Analisis Gangguan Kelelahan pada Aktivitas di Depan Layar Komputer Menggunakan Kuesioner *Zoom Exhaustion And Fatigue* (ZEF) Scale

Analysis of Fatigue Disorders In Activities in front of a Computer Screen Using a Questionnaire Zoom Exhaustion and Fatigue (ZEF) Scale

Aswin Fauziah[1], Agung Kristanto[2*], Farrah Diba Zya Ulfaq[2]

[1]Fakultas Kesehatan Masyarakat Universitas Ahmad Dahlan
[2]Fakultas Teknik Industri Universitas Ahmad Dahlan

Korespondensi Penulis: agung.kristanto@ie.uad.ac.id

ABSTRACT
Computer Interaction (HCI) is a discipline that studies communication between users and systems. Preliminary observations in 2023 at the Faculty of Industrial Engineering, Ahmad Dahlan University, revealed that 99% of students experienced fatigue due to online learning, with 85.7% reporting discomfort in areas such as the waist, neck, eyes, back, and hands. Approximately 61.9% reported significant mental pressure. This study aims to explore the relationship between mental and physical fatigue concerning gender, Body Mass Index (BMI), daily computer usage (hours), and duration of computer use (years). The research design employs a quantitative experimental approach. Physical fatigue is measured through heart rate analysis, while mental fatigue is assessed using the ZEF Scale. The sample consists of 93 students obtained through purposive sampling, with inclusion criteria including ages 19-25, at least 2 years of online learning experience, and daily usage of 2–8 hours. Results indicate that BMI significantly correlates with physical fatigue ($p = 0.036$), while over 4 years of computer usage is significantly related to mental fatigue ($p = 0.039$). Gender and daily computer usage did not show significant relationships. This study integrates modern technology, such as smartwatches and ZEF. Ergonomic practices enviroment are recommended for students to create comfortable work enviroment.
Keywords: HCI; Physical Fatigue; Mental Fatigue; ZEF

ABSTRAK
Human Computer Interaction (HCI) merupakan disiplin ilmu yang mengkaji komunikasi antara pengguna dan sistem. Observasi awal tahun 2023 di Fakultas Teknik Industri Universitas Ahmad Dahlan menunjukkan bahwa 99% mahasiswa mengalami kelelahan akibat pembelajaran daring, 85,7% melaporkan ketidaknyamanan pada area seperti pinggang, leher, mata, punggung, dan tangan. Sekitar 61,9% merasakan tekanan mental signifikan. Penelitian bertujuan mengeksplorasi hubungan antara kelelahan mental dan fisik terkait jenis kelamin, Indeks Massa Tubuh (IMT), penggunaan komputer per hari (jam), dan lama penggunaan komputer (tahun). Desain penelitian menggunakan pendekatan kuantitatif eksperimental. Pengukuran kelelahan fisik menggunakan analisis denyut jantung, kelelahan mental diukur dengan kuesioner *Zoom Exhaustion and Fatigue Scale* (ZEF). Sampel terdiri dari 93 mahasiswa, didapatkan dengan teknik *purposive sampling*. Kriteria inklusi mahasiswa usia 19-25 tahun telah mengikuti pembelajaran daring minimal 2 tahun, durasi penggunaan 2–8 jam per hari. Hasil menunjukkan IMT memiliki hubungan signifikan dengan kelelahan fisik ($p = 0.036$), sedangkan durasi penggunaan komputer > 4 tahun berhubungan signifikan dengan kelelahan mental ($p = 0.039$). Gender dan durasi penggunaan komputer harian tidak menunjukkan hubungan signifikan. Studi ini mengintegrasikan pengukuran kelelahan fisik dan mental menggunakan teknologi modern yaitu *smartwatch* dan kuesioner ZEF. Disarankan mahasiswa menerapkan praktik ergonomi dalam aktivitas di depan komputer untuk menciptakan lingkungan kerja yang nyaman.
Kata Kunci: HCI; Kelelahan Fisik; kelelahan Mental; ZEF

INTRODUCTION

The COVID-19 pandemic has significantly accelerated the adoption of Human-Computer Interaction (HCI) among students, particularly through the shift to online learning. This transition necessitated a movement from traditional classrooms to online platforms, leading to increased use of technologies such as Learning Management Systems and conferencing tools like Zoom and Microsoft Teams (Shanmuga Sundari and Karthikeyan, 2022). Zoom facilitates practical exercises and conceptual understanding, while Microsoft Teams enhances peer interaction and teacher accessibility outside the classroom. Both platforms support a learner-centered approach, maximizing engagement and allowing for deeper exploration of topics (Pawestri, Revani Putri and Ajeng Surya Ariyani Pedo, 2022).

However, numerous issues arise in human-computer interactions, including frequent miscommunications that can evoke emotional distress and contribute to mental health challenges. Besides mental health, physical health can also be impacted due to prolonged interaction with computers. Extended computer use poses risks for health issues related to the eyes, head, neck, shoulders, back, arms, and hands, collectively known as Musculoskeletal Disorders (MSDs). Computer Vision Syndrome (CVS) has emerged as a public health concern due to increased use of electronic devices with visual displays, leading to eye strain and discomfort (Ferusgel, Anjanny and Siregar, 2019).

The prevalence of CVS is notably high among engineering students, reaching 97.2% (Selvaraj, Ganesan, & Jain, 2021), and 94% among medical students in Saudi Arabia (Almousa et al., 2023). Additionally, the prevalence of lower back pain due to prolonged sitting is 39.7%, with 12.6% of students frequently reporting discomfort (Ferusgel, Anjanny, & Siregar, 2019). During the COVID-19 pandemic, 61.1% of students reported experiencing neck pain (Shete & Rane, 2024). The prevalence of MSDs by area includes the back (78.3%), neck (71.7%), head (41.5%), lower limbs (27.4%), pelvis and perineum (20.8%), chest (12.3%), abdomen (12.3%), and upper limbs (11.3%) (Landman and Tagari, 2024).

Research by Amalia Rochimah (2020) found that online learning has negative impacts, including difficulties in understanding material, communicating with peers, and increased workload, which can lead to stress and more serious mental health issues if not addressed properly. A systematic review involving 7,143 students indicated that 0.9% experienced severe anxiety, 2.7% moderate anxiety, and 21.3% mild anxiety. Additionally, delays in academic activities were identified as a risk factor for anxiety symptoms, with 40% of students experiencing financial difficulties related to e-learning platforms (Taufiqy, 2021). About 1 in 4 teenagers with 4 hours or more of daily screen time have experienced anxiety (27.1%) or depression symptoms (25.9%) in the past 2 weeks (Zablotsky *et al.*, 2024).

Initial observations in 2023 revealed that 99% of industrial engineering students od Ahmad Dahlan University reported fatigue from prolonged screen time during online learning, both mentally and physically. Furthermore, 85.7% complained of discomfort in various body parts, including the lower back, neck, eyes, back, and hands. Mentally, around 61.9% of students reported experiencing significant stress due to long hours in front of the screen, excessive workload, and challenges in understanding course material.

While there are several studies addressing the impact of HCI on physical and mental health, research focusing on students in Yogyakarta remains limited. This study aims to investigate the physical and mental health issues related to human-computer interaction. The instruments used include heart rate measurements via smartwatches to assess physical fatigue and the Zoom Exhaustion and Fatigue Scale (ZEF) to evaluate mental fatigue. The study will explore the relationship between physical and mental fatigue with variables such as gender, Body Mass Index (BMI), daily

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computer usage (hours), and duration of computer use (years).

Indicators of physical fatigue include the following: for zoom fatigue, mental indicators consist of continuous work without breaks, multitasking, excessive pressure, and suppressing problems; physical indicators include joint and muscle pain and slowed response times.

METHODS

This study employed a quantitative experimental research to measure levels of physical and mental fatigue. The population of industrial engineering students consisted of 121 individuals, from which a sample of 93 students was obtained. Respondents were selected based on health conditions, specifically excluding those with injuries to the back or neck, as such medical conditions could negatively affect the spine or upper body. Exclusion criteria included chronic diseases affecting muscles, fractures, joint disorders leading to stiffness and pain, the use of sedatives or alcohol within the last 48 hours, and headaches. Respondents had also completed online learning using Zoom for a minimum of 2 years, with Zoom usage durations ranging from 2 to 8 hours per day, and were aged between 19 and 25 years, as summarized in Table 1.

The study was conducted in four stages, each lasting 15 minutes, with an initial break of 5 minutes and a final break of 5 minutes, resulting in a total duration of 70 minutes for the simulation. In the first stage, respondents engaged in online learning, followed by a simulation of reading journal articles in the second stage. The third stage involved typing or summarizing the journals, while the fourth stage included participation in an interactive Q&A session.

Computer usage was categorized into four groups: light (< 2 hours), moderate (2-4 hours), and heavy (> 4 hours). Prior to the simulation in front of the computer screen, respondents' heart rates were measured for 5 minutes using a Suunto 9 Black smartwatch worn on the left wrist. Participants were instructed to sit with knees flexed at 90 degrees, hips flexed above 90 degrees, and their bodies resting on the upper part of the sacrum in a horizontal position.

Two cameras were used to record participants engaged in laptop use from the front, right side, and left side. The cameras were positioned at a clear distance to ensure that the participants' positions were visible during the simulation activities. Increased heart rate activity correlated with greater muscle activity, resulting in more pronounced fluctuations in heart rate. Following the completion of the four stages, participants filled out the Zoom Exhaustion and Fatigue Scale (ZEF) questionnaire to assess their mental fatigue. This study received ethical approval from the Ethics Committee of Ahmad Dahlan University in Yogyakarta.

Statistical analysis was conducted using the Chi-square test to determine the relationship between two groups. The independent variables in this study included gender, Body Mass Index (BMI), daily computer usage (hours), and duration of computer use (years). The dependent variable was physical fatigue, indicated by increases in heart rate, as shown in Table 2, while mental fatigue was measured using the ZEF questionnaire, as illustrated in Figure 2. The hypothesis of this study posits that there is a relationship between respondents' physical and mental fatigue concerning gender, BMI, daily computer usage (hours), and duration of computer use (years).

RESULTS

Respondent Characteristics

Descriptive statistics for the characteristics of the study respondents are summarized in Table 1.

Table 1. Respondent Characteristics

Characteristic	N (%)	Mean ± SD
Gender		
Male	69 (74,20%)	-

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Female	24 (25.80%)	
BMI	-	21,91 ± 2,81
Daily Duration (hours)	-	4,23 ± 1,29
Duration of Computer Use (years)	-	9,12 ± 3,18

Based on Table 1, the majority of respondents were male, with 69 individuals. The average Body Mass Index (BMI) was 21.91 ± 2.81, indicating a normal weight range. The average daily duration of Human-Computer Interaction (HCI) reached 4.23 ± 1.29 hours, and respondents reported an average of 9.12 ± 3.18 years of computer use.

Distribution of Physical Fatigue

Descriptive statistics for the physical fatigue of respondents are illustrated in Figure 1.

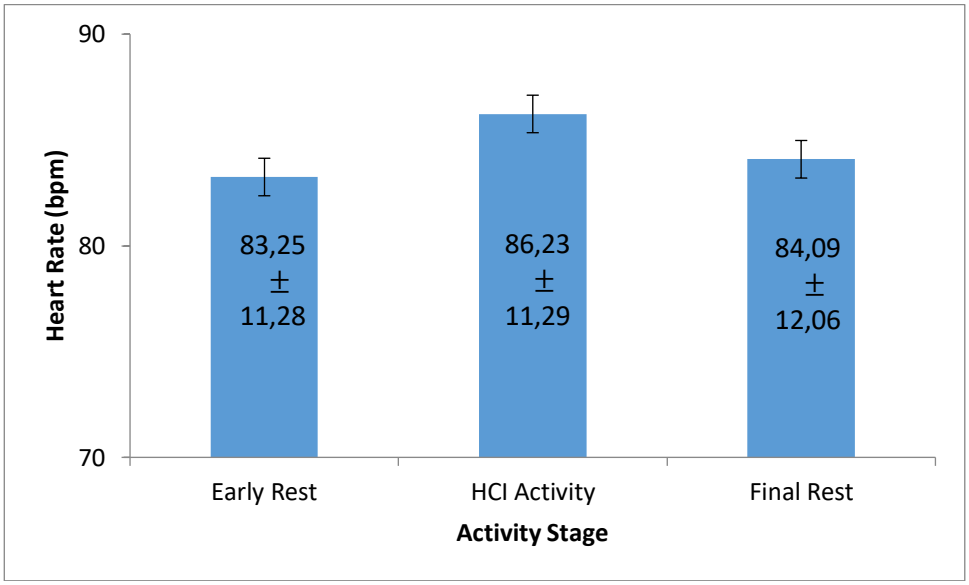
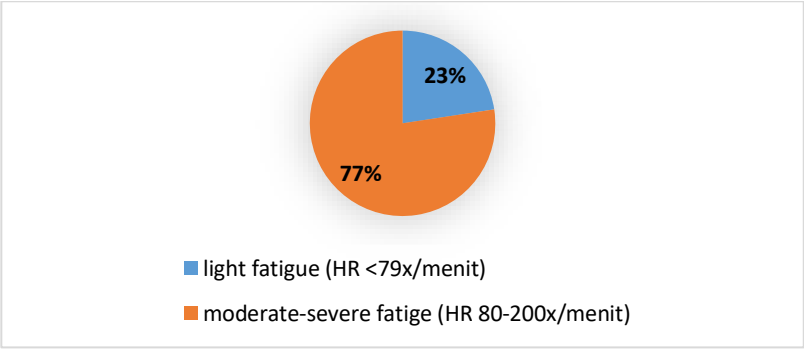


Figure 1. Physical Fatigue of Respondents

Indicators of physical fatigue were assessed based on the heart rate of the respondents. The highest heart rate recorded during activity was 86 beats per minute, while the final resting heart rate was 84 beats per minute, lower than the heart rate during activity but still higher than the initial resting heart rate of 83 beats per minute.

Classification of Physical Fatigue

Based on the 93 respondents, their heart rates were compared to classifications to determine whether their activities fell within the category of physical fatigue. The average results yielded a percentage of mental fatigue experienced during computer interactions, as illustrated in Figure 2.



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Figur 2. Classification of Physical Fatigue

Based on Figure 2, it was found that 23% of students had an average heart rate of less than 79 beats per minute, indicating that they experienced light fatigue. Conversely, 77% of respondents had an average heart rate ranging from 80 to 200 beats per minute, suggesting that these students experienced moderate to severe fatigue.

Data were collected from 93 respondents using the Zoom Exhaustion and Fatigue (ZEF) Scale after simulating activities involving computer interaction across four work stages: simulating a Zoom meeting, reading journals, typing, and answering questions. Descriptive statistics for the mental fatigue of respondents are illustrated in Figure 3.

Distribution of Mental Fatigue

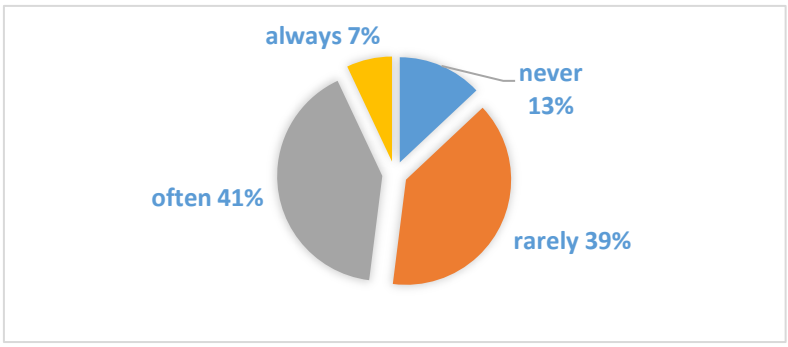

Figure 3. Mental Fatigue of Respondents

It can be seen in Figure 3 that the data on mental fatigue from the ZEF questionnaire indicate that upon completing the simulation, the overall average fatigue score for the 93 respondents was highest in general fatigue (KU1 3.37 ± 0.87). The highest average visual fatigue score was (KV1 2.96 ± 1.11), followed by social fatigue (KS1 2.84 ± 1.14). The highest average score for motivation fatigue was (KM3 3.15 ± 1.36), and the emotional fatigue score yielded a highest average of (KE1 3.09 ± 2.75). Overall, the final average score across all indicators of the questionnaire was (2.88 ± 0.76).

Classification of Mental Fatigue

From the 93 respondents, their scores were compared with the classifications from the ZEF questionnaire to determine whether their activities fell within the category of mental fatigue. The classification of mental fatigue based on the ZEF questionnaire is illustrated in Figure 4.

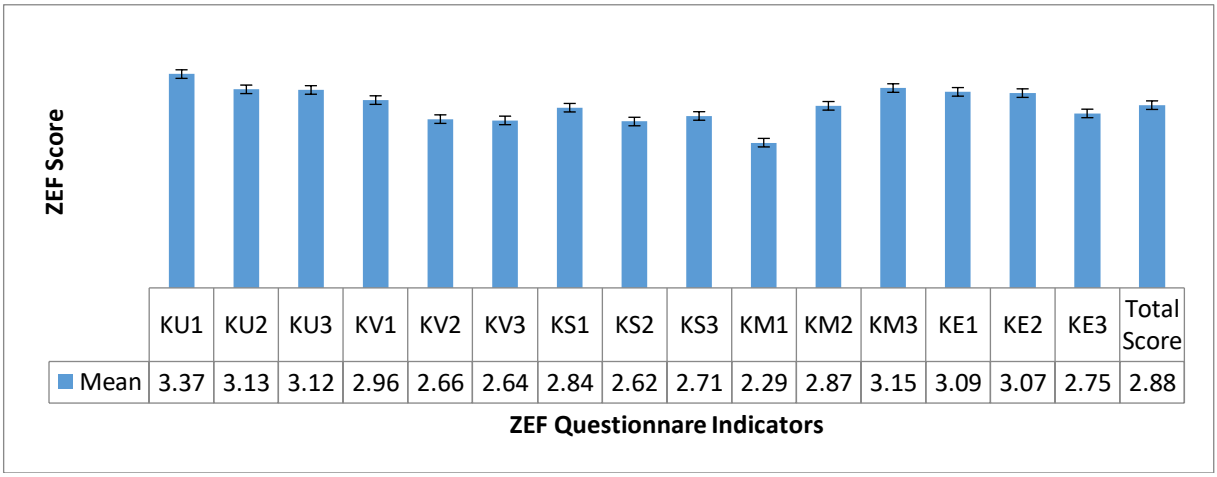

Figure 4. Classification of Mental Fatigue

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Based on Figure 4, it was found that 13% of students reported never experiencing mental fatigue. Additionally, 39% of respondents rarely experienced mental fatigue, while 41% often experienced it, and 7% reported always experiencing mental fatigue. This indicates that prolonged interaction with computers can significantly affect an individual's mental fatigue.

Statistical Analysis

The characteristics of the respondents, including gender, Body Mass Index (BMI), daily duration of computer use (hours), and years of computer use, were analyzed using the Chi-square test in relation to physical and mental fatigue among students. The results can be seen in Table 3 and Table 4.

Table 3. Chi-square Test Results for Respondent Characteristics and Physical Fatigue

Respondent Characteristics	Physical Fatigue		(p-value)
	Mild (%)	Moderate-Severe (%)	
Gender			
Male	18,3	53,8	0,301
Female	4,3	23,7	
BMI			
Underweight-Normal	9,7	52,7	0,036*
Obesity	12,9	24,7	
Duration of Computer Use (hours)			
3-4 hours	7,5	38,7	0,178
5-6 hours	15,1	38,7	
Years of Computer Use			
1-4 tahun	10,8	46,2	0.324
> 4 tahun	11,8	31,2	

* Significant correlation (p-value < 0.05)

Based on Table 3, only BMI has a significant relationship with physical fatigue, indicated by a p-value of 0.036, suggesting that respondents in the underweight-normal category experience higher levels of moderate to heavy physical fatigue compared to those with obesity. In contrast, the p-value for gender is 0.301, indicating no significant difference in physical fatigue levels between males and females, despite males showing a higher percentage of fatigue. Similarly, the daily duration of computer use shows no significant relationship with a p-value of 0.178, meaning that the hours spent in front of a screen do not significantly impact physical fatigue. Additionally, the experience of using a computer for more than 4 years compared to 1-4 years also lacks significance, with a p-value of 0.324, suggesting that this duration is insufficient to affect fatigue levels. Overall, the data indicate that BMI is the primary factor contributing to physical fatigue in this respondent population.

Table 4. Chi-square Test Results for Respondent Characteristics and Mental Fatigue

Karakteristik Responden	Mental Fatigue		(p-value)
	Never-Rarely (%)	Often-Always (%)	
Gender			
Male	41,9	30,1	0,87
Female	10,8	17,2	
BMI			
Underweight-Normal	29,0	33,3	0,127

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Obesity	23,7	14,0	
Duration of Computer Use (hours)	19,4	26,9	0,052
3-4 hours	33,3	20,4	
5-6 hours			
Years of Computer Use			
1-4 tahun	24,7	32,3	0,039*
> 4 tahun	28,0	15,1	

*Significant correlation (p-value < 0.05)

Based on Table 4, it is shown that the duration of computer use has a significant relationship with mental fatigue, with a p-value of 0.039, indicating that respondents who have used a computer for more than 4 years experience lower levels of mental fatigue compared to those using a computer for 1-4 years. In contrast, gender and BMI do not show a significant relationship with mental fatigue, with p-values of 0.87 and 0.127 respectively, suggesting that both males and females, as well as individuals with underweight-normal and obese BMI, experience similar levels of mental fatigue. The daily duration of computer use is also close to significance, with a p-value of 0.052, indicating that using a computer for 5-6 hours per day may be associated with increased mental fatigue. Therefore, the duration of computer use is the most influential factor affecting mental fatigue in this respondent population, while gender and BMI do not serve as significant factors.

DISCUSSION

Among physiological, psychological, and environmental factors. It can be measured using specific instruments. This study assessed levels of physical and mental fatigue using the ZEF questionnaire. The findings indicate that physical fatigue correlates with Body Mass Index (BMI), with a p-value of 0.036 (<0.05), consistent with research conducted Patandung and Widowati (2022) which established a relationship between BMI, physical workload, and complaints of musculoskeletal disorders among bus drivers on the Toraja-Makassar route. High BMI is associated with an increased prevalence of musculoskeletal symptoms, particularly in the lower extremity, particularly for employees with high physical workload. (Hengel *et al.*, 2013). Additionally, a study at the Annika Linden Center showed that higher BMI correlates with increased complaints of musculoskeletal disorders (Novianti *et al.*, 2023).

Various factors contribute to physical fatigue that are not always directly related to body weight. Even individuals with an ideal Body Mass Index (BMI) may experience underlying health issues, such as anemia or metabolic disorders, which can reduce energy and stamina. Additionally, poor sleep patterns and a lack of physical activity are common causes of fatigue, as individuals who do not get adequate rest or exercise tend to feel more tired. Psychological stress from academic pressures or work demands can also significantly impact physical fatigue, as unstable mental conditions often affect overall quality of life. Furthermore, an unbalanced diet or deficiencies in specific nutrients can lead to decreased energy levels, meaning that even physically healthy individuals may still experience fatigue. Physiologically, fatigue occurs when there is a reduction in the muscles' capacity to generate power, caused by the accumulation of lactic acid, decreased muscle glycogen, or disturbances in the central nervous system (Hall, 2015), (Tardy *et al.*, 2020).

Based on the results, the duration of computer use (in years) has a significant correlation with mental fatigue, with a p-value of 0.039 (<0.05). This finding aligns with studies conducted among teachers and academic staff at universities in Istanbul and Edirne, where Zoom fatigue negatively impacted users' physical and mental health. Zoom fatigue was found to cause exhaustion, stress, and increased mental and cognitive load, particularly among women (Kara and Ersoy, 2022). Additionally, another study

involving nursing students in the Philippines found that higher levels of Zoom fatigue predicted decreased satisfaction with online learning. This study underscores that online learning and virtual meetings may negatively affect students' online learning experiences (Amboy *et al.*, 2023).

Gender, daily duration of computer use (in hours), and the number of years of computer use do not show a significant correlation with physical fatigue. This may be due to various other factors influencing physical fatigue, such as activity levels and frequency of movement. Individual physical conditions, such as fitness and nutritional intake, also play important roles. Additionally, dehydration and poor sleep quality can contribute to feelings of fatigue, while stress and mental health issues may exacerbate complaints. An unsupportive work environment and the presence of certain medical conditions can also increase fatigue levels. Respondents more frequently experienced mental fatigue with a duration of computer use of less than 4 hours per day, accounting for 26.9%. This aligns with research indicating that students have high average video conference usage, with more than half of respondents using Zoom for over 5 hours per day. This prolonged use leads to significant feelings of social and emotional fatigue, characterized by feelings of exhaustion, irritability, moodiness, a desire to be alone, and a tendency to avoid social interactions after activities. Additionally, respondents reported symptoms such as blurred vision, eye strain, and discomfort in the eyes following video conferences (De Paula *et al.*, 2024), (Shafa Camila *et al.*, 2021).

Respondents who have used computers for 1-4 years showed a higher percentage of mental fatigue compared to those who have used computers for more than 4 years, possibly due to several factors. Individuals who are newly adapting to the demands of prolonged computer use may not have fully developed effective stress and time management skills, making them more susceptible to fatigue. Additionally, they often face greater pressure to meet academic or professional expectations, which can lead to mental stress and fatigue. This difference may also be attributed to sensitivity to fatigue symptoms; newer users may be more likely to report feelings of fatigue compared to those with more experience, who may have developed better strategies for coping with stress. (Geng *et al.*, 2021), (Ali, Zulkifil and Nurqamar, 2021).

Prolonged interaction with computers can lead to both physical and mental fatigue due to several interconnected factors. Physically, extended computer use often results in poor posture, muscle tension, and vision problems. Mentally, continuous exposure to screens can increase stress and anxiety levels, particularly when users engage in tasks that require high concentration or when they face pressure to meet deadlines. Additionally, intense interaction with digital technology can disrupt sleep patterns and reduce time available for physical activities, contributing to overall mental and physical fatigue. Therefore, it is essential to implement effective time management and rest strategies to mitigate the negative impacts of excessive computer use (Sarkar *et al.*, 2022), (Singh and Devi, 2023).

To create a comfortable work environment, avoid working on a bed or sofa for extended periods and choose a desk that is spacious enough with adequate legroom. Use a chair that supports the lower back, adding cushions if necessary. Keep the keyboard and mouse separate from the laptop to reduce wrist strain, ensuring that the wrists remain in a straight position while typing. Additionally, adjust the height of the laptop or monitor so that the top is level with eye level. Stretching is crucial when engaged in static positions for long periods, such as prolonged sitting, to reduce the risk of muscle and back injuries. It is recommended to stretch if remaining in a static position for 4 hours or more. Spend about 5-10 minutes stretching to relax the muscles of the back, neck, shoulders, hands, and legs (Simanjuntak and Susetyo, 2022), (Yassierli *et al.*, 2020).

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The limitations of this study include the fact that it involved only 93 respondents. Additionally, the assessment of musculoskeletal disorder (MSD) complaints was not conducted using validated forms such as the Rapid Upper Limb Assessment (RULA) and Rapid Entire Body Assessment (REBA), which would have allowed for more specific identification of the locations of complaints among the respondents.

CONCLUSION

The findings from this study indicate that the factors influencing physical and mental fatigue among respondents vary. BMI is significantly associated with physical fatigue, where respondents in the underweight-normal category experience higher levels of moderate to severe physical fatigue compared to those with obesity. In contrast, gender, daily duration of computer use, and years of computer use did not show significant relationships with physical fatigue. Conversely, the duration of computer use has a significant correlation with mental fatigue, with respondents using computers for more than 4 years experiencing lower levels of mental fatigue compared to those using computers for 1-4 years. Gender and BMI, however, did not show significant correlations with mental fatigue.

Thus, BMI and the duration of computer use are key factors contributing to physical and mental fatigue, respectively, in this population. Future research should involve a larger sample of computer or laptop users from diverse backgrounds compared to the current study. Additionally, conducting assessments of musculoskeletal disorder complaints using validated forms such as the Rapid Upper Limb Assessment (RULA) and Rapid Entire Body Assessment (REBA) would help to more specifically identify the locations of complaints among respondents. Such research could ultimately enhance the health of computer and laptop users in Indonesia and facilitate the dissemination of useful information.

RECOMMENDATION

It is recommended that students enhance their awareness of physical and mental health, particularly by implementing confortable work enviroment and incorporating physical activities into their daily routines. For future research, conducting studies would be advantageous to examine the broader implications of computer use on health. Additionally, including supplementary variables such as stress levels and sleep quality, as well as comparing different demographic groups, such as engineering and non-engineering students, could provide a more comprehensive understanding of the varying health impacts.

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