Cybersickness Response Among Nursing Students In Using Virtual Reality: A Pre-Experimental Study

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Abstract

The rapid growth of information and communication technology, such as virtual reality, affects students' learning outcomes and their success in providing health services in the future. However, prolonged use of immersive technology could lead to health problems due to repetitive interaction with hardware devices, resulting in a sensory conflict called cybersickness. This study aimed to identify the cybersickness response among nursing students in using virtual reality. This research used a pre-experiment design, and a total of 49 nursing students participated. The Simulator Sickness Questionnaire was used to assess cybersickness and physiological responses. The data were analyzed using the Wilcoxon signed-rank test. The median post-test values for the three components (nausea, oculomotor, disorientation) in cybersickness were 28.7; 45.5; 83.6; and 606.1, respectively. We found statistically significant differences in cybersickness between pre- and post-intervention periods ($p < .001$). Heart rate and body temperature increased significantly ($p < .001$; $p < .001$, respectively), while in both systolic and diastolic blood pressure decreased ($p < .001$). According to the findings, using VR as an alternative learning media could initiate cybersickness on a certain level. Thus, the physiological response would be different for each participant.

Keywords: Cybersickness; physiological response; virtual reality (VR).

Introduction

Digitalization, or the use of technology in daily life, largely contributes to the productivity of an individual. Education is one of many areas in human's life that affected by digitalization. Various types of technology are being developed to help the learning process to be more interactive and comprehensive. Immersive technology, such as virtual reality (VR), is widely used and is transforming a new method of learning. VR refers to an artificial digital environment or virtual environment where computer simulations are applied to create a virtual world in a three-dimensional space (Passig et al., 2016; Chang et al., 2020). Using VR in education, especially in the nursing field, could improve students' clinical skills, reduce the risk of injury to patients due to inexperience, and provide continuous opportunities to improve skills through repeated practice. As a result, this will have an impact on students' learning outcomes and success in providing nursing care in the future (Werrlich et al., 2018).

Prolonged use of VR could create a psychological state in which users continuously feel present within a virtual environment, called immersion (Trahan et al., 2019). In order to create an adequate VR experience, individuals are expected to be immersed in the virtual environment created. Hence, the phenomenon of immersion is common in the digital world. However, repeated immersion could lead to a health issue resulting in conflict between the visual and vestibular systems. In addition, individuals who experienced a higher degree of immersion could develop some negative effects in the form of cybersickness symptoms. Cybersickness is a series of negative effects due to the interaction between the body and hardware devices, resulting in sensory conflicts to distinguish the virtual world from the real world (Rebenitsch & Owen, 2021). Cybersickness are influenced by several factors, including human factors (demographic characteristics, history of experiencing motion sickness, and others), immersive technology content (navigation profile and visual content), and interaction between users and VR content (Palmisano et al., 2020).

The human body that experiences cybersickness symptoms will respond by changing physiologically because it considers the use of immersive technology as a new stressor. According to Kim et al. (2022) there is a relationship between the occurrence of cybersickness and changes in physiological responses to the use of VR. Most changes that occur are generally related to the autonomic nervous system, such as increased heart rate frequency, body temperature, and blood pressure. Although an increase in heart rate is frequently associated with an increase in blood pressure, in a study conducted by Kim et al. (2022), the participants' blood pressure actually decreased. This is due to a mismatch in perceptions generated by the vestibular system and the visual system in the central nervous system.

Using immersive technologies such as VR during the COVID-19 pandemic transition could provide a safe and non-threatening simulated experience for improving clinical skills. The health implications of cybersickness, on the other hand, are a concern for any user of immersive technology. Since cybersickness is a subjective feeling, the manifestation may vary in each individual. This is due to culture, race, and individual differences, as well as the type of virtual environment encountered. Furthermore, as stated in the study conducted by Kim et al. (2022), each individual's physiological changes will differ when they encounter cybersickness due to the variability of their pain response. Therefore, this study aims to identify the cybersickness and physiological response changes (blood pressure, heart rate, and body temperature) caused by using VR in nursing students.

Research Methods

A pre-experimental study design with a one group pre-post-test design was used to identify the differences in student cybersickness symptoms and their physiological response to the use of VR. Due to the difficulties in conducting randomization, this design was chosen. The research was conducted at the VNursLab Laboratory (www.vnurslab.com) of the Faculty of Nursing in Universitas Padjadjaran, Bandung, Indonesia, from

December 12th to 21st, 2022.

Potential participants were recruited using purposive sampling. Second- to fourth-year undergraduate nursing students in stable psychological and physiological conditions who had taken the medical-surgical nursing course and completed the practice of installing urinary catheterization were included. Those who take medication and are at a high risk of motion sickness or have a history of disorientation-disease were excluded. Participants who fit the inclusion criteria were asked to fill out the Google form according to the schedule determined by the researcher. The sample was calculated using Windows G*Power with total of 49 students who met the inclusion criteria consented to participate in this study. Each participants received an intervention of urinary catheterization using VR. Since this research's sample consists of three batches of nursing students, there is a possibility of confounding bias. To minimize the effect of confounding bias, the researcher used a restriction method that limits participation in each batch of nursing students who are similar in relation to the confounder.

The independent variable was the simulation of urinary catheterization using VR. Urinary catheterization was chosen because the procedure is related to the human genitalia area, making it quite difficult to imagine through traditional teaching methods. The dependent variables in this study were cybersickness and physiological responses (blood pressure, heart rate, and body temperature). The Simulator Sickness Questionnaire (SSQ) was used to measure the participants' subjective symptoms of cybersickness. It was a standardized questionnaire developed by Kennedy et al. (1993) (Sevinc & Berkman, 2020), to match the language of the participants, the researcher adapted this questionnaire into Bahasa Indonesia. The questionnaire contained 16 cybersickness symptoms divided into the components of nausea, oculomotor, and disorientation. This questionnaire uses a Likert scale for each question item, namely none (0), slight (1), moderate (2), and severe (3). Participants were asked to categorize them based on their subjective feeling. Pearson correlation with an r table was used to tested construct validity. The value (r count) of all the questions was greater than 0.45. The Cronbach alpha results for reliability were 0.874.

Prior to the intervention, a total of 49 nursing students were given instructions regarding the details of the simulation, including the benefits and side effects of the intervention. The participants were asked to filled google form to assess their characteristics demographics and their current state of cybersickness. Straight after that, participants' vital signs (blood pressure, heart rate, and body temperature) were being checked. VR orientation were given to carry out the urinary catheterization intervention. The intervention lasted for ±30 minutes. Lastly, participants were given a Google form to filled out the post-test containing cybersickness symptoms. Following the post-test, participants' vital signs were re-evaluated. Shortly after the measurement, the researcher transferred the data to Microsoft Excel for further analysis. No participants dropped out during the intervention process ($n = 49$).

The data analysis stages contained of data editing, coding, data entry, data cleaning, and tabulation. To describe the characteristics of the participants, descriptive statistics were used. The Shapiro-Wilk test was conducted to determine the normality of the data. Since the data was not normally distributed, the variable was analyzed using the Wilcoxon signed-rank test to see the difference in means in the same group. In this study, the Helsinki Ethical Principles were applied to respect human dignity, being fair to each participant, not causing harm, and benefiting this study to each participant. This study obtained approval and ethical consideration from Universitas Padjadjaran with the number 1005/UN6. KEP/EC/2022. Informed consent was given and signed by the participants manually. The hypotheses were analyzed using the p-value approach. The level of significance in this study was validated by the p-value ($p < 0.05$) obtained for the occurrence of cybersickness and physiologically changes in participants. No missing data were identified, as all of the required items in the questionnaire were filled.

Results

Demographic and characteristics of participants

The results of demographics and characteristics presented before and after the intervention are shown in Table 1.

Table 1. Demographics and characteristics (n = 49)

Categories	Frequency (n)	Percentage (%)
Gender		
Female	44	89.8
Male	5	10.2
Age		
18	2	4.1
19	15	30.6
20	17	34.7
21	10	20.4
22	5	10.2
Student cohort		
Second-year	18	36.7
Third-year	17	34.7
Fourth-year	14	28.6
BMI		
Underweight	12	24.5
Normal	30	61.2
Overweight	6	12.2
Obese	1	2.1
Previous Illness		
Yes	11	22.4
None	38	77.6
Current Illness		
Yes	2	4.1
None	47	95.9
Psychosocial Complaints		
Yes	7	14.3
None	42	85.7
VR Experience		
Yes	13	26.5
No	36	73.5
3D Games Experience		
Yes	14	28.6
No	35	71.4
Migraine Propensity		
Yes	17	34.7
No	32	65.3

Motion Sickness Propensity		
Yes	**14**	**28.6**
No	**35**	**71.4**
Eye Disorders and Diseases		
Myopia	**25**	**51.0**
Hypermetropia	**1**	**2.0**
Astigmatism	**2**	**4.1**
None	**21**	**42.9**
Adequacy of sleep		
Normal (> 6 hours)	**16**	**32.7**
Lack of sleep (> 4 hours)	**28**	**57.1**
Extreme lack of sleep (< 3 hours)	**5**	**10.2**
Adequacy of meal		
Full Stomach (< 2 hours of last meal)	**13**	**26.5**
Normal (< 4 hours of last meal)	**15**	**30.6**
Empty Stomach (> 5 hours of last meal)	**21**	**42.9**

According to Table 1 the majority of participants were female (89.8%), aged 20 (34.7%), had a normal BMI ranged from 18.5 – 24.9 (61.2%). Among 49 participants, 38 people (77.6%) stated having a prior illness ranging from GERD, anemia, typhus, and dengue fever, and 47 people (95.9%) stated there was no current illness and had no psychosocial complaints (85.7%). Regarding the factors that influence cybersickness, Table 1 shows that the majority of participants had no experience in operating VR (73.5%), had no experience in playing 3D Games (71.4%), had a low tendency to developing migraine (65.3%) along with motion sickness (71.4%), and had a visual impairment, mainly myopia (51%). Prior to the intervention, most participants were in a condition of insufficient sleep (less than 4 hours of sleep) (57.1%) with an empty stomach (more than 5 hours of last meal) (42%).

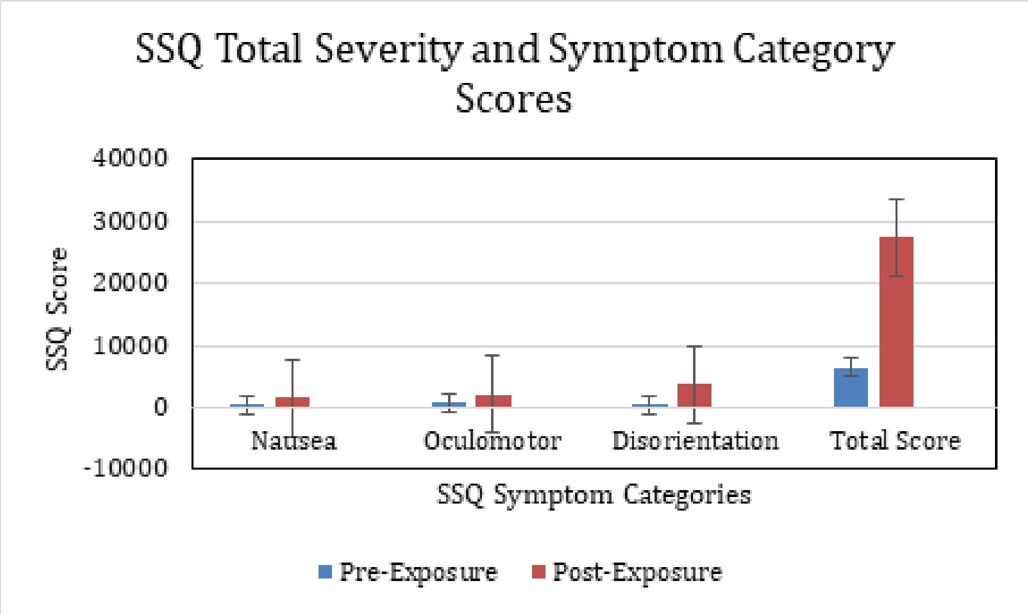
The Analysis of SSQ (Simulator Sickness Questionnaire) Scores

The result of SSQ analysis scores presented pre- and post-intervention are shown in Table 2 and Chart 1.

Table 2. Distribution of participants' mean SSQ scores (n = 49)

SSQ Scale	Pre-Intervention			Post-Intervention			p-value
	Min	Max	Me	Min	Max	Me	
N	0	57.3	9.6	0	76.4	28.7	p < .001
O	0	53.1	7.6	0	128.9	45.5	p < .001
D	0	41.8	0	0	208.8	83.6	p < .001
Total Score	0	533.1	99.8	0	1512.7	606.1	p < .001

Chart 1. Distribution medians scores of SSQ components



According to Table 2, before intervention conducted, the median of SSQ scores for the components of nausea, oculomotor, disorientation, and total score were 9.6; 7.6; 0; 99.8, respectively. After the intervention, the median scores increased to 28.7; 45.5; 83.6; and 606.1, respectively. The calculation results showed that all SSQ scores increased significantly (p < .001), as seen in Chart 1. This indicates that each participant experienced cybersickness symptoms after the urinary catheterization intervention.

The Analysis of Physiological Responses

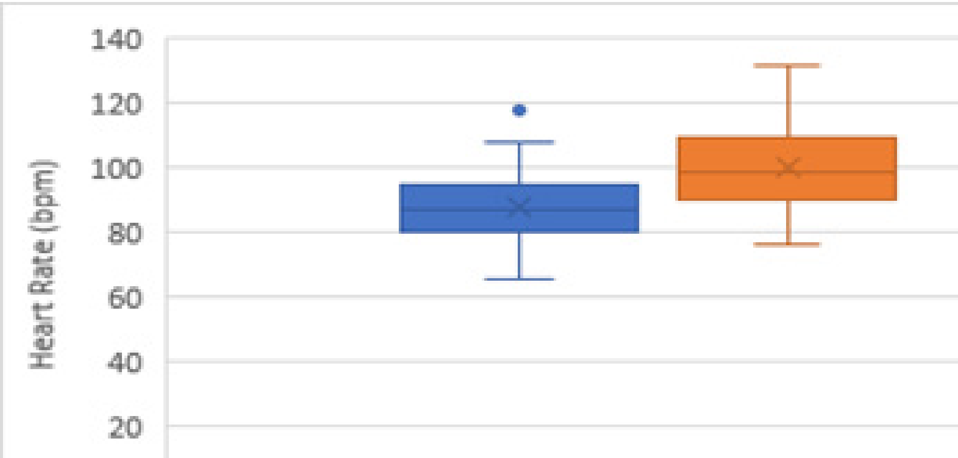
The results of physiological response scores presented pre- and post-intervention are shown in Table 3.

Table 3. Distribution of participants' physiological response (n = 49)

SSQ Scale	Pre-Intervention			Post-Intervention			p-value
	Min	Max	Me	Min	Max	Me	
Heart Rate	66	118	87	76	132	85	p < .001
Blood Pressure							
Systolic	93	139	112	80	136	102	p < .001
Diastolic	66	107	79	59	106	74	p < .001
Temperature	34	36.7	36	34.2	36.9	36.4	p < .001

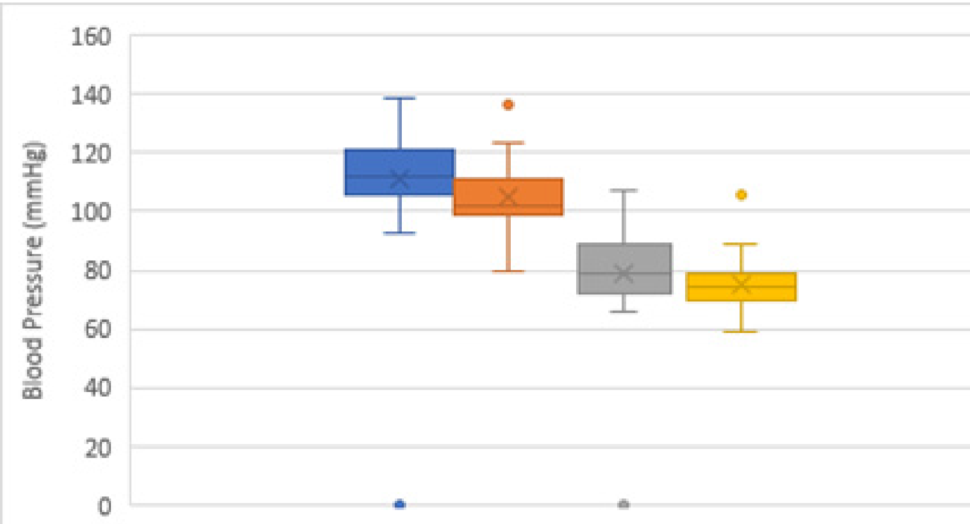
Table 2 shows that after an intervention conducted for ±30 minutes, there were some physiological changes in participants' vital signs. It can be seen that the heart rate increased after the intervention (p < .001). The temperature was also seen increased after the intervention (p <.001), while blood pressure decreased in both systolic and diastolic pressure (p < .001). The results of heart rate scores presented pre- and post-intervention are shown in Chart 2.

Chart 2. Heart rate measured in the pre- and post-intervention



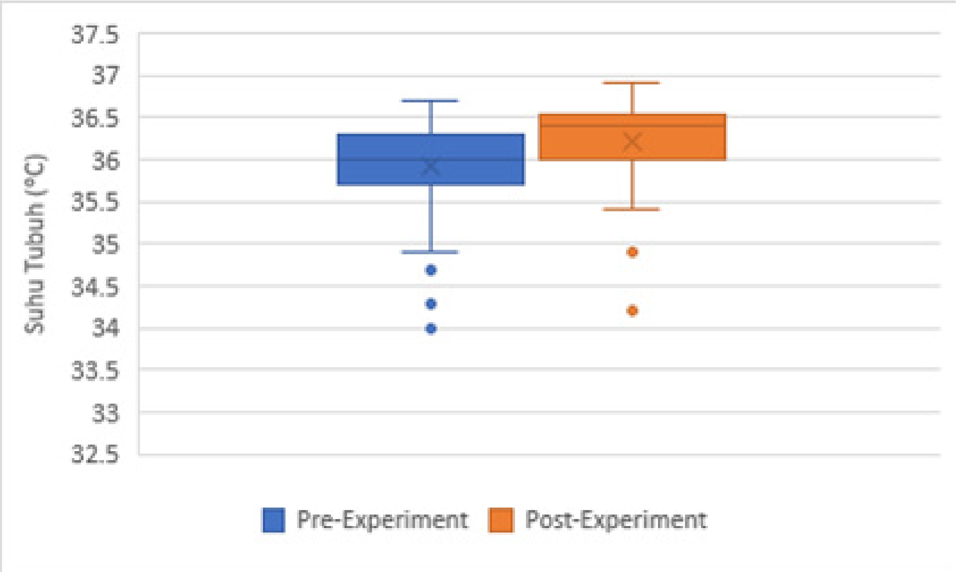
The median heart rate pre-intervention was 88 bpm, while the post-intervention was 100 bpm. This study showed that each participant's heart rate increased significantly (p < .001). Thus, it can be stated that the heart rate also increased when participants experienced cybersickness symptoms after the urinary catheterization intervention. The results of blood pressure scores presented pre- and post-intervention are shown in Chart 3.

Chart 3. Blood Pressure measured in the pre- and post-intervention



The median of systolic blood pressure pre- and post-intervention was 114 mmHg and 105 mmHg, respectively. Meanwhile, the median of diastolic blood pressure was 81 mmHg and 76 mmHg, respectively. The results of this study showed that the participants' blood pressure decreased significantly, as shown in Chart 3. Thus, along with the appearance of cybersickness symptoms and increased heart rate, the participants' blood pressure decreased after the urinary catheterization intervention. The results of temperature scores presented pre- and post-intervention are shown in Chart 4.

Chart 4. Temperature measured in the pre- and post-intervention



Furthermore, the median of body temperature pre-intervention was 36 °C and post-intervention was 36.2 °C. The result of this study showed that the participants' body temperature increased ($p < .001$), as shown in the Chart 4. Thus, in addition to sweating, one of the many symptoms of cybersickness, the participants' body temperature increased following the urinary catheterization intervention.

Discussion

In general, the result shows that the majority of participants were female nursing students, mostly aged 20, with a normal BMI, and had reported experiencing cybersickness following VR exposure. Participants who had a tendency to suffer migraines and motion sickness in daily life and currently has an eye disorder, reported had a higher propensity to suffer more from severe cybersickness. Meanwhile, there was no significant differences in the scale of cybersickness between participants who reported psychosocial complaints and those who did not. Contrary to that, participants with prior VR and 3D games experience, had lower rates of cybersickness. In addition, in terms of hours before conducting the intervention, the adequacy of sleep and meals did not significantly affect the occurrence of cybersickness. Furthermore, the disorientation component was the major cybersickness symptoms that mostly affected participants. Participants' vital signs also changed after the onset of cybersickness. The heart rate and body temperature were reported to increase, while blood pressure decreased.

The Analysis of Cybersickness Response

This study aimed to identify nursing students' cybersickness responses while using VR. This study analyzed the participants' SSQ scores and physiological responses (blood pressure, heart rate, and body temperature) pre- and post-intervention. SSQ scores were used to identify cybersickness symptoms occur from the simulation of urinary catheterization using VR. Cybersickness symptoms consist of nausea, oculomotor, and disorientation components (Sevinc & Berkman, 2020). In this study, Table 2 shows that the disorientation symptom component increased the most after the intervention was implemented compared to nausea and oculomotor component. According to this finding, the disorientation component is the most common symptom that causes participants to experience cybersickness. This is due to a misalignment of the vestibular system and the visual system, resulting in sensory conflict between the virtual and real worlds (Yu et al., 2019).

Factors of Cybersickness

The characteristics of each individual will affect the occurrence of cybersickness in participants. Demographic characteristics (age, gender, and duration of VR exposure), the user's tendency to experience motion sickness, bodily trait factors (BMI, adequacy of sleep, adequacy of meal, migraine propensity, individual comorbidities, binocular parallax, psychological problems, and current conditions) are all human factors that influence the appearance of cybersickness symptoms (Bockelman & Lingum, 2017). Moreover, user factors such as VR experience and 3D game experience could influence the appearance of cybersickness symptoms. The finding of this research shows factors that contribute the most to the occurrence of severe cybersickness in participants were; high tendency to develop motion sickness and migraines and individuals with eye disorder, particularly myopia.

Furthermore, external factors such as visual content influence, navigation directions, and participants' interaction with VR devices are other pre-dominant factors that could initiate cybersickness. Research by Gavgani et al. (2017) explains that the navigation profile is directly related to the amount of optical flow in peripheral vision, which significantly impacts the severity of cybersickness symptoms. Moreover, visual content which needs backward navigation caused more severe cybersickness symptoms than visual content with forward navigation (Gallagher & Ferrè, 2018). In addition, visual content with dynamic motion triggers more cybersickness symptoms than static motion. In this study, the visual content in the intervention used dynamic motion features. Thus, participants were given an orientation regarding the navigation's direction and ways to control of its intervention. This was intended to anticipate participants' movement that would interfere the vestibular system, specifically backward movement (Guna et al., 2020).

The Analysis of Physiological Response

Due to the subjective feeling of cybersickness symptoms, each individual will have different manifestations. Analysis of pre- and post-intervention physiological responses was identified to see the body's physiological response to cybersickness symptoms in each participant. In Table 3, it shows differences in the results of blood pressure, heart rate, and body temperature pre- and post-intervention. The heart rate increased significantly after the intervention was implemented, as shown in Chart 2. While in Chart 3 it can be seen that blood pressure decreased after participants carried out the intervention.

When using immersive technology such as VR, the body will perceive it as a new stressor. Thus, it can be seen as changes in physiological responses. In their research, Dhabhar et al. (2013) explained that when the body gets a new stressor, the number of white blood cells will increase immediately and start releasing the cortisol hormone. Consequently, it will force the increase of heart rate. Furthermore, the heart-body connection hypothesis states that when the body is active, the metabolism will increase and contributing to an increase in heart rate. Research study conducted by Zwart et al. (2021) shows that when user is viewing visual content in 3D, the heart rate will increase and causing stress.

In addition, cybersickness could be caused by a conflict between the visual and vestibular systems. The effects of vestibular stimulation will indirectly influence changes in autonomic nervous parameters such as heart rate, blood pressure, and breathing patterns. In this study, the participants' heart rate increased, while its blood pressure decreased. Typically, an increase in heart rate is accompanied by an increase in blood pressure. Cahan et al. (2012) has stated that low blood pressure accompanied by high heart rate is expected in some situations, but not in the long term. When individuals have low blood pressure, the blood flow against the artery walls is weaker than usual, so the heart will pump more strongly to supply oxygen-rich blood to other organs. This process may cause the body to react by increasing its heart rate. A drop in blood pressure accompanied by an increase in heart rate usually shows symptoms such as dizziness, headache, nausea, blurred vision, and fatigue. Individuals suffering from cybersickness frequently exhibit these symptoms.

According to Chart 4, the participants' body temperature increased after the intervention. Research conducted by Nesbitt (2018) showed that cybersickness can modulate thermoregulatory processes, including increased body temperature and sweating. This may result from the maladaptive relationship between cybersickness and thermoregulatory control. Cybersickness can significantly reduce vasoconstriction induced by the body's perception of cold, leading to peripheral vasodilation and an increased in sweat production. Therefore, the results in this study are in line with research conducted by Nesbitt (2018).

Unlike the previous researches, this study was conducted using 3 batches of nursing students (second-year to fourth-year undergraduates) which could potentially be confounding variables. This could arise since the divergence in the students' knowledge of simulating urinary catheterization would affect their duration when using VR.

Conclusion

Long-term use of VR for urinary catheterization in nursing students could cause cybersickness. When compared to the other three components of its symptoms, such as nausea and oculomotor, disorientation symptoms have significantly increased. Human factors such as the tendency to experience motion sickness, migraine propensity, and comorbidities in the form of visual impairment are the most common causes of cybersickness. When cybersickness occurs, the body immediately responds by increasing its heart rate and body temperature while lowering its blood pressure. Thus, it can be stated that the conflict between the visual and vestibular systems affects the changes in autonomic parameters. Further research should consider the type of intervention and its duration to ensure the symptoms of cybersickness and physiological response are thoroughly measured.

References

Bockelman, P., & Lingum, D. (2017). Factors of cybersickness. *Communications in Computer and Information Science,* 714, 3–8. https://doi.org/10.1007/978-3-319-58753-0_1

Cahan, A., Ben-Dov, I. Z., & Bursztyn, M. (2012). Association of heart rate with blood pressure variability: Implications for blood pressure measurement. *American Journal of Hypertension*, 25(3), 313–318. https://doi.org/10.1038/ajh.2011.230

Chang, E., Kim, H. T., & Yoo, B. (2020). Virtual reality sickness: A review of causes and measurements. *International Journal of Human-Computer Interaction*, 36(17), 1658–1682. https://doi.org/10.1080/10447318.2020.1778351

Dhabhar, F. S., Malarkey, W. B., Neri, E., & McEwen, B. S. (2012). Stress-induced redistribution of immune cells—From barracks to boulevards to battlefields: A tale of three hormones–Curt Richter Award Winner. *Psychoneuroendocrinology*, 37(9), 1345-1368.

Gallagher, M., & Ferrè, E. R. (2018). Cybersickness: A multisensory integration perspective. *Multisensory Research*, 31(7), 645–674. https://doi.org/10.1163/22134808-20181293

Gavgani, A. M., Nesbitt, K. V., Blackmore, K. L., & Nalivaiko, E. (2017). Profiling subjective symptoms and autonomic changes associated with cybersickness. *Autonomic Neuroscience: Basic and Clinical*, 203, 41–50. https://doi.org/10.1016/j.autneu.2016.12.004

Guna, J., Geršak, G., Humar, I., Krebl, M., Orel, M., Lu, H., & Pogačnik, M. (2020). Virtual reality sickness and challenges behind different technology and content settings. *Mobile Networks and Applications*, 25(4), 1436–1445. https://doi.org/10.1007/s11036-019-01373-w

Kim, Y. S., Won, J., Jang, S.-W., & Ko, J. (2022). Effects of cybersickness caused by head-mounted display–based virtual reality on physiological responses: Cross-sectional study. *JMIR Serious Games*, 10(4), e37938. https://doi.org/10.2196/37938

Nesbitt, N. &. (2018). *Cybersickness. In Digital Diseases* (pp. 15–52). Peter Lang AG. https://doi.org/10.1007/978-3-319-08234-9_252-1

Palmisano, S., Allison, R. S., & Kim, J. (2020). Cybersickness in head-mounted displays is caused by differences in the user's virtual and physical head pose. *Frontiers in Virtual Reality*, 1. https://doi.org/10.3389/frvir.2020.587698

Passig, D., Tzuriel, D., & Eshel-Kedmi, G. (2016). Improving children's cognitive modifiability by dynamic assessment in 3D Immersive Virtual Reality environments. *Computers and Education*, 95, 296–308. https://doi.org/10.1016/j.compedu.2016.01.009

Rebenitsch, L., & Owen, C. (2021). Estimating cybersickness from virtual reality applications. *Virtual Reality*, 25(1), 165–174. https://doi.org/10.1007/s10055-020-00446-6

Sevinc, V., & Berkman, M. I. (2020). Psychometric evaluation of Simulator Sickness Questionnaire and its variants as a measure of cybersickness in consumer virtual environments. *Applied Ergonomics*, 82(September 2019). https://doi.org/10.1016/j.apergo.2019.102958

Trahan, M. H., Smith, K. S., & Talbot, T. B. (2019). Past, present, and future: Editorial on virtual reality applications to human services. *Journal of Technology in Human Services,* 37(1), 1–12. https://doi.org/10.1080/15228835.2019.1587334

Werrlich, S., Lorber, C., & Nguyen, P. (2018). Virtual, augmented and mixed reality: Interaction, navigation, visualization, embodiment, and simulation. *In 10th International Conference, VAMR* (pp. 15-20).

Yu, J., Chung, Y., Lee, J. E., Suh, D. H., Wie, J. H., Ko, H. S., Park, I. Y., & Shin, J. C. (2019). The educational effects of a pregnancy simulation in medical/nursing students and professionals. *BMC Medical Education*, 19(1). https://doi.org/10.1186/s12909-019-1589-8

Zwart, D. P., Goei, S. L., Noroozi, O., & Van Luit, J. E. H. (2021). The effects of computer-based virtual learning environments on nursing students' mathematical learning in medication processes. R*esearch and Practice in Technology Enhanced Learning*, 16(1). https://doi.org/10.1186/s41039-021-00147-x