

Zoom fatigue and its risk factors in online learning during the COVID-19 pandemic

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ABSTRACT

BACKGROUND Global nations have enforced strict health protocols because of the COVID-19's high transmission, infectivity, and mortality. As shown by increased online learning and video conferencing, the employment and education sectors are shifting to home-based activities. Video conferencing as a communication medium has subtly led to zoom fatigue. This study aimed to analyze the risk factors of zoom fatigue for early prevention and treatment.

METHODS This cross-sectional study was conducted on 335 Indonesian university students selected by purposive sampling in July 2021. Data were collected using a demographic questionnaire including online courses duration during the COVID-19 pandemic; Pittsburgh sleep quality index; depression, anxiety and stress scale-21; and zoom & exhaustion fatigue (ZEF) scale through Google Form (Google LLC, USA) distributed via social media and student forums. Association and correlation tests were used, and the model was developed using linear regression.

RESULTS The respondents were aged 21.3 (1.8) years with 12.8 (5.1) months of online courses during the COVID-19 pandemic and a ZEF scale of 2.8 (0.9). Students with higher ZEF had irregular physical exercise, poorer sleep quality, longer video conferencing sessions, longer months of courses during the COVID-19 pandemic, and higher mental illness (i.e., stress, anxiety, and depression). Smoking negatively correlated with fatigue ($r = -0.12$). The model for ZEF showed good predictability for zoom fatigue ($p < 0.001$, $R^2 = 0.57$).

CONCLUSIONS Daily exposure to video conferencing in educational settings throughout the pandemic has drastically increased zoom fatigue. The stakeholders must act immediately to minimize the risks while providing maximum benefits.

KEYWORDS fatigue, Indonesia, mental illness, online education, risk factors

Social and physical distancing have been strictly enforced since the first coronavirus disease 2019 (COVID-19) case was announced on March 2, 2020.¹ The pandemic has adversely affected the employment and education sectors as they shifted to home-based activities to minimize the transmission. In 2021, the Ministry of Education and Culture Republic of Indonesia also noted that most educational institutions in Indonesia were at a moderate to high risk of COVID-19 infections (96.54%).² Consequently,

the educational sector widely adopted the online learning technique.³ From early February to late March 2020, there was also an increment of users who actively used video conferencing platforms (e.g., Zoom, Google Meet, and Skype) (17.32–2,859.07%) in Indonesia.⁴ Therefore, these transitions prominently increase the zoom fatigue risk and prevalence.

University students are heavily affected by the pandemic transition. They collectively had more screen time and video conferencing duration for their

educational needs.⁵ This is even more supported by their decent technology competency and greater freedom in choosing their study location.^{6,7} They are also in the most productive age category (15–35 years old);⁸ hence, less fatigue may boost productivity.

Numerous risk factors could predispose the incidence of zoom fatigue. Disparity on the sex hormones and stress adaptation may augment fatigue susceptibility.⁹ Moreover, people with older age secrete more pro-inflammatory cytokines and have more mutation and immunosenescence, which negatively impact energy and exhaustion. Poor sleep quality and physical exercise display similar effects with deteriorating cell organelle and anaerobic respiration, which generate by-products and less energy.¹⁰

Video conferencing is an increasing trend, and zoom fatigue has diverse risk factors. The previous study only assessed gender, video conferencing duration, and nonverbal cues influences.¹¹ Thus, this study aimed to conduct a more profound analysis and understanding of zoom fatigue and its risk factors for early prevention and management.

METHODS

Study design

This cross-sectional study recruited 335 online respondents from purposively selected university students across Indonesia. Six respondents (1.79%) were removed due to either incomplete data or having non-binary gender. This study was approved by the Ethics Committee of the Faculty of Medicine, Universitas Pelita Harapan (No: 157/K-LKJ/ETIK/VII/2021) following the institutional review board and Declaration of Helsinki. All respondents understood, agreed, and signed the informed consent before the study.

Sample size

The minimal sample size was 212 participants, calculated from correlation formula with an assumption of 5% alpha ($Z_{\alpha} = 1.64$), 80% power ($Z_{\beta} = 0.84$), and $r = 0.17$ obtained from the previous study by Fauville et al.¹¹ Ten percent of additional samples were included to overcome any loss to follow-up or incomplete data.

Subject enrollment

The inclusion criteria of the eligible respondents included (1) Indonesian university students, (2) aged

over 17 years, and (3) had participated in classroom video conferencing. However, the respondents were excluded if they had communication difficulties or refused to participate. In July 2021, the respondents were recruited through social media, student forums, and direct contact across Indonesia.

Data collection

Data were collected using a questionnaire on Google Form (Google LLC, USA), which comprised four sections: demographic, mental status, sleep quality, and zoom fatigue. All aspects were measured using a validated and reliable questionnaire to prevent unnecessary face-to-face interaction. The Indonesian version of the questionnaire was used to prevent any language barrier except for the zoom & exhaustion fatigue (ZEF) due to unavailability.

Demographic data

Several demographics, intrinsic, extrinsic, and academic parameters were obtained as the potential risk factors for zoom fatigue. The grade point average was measured in a numerical form (i.e., 0–4), video conferencing duration in minutes, video conferencing frequency in times a day, alcohol consumption in milliliter per day, cigarette consumption in cigars per day, and online courses during the COVID-19 pandemic in months. Physical exercise was regular if performed on ≥ 3 consecutive days without > 2 days in between. Furthermore, body mass index (BMI) was classified following the Asian cut-off points: underweight (< 18.5), normal (18.5–22.9), overweight (23.0–24.9), pre-obese (25.0–29.9), and obese (≥ 30.0).¹²

Mental status

The depression, anxiety and stress scale (DASS) questionnaire is a validated and reliable 21-item questionnaire to measure an individual's stress, anxiety, and depression level. Each mental ailment is scored by summing the frequency of the specific event and divided according to its severity by a specific cut-off. Those categories were normal (stress [S] < 8 , anxiety [A] < 4 , & depression [D] < 5), mild (S < 10 , A < 6 , & D < 7), moderate (S < 13 , A < 8 , & D < 11), severe (S < 17 , A < 10 , & D < 14), and extremely severe (S > 16 , A > 9 , & D > 13).¹³

The DASS-21 could screen mental issues within rural communities (0.79–0.81 sensitivity and 0.72–0.77 specificity) and Indonesian general population (0.79–

0.80 McDonald's Ω , $R^2 = 0.42-0.43$, and Bayes factor [BF_{10}] = $2.97 \times 10^{46}-8.74 \times 10^{47}$), even across various types of administration.^{14,15} A previous study had shown that the Indonesian version of the DASS-21 had satisfactory validity and reliability, with a 0.91 Cronbach's alpha, 0.29–0.76 discriminatory capacity, and $-0.41-0.37$ validity correlation ($p < 0.001$).¹⁶

Sleep quality

The Pittsburgh sleep quality index (PSQI) is the optimal questionnaire for measuring sleep quality. The index comprises 10 questions corresponding to seven domains: quality, latency, duration, efficiency, disturbance, medication, and daytime dysfunction. Students' sleep quality reached a decent PSQI score, with 0.74 Cronbach's alpha value and 0.33–0.82 correlation.¹⁷ The Indonesian version also had good validity and reliability with Cronbach's alpha of 0.79, content validity of 0.89, and significant known-group validity ($p < 0.001$).¹⁸

Zoom fatigue

The ZEF scale is a novel yet reliable tool to measure zoom fatigue upon the general, visual, social, motivational, and emotional domains with three Likert scale questions. The instrument has exceptional construct validity where each ZEF items have substantial correlations ($r = 0.67-0.90$, $p < 0.001$), domains reliability (Cronbach's alpha = 0.85–0.90), and data fitness with 0.96 comparative fit index, 0.95 Tucker-Lewis index, 0.08 root mean square error of approximation, and 0.05 standardized root mean square error.¹⁹ Unfortunately, the Indonesian version of the ZEF scale had not been validated; hence, this study implemented the English version of the ZEF scale, which is available from <http://comm.stanford.edu/ZEF>.

Bias and blinding techniques

Some techniques have been implemented in the current study to reduce the potential bias. Therefore, the Indonesian version of the questionnaire eliminated any language barrier, except for the ZEF due to unavailability. A social media account was created as an information center to minimize any language barrier of the English version of the ZEF scale. There were also representatives in each location to quickly help those with inquiries. The anonymity and confidentiality of the respondents were insured to limit any acquiescence

and desirability bias. The statisticians who analyzed the study and the data curators were blinded. The questionnaire was also arranged from general to more detailed questions to suppress any chance of question-order bias.

Statistical analysis

Microsoft Excel 365 (Microsoft Corporation, USA) was used for data tabulation, and SPSS software version 26 (IBM Corp., USA) was used for the statistical analysis. All numerical factors were tested for their normality using Kolmogorov-Smirnov test. The parametric data were then assessed to the ZEF scale with Pearson correlation, while Spearman correlation was used for the alternative. Meanwhile, Mann-Whitney test was used to analyze mean differences between the ZEF scale among two categories, and Kruskal-Wallis test was used if the variables had more than two categories.

For the multivariate analysis, linear regression was used. All variables with a p -value of < 0.25 in the bivariate analysis were included in the multivariate analysis. A variable was considered confounders and excluded if there were changes in R^2 or adjusted odds ratio by $< 10\%$. The model was created with five different assumptions: existence, independency, linearity, homoscedasticity, and normality, which were all fulfilled by the current model.

RESULTS

A total of 329 Indonesian university students were recruited. The mean age was 21.3 (1.8) years old, BMI was 22.7 (6.97) kg/m^2 , and online courses duration was 12.8 (5.1) months. The majority were women, and only a few were married. The mean of the ZEF scale was 2.8 (0.9), and there was a high prevalence of mental issues (i.e., stress = 40.9%, anxiety = 66.1%, and depression = 57.3%). The respondents' characteristics are shown in Table 1.

Risk factors of zoom fatigue were gender, regular exercise, and mental issues (Table 1). Although many risk factors had weak correlations, sleep quality and mental issues had moderate and strong correlations. A higher ZEF scale was found in female students with irregular physical exercise, poorer sleep quality, longer video conferencing sessions, longer months of courses during the COVID-19 pandemic, and worse mental illness. Interestingly, smoking was not

Table 1. Zoom fatigue and its risk factors in Indonesian university students

Factors	n (%) (N = 329)	ZEF scale, mean (SD)	Bivariate analysis		Multivariate analysis*				
			<i>r</i>	<i>p</i>	Estimate	SE	95% CI		<i>p</i> [†]
							Lower limit	Upper limit	
Gender				0.005[‡]	-0.182	0.075	-0.330	-0.034	0.016
Male	100 (30.4)	2.62 (0.87)							
Female	229 (69.6)	2.92 (0.91)							
Age (year), mean (SD)	21.33 (1.77)		-0.089	0.054 [§]	-	-	-	-	-
Occupation				0.576 [‡]	-	-	-	-	-
Yes	112 (34.0)	2.78 (0.92)							
No	217 (66.0)	2.85 (0.91)							
Marriage status				0.107 [‡]	-	-	-	-	-
Unmarried	327 (99.4)	2.83 (0.91)							
Married/divorced	2 (0.6)	1.80 (0.28)							
Residency, mean (SD)				0.420 [‡]	-	-	-	-	-
Urban	296 (90.0)	2.81 (0.92)							
Rural	33 (10.0)	2.94 (0.81)							
BMI* (kg/m ²), mean (SD)	22.69 (6.97)		0.047	0.199 [§]	-	-	-	-	-
Normal, n (%)	207 (62.9)	2.80 (0.91)		0.566 [¶]					
Overweight, n (%)	29 (8.8)	2.83 (0.95)							
Pre-obese, n (%)	71 (21.6)	2.80 (0.92)							
Obese, n (%)	22 (6.7)	3.09 (0.82)							
Education				0.587 [¶]	-	-	-	-	-
3-year-Diploma/equivalent	8 (2.4)	2.63 (1.14)							
4-year-Diploma/equivalent	1 (0.3)	3.93 (0.00)							
Bachelor/equivalent	314 (95.4)	2.83 (0.90)							
Master/equivalent	6 (1.8)	2.91 (1.04)							
Regular exercise				0.004[‡]	-	-	-	-	-
Yes	108 (32.8)	2.62 (0.92)							
No	221 (67.2)	2.93 (0.89)							
Grade point average				0.558 [‡]	-	-	-	-	-
≥3.00	287 (87.2)	2.84 (0.91)							
<3.00	42 (12.8)	2.76 (0.92)							
Stress level*, mean (SD)	6.64 (4.51)		0.680	<0.001[§]	0.045	0.015	0.014	0.075	0.004
Normal, n (%)	195 (59.3)	2.40 (0.81)		<0.001[¶]					
Mild, n (%)	46 (14.0)	3.13 (0.56)							
Moderate, n (%)	49 (14.9)	3.46 (0.53)							
Severe, n (%)	33 (10.0)	3.78 (0.66)							
Extreme, n (%)	6 (1.8)	4.08 (0.83)							
Anxiety level*, mean (SD)	5.49 (3.79)		0.628	<0.001[§]	0.043	0.015	0.014	0.075	0.004
Normal, n (%)	112 (34.0)	2.30 (0.80)		<0.001[¶]					
Mild, n (%)	78 (23.7)	2.55 (0.76)							
Moderate, n (%)	42 (12.8)	2.94 (0.66)							
Severe, n (%)	38 (11.6)	3.40 (0.61)							
Extreme, n (%)	59 (17.9)	3.74 (0.64)							

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Table 1. (continued)

Factors	n (%) (N = 329)	ZEF scale, mean (SD)	Bivariate analysis		Multivariate analysis*				
			r	p	Estimate	SE	95% CI		p [†]
							Lower limit	Upper limit	
Depression level*, mean (SD)	6.34 (4.70)		0.665	<0.001 [§]	0.055	0.012	0.031	0.079	<0.001
Normal, n (%)	141 (42.9)	2.22 (0.76)		<0.001 [¶]					
Mild, n (%)	47 (14.3)	2.74 (0.66)							
Moderate, n (%)	72 (21.9)	3.24 (0.62)							
Severe, n (%)	41 (12.5)	3.66 (0.56)							
Extreme, n (%)	28 (8.5)	3.75 (0.68)							
Alcohol (ml/day), mean (SD)	2.59 (19.65)		0.024	0.333 [§]	-	-	-	-	-
Smoking (cigarette/day), mean (SD)	0.30 (1.81)		-0.119	0.016 [§]	-	-	-	-	-
Online courses duration during the COVID-19 pandemic (month), mean (SD)	12.82 (5.10)		0.277	<0.001 [§]	0.023	0.007	0.010	0.036	0.001
Sleep quality, mean (SD)	7.34 (2.35)		0.444	<0.001 [§]	0.049	0.016	0.018	0.081	0.002
Video conferencing duration (min), mean (SD)	83.42 (67.96)		0.156	0.002 [§]	0.001	0.000	0.000	0.002	0.022
Video conferencing frequency (times/day), mean (SD)	2.55 (1.74)		0.090	0.052 [§]	-	-	-	-	-

BMI=body mass index; CI=confidence interval; COVID-19=coronavirus disease 2019; SD=standard deviation; SE=standard error; ZEF=zoom exhaustion & fatigue

*F (7,321) = 61.42, $p < 0.001$, $R^2 = 0.57$, equation formula of the ZEF scale = $1.248 - 0.128 * \text{gender} + 0.045 * \text{stress} + 0.043 * \text{anxiety} + 0.055 * \text{depression} + 0.023 * \text{online courses duration during the COVID-19 pandemic} + 0.049 * \text{sleep quality} + 0.001 * \text{video conferencing duration}$. Note: male = 1 & female = 0 for the gender category; [†]linear regression; [¶]Mann-Whitney test, [§]Pearson correlation test, [¶]Kruskal-Wallis test

correlated with the ZEF scale ($r = -0.119$). Meanwhile, BMI, residency, marital status, education level, and grade point average were not related to zoom fatigue.

From the multivariate analysis, online courses duration during the COVID-19 pandemic, video conference duration, sleep quality, gender, and mental issues were significant without any confounders (Table 1). The model also had good predictability on the ZEF scale.

DISCUSSION

Among the university students, zoom fatigue was positively correlated to months of online courses during the COVID-19 pandemic, video conferencing duration, sleep quality, mental issues, and gender ($p < 0.05$). Maintaining sleep quality and mental conditions are crucial to reducing zoom fatigue. Good attitudes and practices on sleep hygiene and mental calming exercises such as meditation are necessary.

Furthermore, academic institutions should consider the course duration and provide adequate break time between the courses.¹¹

Zoom fatigue is not merely a local phenomenon, but it appears globally. A study in the USA¹¹ showed that the average ZEF scale was 3.0 (0.8), which is similar to our study. Moreover, that study also confirmed that video conferencing duration led to zoom fatigue ($p < 0.001$).¹¹ This may be developed through four mechanisms (mirroring, physiologic trap, hyper-gaze, and nonverbal intention). During video conferencing, self-reflection on the screen may trigger mirror anxiety and visual distortions through unwanted yet greater self-focused attention.²⁰ Moreover, the person may feel physically trapped for constantly being on camera instead of offline meeting with no physical restriction. The isolation and limitation of mobility can induce depression and fatigue.^{21,22}

Furthermore, virtual conferencing forces a constant gaze from all attendees regardless of the presenter. This constant gaze triggers negative

physiological impacts and cognitive loads.²³ Although nonverbal cues may unconsciously be transmitted in face-to-face communication, more effort is required in virtual conferences. For example, being in a gallery view, a person tends to match his/her eye perspective to others, yet people's gaze may be challenging due to varying camera locations and internet lag. Nonetheless, this escalates the psychological burdens.^{24,25}

In our study, we also found that women were more prone to zoom fatigue. A high presence of zoom fatigue in women is also shown in some studies; for example, investigations in Sweden and the USA reported a 13.8% higher zoom fatigue proportion in women than in men.¹¹ This may be due to women are more affected by mirror anxiety.^{26,27} Women also express greater awareness of being observed in video conferencing by showing deeper emotional characteristics such as smiling, frowning, and maintaining facial posture than men.²⁸ Males additionally have a lower secretion rate of dopamine in the nucleus accumbens that its instability has a positive effect on fatigue.^{29,30} Dopamine agonist medications have been proven to relieve fatigue from a head injury, chronic fatigue syndrome, or cancer.³¹

Physical exercise often requires muscular strength for adequate exercise. Reduced oxygen availability in this condition causes a shift from aerobic to anaerobic metabolism that produces less energy but more lactic acid by-products. Lactate accumulation decreases pH and will denature essential proteins. For instance, deterioration of calcium receptor bonding with troponin results in mitochondrial dysfunction and energy decrement.³² A study in Columbia showed a weak correlation between physical exercise and fatigue ($p \leq 0.01$; $r = -0.25$).³³

This study also found that poor sleepers had a higher zoom fatigue. Similarly, a study by Chatlaong et al³⁴ in Thailand found that exhaustion was higher in poor sleepers (86.1% versus 64.3%, $p < 0.001$). Sleep quality reflects overall energy through modulation of mitochondrial function and energy production.³⁵

Mental issues were also the significant factors to zoom fatigue in our study. Solopchuk et al³⁶ in Belgium confirmed that depression was correlated to exhaustion levels. Abnormalities of the neurotransmitter in the central nervous system cause many mental issues, particularly the catecholamines and their derivatives. For example, low dopamine

is linked to low motivation through anhedonia, suggesting a major depressive disorder.³⁷

Smoking also has a significant yet poor correlation with zoom fatigue. Ozdogar et al³⁸ found a similar issue regardless of age, gender, and diseases. Cigarettes act as an anxiolytic and antidepressant by controlling serotonin, dopamine, and glutamine secretion via the nicotine to nicotinic acetylcholine receptors.³⁹ However, the harmful effects of smoking (e.g., heart failure, myocardial infarction, and chronic obstructive pulmonary disease) disrupt the oxygen demand and supply balance and its flow to the vital organs. These conditions stimulate dyspnea, anaerobic respiration, reduced energy, and fatigue.⁴⁰

This study had limitations such as few samples size, inability to generate causal relationships due to the cross-sectional design, and the recall or respondent bias because the data were collected using a self-reported questionnaire. This study also only employed Indonesian university students who could not be generalized to other countries. Accordingly, future investigations with a more varied subjects, cohort or experimental designs, and direct examinations may provide multiplicity analysis with deeper and further acknowledgment of the risk relations.

In conclusion, zoom fatigue in Indonesian university students was significantly influenced by online courses duration during the COVID-19 pandemic, video conferencing duration, sleep quality, mental issues, and gender. Therefore, universities should consider effective time management and lecture duration, while individuals should raise their mental health and sleep behavior awareness.

Conflict of Interest

The authors affirm no conflict of interest in this study.

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