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Gender Effect on Motion Sickness Susceptibility

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Abstract

The study aimed was to determine whether there was a gender difference in sensitivity to visual stimulation-induced motion sickness (MS). Forty-nine participants (Female: 24, Male: 25) volunteered to join in the study. Participants were exposed to a visual video-recording stimulus to evoke the MS. Simulator Sickness Questionnaire (SSQ) was administered before, after, and 30 min after the MS stimulation to determine MS symptoms. Participants' self-report was used to identify motion sickness. Postural sway (PS) was measured before and immediately after MS stimulation. 58.3% of the female and 48.0% of the male reported that they had MS, while 41.7% of the female and 52.0% of the male reported that they did not have MS. Gender and MS distributions were not significant (p=0.469). Participants with MS before the stimulation had higher PS than those who declared no MS (p=0.008), but PS was not different after the stimulation (p=0.102). Although there was no difference in the pre-test (p=0.231), men with MS had higher PS than women with MS at the post-test (p=0.013). There was a significant increase in PS of men who declared that they had MS after the stimulation (p=0.012). The pre-test (p=0.899) and post-test (p=0.434) SSQ scores of men and women with MS were not different, while women had higher SSQ scores than men at the post-test 30 (p=0.020). Finally, there was no correlation between gender and rates of MS. In terms of symptom severity, females appear to be more susceptible to MS. PS may be a precursor to MS.

Keywords: Gender, Motion sickness, Sensitivity, Postural instability

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INTRODUCTION

Motion sickness is thought to be caused by a conflict between the vestibular, visual and proprioceptive sensory systems (Yardley, 1992). Overstimulation of the balance system due to a physical movement (e.g. passive transportation) is the main factor causing the motion sickness (Reason and Brand, 1975). Visually evoked motion sickness (viewing moving visual scenes involving perceptual systems) is a phenomenon similar to traditional motion sickness, but in individuals susceptible to motion sickness, gastric activity (e.g., nausea, vomiting), autonomic responses (e.g., paleness, sweating), arousal (e.g, fatigue, lethargy, difficulty concentrating), disorientation (e.g. dizziness, vertigo) and/or oculomotor problems (e.g. eye strain, blurred vision, headache) (Bos et al., 2008; Golding & Gresty, 2015; Keshavarz et al., 2014; Owen et al., 1998). The symptoms of MS are uncomfortable (Lawson, 2014), and yet MS is known to negatively affect various areas of human performance (Colwell et al., 2009; Smyth et al., 2018). Nevertheless, most scientists in this field do not agree on a common theory that leads to the development of motion sickness, nor do they agree on a single method to mitigate the negative effects on individuals susceptible to motion sickness.

Almost everybody has experienced motion sickness at least once in his/her lifetime (Herron, 2010). Since the incidence of motion sickness in individuals is very high, this concept should not be thought of as a sickness, but as a normal response to an abnormal environment, that is, as the organism's response to a movement stimulus to which it cannot adapt (Gahlinger, 1999; Treisman, 1977). The exact prevalence of motion sickness (visually induced motion sickness) remains unclear, but laboratory studies suggest that the percentage of people with motion sickness can range from 1% (Klüver et al., 2015) to 80% under certain conditions (Cobb, 1999; Stanney et al., 1999).

It is known that susceptibility to motion sickness is influenced by different conditions such as age (Lawther and Griffin, 1987; Özkan and Köse Özkan, 2014; Paillard et al., 2013), gender (Lawther and Griffin, 1987), genetics (Murdin et al., 2011; Oman 2012), difficulties in body movements and postural control (Henriques et al., 2014; Riccio and Stoffregen, 1991). In addition, it is reported that the young age group is most affected among the child, young and elderly population (Domeyer et al., 2013; Keshavarz et al., 2018) and in terms of gender, women are more susceptible to motion sickness than men (Flanagan et al., 2005; Klosterhalfen et al., 2006; Stanney et al., 2020), but the certainty of this finding remains uncertain, given that some studies have not been able to determine gender-related differences (Curry et al., 2020; Klosterhalfen et al., 2006). In addition, the number of studies that reveal and directly examine this distinction is quite small.

Motion sickness, which is a condition faced by people all over the world, is a phenomenon that is frequently exposed in our country. However, there is a lack of information on the level of susceptibility of individuals in our country to motion sickness. The historical progression of motion sickness symptoms, which started with traveling in various vehicles, is now reported with the widespread use of developing technology. This study, which will help to determine the effect of gender difference on susceptibility to motion sickness and postural sway, is important in terms of revealing the data on the susceptibility to motion sickness of male and female individuals in our country for the first time and comparing the data obtained from the study with the motion sickness data of individuals of other races.

In order to further develop the literature on the role of gender difference in motion sickness, gender effect was taken into account in this study. For these reasons, the study aims to evaluate the role of gender in susceptibility to motion sickness as well as the postural sway of men and women susceptible to motion sickness.

METHODS

Participants

A total of 49 participants (female: 24; male: 25) who did not have vestibular or neurologic diseases and were not actively involved in sports participated in the study. The mean age of the female participants was 20.21 ± 1.77 years, mean height 162.79 ± 5.27 cm, and body weight 52.87 ± 5.53 kg; the mean age of the male participants was 21.32 ± 2.90 years, mean height 177.68 ± 5.96 cm, and body weight 73.89 ± 15.52 kg.

Participants participated in the study voluntarily after their informed consent was obtained. Before the study, each participant was informed that they could withdraw from the study at any time. Participants who were taking any medications known to cause dizziness were excluded from the study. All participants were informed in detail about the risks they might encounter and the tests to be performed before the study.

Ethical Approval

The study was approved by the Non-Interventional Ethics Committee of the Faculty of Sports Sciences of Selcuk University ethics committee (Approval Date: 04.23.2022; Decision number: 28). It was carried out in accordance with the Code of Ethics of the World Medical Association also known as a declaration of Helsinki.

Experimental Design

Symptom Severity Measurement

The video image of motion sickness was shown in a laboratory environment where lighting and ventilation could be controlled. The Simulator Sickness Questionnaire (SSQ), a validated and widely used assessment method, was used to measure motion sickness (Kennedy et al., 1993). The SSQ is a questionnaire consisting of 16 symptoms rated on a 4-point scale of none, mild, moderate, and severe to report the presence and severity of various symptoms after exposure to motion sickness. Motion sickness susceptibility with SSQ was assessed 3 times: Before, after, and 30 minutes after watching the video. Immediately after the SSQ, participants answered the question "Do you have motion sickness?" 3 times as "Yes or No". Participants were informed that they could discontinue the test if they experienced symptoms of motion sickness severe enough to stop watching the stimulus video.

Postural Sway

The Biodex Balance System (BBS, Biodex Medical Systems Inc, Shirley, NY), which measures and records participants' ability to maintain their posture under dynamic stress, was used to determine postural sway performance. There are studies showing that this system is a reliable tool for determining dynamic postural performance (Arnold and Schmitz, 1998; Cachupe et al., 2001; Hinman, 2000). High scores obtained from the BBS indicate decreased balance performance. Postural sway measurements were taken before and immediately after watching the stimulus video record on the dominant leg in the eyes-open condition as "difficulty level 8" of the measurement tool, after the participants' dominant legs were determined according to their answers to the question "which leg do you use first when kicking a ball". The participants were allowed to move the platform freely while looking at the screen in order to determine the coordinates of the foot position and determine the ideal foot position. They were asked to adjust the position of the support leg until they reached a balanced position and to place their hands diagonally on their right and left shoulders to eliminate the influence of the arms during the tests. After the appropriate position was found, the platform was locked according to the participants' foot position, and the test was performed after the coordinates of this position were recorded by the device. In order to evaluate the postural sway performance of the participants, postural sway measurements on both legs were taken twice, before and after the stimulation of motion sickness, for 20 seconds in eyes open (GA) condition. Participants were asked to participate in all tests barefoot and in comfortable sportswear and to practice sufficiently before the measurement in order to get used to the measurement tool.

Apparatus and Stimuli

The study was conducted in a laboratory with controlled ambient lighting. The stimulus video consisted of a video of cycling recorded from a first-person perspective captured by a video camera mounted on the handlebars of the bicycle. Each participant was shown a total of 23 minutes of video recording of a non-stop bicycle ride in a mountainous terrain to induce motion sickness, including bicycle sounds to enhance immersion, on a 65-inch monitor (Vestel 65U9500 65" 4K SMART TV) with wireless on-ear headphones (JBL, Tune500BT). Original video links; https://www.youtube.com/watch?v=IAulM9LPe7Q,https://www.youtube.com/watch?v=8a4gQpwzbuU (Hemmerich et al., 2019). The stimulation of motion sickness in the participants was created with this method after the pre-tests. This video record, which has been used in previous studies, was chosen because it is highly effective in inducing nausea due to the vibration caused by the absence of any processing to stabilize the recording process (Keshavarz and Hecht, 2012) and because it can adequately stimulate motion sickness visually (Hemmerich et al., 2019).

Data Analysis

The variables measured in the study were summarized as mean and standard deviation (SD). Normality distribution was tested by Shapiro Wilk test. According to the results of the normality analysis, t-test for independent samples and Mann Whitney U test were used to compare independent paired groups. Wilcoxon Paired Two-Sample Test was used to compare two dependent groups and Friedman test was used to compare more than two dependent groups. Chi-Square test was used to determine whether the rates of motion sickness varied according to gender. SPSS 26.0 package program was used in all statistical calculations and statistical significance level was accepted as 0.05.

RESULTS

Table 1. Descriptive characteristics of the participants

Variables	Gender	n	Mean	SD
Age (year)	Female	24	20.21	1.77
	Male	25	21.32	2.90
	Total	49	20.78	2.45
Height (cm)	Female	24	162.79	5.27
	Male	25	177.68	5.96
	Total	49	170.39	9.36
Body Weight (kg)	Female	24	52.87	5.53
	Male	25	73.89	15.52
	Total	49	63.60	15.74

Table 1 presents the descriptive characteristics of the participants. There was no difference between the ages of male and female participants (t=-1.613; p=0.113). As expected, the height (t=-9.255; p=0.000) and body weight (t=-6.263; p=0.000) of male participants were statistically higher than female participants.

Table 2. Motion sickness statements of the participants according to the tests

			Gender		
			Female	**Male**	**Total**
Pre Test	Sick	n	0	0	0
		%	0	0	0
	Well	n	24	25	49
		%	49.0	51.0	100.0
Post Test	Sick	n	14	11	25
		%	56.0	44.0	100.0
	Well	n	10	14	24
		%	41.7	58.3	100.0
Post Test 30	Sick	n	9	4	13
		%	69.2	30.8	100.0
	Well	n	15	21	36
		%	41.7	58.3	100.0

Table 3. The overall incidence of motion sickness

Variables		Sick	Well
Female	n	14	10
	%	58.3	41.7
Male	n	12	13
	%	48.0	52.0
Total	n	26	23
	%	53.1	46.9

Table 2 shows the MS statements for each measurement. Table 3 shows the MS statements during the entire test period. As a result of the application to induce motion sickness, 26 (53.1%) of the 49 participants declared that they had motion sickness, while 23 (46.9%) declared that they did not have motion sickness. While 14 (58.3%) of the female participants declared that they had MS, 10 (41.7%) declared that they did not have MS. Among the male participants, 12 (48.0%) reported having MS. 13 (52.0%) declared that they did not have MS. According to the results of Chi-Square analysis, the distributions of gender and having motion sickness were not statistically significant (Pearson Chi-Square=0.525; p=0.469).

Table 4. Postural sway scores in the pretest and posttest

		Pre Test		Post Test	
Gender		**Mean**	**SD**	**Mean**	**SD**
Female	**Sick**	1.74	0.87	2.14	1.35
	Well	1.21	0.44	1.73	1.06
	Total	1.52	0.76	1.97	1.23
Male	**Sick**	2.14	1.04	3.09	1.11
	Well	1.38	0.42	2.09	0.77
	Total	1.74	0.86	2.57	1.06
Total	**Sick**	1.92	0.95	2.58	1.31
	Well	1.30	0.43	1.93	0.90
	Total	1.63	0.81	2.28	1.17

Table 5. Comparisons of the postural sway scores in female and male participants

	Gender	Mean Rank	Sum of Ranks	U	p
Pretest	Female	22.81	547.50	247.500	0.293
	Male	27.10	677.50		
Posttes	Female	20.00	480.00	180.000	0.016*
	Male	29.80	745.00		

While pretest postural sway scores did not differ between men and women regardless of MS statements (U=247.500; p=0.293), posttest postural sway scores of female participants were significantly lower than those of men (U=180.000; p=0.016).

Table 6. Comparisons of the postural sway scores between pretest and posttest

	Mean Rank	Sum of Ranks	Z	p
All participants	15.29	183.50	-4.031	0.000*
	26.99	944.50		
Female	9.38	75.00	-1.918	0.055
	13.40	201.00		
Male	6.25	25.00	-3.576	0.000*
	13.75	275.00		

*** p<0.05**

There was a significant increase in the postural sway scores of the participants in the posttest (Z=-4.031; p=0.000). This increase in postural sway scores was not significant in female participants (Z=-1.918; p=0.055) but statistically significant in male participants (Z=-3.576; p=0.000).

Table 7. Comparisons of the postural sway scores between sick and well participants in pretest and posttest

			Mean Rank	Sum of Ranks	U	p
All participants	**Pretest**	Sick	30.06	781.50	167.500	0.008*
		Well	19.28	443.50		
	Posttest	Sick	28.13	731.50	217.500	0.102
		Well	21.46	493.50		
Female	**Pretest**	Sick	14.71	206.00	39.000	0.074
		Well	9.40	94.00		
	Posttest	Sick	13.93	195.00	50.000	0.259
		Well	10.50	105.00		
Male	**Pretest**	Sick	16.29	195.50	38.500	0.030*
		Well	9.96	129.50		
	Posttest	Sick	16.13	193.50	40.500	0.040*
		Well	10.12	131.50		

*** p<0.05**

Sick participants had higher pre-test postural sway scores than well participants (U=167.500; p=0.008) but there was no difference between post-test postural sway scores of sick and well participants (U=217.500; p=0.102). The postural sway scores of female participants at the pretest (U=39.000; p=0.074) and posttest (U=50.000; p=0.259) were not different between sick and well participants. Both pre-test (U=38.500; p=0.030) and post-test (U=40.500; p=0.040) postural sway scores of sick male participants were higher than those of wells.

Table 8. Comparison of postural sway scores of male and female participants with and without motion sickness

		Gender	Mean Rank	Sum of Ranks	U	P
Sick	**Pretest**	Female	11.82	165.50	60.500	0.231
		Male	15.46	185.50		
	Posttest	Female	10.07	141.00	36.000	0.013*
		Male	17.50	210.00		
Well	**Pretest**	Female	10.60	106.00	51.000	0.410
		Male	13.08	170.00		
	Posttest	Female	10.20	102.00	47.000	0.284
		Male	13.38	174.00		

*** p<0.05**

There was no significant difference between the pretest postural sway scores of sick women and sick men (U=60.500; p=0.231), but the posttest postural sway scores of sick men were higher than sick women (U=36.000; p=0.013). There was no significant difference between the postural sway scores of well women and well men both at pretest (U=51.000; p=0.410) and posttest (U=47.000; p=0.284).

Table 9. Comparisons of the postural sway scores between the pretest and posttest in sick and well participants

		Mean Rank	Sum of Ranks	Z	p
Female	**Sick**	5.63	22.50	-1.610	0.107
		7.61	68.50		
	Well	4.00	16.00	-1.174	0.241
		6.50	39.00		
Male	**Sick**	3.50	7.00	-2.514	0.012*
		7.10	71.00		
	Well	2.00	4.00	-2.751	0.006*
		7.40	74.00		

*** p<0.05**

The increase in postural sway scores of sick women after motion sickness stimulation was not significant (Z=-1.610; p=0.107), and the increase in postural sway scores of well women after stimulation was not significant (Z=-1.174; p=0.241). There was a statistically significant increase in postural sway scores of sick men after motion sickness stimulation (Z=-2.514; p=0.012). The increase in postural sway scores of well men after stimulation was statistically significant (Z=-2.751; p=0.006).

Table 10. The SSQ scores of the sick and well participants

Gender		Pretest		Posttest		Posttest 30	
		Mean	SD	Mean	SD	Mean	SD
Female	**Sick**	1.64	2.37	15.36	7.40	7.79	7.42
	Well	0.20	0.42	3.40	2.84	1.10	1.20
	Total	1.04	1.94	10.38	8.39	5.00	6.56
Male	**Sick**	1.55	1.86	14.00	9.35	4.27	6.13
	Well	0.69	1.97	3.69	3.92	1.38	2.66
	Total	1.08	1.93	8.42	8.58	2.71	4.71
Total	**Sick**	1.60	2.12	14.76	8.16	6.24	6.98
	Well	0.48	1.50	3.57	3.42	1.26	2.11
	Total	1.06	1.92	9.40	8.45	3.85	5.77

Table 11. Comparisons of the SSQ scores between sick and well participants

			Mean Rank	Sum of Ranks	U	p
All Participants	**Pretest**	Sick	30.04	781.00	168.000	0.003*
		Well	19.30	444.00		
	Posttest	Sick	34.22	855.50	44.500	0.000*
		Well	13.93	320.50		
	Posttest 30	Sick	31.81	827.00	122.000	0.000*
		Well	17.30	398.00		
Female	**Pretest**	Sick	15.00	210.00	35.000	0.042*
		Well	9.00	90.00		
	Posttest	Sick	17.29	242.00	3.000	0.000*
		Well	5.80	58.00		
	Posttest 30	Sick	16.75	234.50	10.500	0.000*
		Well	6.55	65.50		
Male	**Pretest**	Sick	15.46	185.50	48.500	0.110
		Well	10.73	139.50		
	Posttest	Sick	17.27	190.00	19.000	0.002*
		Well	8.46	110.00		
	Posttest 30	Sick	15.42	185.00	49.000	0.123
		Well	10.77	140.00		

* p<0.05

The SSQ scores of the participants according to their report of motion sickness are given in Table 10 and comparisons are given in Table 11. Sick participants had statistically higher SSQ scores at the pretest (U=168.000; p=0.003), posttest (U=44.500; p=0.000), and posttest 30 (U=122.000; p=0.000) than well participants. Similarly, the pretest SSQ (U=35.000; p=0.042), posttest SSQ (U=3.000; p=0.000) and posttest 30 SSQ (U=10.500; p=0.000) scores of patient women were statistically higher than those of well women. While the pretest SSQ (U=48.500; p=0.110) and posttest 30 SSQ (U=49.000; p=0.123) scores of sick and well men were not different, the posttest SSQ scores of sick men were statistically higher than well men (U=19.000; p=0.002).

Table 12. Comparisons of the SSQ scores in all participants

		Mean Rank	Chi-Square	df	p	Difference
All Participants	**Pretest**	1.28	66.880	2	0.000*	Pretest - Posttest
	Posttest	2.82				Pretest - Posttest 30
	Posttest 30	1.90				Posttest - Posttest 30
Female	**Pretest**	1.27	35.024	2	0.000*	Pretest - Posttest
	Posttest	2.85				Pretest - Posttest 30
	Posttest 30	1.88				Posttest - Posttest 30
Male	**Pretest**	1.29	31.902	2	0.000*	Pretest - Posttest
	Posttest	2.79				Pretest - Posttest 30
	Posttest 30	1.92				Posttest - Posttest 30

*** p<0.05**

There was a significant difference between the SSQ scores of the participants at pretest, posttest and posttest 30 (Chi-Square=66.880; p=0.000). According to pairwise comparisons, SSQ scores at posttest (Z=-5.716; p=0.000) and posttest 30 (Z=-4.488; p=0.000) were statistically higher than SSQ scores at pretest, and SSQ scores at posttest 30 (Z=-5.266; p=0.000). There was a significant difference between the pretest SSQ, posttest SSQ and posttest 30 SSQ scores of female participants

(Chi-Square=35.024; p=0.000). According to pairwise comparisons, it was determined that women's SSQ scores in the posttest (Z=-4.109; p=0.000) and posttest 30 (Z=-3.370; p=0.001) were statistically higher than those in the pretest, and SSQ scores in the posttest were statistically higher than those in the posttest 30 (Z=-3.829; p=0.000). There was a significant difference between the pre-test SSQ, post-test SSQ, and posttest 30 SSQ scores of male participants (Chi-Square=31.902; p=0.000). According to pairwise comparisons, it was determined that the SSQ scores of men in the posttest SSQ (Z=-4.020; p=0.000) and posttest 30 (Z=-3.153; p=0.002) were statistically higher than the pretest, and the SSQ scores in the posttest 30 (Z=-3.675; p=0.000) were statistically higher than the posttest 30 (Table 12).

Table 13. Comparisons of the SSQ scores between the tests in sick and well participants

			Mean Rank	**Chi-Square**	**df**	**p**	**Difference**
Sick	All Participants	Pretest	1.20	37.389	2	0.000*	Pretest - Posttest
		Posttest	2.88				Pretest - Posttest 30
		Posttest 30	1.92				Posttest - Posttest 30
	Female	Pretest	1.18	21.444	2	0.000*	Pretest - Posttest
		Posttest	2.89				Pretest - Posttest 30
		Posttest 30	1.93				Posttest - Posttest 30
	Male	Pretest	1.23	15.951	2	0.000*	Pretest - Posttest
		Posttest	2.86				Pretest - Posttest 30
		Posttest 30	1.91				Posttest - Posttest 30
Well	All Participants	Pretest	1.37	29.606	2	0.000*	Pretest - Posttest
		Posttest	2.76				Pretest - Posttest 30
		Posttest 30	1.87				Posttest - Posttest 30
	Female	Pretest	1.40	13.867	2	0.001*	Pretest - Posttest
		Posttest	2.80				Posttest - Posttest 30
		Posttest 30	1.80				
	Male	Pretest	1.35	15.951	2	0.000*	Pretest - Posttest
		Posttest	2.73				Pretest - Posttest 30
		Posttest 30	1.92				Posttest - Posttest 30

*** p<0.05**

A statistically significant difference was found between the pretest SSQ, posttest SSQ and posttest 30 SSQ scores of the well participants (Chi-Square: 37.389; p=0.000). Posttest SSQ (Z=-4.289; p=0.000) and posttest 30 SSQ (Z=-3.603; p=0.000) scores were statistically higher than pretest SSQ scores and posttest SSQ scores were statistically higher than posttest 30 SSQ (Z=-4.132; p=0.000). There was a statistically significant difference between the SSQ scores of sick women at the pretest, posttest, and posttest 30 (Chi-Square: 21.444; p=0.000). SSQ scores at posttest (Z=-3.298; p=0.001) and posttest 30 (Z=-2.871; p=0.004) were statistically higher than those at the pretest and SSQ scores at posttest 30 (Z=-3.081; p=0.002). There was a statistically significant difference between the SSQ scores at the pretest, posttest, and posttest 30 (Chi-Square: 15.951; p=0.000). The posttest SSQ (Z=-2.298; p=0.005) and posttest 30 SSQ (Z=-2.354; p=0.019) scores were statistically higher than the pretest SSQ and the posttest SSQ scores were statistically higher than the posttest 30 SSQ (Z=-2.805; p=0.005). There was a statistically significant difference between the pre-test SSQ, post-test SSQ, and posttest 30 SSQ scores of all participants who had no motion sickness (Chi-Square: 29.606; p=0.000). Posttest SSQ (Z=-3.835; p=0.000) and posttest 30 SSQ (Z=-2.797; p=0.005) scores were statistically higher than pretest SSQ scores and posttest

SSQ scores were statistically higher than posttest 30 SSQ (Z=-3.437; p=0.001). There was a statistically significant difference between the SSQ scores of well women at the pretest, posttest, and posttest 30 (Chi-Square: 13.867; p=0.001). SSQ scores at posttest were higher than those at pretest (Z=-2.524; p=0.012) and posttest 30 (Z=-2.536; p=0.011). The difference between posttest SSQ and posttest 30 SSQ scores was not significant (Z=-1.913; p=0.056). There was a statistically significant difference between the pretest, posttest, and posttest 30 SSQ scores of the well male participants (Chi-Square: 15.951; p=0.000). Posttest SSQ (Z=-2.944; p=0.003) and posttest 30 SSQ (Z=-2.124; p=0.034) scores were statistically higher than pretest SSQ scores, and posttest SSQ scores were statistically higher than posttest 30 (Z=-3.437; p=0.001) (Table 13).

Table 14. Comparisons of the SSQ scores according to the gender

		Gender	Mean Rank	Sum of Ranks	U	p
Sick	**Pretest**	Female	13.71	192.00	81.000	0.899
		Male	13.25	159.00		
	Posttest	Female	14.04	196.50	62.500	0.434
		Male	11.68	128.50		
	Posttest 30	Female	16.71	234.00	39.000	0.020*
		Male	9.75	117.00		
Well	**Pretest**	Female	12.10	121.00	64.000	0.976
		Male	11.92	155.00		
	Posttest	Female	12.15	121.50	63.500	0.927
		Male	11.88	154.50		
	Posttest 30	Female	12.55	125.50	59.500	0.738
		Male	11.58	150.50		

The pretest (U=81.000; p=0.899) and posttest (U=62.500; p=0.434) SSQ scores of patient women and patient men were not statistically different, whereas the SSQ scores of patient women were higher than patient men at posttest 30 (U=39.000; p=0.020). The pretest (U=64.000; p=0.976), posttest (U=63.500; p=0.927), and posttest 30 (U=59.500; p=0.738) SSQ scores of well women and well men were not statistically different (Table 14).

DISCUSSION

The first aim of the study was to determine whether there is a difference (superiority) in sensitivity to motion sickness between men and women, and the second aim was to determine whether motion sickness impacts how well people perform in postural sway tests when they are vulnerable to it. In keeping with these objectives, the current study examined the role of gender in motion sickness susceptibility as well as whether it affects how men and women who are vulnerable to motion sickness perform during postural sway tests.

To induce motion sickness, an approximately 23-minute motion sickness-inducing video was watched by two different groups of participants (24 women, and 24 men). At the end of the induction, 26 out of 49 participants (53.1%) reported having motion sickness (sick) and 23 (46.9%) reported not having motion sickness (well). There was no statistically significant difference between gender and the incidence of motion sickness, although the proportion of female participants (58.3%) reporting a motion sickness was higher than that of male participants (48.0%). Munafo et al., (2017) reported that after the first game using a virtual reality screen, 22% of the participants reported motion sickness and the difference in the rate between men and women was not significant; after the second game, 56% of the participants reported motion sickness and the rate among women (77.78%) was significantly higher than men (33.33%).

It has also been speculated that women may be more open and willing to report motion sickness as a result of visual stimulation than men (Ladwig et al., 2000), but the scientific evidence supporting this claim is weak (Dobie et al., 2001; Curry et al., 2020). Nevertheless, one study reviewed 46 studies examining gender differences in motion sickness and found that only 26/46 (56.5%) reported higher levels of sensitivity in women compared to men (Lawson, 2014).

A recent study found results that support the idea that women are more susceptible to motion sickness. However, a person's history of motion sickness was not associated with cybersickness symptoms. Accordingly, it was reported that the difference in the history of motion sickness between genders did not translate into cybersickness experiences as men and women experienced similar levels of cybersickness (Pöhlmann et al., 2023).

Authors studying many forms of motion sickness (Cooper et al., 1997; Dobie et al., 2001; Flanagan et al., 2005; Klosterhalfen et al., 2006; Lawther and Griffin, 1986; Lawther and Griffin, 1987; Munafo et al., 2017; Stanney et al., 2003; Turner et al., 2000) have documented gender differences in previous studies, with the majority finding women more susceptible to motion sickness than men across different stimulus types. While the exact cause of these gender differences is unknown, hormonal influences have been investigated as a possible cause, as the menstrual cycle has been shown to affect women's susceptibility to motion sickness (Golding et al., 2005; Hemmerich et al., 2019; Matchock et al., 2008; Schwab, 1954). In addition, it has been stated as another reason that women exhibit wider fields of vision than men in terms of environmental space (Burg, 1968).

In the study evaluating what triggers gender-based differences in the experience of cybersickness (motion sickness) in virtual environments, it was found that interpupillary distance mismatch was the primary cause of gender differences in cybersickness and was defined as the secondary cause of susceptibility to motion sickness. Women with poorly fitting interpupillary distance to the visual reality headset and a high prevalence of a history of motion sickness were most affected by cybersickness, and women did not fully return to normal within 1 hour of exposure. It was reported that women experienced cybersickness similar to men when their interpupillary distance was appropriately positioned on the VR headset, experienced high cybersickness immediately after cessation of VR exposure, but recovered within 1 hour of exposure (Stanney et al., 2020).

In this study, the pretest SSQ, posttest SSQ and posttest 30 scores of sick participants were statistically higher than those of well participants. Similarly, sick women had statistically higher pretest SSQ, posttest SSQ and posttest 30 SSQ scores than well women. In sick and well men, pretest SSQ and post-test 30 SSQ scores were not different, while sick men had statistically higher post-test SSQ scores than well men. This emphasizes that women are more sensitive to motion sickness. Similar findings to the current study were reported in the study by Koslucher et al., (2016). It was stated that SSQ symptom severity scores were higher among those who reported being sick after visual motion stimuli. Unlike this study, SSQ scores did not differ between sick and well men and women, and there was no gender difference in the severity of motion sickness, but the difference was in the incidence of motion sickness.

When the temporal changes of SSQ symptom severity (sensitivity), another finding of this study, were evaluated, it was found that there was a significant difference between the pretest SSQ, posttest SSQ and posttest 30 SSQ scores of both female and male participants. For both genders, posttest SSQ and posttest 30 SSQ scores were higher than pretest SSQ, and posttest SSQ scores were higher than posttest 30 SSQ. This finding confirms the results of Bos et al., (2013) who reported that motion sickness symptoms increased immediately after exposure to the stimulus (or immediately after the end of the exposure) and that this increase occurred immediately after exposure to the stimulus. In general, the severity of motion sickness symptoms decreases rapidly after the end of the movement stimulus (Kousoulis et al., 2016). In this study, posttest 30 SSQ scores were lower than posttest scores, indicating that motion sickness symptoms tended to decrease as time progressed for both male and female participants. Keshavarz et al., (2023) reported that the sensitivity of female participants was higher than that of male participants and that women reported significantly higher visually evoked motion sickness scores compared to men for all symptoms except nausea. The most noticeable symptom was reported to be eye fatigue.

Motion sickness symptoms can occur during or after exposure to certain dynamic visual displays (Hettinger and Riccio, 1992). Symptoms can be caused by visually perceived motion and are classified as the effects of visually evoked motion sickness (Kennedy et al., 2010). Visually evoked motion sickness can worsen an underlying medical condition such as migraine and vestibular disorders, especially symptoms such as nausea, headache, or dizziness, and may pose a danger to people with health problems (Keshavarz et al., 2023).

When the findings of motion sickness on postural sway in terms of gender were examined; the pretest and posttest postural sway scores of female participants were not different between sick and well participants. As expected, both pretest and posttest postural sway scores of sick men were higher than those of well men. There was no significant difference between the pretest postural sway scores of sick women and sick men, but the posttest postural sway scores of sick men were higher than those of sick women. This result shows that the postural sway of sick men is more affected by the stimulation. The increase in postural sway scores of sick and well women after motion sickness stimulation was not significant. On the other hand, sick and well men showed a significant increase in postural sway scores after stimulation. It is understood that the present study shows that gender has mixed results in terms of postural sway scores in motion sickness. It is also known that motion sickness is highly influenced by individual differences (Golding, 2006). We think that individual differences rather than gender may have contributed to these complex results in our study.

Munafo et al., (2017) reported that postural sway patterns before and after using the display system differed between sick and well participants. In addition, the results of other studies linking postural activity with motion sickness suggest that postural sway may be a defining feature of susceptibility to motion sickness and that gender differences in postural sway may be related to gender differences in susceptibility (Koslucher et al., 2016; Stoffregen et al., 2013; Villard et al., 2008).

CONCLUSION

In this study, we first investigated the effect of gender difference on motion sickness susceptibility and secondly, whether postural sway is a predictor of motion sickness. The results showed that although female participants had a higher rate of motion sickness than male participants, gender differences had no effect on motion sickness. When the symptom severity of motion sickness was evaluated, it was found that women were more sensitive to motion sickness. In the temporal changes of SSQ symptom severity (sensitivity), it was observed that both female and male participants showed an increase in symptom severity immediately after exposure to the motion sickness stimulus and this increase occurred immediately after exposure to the stimulus, and as time progressed, symptoms tended to decrease for both female and male participants. Motion sickness did not affect women's postural sway performance; whereas it was found to affect men's postural sway more. The motion sickness literature suggests that women are more susceptible to motion sickness. While this was expected to result in a negative outcome for women in terms of postural sway scores, the findings of this study resulted in a lower postural sway performance of sick men. The fact that postural sway before the motion sickness stimulus was higher in patients compared to well men suggests that postural sway may be a predictor of motion sickness. More comprehensive and systematic studies are needed to clarify these complex relationships and the mechanism of motion sickness and to better understand the relationship between gender and motion sickness.

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