Analysis of Mental Workload and Musculoskeletal Disorders among IT Workers

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Abstract: Interaction between human and computer for long periods has the potential impact of discomfort and musculoskeletal disorders. The purpose of this study was to analyze subjective mental workload and its correlation with musculoskeletal disorders among Information Technology (IT) workers in Bandung, Indonesia. This research consisted of eighty-seven IT workers, with an average of 25 years (21 to 34 years). Participants were asked to fill out questionnaires about demographic data, NASA Task Load Index (TLX) and Nordic Musculoskeletal Questionnaire (NMQ). Generally, IT workers have experienced pain in the neck (35%), shoulder (29%), and upper back (24%). The result of mental workload assessment using NASA-TLX concluded that mental demands with 84% rating score and temporal demands with 64% contributed most of the total NASA-TLX score (69.5% ± 10.24). Pearson correlation result showed a significant correlation between NASA-TLX score and one of NMQ dimension (lower back) with value r (87) = 0.216 ($p<0.05$).

1 INTRODUCTION

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Human-computer interaction between workers and computers had the risk of causing physical and mental discomfort and injury. About 70% of professional IT workers experienced muscle injuries due to using a computer in the long-term (Sharan et al, 2011). Mehta and Parijat's research reported that

about 25% of IT employees suffered muscle injuries to the neck and back (Mehta.and Parijat, 2012). Injuries and discomfort are also experienced by bank employees in Iran where a total of 78.5% complained of musculoskeletal disorders in the neck and back (Darvishi et al, 2016). In addition, complaints and injuries are experienced by workers who usually interact with computers. The results showed that 73% of workers had complaints in the back and 71% had complaints in the neck of a total of 254 respondents using the Musculoskeletal Symptoms of the Questionnaire (Cho et al, 2012). Jafari and colleagues have been proved that 56.9% of Bank employees in Yazd-Iran had musculoskeletal complaints, especially in the neck and lower back [6]. Similar findings were found that bank employees had a musculoskeletal disorder highly distributed to parts of the body namely 48% in the neck, 44% in the lower back and 36% in the upper back (Darvishi et al, 2016). Musculoskeletal disorder can be assessed using the NORDIC questionnaire, consisting of 11 rating scales from 0 to 10 where scale 0 means no pain until scale 10 means feels very painful or injured (Kuorinka et al, 1987).

There are two classifications of workload, namely physical and mental workload. Physical workload is commonly defined as a workload that required physical activity and often results in long-term musculoskeletal disorder. Meanwhile, mental workload is a load that arises due to work activities related to cognitive processes such as attention, planning, logical reasoning, and decision making (Toomingas et al, 2012). Several approaches can be used in evaluating and predicting mental workload include subjective approaches, assessment of

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performance and physiological measurements. Subjective assessment is important in evaluating workloads because it has practical advantages, easy implementation and non-intrusiveness. The interaction between human-machine systems in the activities of IT companies was very complex so evaluating employee workloads will become more difficult. In this case, subjective workload assessment will greatly useful to assess mental workload effectively (Toomingas et al, 2012; Rubio et al, 2004).

Subjective mental workload is an assessment of mental workload based on the perceptions of each individual. There are several commonly used approaches namely Cooper Harper Scale, NASA Task Load Index (TLX), Subjective Workload Assessment Technique (SWAT), Rating Scale Mental Effort (RSME) and Workload Profile [8-9]. NASA-TLX is one of the most widely used multi-dimensional tools because it was practical with great validity and reliability.

NASA TLX can be used to measure mental workload which pioneered by Sandra G. H. and continues to be developed by Human Performance Group NASA's Ames Research Center. In the NASA-TLX, six dimensions are used to measure workload including mental demand, physical demand, temporal demand, performance, effort, and frustration. Each dimensions of NASA-TLX is assessed by individual perceptions on a scale of 0-100 (Hart and Staveland, 1988).

NASA-TLX can be used in various research such as the following studies. Ning et al. tested the activity of using a touch screen device with NASA-TLX. Some findings from the experiment that typing was an activity with the highest mental workload, followed by reading and playing games

(Ning et al , 2015)The use of NASA-TLX in the field of aviation has been done to air traffic controllers, the test results showed that the NASA-TLX rating is getting higher along with the increasing number of aircraft (Collet et al, 2009). Research on emergency medical services also showed that the hardest task is evacuated casualties who fall into the mud on steep surfaces with the condition of patients already very fragile due to the effects of chemotherapy. In this task, almost all dimensions had very high ratings except the performance and frustration dimensions that tend to be moderate. The smallest mental workload score from medical personnel's emergency was on the activity of testing blood sugar samples (Reuter and Camba, 2017). NASA-TLX has been used to examine workers who do physical work such as lifting, lowering, pushing, and pulling. The worker is also suffered from pain in the lower back. The highest rating was mental demand dimensions which reached 67.12% and followed by effort (62.8%) and temporal demand (60.8%), while the other dimensions included a rather high category

(Darvishi et al, 2017) In the nuclear industry, the user interface layout affected the mental workload of the operator. Regardless of the good or bad design, mental demand, temporal demand, and frustration are contributed significantly to the mental workload by workers, while the other three dimensions were in the medium level category (Yan et al, 2017).

Mental workload investigation using NASA-TLX was used to analyze Bank employee's workload in Iran. Major findings from this research that effort had the highest score (72.8%) and followed by mental workload (62.7%). Other findings suggest that subjective mental workload had a strong correlation with working experience and marital status (Darvishi et al, 2016). According to Darvishi et.al, there was a correlation between mental workload and demographic aspect. There has been limited research that analyzes about mental workload and musculoskeletal disorder assessment using NASA-TLX and Nordic Musculoskeletal Questionnaire (NMQ) in Indonesia. This study sought to investigate mental workload and its correlation to the prevalence of musculoskeletal disorders among IT workers in Indonesia.

2 METHODS

Eighty-seven respondents (72 male and 15 female) volunteered to respond to several questionnaires in this research. The subjects were between the ages of 21 and 34 years (M= 24.8, SD= 2.55). All of the respondents were IT workers at Bandung, Indonesia. The subjects must fill a questionnaire about demographics such as age, education, gender, and working experience. Subjective mental workload was assessed using the NASA-TLX (Table 1) (Hart and Staveland, 1988). Participants also completed Nordic Musculoskeletal Questionnaire (NMQ) which is slightly modified by Indonesian Ergonomics Society in Indonesian version (Fig. 1) (Perhimpunan Ergonomi Indonesia or Indonesian Ergonomic Society, 22 July 2019).

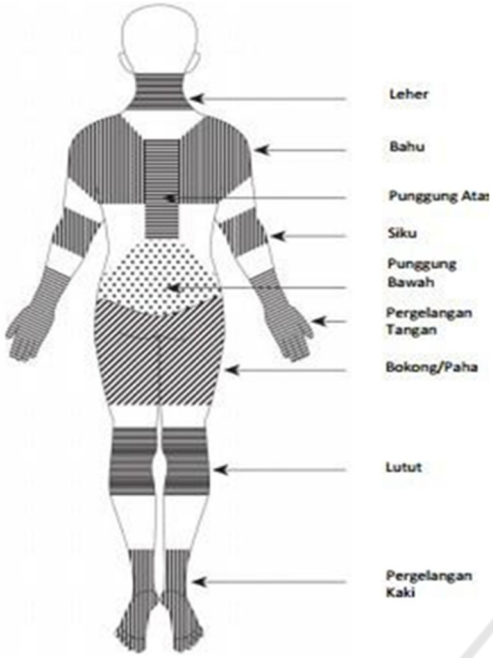

Figure 1: Body Sketch used in the Nordic Questionnaire (Indonesian version).

Table 1: NASA-TLX questionnaire.

Title	Scale	Descriptions
Mental Demand	Low/ High	How much mental and perceptual activity was required?(e.g.thinking, calculating, the task easyor remembering) Was demanding, simple or complex, exacting or forgiving?
Physical Demand	Low/ High	How much physical activity was required? (e.g. pushing, pulling, turning, controlling)
Temporal Demand	Low/ High	How much time pressure did you feel due to Date or pace at which the tasks or task elements occurred?
Effort	Low/ High	How hard did you have to work (mentally or physically) to accomplish your performance?
Performance	Good / Poor	How successful do you think you were in accomplishing the goals of the task set by the experimenter?
Frustration	Low/ High	How insecure, discouraged, irritated, stressed, and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

3 RESULTS AND DISCUSSIONS

3.1 Demographic Data

Eighty-seven participants were conducted to fill a questionnaire about demographic data such as age, gender, working experience, and education background. Working experience of employees was 1.2 years with the shortest time being 0.5 months and a maximum of 6.1 years at the time this research was conducted. In a day, employees worked with an average of 8.6 ± 1.1 hours excluding 1 hour of free rest at any time. Mostly, IT workers had undergraduate education (79.3%) and 18 others had higher or lower education than undergraduate (20.7%).

3.2 The Prevalence of Musculoskeletal Disorders

According to NMQ questionnaire, it was found that 94.25% of respondents had felt pain at least in one of the nine musculoskeletal body parts. This finding was in line with Darvishi and colleague's research that there was 78.5% of employees who experienced musculoskeletal complaints during the last 12 months (Darvishi et al, 2016).

Table 2: The prevalence of musculoskeletal disorders of it.

WORKERS

Parts of Body	Prevalence of *Musculoskeletal Disorder* (%)
Neck	35.2
Shoulder	29.2
Upper Back	23.8
Elbow	7.7
Lower Back	23.9
Wrist	15.4
Hip/thigh	10.6
Knee	5.5
Ankle	3.2

Table 2 shows the prevalence of musculoskeletal disorders of IT workers during they worked for the company. Neck had the highest prevalence of 35.2% followed by shoulder with 29.2%. The upper back and lower back also had a high prevalence with almost the same values of 23.8% and 23.9% respectively. This was slightly different from Cho and colleague's research where the shoulder had the highest prevalence of 73% followed by 71% neck and upper back by 60% (Cho et al, 2012). The characteristics of work mostly sat in front of a laptop or computer, this was a very common thing if the

position or placement of the monitor, keyboard, mouse, and table was discomfort. Another possibility that was the condition of the seat was not in accordance with anthropometry's size.

Table 3: Correlation test between demographic and prevalence of musculoskeletal disorders (%).

CorrelationTest	Education	Gender	Age	Working Experience
Neck	-0.052	-0.059	0.13	0.082
Shoulder	-0.03	-0.127	0.74	**0.211***
Upper back	-0.114	-0.036	0.045	-0.027
Elbow	-0.107	-0.007	0.01	0.023
Lower back	-0.12	-0.054	0.05	0.054
Wrist	**0.232***	-0.203	-0.019	0.088
Hip	-0.041	-0.121	-0.019	0.088
Knee	-0.005	**-0.215***	-0.068	0.023
Ankle	-0.11	**-0.243***	-0.025	-0.091

Correlation test using Pearson between demographic data and the prevalence of musculoskeletal disorder showed a significant correlation with $p \leq 0.05$ (Table 3). The correlation between work experience with shoulder pain was r (87) = 0.211, education level with wrist pain with a correlation r (87) = 0.232, and gender with pain in the knee and ankle with a correlation value of r (87) = -0.215 and r (87) = - 0.243 (Table 4). Others attribute had a non-significant correlation. This was in line with Darvishi's research which concluded that there was a significant correlation between subjective workload assessment of marital status and employee work experience (p <0.001) [4].

3.3 NASA-TLX Score

NASA-TLX rating showed that mental demand was a greatly factor influencing worker's workload. Mostly, employees gave a rating of 84.05 out of 100 on mental demand. The smallest workload was physical demand with a rating of 21.67. The physical demand rating was very small because the employees felt comfortable while sitting at the computer without doing heavy physical activity. Other dimensions such as performance, temporal demand, effort, and frustration have almost the same range of values, namely between range 59.44 and 69.50. The results of this study suggested that mental demand had the greatest influence on the assessment of the mental workload of IT workers. This was different from the findings obtained by Darvishi and colleagues where the parameter effort had the highest weighting value 72.8% (Darvishi et al, 2016) This could happen because of the different job characteristics of Bank employees and IT employees. Weight values are calculated based on participant answers about which dimensions are the more influential increasing mental workload. The overall rating of subjective mental demand can be calculated by entering the weight into the rating. The result is concluded that the average employee felt a subjective mental workload with rating reached 69.5 (SD=10.24). This value showed that the mental workload of employees on a rather high scale (30-49) is experienced by 2 people, high (50-79) is experienced by 68 people and very high ≥80 by 17 people. Table 4 shows complete information about the assessment of the mental workload using NASA-TLX.

Table 4: NASA-TLX score.

Statistics		Scales						
		MD	**PD**	**P**	**TD**	**E**	**Fr**	**O**
Rating	M	**84.05**	21.67	69.03	66.71	59.44	67.09	**69.5**
	SD	11.56	17.9	18.62	15.64	21.65	12.54	10.2
	Min	52	2	22	18	12	34	42.7
	Max	98	77	99	88	98	97	88.8
Weight	M	0.20	0.02	0.21	0.21	0.15	0.20	-
	SD	0.08	0.05	0.08	0.09	0.12	0.08	-
	Min	0.07	0	0	0	0	0	-
	Max	0.33	0.27	0.33	0.33	0.33	0.33	-
Tally	M	3.03	0.32	3.10	3.18	2.32	3.03	-
	SD	1.16	0.80	1.26	1.29	1.75	1.20	-
	Min	1	0	0	0	0	0	-
	Max	5	4	5	5	5	5	-

3.4 Correlation Test between SMWL and Musculoskeletal Disorders

Correlation test is conducted using Pearson product-moment to investigate the relationship between subjective mental workload and prevalence of musculoskeletal disorders. Table 5 shows that there was a significant correlation between the Subjective Mental Workload (SMWL) score and the prevalence of lower back pain with $r(87)= 0.216$ ($p <0.05$).This result explained that complaints on the lower back can represent 21.6% of the subjective mental workload. The eight other body parts did not show a significant correlation, it was possible because the working experience of the employees was still relatively short with an average of 1.2 years.

Table 2: Correlation test between SMWL and prevalence of musculoskeletal disorder.

Correlation Test		**SMWL**	**Correlation Test**		**SMWL**
Neck	Pearson Cor	0.109	Wrist	Pearson Cor	0.015
	Sig (2 tailed)	0.315		Sig (2 tailed)	0.889
Shoulder	Pearson Cor	0.123	Hip	Pearson Cor	0.07
	Sig (2 tailed)	0.255		Sig (2 tailed)	0.518
Upper Back	Pearson Cor	0.068	Knee	Pearson Cor	-0.038
	Sig (2 tailed)	0.534		Sig (2 tailed)	0.728
Elbow	Pearson Cor	0.084	Ankle	Pearson Cor	-0.105
	Sig (2 tailed)	0.44		Sig (2 tailed)	0.335
Lower Back	Pearson Cor	**0.216***			
	Sig (2 tailed)	**0.045**			

3.5 Ergonomic Design for Office Workstation

The issue of musculoskeletal disorders and mental workload among office workers are important to investigate. Office workstation design should match with the user-centered requirements or ergonomics principles to reduce the negative effect of discomfort, for example, design of space and furniture need to be associated with specific tasks and anthropometry's size (Kroemer and Kroemer, 2017). IT workers had been struggling with some degree of pain and discomfort especially at neck (Based on NMQ's results, neck had the highest prevalence of disorders with 35.2%). According to Kroemer and Kroemer (2017), there were several activities that workers must do to solve this problem. Firstly, IT workers must avoid sitting over long periods of time and take 30 minutes of break (standing, walking and stretching). Secondly, employees need to change their body position often to avoid continued compression of tissue, especially at spinal and muscular fatigue. Finally, workers need to improve their body movement and posture, for instance, their trunk, neck, and head erect with only slight bending, hands-on keyboard and eyes position on PC/laptop's screen ((Kroemer and Kroemer, 2017)). Not only workstation components like computers, furniture, and environment but also other factor-like job tasks, social activities and the organizational task should fit IT workers to support her or his job.

4 CONCLUSIONS

Musculoskeletal disorders and high mental workload were common problems impact discomfort and stress among IT workers. This study demonstrated that almost all IT workers have experienced complaints at least in one part of the musculoskeletal body. The greatest prevalence is experienced in the neck, shoulders, upper back and lower back reached 35%. Complaints in this section are thought to be due to the characteristics of work that sit more at the computer and do work that requires high mental activity so that the body parts are exposed to unnatural postures. The subjective mental workload felt by employees is at a rather high to a very high interval, reached 84% of the score which indicated the need for re-analysis of the workload received by employees. The relationship between the value of the total subjective mental workload and musculoskeletal disorders can be seen from

complaints on the lower back. This research provides evidence of a link between musculoskeletal disorder and mental workload. The prevalence of musculoskeletal disorders at lower back had a significant correlation with the employee's mental workload.

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