discussion

In the present study, the effects of head motion on postural stability were investigated in healthy adults with and without CMS. The results demonstrated that postural stability during head motion was worse in the CMS group compared to the non-CMS group. The effects of head motion direction (horizontal versus vertical) on postural stability were also considered, and there was no significant difference in mean postural stability between horizontal and vertical head motions within each group.

The major finding of the present study was that healthy adults with CMS have more postural instability during head motion. Our result is consistent with Paloski et al. [21] who found that postural instability was increased during dynamic head tilts in healthy subjects. Previous studies [14-16] have shown a relationship between motion sensitivity and postural instability. Owen et al. [16] demonstrated that greater postural instability was correlated with motion sensitivity.

Sensory systems (visual, somatosensory, and vestibular), central processing, musculoskeletal systems, and neural pathways are essential for postural stability [31,32]. To maintain postural stability, the vestibular system provides information about head motion relative to space [33]. Stimulation of the vestibular system activates the VOR and the VSR, while stimulation of the upper neck-joint receptors activates the COR [17]. The VOR provides visual stability when the head is moving, which enables reading while walking [34]. Consequently, both head and neck rotation contribute to stimulating these reflexes [18]. Most functional daily tasks require active range of motion of the cervical spine [23]. The horizontal movements are likely more relevant to routine activities of daily life and comprise a fundamental portion of head movements associated with daily balance activities [19]. Lackner and Graybiel [26] demonstrated that all movements (yaw, roll, and pitch) provoked motion sensitivity. Prior studies have indicated that active head movements increase postural instability in both patients with vestibular dysfunction [19,20] and healthy subjects [21,22].

The head needs to move freely while walking to detect the surrounding environment and guide locomotion [35]. In the present study, the authors considered both the velocity and amplitude of head motions during the functional activity of walking at slow speed. Based on normal head velocity and amplitude during walking, the authors utilized a velocity of 1.5 Hz [27] and 11° horizontal amplitude and 8° vertical amplitude [28]. Nevertheless, the authors in the present study hypothesized that postural instability would be worse during vertical head motion compared to horizontal head motion. Our findings indicated that there was no significant difference in postural stability between horizontal and vertical head movements. The amplitude of horizontal head motion was greater than vertical head motion. Moreover, the authors think that the difference in amplitude of head range of motions (horizontal versus vertical) can explain why no significant differences between the directions of head motion were found. Additionally, the authors suggest that the velocity at faster speeds may show a significant difference between horizontal and vertical head movements. Kogler et al. [36] showed that head extension positioning increases postural sway velocity more than either head flexion or right/left rotation positioning and indicated that head extension leads to disturbances in vision and vestibular systems as well as increases somatosensory dependence. Therefore, head extension increases postural sway because the utricular otoliths are placed in a disadvantageous position [37]. Thus, head movements, the head-extended posture, and disturbances in cervical proprioception can affect postural stability [21,38].

Limitations

This study had several limitations. A main limitation was the narrow age range of participants (20 to 40 years of age). Consequently, the findings may not be generalizable to older adults. Another limitation was that the authors did not utilize a valid and reliable physical activity questionnaire, and inactivity can affect postural stability [39]. Several studies have demonstrated that physical and sports activities may improve postural stability [40-42]. Future studies should include groups with a wider age range and consider varying velocities and amplitudes of head motions.

Conclusions

Results of this study indicate that healthy young adults without CMS have better postural stability during head motion than those with CMS. Our results also demonstrate that the direction of head motion (horizontal versus vertical) does not influence postural stability within each group.

Conflicts of interest

The authors declare no conflict of interest.

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CHAPTER THREE

VALIDITY AND RELIABILITY OF THE ACTIVITY AVOIDANCE QUESTIONNAIRE TO ASSESS MOTION SENSITIVITY

Abdulaziz A. Albalwi[1*], Ahmad A. Alharbi[1], Eric G. Johnson[1], Noha S. Daher[2], Tim K. Cordett[1], Oluwaseun I. Ambode[1], Fahad H. Alshehri[1]

[1]Department of Physical Therapy, School of Allied Health Professions, Loma Linda University, Loma Linda, CA, USA

[2]Department of Allied Health Studies, School of Allied Health Professions, Loma Linda University, Loma Linda, CA, USA

*Correspondence: Abdulaziz Albalwi, MPT, PT, DSc Candidate, 24951 North Circle Drive, Nichol Hall A-712, Loma Linda, California 92350, Phone: (909) 558-4632 ext. 47471, Fax: (909) 558-0459, aalbalwi@llu.edu

Abstract

Objective: This investigation aimed to examine the criterion validity and test-retest reliability of a new questionnaire, the Activity Avoidance Questionnaire (AAQ), which was designed to be a simple assessment tool for determining susceptibility to motion sensitivity.

Background: Motion sensitivity, or motion sickness, is a common syndrome and can play a role in diminished work performance. Consequently, it is important to accurately assess motion sensitivity to assist in evaluating the effectiveness of countermeasures and to promote current therapies, such as gaze-stability exercises.

Methods: Sixty-four healthy adults with a mean age of 26.6 ± 4.2 years participated in this study; however, five of those did not complete the AAQ a second time. Thus, 59 participants with a mean age of 26.8 ± 4.3 years were recruited to assess the reliability of the AAQ. The Motion Sickness Susceptibility Questionnaire-Short Form (MSSQ-SF) was completed first, followed by the AAQ. Three weeks after the first visit, the investigator sent the AAQ to all participants via email, requesting that they complete it a second time and return it to him.

Results: When correlating the MSSQ-SF and the AAQ, results showed that the AAQ is highly valid ($\rho = 0.80$, 95% CI: 0.69, 0.87, $p < 0.001$). The test-retest reliability of the AAQ is excellent (ICC = 0.93, 95% CI: 0.88, 0.96, $p < 0.001$).

Conclusion: The AAQ is a valid and reliable tool for assessing susceptibility to motion sensitivity.

Application: The authors recommend using the AAQ as a simple and quick tool for determining motion sensitivity.

Keywords: motion sensitivity, motion sensitivity assessment, motion sickness, validity, reliability

Précis: The activity avoidance questionnaire (AAQ) was designed to assess susceptibility to motion sensitivity subjectively. For validation purposes, the authors compared the AAQ to the Motion Sickness Susceptibility Questionnaire-Short Form (MSSQ-SF). The results showed that the AAQ is a valid and reliable tool for assessing susceptibility to motion sensitivity.

Introduction

Nearly 2,400 years ago, the Greek physician Hippocrates wrote, "Sailing on the sea proves that motion disorders the body" [1,2]. Motion sensitivity, also known as motion sickness, is defined as sickness (especially nausea and vomiting) produced by certain types of motion [3]. Previous studies have identified nausea and vomiting as the major indicators for motion sensitivity [4,5]. Other signs and symptoms include dizziness, postural instability, cold sweats, pallor, repetitive yawning, excess salivation, drowsiness, headache, and even severe pain [5-7].

Although the pathophysiological mechanisms of motion sensitivity are not fully known [7], several theories address its causation. The most widely accepted theory is the sensory conflict theory, which states that motion sensitivity results from a conflict or mismatch between sensory inputs (commonly between the visual and vestibular systems) [8-10]. Additional theories include the postural instability and subjective vertical conflict theories. The postural instability theory proposed by Riccio and Stoffregen states that motion sensitivity does not occur as a result of sensory conflict, but is caused by an inability to control one's posture [11,12]. The subjective vertical conflict theory states, "All situations which provoke motion sickness are characterized by a condition in which the sensed vertical as determined on the basis of integrated information from the eyes, the vestibular system and the non-vestibular proprioceptors is at variance with the subjective vertical as expected from previous experience" [13].

Driving or riding in cars, buses, trains, or other forms of transportation are activities of daily living for most individuals [10]. Therefore, motion sensitivity is a common syndrome for individuals in both modern transportation and in virtual reality environments such as the cinema or video games [5,10]. According to Sharma [14], motion sensitivity affects nearly one-third of travelers by air, land, and sea, and females are more susceptible to this condition than males. Modern transportation and entertainment innovations, such as virtual reality, play a significant role in increasing the prevalence of motion sensitivity [15], and motion sensitivity can influence all individuals who have an intact vestibular system [8].

During World War II, many individuals became susceptible to motion sensitivity during air and ocean transport, prompting researchers to explore this phenomenon [16]. One of the earliest assessments used to identify motion sensitivity was the Pensacola Motion Sickness Questionnaire (MSQ), which included more than 20 symptoms [17]. Wood et al. [18] later developed a shorter version using only seven symptoms. From there, the list was narrowed to what is now considered the four most common symptoms of motion sensitivity: nausea, vomiting, pallor, and cold sweats [17]. Most assessments of motion sensitivity are conducted via reported symptoms in the presence of motion in real or virtual environments [10], and subjective symptom severity is obtained via verbal or written reports [19].

Motion sensitivity can reduce work performance [20,21]. Matsangas et al. [21] found that mild motion sensitivity reduces cognitive multitask performance. Consequently, it is important to accurately assess motion sensitivity to assist in evaluating the effectiveness of countermeasures and to promote current therapies [19], such as gaze- stability exercises [22,23]. In 1968, Reason designed the first form of the Motion Sickness Susceptibility Questionnaire (MSSQ) to assess the types of motion that cause this sickness in children and adults [24]. Reason and Brand fully developed the questionnaire in 1975 [20]. The MSSQ then became commonly used to assess susceptibility to motion sensitivity [20,25]. In 1998, Golding developed the Motion Sickness Susceptibility Questionnaire-Short Form (MSSQ-SF), which included only 18 items instead of the 54 items in the long form [20]. Notably, the MSSQ-SF has certain limitations, including that some individuals may have difficulty remembering past events of motion sensitivity from childhood, no cut-off is set for assessing motion sensitivity, and it requires some time for both completion and score calculation. Therefore, this investigation aimed to examine the criterion validity and test-retest reliability of a new questionnaire, the Activity Avoidance Questionnaire (AAQ), which was designed to be a simple assessment tool for determining susceptibility to motion sensitivity.

Methods

Participants

Sixty-four volunteers (32 males and 32 females) with a mean age of 26.6 ± 4.2 years participated in this study via flyers, emails, and word of mouth. Of the participants, 59 (30 males and 29 females) with a mean age of 26.8 ± 4.3 years were involved to assess the test-retest reliability. Sixty-four healthy participants with and without chronic motion sensitivity filled out two questionnaires: the MSSQ-SF and the AAQ in the first visit; 59 participants completed the AAQ again three weeks after the first session. This research complied with the tenets of the Declaration of Helsinki and was approved by the Institutional Review Board at Loma Linda University. Informed consent was obtained from each participant.

Instrumentation

The MSSQ-SF used in this study had a high correlation with the MSSQ-Long Form ($r = 0.93$) and appeared to have a moderate to strong correlation with the reported time to nausea during susceptibility to motion in a laboratory ($r = 0.51$, $p < 0.001$) [24]. Additionally, the MSSQ-SF had a high internal consistency (Cronbach's alpha = 0.87); test-retest reliability ($r = 0.9$, $p < 0.001$), and a significant correlation between Section A (Child) with Section B (Adult) result of ($r = 0.68$, $p < 0.001$) [24].

The MSSQ-SF included 18 items. Participants indicated, using a Likert scale, how often they felt nauseated during exposure to nine types of either transport or entertainment motion, such as cars, buses, trains, swings on playgrounds, etc., during both childhood (before the age of 12) and adulthood (over the past 10 years). The five-point scale was as follows: 1 = not applicable/never traveled, 2 = never felt sick, 3 = rarely felt sick, 4 = sometimes felt sick, and 5 = frequently felt sick [24]. Each of the nine kinds of motion was scored from zero to 3, with the "t" considered as zero. The MSSQ-SF scores were calculated with the following formula:

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

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

MSSQ-Short raw score (range from minimum 0 to maximum 54) = MSA + MSB

Vehicles, boats, airplanes, and entertainment environments are the most common places that provoke motion sensitivity [5]; therefore, the investigators included these types of motion in the AAQ in addition to common symptoms that accompany motion sensitivity. The AAQ includes six activities that are reading in a moving vehicle, being in a moving vehicle on winding roads, riding in boats and airplanes, riding on roller coasters, and quick movement (Figure 1). In this questionnaire, the investigators focused on activities that are avoided because they produce symptoms of motion sensitivity, including dizziness, nausea, imbalance, and blurry vision, as well as severe symptoms that lead to vomiting. Regarding activities that produce symptoms, individuals answered either “Yes,” “No,” or skip the activity if it was not applicable (Figure 1). Each participant who answered “Yes” to at least one of the activities was considered to have motion sensitivity.

Activity Avoidance Questionnaire

Do you avoid any of the activities below because they produce dizziness, nausea, imbalance, and/or blurry vision? If "Yes" please rate the symptom using the following scale:

Activity			**Rating Scale**
Reading in a Moving Vehicle	No	Yes	**BEST** 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / 10 **WORST**
Being in a Moving Vehicle on Winding Roads	No	Yes	**BEST** 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / 10 **WORST**
Riding in Boats	No	Yes	**BEST** 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / 10 **WORST**
Riding in Airplanes	No	Yes	**BEST** 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / 10 **WORST**
Riding Roller Coasters	No	Yes	**BEST** 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / 10 **WORST**
Quick Movements	No	Yes	**BEST** 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / 10 **WORST**

Figure 1. Activity Avoidance Questionnaire Form

Procedures

All participants came to the Loma Linda University physical therapy neurology research laboratory to complete the participants' information form, which included their name, contact number, and email address, and to fill out the MSSQ-SF and AAQ. The investigators allowed the participants enough time to read and understand each questionnaire prior to completion. Additionally, the participants were free to ask questions regarding any ambiguous items on the questionnaires. The MSSQ-SF was completed first, followed by the AAQ. Because the MSSQ-SF does not have a cut-off, the investigators used the 30^{th} percentile as the cut-off, which was based on the results of a previous study [23]. Three weeks after the first visit, the investigator sent the AAQ to all participants via email, requesting that they complete it a second time and return it to the investigator via email.

Statistical Analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 23.0 software. The general characteristics of the participants were summarized using means and standard deviations for quantitative variables and frequencies and relative frequencies for categorical variables. The criterion validity was assessed using Spearman's correlation between the MSSQ-SF and the AAQ. For test-retest reliability, intra-class correlation coefficients (ICCs) and corresponding 95% confidence intervals (CIs) were calculated. ICCs that were less than 0.40 were considered poor, those from 0.41 to 0.60 were considered moderate, those from 0.61 to 0.80 were considered substantial, and ICCs above 0.80 were regarded as excellent [26]. The level of significance was set at $p \leq 0.05$.

Results

The study sample was comprised of 64 participants (32 males and 32 females) with a mean age of 26.6 ± 4.2 years. Five participants did not respond to the emails regarding completion of the AAQ for a second time (see Figure 2). To assess the test-retest reliability of the AAQ, data from 59 participants (30 males and 29 females) with a mean age of 26.8 ± 4.3 years were used. The findings of the test-retest reliability for each activity of the AAQ are displayed in Table 1. The test-retest reliability of the AAQ was excellent (ICC = 0.93, 95% CI: 0.88, 0.96, $p < 0.001$). Reading in a moving vehicle and being in a moving vehicle on winding roads showed the highest reliability among the activities (ICC = 0.98, Table 1), while riding in a boat had the lowest (ICC = 0.70, Table 1) Regarding the criterion validity, when correlating MSSQ-SF and the AAQ, results showed that AAQ is highly valid ($\rho = 0.80$, 95% CI: 0.69, 0.87, $p < 0.001$).

Table 1. Test-retest reliability for each activity in the Activity Avoidance Questionnaire

Activity	Intra-class Correlation	95% Confidence Interval	
		Lower Bound	Upper Bound
Reading in Moving Vehicle	0.98	0.97	0.99
Being in Moving Vehicle on Winding Roads	0.92	0.87	0.95
Riding in Boats	0.70	0.49	0.82
Riding in Airplanes	0.83	0.71	0.90
Riding Roller Coasters	0.78	0.62	0.87
Quick Movements	0.84	0.73	0.90

* $p < 0.001$

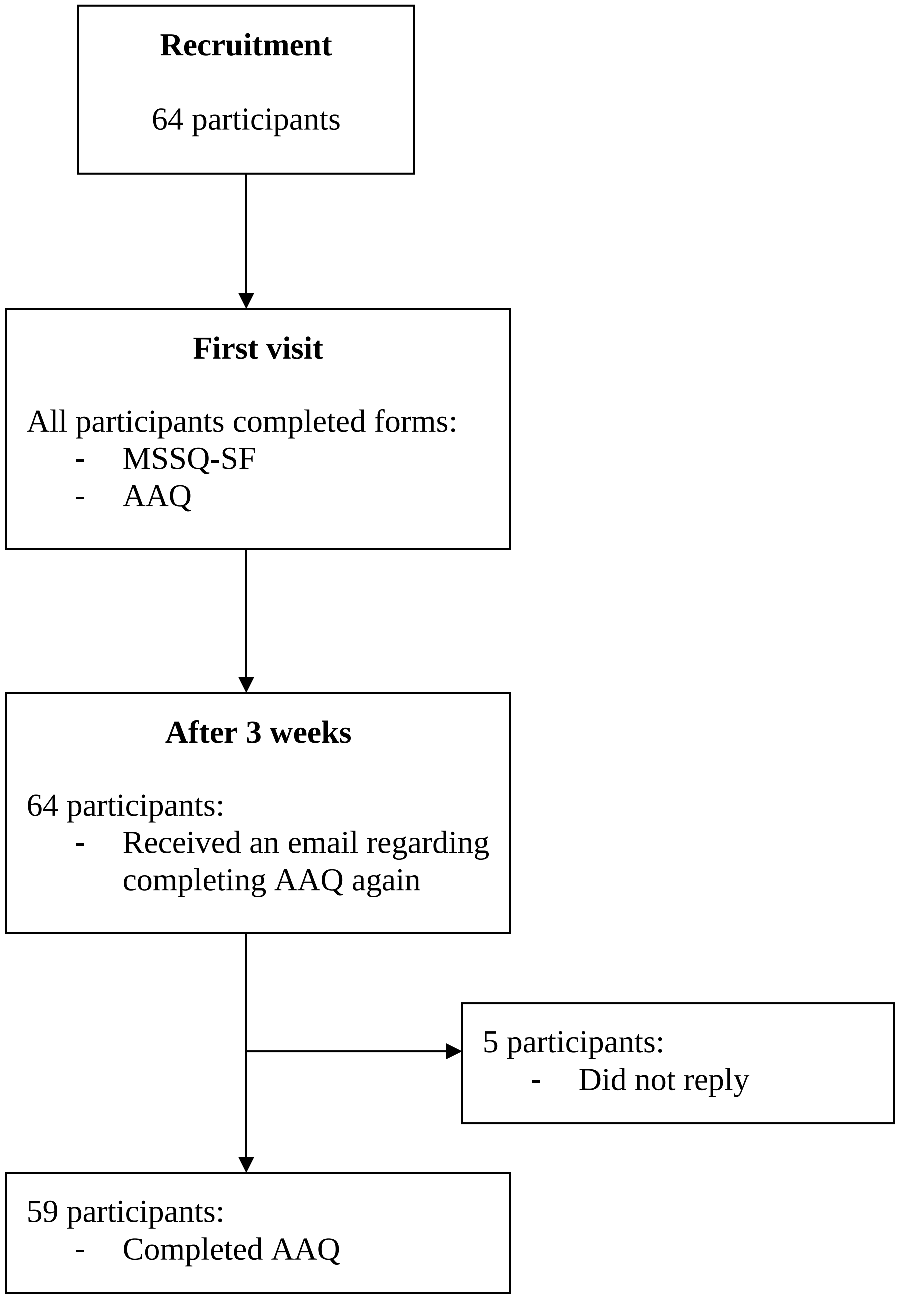

Figure 2. Diagram illustrating flow of participants

Discussion

The present study was designed to provide an effective and precise tool to determine and evaluate susceptibility to motion sensitivity. The AAQ has several potential advantages over currently used questionnaires that assess motion sensitivity, including a reduced chance of making mistakes due to questionnaire fatigue [24], ease of understanding, and a shorter completion time. For validation purposes, the authors compared the AAQ to the MSSQ-SF. The second aim of the current study was to assess the test-retest reliability of the AAQ.

The results of this study have shown that the AAQ has high validity when compared with the MSSQ-SF and excellent reliability. The authors noticed that the two activities with the highest reliability involved car transportation, the motion activity that is most frequently used in daily life [27]. To assess reliability, participants filled out the AAQ twice: the first time, they completed it in the physical therapy neurology research laboratory at Loma Linda University; the second time, they completed it at home, returning it via email. The investigators encountered some questions regarding riding both in a boat and on roller coasters during the first completion of the AAQ. It is possible that the second completion of the AAQ should also have occurred in person in the research laboratory to ensure that all activities were clear.

Although different assessment methods are available regarding motion sensitivity, questionnaires are considered the most common technique. Instead of copying previous methods to determine motion sensitivity, the investigators in this study were careful to design a new questionnaire that is both effective and accurate in assessing this condition. Most motion sensitivity assessments, including the MSSQ-SF, are designed on the basis of symptomatology in the presence of either real motion or virtual environments [10]. However, the MSSQ-SF lacks a specific cut-off for identifying motion sensitivity. Therefore, the investigators determined their cut-off in this study based on the results of a previous study [23]. The MSSQ-SF includes both child and adult sections because children age 2 to 12 years are more susceptible to motion sensitivity than adults [10, 28]. In addition, Golding [24] reported that the scores in the childhood section were higher than in the adult section. Moreover, the childhood section of the MSSQ-SF can influence the results and shows that an individual has motion sensitivity, even if he or she as an adult does not currently have motion sensitivity.

Passive motion such as car, boat, and airplane travel is abundant in modern life; consequently, motion sensitivity has become a common syndrome [1,29]. Because automobiles, boats, airplanes, and entertainment environments are the most common places that provoke motion sensitivity [5], the investigators included these types of motion in the AAQ in addition to common symptoms that accompany motion sensitivity. Although a rating scale is available in the questionnaire, it was not considered in assessing motion sensitivity in this study. The rating scale of symptoms also aims to evaluate the effectiveness of therapies. The AAQ was designed to assess susceptibility to motion sensitivity subjectively.

Conclusion

The AAQ is both a valid and reliable tool for assessing susceptibility to motion sensitivity. The authors recommend using the AAQ as a simple and quick tool for determining motion sensitivity.

Key Points

- The authors designed the activity avoidance questionnaire (AAQ) as a simple and quick tool for determining motion sensitivity.
- The AAQ was validated by correlating the Motion Sickness Susceptibility Questionnaire-Short Form (MSSQ-SF) and the AAQ.
- Results indicated that the AAQ is highly valid and has an excellent reliability for assessing susceptibility to motion sensitivity.

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CHAPTER FOUR

EFFECT OF SITTING PAUSE TIMES ON BALANCE AFTER SUPINE TO STANDING TRANSFER IN DIM LIGHT

Eric G. Johnson[1*], Abdulaziz A. Albalwi[1], Fuad M. Al-Dabbak[1], Noha S. Daher[2]

[1]Department of Physical Therapy, School of Allied Health Professions, Loma Linda University, Loma Linda, CA, USA

[2]Department of Allied Health Studies, School of Allied Health Professions, Loma Linda University, Loma Linda, CA, USA

*Address to Eric G. Johnson, PT, DSc, MS-HPEd, NCS, Loma Linda University School of Allied Health Professions, Nichol Hall Office A-712, Loma Linda, CA 92350 (ejohnson@llu.edu).

Abstract

Background: The risk of falling for older adults increases in dimly lit environments. Longer sitting pause times, before getting out of bed and standing during the night may improve postural stability.

Objective: The purpose of this study was to measure the effect of sitting pause times on postural sway velocity immediately after a supine to standing transfer in a dimly lit room in older adult women.

Methods: Eighteen healthy women aged 65 to 75 years who were able to independently perform supine to standing transfers participated in the study. On each of 2 consecutive days, participants assumed the supine position on a mat table and closed their eyes for 45 minutes. Then, participants were instructed to open their eyes and transfer from supine to sitting, with either 2- or 30-second pause in the sitting position followed by standing. The sitting pause time order was randomized.

Results: A significant difference was observed in postural sway velocity between the 2- and 30-second sitting pause times. The results revealed that there was less postural sway velocity after 30-second than 2-second sitting pause time (0.61 ± 0.19 vs. 1.22 ± 0.68, $p < .001$).

Discussion: Falls related to bathroom usage at night are the most common reported falls among older adults. In the present study, the investigators studied the effect of sitting pause times on postural sway velocity after changing position from supine to standing in a dimly lit environment. The findings showed that the mean postural sway velocity was significantly less after 30-second sitting pause time compared to 2-second sitting pause time.

Conclusions: Postural sway velocity decreased when participants performed a sitting pause of 30 seconds before standing in a dimly lit environment. These results suggest that longer sitting pause times may improve adaptability to dimly lit environments contributing to improved postural stability and reduced risk of fall in older adult women when getting out of bed at night.

Key Words: balance, dimly lit environments, falls, older adults, postural stability

Introduction

Falls represent a major health problem for older adults and often lead to disability and mortality in the older adult population [1-3]. Each year an estimated 30% to 50% of community-dwelling adults 65 years and older report a fall [4-6]. Nearly 75% of falls occurred in the bedrooms or in the bathrooms, and 41% of all falls occurred during transfers [7]. According to Centers for Disease Control and Prevention, the incidence of falls and the resulting fatal injuries or nonfatal injuries is significantly higher in older adults [8]. The cost of falls among people 65 years and older is enormous because of the high death toll, disabling conditions, and hospitalization [9]. In the United States, the cost was about $23.3 billion in 2008 [10]; however, the cost is projected to exceed $54 billion by 2020 [11].

Several risk factors for falls include older age, female gender, chronic diseases, gait and balance disorders, visual problems, cognitive impairment, urinary incontinence, and use of medications [12,13]. Researchers report that the risk of falling increases with age in both genders but is higher in women [14,15]. Often, older adults think that falls are a normal part of aging; subsequently, they may never report falling episodes to their physicians [16]. Therefore, physicians should specifically screen for risk factors contributing to falls as a preventive measure. Fear of falling as a result of falls that do not lead to injury may result in limitation of activities and decreased muscle strength as well as balance [16]. Thus, this can lead to poor quality of life, resulting in loss of function and independence.

Vision is one of the sensory inputs that play a significant role in maintaining postural stability by providing the nervous system with continually updated information regarding the position and movements of the body in relation to each other and the environment [17]. Visual acuity, depth perception, peripheral vision, visual perception, and dim lighting conditions are most relevant to the detection and avoidance of environmental risks [18]. Researchers have reported that impaired vision affects postural stability and increases the risk of falling and hip fractures in older adults [12,17]. When individuals stand with their eyes closed, postural sway velocity increases by an estimated 20% to 70% [19,20].

Standing suddenly after being in a supine position challenges the sensory-motor processes for maintaining postural stability [21]. Consequently, getting up from bed can lead to falls in older adults [22]. Also, when older adults quickly leave the bed at night with diminished lighting, the probability of falls is likely to increase [21]. Prevention of falls in older adults related to bathroom use is a significant concern, especially during the night [21]. Urinary incontinence is a major problem in older adults and is frequently reported by individuals who fall as a contributing risk factor [23]. Takazawa and Arisawa [23] found that mixed incontinence, defined as leaking associated with urgency, exertion, coughing or sneezing, is correlated with an increased risk of falling. Females 65 years and older with this condition are 3 times more likely to fall than those who do not, and are likely to fall while going to the bathroom at night [23].

Brooke-Wavell et al. [24] demonstrated that, in dim lighting conditions, postural sway velocity significantly increased in older adults and concluded that dim lighting conditions are associated with increased fall risk in the older adult population. Johnson and Meltzer [25] reported that postural sway velocity for younger and older adults was significantly less after 30-second pause time compared to 2-second pause time. Because the results were based on a pilot study of 5 older adults aged 65-70 years compared to 5 younger adults aged 20-30, the authors recommended recruiting a larger sample size of older adults in future research [25]. Therefore, the purpose of this study was to measure the effect of sitting pause times on postural sway velocity immediately after a supine to standing transfer in a dimly lit room among 18 older adult women aged 65-75 years. We hypothesized that longer sitting pause times would result in reduced postural sway velocity upon initial standing.

Methods

Study Design

This study was an observational cross-sectional design.

Participants

Eighteen women aged 65 to 75 years (*mean* ± *SD*, 69.0 ± 3.1) were recruited from the local community through flyers and word of mouth. Participants were healthy community-dwelling adults who were able to independently perform supine to standing transfers. Exclusion criteria included any neurological, orthopedic, vestibular disorders, inability to perform testing protocol independently due to physical, visual, or cognitive impairments, or medications that impaired balance. Before data collection, all participants read and signed an informed consent document, approved by the institution review board at Loma Linda University.

Instrumentation

The Digital Lux Light Meter (HQRP Digital LUX / Light Meter LX-1010BS with LCD display plus HQRP Coaster) was used to measure lighting in the room where the room was set to a dim lighting condition of 1 lux. A standard gait belt was used to ensure the participant's safety when transferring to standing after sitting pause times where the belt was adjusted on participant before the beginning of the test. The NeuroCom® BASIC Balance Master force plate (Balance Master, NeuroCom, Clackamas, Oregon, USA), a digital force plate that is connected to a computer with software was used to measure participant's anterior-posterior postural sway velocity [26].

Procedures

Data collection was performed in a university research laboratory setting. Before beginning data collection, all participants performed 5 practice trials of supine to standing transfers for pretest positioning of equipment and familiarization of the testing environment. Participants assumed a supine position on a standard hi-lo mat table modified to the approximate self-reported height of their bed at home. This height was measured and registered for subsequent testing. For postural stability measurements once in standing position, the NeuroCom® BASIC Balance Master 18'X18" fixed force plate was placed close to the mat table [26]. The NeuroCom® force plate calculates a mean sway velocity in units of degrees per second [26]. During the 5 practice trials, investigators adjusted the NeuroCom® force plate to the proper position using a standardized foot positioning protocol [26]. The investigators instructed participants to perform the supine to sit transfer as if they were getting up from their bed at home. The order of the sitting pause times of 2 and 30 seconds was randomized for the 2 consecutive days of testing. Sitting pause time was operationally defined as the number of seconds participants sat at the edge of the mat table before standing. All testing was completed in a dimly lit room (defined as 1 Lux via Digital Lux Light Meter). Participants assumed the supine position on the mat table and closed their eyes for 45 minutes. Dark adaptation is the process where the eyes adjust to the dark following exposure to light [27]. The cones of the eyes need 5 to 7 minutes to reach the maximum dark adaptation; however, it takes 30 to 45 minutes to attain the full dark adaptation [28,29]. Then, one of the investigators instructed each participant to open her eyes and transfer from supine to sitting with either 2- or 30-second pause in the sitting position followed by standing. Immediately upon transferring from supine to sitting, the investigator positioned the participant's feet on the NeuroCom® force plate before standing using their foot positioning protocol [26]. All participants attended 2 testing sessions at the same time of day. Participants wore a gait belt to ensure their safety during the tests. Total mean postural sway velocity during each standing trial was measured for a period of 10 seconds [26]. The researchers selected a 2-second sitting pause time because that was the minimal amount of time needed to position participant's feet on the force plate once in sitting. The rationale for selecting a 30-second sitting pause time was based on reports that as many as 63% of women older than 60 years of age have some form of urinary incontinence [30]. Pause times of more than 30 seconds might not be a realistic timeframe.

Statistical Analysis

Data were analyzed using SPSS Version 22.0 (SPSS, Inc., Chicago, IL). Means and standard deviations were used to describe the characteristics of the participants and outcome measures. The distribution of sway velocity was examined using the Kolmogorov-Smirnov test. Because the distribution of the sway velocity was not normal, the Wilcoxon signed rank test was used to compare the total mean sway velocity (degrees per second) following 2- versus 30-second sitting pause times for all participants. A post-hoc power analysis (power $=1 - \beta$ and $\alpha = .05$, 2-tailed) revealed power of 0.97 with an effect size of 0.96. The level of significance was set at $p \leq .05$.

Results

All participants completed the study and there were no missing data. There was a significant difference in mean postural sway velocity between the 2 pause times, and 30-second sitting pause time revealed less postural sway velocity than 2-second sitting pause time (61 ± 0.19 vs. 1.22 ± 0.68, $p < .001$, Figure and Table).

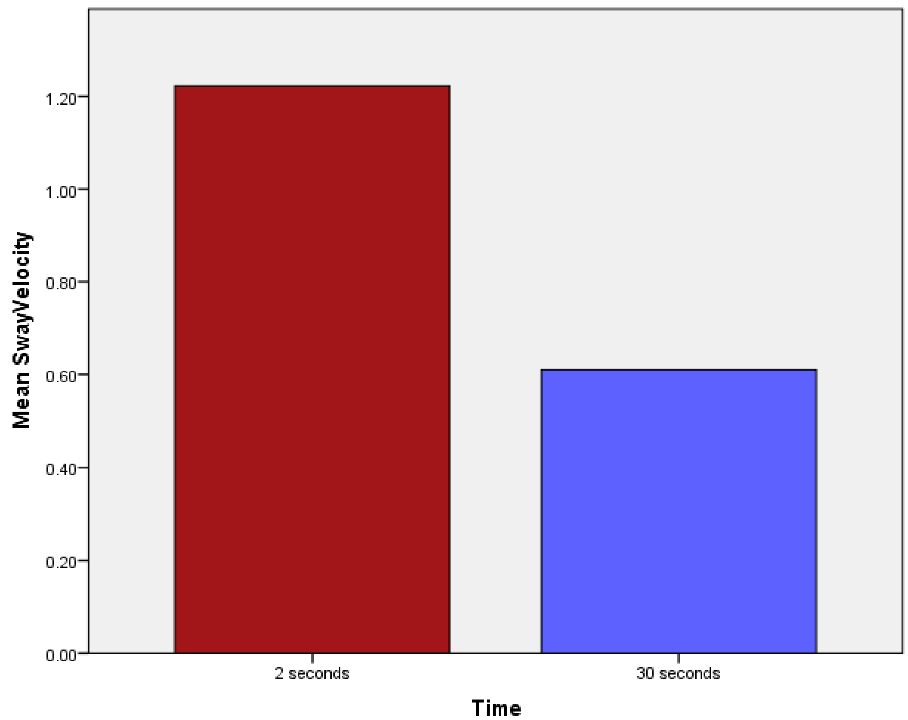

Figure. Mean (standard deviation) of sway velocity by sitting pause time (N = 18)

Table. Statistical results of paired *t*-test and descriptive statistics for sitting pause time of 2 sec. vs. 30 sec.

	2 Second Pause Time		30 Second Pause Time			95% CI for Mean Difference			
Outcome	*M*	*SD*	*M*	*SD*	*n*		*p*	*t*	*df*
	1.22	.68	.61	.19	18	.29 , .92	.001*	4.12*	17

- $p < .05$

Discussion

In the present study, the investigators studied the effect of sitting pause times on postural sway velocity after changing position from supine to standing in a dimly lit environment. The results showed that the mean postural sway velocity was significantly less after 30-second sitting pause time compared to 2-second sitting pause time.

The sensory-motor processes for maintaining postural stability are challenged when an individual stands suddenly after being in a supine position [21]. Also, when individuals quickly get out of the bed at night with lack of lighting, the probability of falls is likely to increase [21]. Consequently, getting up from bed quickly can lead to falling in older adults [22]. Previous studies have shown that impaired vision and dim lighting levels affect postural stability and increase the risk of falling and hip fractures in the older adult population [12,17,24].

After changing position, postural sway significantly increases in older adults. Sada et al. [21] reported that both clear vision and sitting pause pre-standing can lead to less postural sway. Also, Johnson and Meltzer [25] reported that postural sway velocity for younger and older groups was less after 30-second pause time than that after 2-second pause time. The authors concluded that adequate time is needed to stabilize posture when sitting up in bed in dimly lit room before standing [25]. The findings of the present study support the results of these previous studies.

The present study suggests that, when older adults wake up at night to get out of bed, they should sit at bedside for 30 seconds before standing to have better postural stability. Sitting for 30 seconds provides increased opportunity for visual adaptation to dimly lit rooms and decreased postural sway velocity.

The present study has several limitations including a narrow age range of older adult women ages 65 to 75 years. Gender was another limitation as males were not included in the study. Therefore, the findings of this study cannot be generalizable to older adult males or to females older than 75 years. Also, future studies should consider adding sitting pause times of less than 30 seconds to determine if similar postural stability benefits can be realized through shorter duration sitting pause times. Another limitation was that the authors did not consider orthostatic hypotension in this study. Orthostatic hypotension has a 10% to 30% prevalence among older adults living at home and is defined as a reduction of over 20 mm Hg of systolic blood pressure between lying and standing [31]. Also, the authors did not examine lower extremity muscle strength, which has been considered a major contributing factor of falls in older adults [31,32]. Future studies should compare differences in postural sway velocity for 2- and 30-second sitting pause times in well lit versus dimly lit environments and consider whether a 30-second pause time will decrease postural sway velocity in older adults who have orthostatic hypotension. The standardized force plate foot position can also be considered a limitation because it may not be a natural position for some people.

Conclusion

Postural sway velocity was significantly less when participants performed a sitting pause time of 30 seconds before standing in a dimly lit environment. In consideration of increased fall risk in older adults, the results of this study suggest that longer sitting pause times may contribute to improved postural stability and reduced risk of fall in older adult women aged 65 to 75 years when getting out of bed at night.

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CHAPTER FIVE

DISCUSSION

Motion sensitivity is a common syndrome for individuals in both modern transportation and in virtual reality environments such as the cinema or video games [1,2]. Modern transportation and entertainment innovations can play a significant role in increasing the prevalence of motion sensitivity [3], and people with normal vestibular function are susceptible to this condition [1,4]. The sensory inputs, which are visual, vestibular, and proprioceptive systems, play a significant role in maintaining postural stability [5]. The vestibular system provides information about head motion relative to space to maintain postural stability [6]. Stimulation of the VOR and the VSR, while stimulation of the upper neck-joint receptors activates the COR [7]. Consequently, both head and neck rotation contribute to stimulating these reflexes [8]. Furthermore, increased postural instability can be stimulated by either active head rotation or head tilt in patients with vestibular dysfunction [9,10] as well as in healthy people [11,12]. In addition, several studies [13-15] have shown a relationship between motion sensitivity and postural instability.

Though, some studies have investigated the relationship between motion sensitivity and postural stability, to our knowledge, none has compared the effects of head motion on postural stability in participants with versus without CMS. Therefore, the primary study aimed to compare the effects of head motion on postural stability in healthy adults with versus without CMS as well as the effects of head motion direction (horizontal versus vertical) on postural stability. The secondary study aimed to examine the criterion validity and test-retest reliability of a new questionnaire, the Activity

Avoidance Questionnaire (AAQ), which was designed to be a simple assessment tool for determining susceptibility to motion sensitivity. The primary hypothesis was that postural stability during head motion would be worse in the CMS group compared to the non-CMS group. The secondary hypothesis was that postural stability would be worse during vertical head motion compared to horizontal head motion within each study group. The third hypothesis was that the AAQ is both a valid and reliable tool for assessing susceptibility to motion sensitivity.

In the primary study, the effects of head motion on postural stability were compared in healthy adults with and without CMS. The results showed that postural stability during head motion was worse in the CMS group compared to the non-CMS group. Our result is consistent with Paloski et al. [11] who found that postural instability was increased during dynamic head tilts in healthy subjects. Owen et al. [15] reported that greater postural instability was correlated with motion sensitivity.

Most functional daily tasks require active range of motion of the cervical spine [16]. The horizontal movements are likely more relevant to routine activities of daily life and comprise a fundamental portion of head movements associated with daily balance activities [9]. The effects of head motion direction (horizontal versus vertical) on postural stability were also considered, and it was hypothesized that postural stability would be worse during vertical head motion compared to horizontal head motion. However, the results indicated that there was no significant difference in mean postural stability between horizontal and vertical head motions within groups. The amplitude of horizontal head motion was greater than vertical head motion. Moreover, the authors think that the difference in amplitude of head range of motions (horizontal versus vertical) can explain why no significant differences between the directions of head motion were found. Additionally, the authors suggest that the velocity at faster speeds may show a significant difference between horizontal and vertical head movements. Lackner and Graybiel [17] demonstrated that all movements (yaw, roll, and pitch) provoked motion sensitivity. Kogler et al. [18] showed that head extension positioning increases postural sway velocity more than either head flexion or right/left rotation positioning and indicated that head extension leads to disturbances in vision and vestibular systems as well as increases somatosensory dependence. Consequently, head extension increases postural sway because the utricular otoliths are placed in a disadvantageous position [19].

Motion sensitivity can diminish work performance [20,21]. Matsangas et al. [21] found that mild motion sensitivity reduces cognitive multitask performance. Therefore, it is important to accurately assess motion sensitivity to assist in evaluating the effectiveness of countermeasures and to promote current therapies [22], such as gaze-stability exercises [23,24]. In the secondary study, the AAQ was designed to provide an effective and precise tool to determine motion sensitivity. The results of this secondary study have shown that the AAQ has high validity when compared with the MSSQ-SF and excellent reliability. The authors noticed that the two activities with the highest reliability involved car transportation, the motion activity that is most frequently used in daily life [25].

To assess reliability, participants filled out the AAQ twice: the first time, they completed it in the physical therapy neurology research laboratory at Loma Linda University; the second time, they completed it at home, returning it via email. The investigators encountered some questions regarding riding both in a boat and on roller coasters during the first completion of the AAQ. It is possible that the second completion of the AAQ should also have occurred in person in the research laboratory to ensure that all activities were clear.

Because automobiles, boats, airplanes, and entertainment environments are the most common places that provoke motion sensitivity [1], the authors included these types of motion in the AAQ in addition to common symptoms that accompany motion sensitivity. The AAQ has several potential advantages over currently used questionnaires that assess motion sensitivity, including a reduced chance of making mistakes due to questionnaire fatigue [26], ease of understanding, and a shorter completion time. The authors recommend using the AAQ as a simple and quick tool for determining motion sensitivity.

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APPENDIX A

HEALTH HISTORY SCREENING FORM

LOMA LINDA UNIVERSITY
School of Allied Health Professions

Effects of Head Motion on Postural Stability in Healthy Young Adults with and without 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

LOMA LINDA UNIVERSITY

School of Allied Health Professions

<u>Participant's Information</u>

Name:

Date of Birth:

Weight:

Height:

How often do you work out? Never Sometimes Often

Email:

Contact Number:

APPENDIX C

INFORMED CONSENT FORM

LOMA LINDA UNIVERSITY
School of Allied Health Professions

TITLE: **EFFECTS OF HEAD MOTION ON POSTURAL STABILITY IN HEALTHY YOUNG ADULTS WITH AND WITHOUT 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 study is to examine the effect of head motion on postural stability in healthy adults with and without chronic motion sensitivity, and to compare the effect of direction of head motion (horizontal versus vertical) on postural stability. To our knowledge, there is no previous study to compare the effect of head motion on postural stability in subjects with or without chronic motion sensitivity. You are invited to participate in this research study because you are a healthy adult between 20-40 years of age.

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 two sessions. The first session will be approximately 90 minutes in the research lab and the second session will be a follow-up questionnaire via email two weeks after the first session.

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 motion sensitivity questionnaire for group assignment. Group 1 is adults with chronic motion sensitivity and Group 2 is adults without chronic motion sensitivity.
- Next, you will complete an activity avoidance questionnaire.
- Next, your balance will be measured using a non-invasive computerized device.
- Finally, after two weeks you will receive an email asking you to complete the same activity avoidance questionnaire.

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 head motion. 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?

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 beyond the time involved to participate.

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

You will receive a $40 gift card on the first day of data collection.

12. WHO DO I CALL IF I HAVE QUESTIONS?

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

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:	Effects of Head Motion on Postural Stability in Healthy Young Adults with and without 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

"Effects of Head Motion on Postural Stability in Healthy Young Adults with and without Chronic Motion Sensitivity"

The Department of Physical Therapy of the School of Allied Health Profession, Loma Linda University is conducting a research study examining the effect of head motion on postural stability in healthy adults with and 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 **Abdulaziz Albalwi** at **412-482-4115** or email at aalbalwi@llu.edu
Principle investigator: **Dr. Eric Johnson,** email at ejohnson@llu.edu

APPENDIX F

ACTIVITY AVOIDANCE QUESTIONNAIRE FORM

Code:

LOMA LINDA UNIVERSITY
School of Allied Health Professions

Activity Avoidance Questionnaire

Do you avoid any of the activities below because they produce dizziness, nausea, imbalance, and/or blurry vision? If "Yes" please rate the symptom using the following scale:

Activity			Rating Scale
Reading in Moving Vehicle	No	Yes	**BEST** 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / 10 **WORST**
Being in Moving Vehicle on Winding Roads	No	Yes	**BEST** 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / 10 **WORST**
Riding in Boats	No	Yes	**BEST** 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / 10 **WORST**
Riding in Airplanes	No	Yes	**BEST** 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / 10 **WORST**
Riding Roller Coasters	No	Yes	**BEST** 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / 10 **WORST**
Quick Movements	No	Yes	**BEST** 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8 / 9 / 10 **WORST**

Loma Linda University
Adventist Health Science Center
Institutional Review Board
Approved 7/12/16
5160219 Chair

APPENDIX G

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					
	t	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					
	t	0	1	2	3

Loma Linda University
Adventist Health Science Center
Institutional Review Board
Approved 7/12/16
#5160219 Chair

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

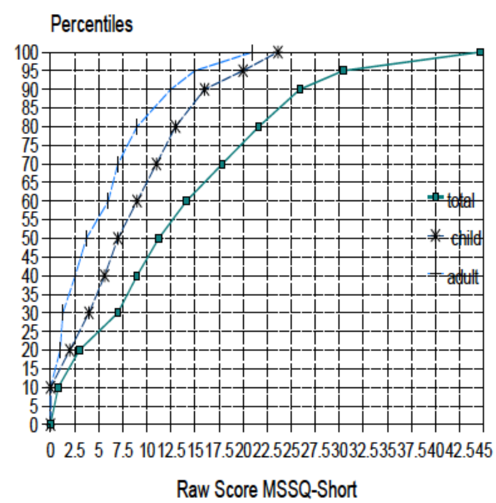

Figure 1. Cumulative distribution Percentiles of the Raw Scores of the MSSQ-Short (n=257 subjects).