



# Effects of Virtual Reality Immersion During Using Uni-Treadmill for Exercise

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**Abstract.** The use of virtual reality is growing rapidly, not only in gaming but also in sports. However, using virtual reality can lead to cybersickness, with symptoms such as nausea, oculomotor disturbances, and disorientation. This study aims to measure the onset of cybersickness during treadmill exercise and to determine the time it takes for these symptoms to appear. Cybersickness was assessed using a Simulator Sickness Questionnaire and a Fast Motion Sickness scale. The study involved 20 male participants, and the experiment lasted for 50 minutes. The results showed that using virtual reality while on a treadmill significantly induced cybersickness ( $p \leq 0.05$ ), with disorientation being the most pronounced symptom. Cybersickness began to manifest between the 9th until 15th minute ( $p \leq 0.05$ ).

**Keywords:** Cybersickness, Virtual Reality, Treadmill, Sport, Immerse.

## 1 BACKGROUND

Walking is one of the most effective physical activities for reducing the risk of non-communicable diseases (NCDs) and enhancing health benefits [1], [2]. Globally, physical activity guidelines recommend that adults engage in regular physical activity (PA) based on the activity's type, intensity, and duration [3]. As a moderate-intensity PA, walking offers significant health benefits [4], [5]. Studies have shown that urban environmental factors, such as reliance on passive transportation [6] and limited open spaces [7], may contribute to the obesity epidemic. To address this, activities like treadmill exercise in fitness centres provide a practical alternative to physical activity.

A study examining the effects of exercising on a treadmill while viewing nature images found that it can enhance enthusiasm and motivation more effectively than exercising without stimuli [8], [9]. In addition to using static images, virtual reality—more immersive—offers an even more significant potential to boost motivation during exercise. VR applications are increasingly expanding into the field of sports [10], [11], [12], [13], allowing virtual activities to be experienced through Head-Mounted Displays (HMDs). Modern HMDs, such as the Oculus Rift, HTC Vive, and PlayStation VR, offer immersive and realistic VR-based entertainment. However, despite its significant benefits, virtual reality can also cause some adverse side effects. One potential side effect of virtual reality (VR) use is cybersickness [14], [15], [16]. Cybersickness is characterized by symptoms similar to motion sickness, including

nausea, dizziness, disorientation, and discomfort, which can occur during or after VR use [17], [18], [19].

Previous studies have shown that users are less likely to experience cybersickness when walking on a treadmill [20], [21]. However, other studies have reported that 60-95% of users in active positions, such as walking, moving side to side, and jumping, experienced significant cybersickness during VR exposure. Additionally, 6-12.9% of participants had to stop using VR before the end of the experiment due to worsening symptoms of cybersickness [14], [22], [23]. The results also indicated that cybersickness was more common in users standing while using Head-Mounted Displays (HMDs) than those sitting [24], [25], [26]. Similar findings were observed in athletes using HMDs for tactical training [27] and observational learning [28], where those in a seated position generally experienced fewer issues with cybersickness. This study aims to examine further cybersickness that occurs while using a treadmill in combination with virtual reality. Cybersickness can be measured using the Simulator Sickness Questionnaire (SSQ), which assesses nausea, oculomotor disturbances, and disorientation symptoms[20]. Study found that nausea was the most significant effect, while previous research indicated that disorientation received the highest scores in active postures such as walking, moving side to side, and jumping [17], [23], [29], [30], [31], [32], [33].

In addition to measurements using the Simulator Sickness Questionnaire (SSQ), the Fast Motion Sickness Scale (FMS) can be utilized to observe the formation of cybersickness in more detail. The FMS allows users to report their level of discomfort every minute verbally. It presents a score range from 0 (no discomfort at all) to 20 (severe discomfort), and participants are required to report scores based on their criteria[34].

This study aims to measure the cybersickness that occurs during virtual reality while exercising on a treadmill and to determine the time it takes for cybersickness to develop so that appropriate mitigation strategies can be implemented in the future.

## **2 METHODOLOGY**

### **2.1 Participant**

The study involved twenty male participants, aged 18 to 25, who were not professional athletes. They exercised at the gym at least twice a week, primarily using a treadmill. All participants had normal foot function, walked with a normal gait, had normal vision, did not wear glasses, and had no prior experience with virtual reality. Only male participants were used because recent research confirms the findings of previous studies, which indicated that women tend to experience cybersickness more quickly than men. Women are more susceptible to cybersickness due to several factors, including differences in Field of View (FOV), hormonal levels, and a higher predisposition to motion sickness [35], [36], [37].

## 2.2 Apparatus

The HMD-based virtual reality used in this study was Meta Quest 2, which had a resolution of 1832 x 1920 pixels, a Qualcomm Snapdragon XR2 processor, 6GB of RAM, a 90Hz refresh rate, and weighs 503 grams. The treadmill had a maximum weight capacity of 100kg, a 350-watt motor, and a speed range of up to 10 kilometers per hour.



**Fig. 1.** Participant during immersion in virtual reality and view of content.

## 2.3 Protocol Experiments

The experiments were conducted in the Ergonomics Laboratory of the Gadjah Mada University. Before commencing the experiment, participants were explained the details of the experiment protocol, as well as the benefits and potential risks regarding the experiment. Once they agreed to participate in this study, they provided their consent before participating. The experiment protocol of this study had been approved by the research ethics committee under Approval No: KE/UGM/064/EC/2023 before commencing the study.

Subsequently, participants filled out the pre-simulator sickness questionnaire (SSQ pre) for 5 minutes. Following this, the participants stood on a treadmill and were exposed to virtual reality (VR) content, specifically a street view. During the 15-minute treadmill session, participants walked at a speed tailored to their capabilities. Throughout this period, participants were verbally queried using the fast motion sickness scale (FMS) at intervals of 3, 6, 9, 12, and 15 minutes, aiding in assessing any changes in cybersickness experienced while using VR.

After the 15-minute treadmill and VR sessions, participants discontinued treadmill use and exited VR. Subsequently, participants completed the Post-Simulator Sickness Questionnaire (SSQ post) within a 5-minutes. Following this, the participants were instructed to rest for 10 minutes before proceeding with subsequent activities.

The treadmill speed was set between 2 and 3.5 MPH to maintain a natural walking pace, as higher speeds can lead to a visual-proprioceptive mismatch, where leg movements do not align with the perceived visual speed. This mismatch can accelerate the onset of cybersickness [21].

## 2.4 Measurements

Participants' cybersickness level was measured using the Simulator Sickness Questionnaire (SSQ) questionnaire developed by [38]. The SSQ consists of 16 items,

with answers ranging from 0 to 3 depending on the severity of the participant's symptoms. The SSQ can be divided into three subscales: nausea, oculomotor, and disorientation. A higher SSQ score indicates that the participant had experienced more severe cybersickness. If the total SSQ score was higher than 33.3 points, the participant was assessed as experiencing a high level of cybersickness. In addition to SSQ, this study measured the cybersickness level using the Fast Motion Sickness Scale (FMS) [34]. The FMS presents a score range from 0: not at all ill to 20: severely ill. The participants reported their sickness level using FMS every 3 minutes during the VR immersion.

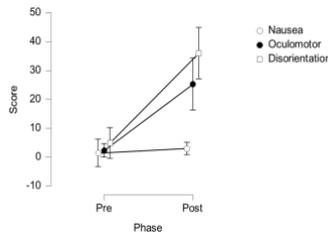
**2.5 Statistical Data Analysis**

Before processing and analyzing the data, the normality of the data was tested using the Shapiro-Wilk test, and all data in this study were found to be normally distributed. A T-test was used to determine if there was a significant difference between the means of the two groups and to assess the relationship between them. The T-test was applied to the SSQ data between the pre-and post-test phases.

Repeated Measures Analysis of Variance (RM ANOVA) was used for the FMS data to evaluate the relationship between three or more factors. If the RM ANOVA reveals significant main or interaction effects, post-hoc tests with Bonferroni correction will be used to identify the specific sources of these effects. The significance level ( $\alpha$ ) was set at  $\leq 0.05$ . All statistical data processing in this study was conducted using the open-source software JASP (version 0.17.02).

**3 RESULT**

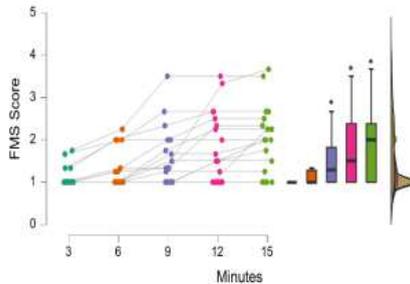
The results of the T-test showed significant differences in the Simulator Sickness Questionnaire (SSQ) scores for nausea between the pre- and post-test phases,  $t_{(19)} = -5.000$ ,  $p < 0.001$ , with a mean of 25.281. Oculomotor scores were also significant,  $t_{(19)} = -7.699$ ,  $p < 0.001$ , with a mean of 36.005. Disorientation scores were similarly significant,  $t_{(19)} = -4.753$ ,  $p < 0.001$ , with a mean of 38.976. Among these, the disorientation score had the highest value.



**Fig. 2.** Nausea, Oculomotor, Disorientation, of SSQ before and after VR immersion.

The results from the Fast Motion Sickness Scale showed changes over the 15 minutes of using virtual reality. Based on the RM ANOVA, there were significant results from

the 3rd minute to the 15th minute ( $F(4, 76) = 16.04, p < 0.001$ ). The post-hoc test revealed that significant cybersickness began to develop at the 9th minute,  $p_{\text{bonf}} < 0.001$ .



**Fig. 3.** Changes in cybersickness level from Minute 3 to 15, Significant cybersickness develops from the 9th and 15th minutes

## 4 DISCUSSION

This study aims to measure cybersickness while using a treadmill in combination with virtual reality. The results indicate that, based on SSQ measurements, disorientation (SSQ-D) was the most prominent effect experienced by users. This aligns with previous studies on cybersickness, which generally report disorientation as the most dominant symptom [17], [23], [29], [31], [32], [33], [39]. However, the findings of this study contradict the research by Bashir (2023), which identified nausea as the most significant symptom.

Disorientation is the most significant effect, attributed to limited user control and reduced reliance on natural sensory cues in the VR environment. Unlike the real world, VR does not provide users with the same vestibular and proprioceptive information that aids spatial orientation. This sensory conflict can lead to disorientation as users struggle to maintain balance and self-awareness in the virtual space [40], [41], [42]. Cybersickness is influenced by prior experience with Virtual Reality (VR) and long-term sports experience. Professional athletes who use HeadMounted Displays (HMDs) for tactical training [43] and observational learning [28] generally experience minimal issues with cybersickness. Additionally, professional athletes aged 18 to 60 exhibited minimal symptoms of cybersickness when using VR for 10 minutes [44]. The results of the FMS scale showed that cybersickness began to appear in participants starting at the 9th minute and intensified by the 15th minute. This is consistent with findings that VR use for more than 10 minutes in an active posture can cause cybersickness [36], [45], [46], [47].

Additionally, several studies have shown that prolonged VR use for 30 minutes in an active posture further increases the severity of cybersickness [14], [31], [48], [49]. The study results showed that using virtual reality as an alternative while on a treadmill is feasible if usage is at most 10 minutes. For longer sessions, taking a break every 10 minutes is recommended. Taking a break in which the user exits the VR environment and sits down can help reduce symptoms of cybersickness. Adopting a passive posture has been shown to alleviate the discomfort that often develops after using VR [50]. To

reduce cybersickness that occurs after more than 10 minutes of VR use, repeated exposure to VR has been shown to be effective. Research indicates that adaptation through repeated VR use can decrease symptoms of cybersickness [25], [33], [51], [52], [53], [54].

Research has examined body posture at three basic levels—sitting, standing, and lying down—and found that sitting generally reduces cybersickness compared to standing [55], [56]. The research conducted has some limitations. Future studies should not rely solely on subjective measures of cybersickness but also incorporate objective measures, such as Heart Rate Variability (HRV) or EEG, to provide more comprehensive results.

## 5 CONCLUSION

Using virtual reality while on a treadmill as an exercise alternative can lead to cybersickness, with disorientation being the most severe symptom. This is caused by limited user control and reduced reliance on natural sensory cues in the VR environment. The sensory conflict can cause disorientation as users struggle to maintain balance and spatial orientation in the virtual space. Symptoms of cybersickness typically begin around the 9th minute and persist for the duration of VR use. Therefore, it is recommended to limit the use of virtual reality while on a treadmill to a maximum of 10 minutes, with breaks in between sessions.

**Acknowledgements.** This study was financially supported by the Rekognisi Tugas Akhir (RTA) grant (grant number: 5286/UN1.P1/PT.01.03/2024) from Universitas Gadjah Mada, Indonesia.

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