Physical Demand, Fatigue and Shift Work in the Installation and Maintenance of Window Air-Conditioner Units

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Abstract: The goal of the current study was to investigate the effects of the physical workload involved in manually lifting, repairing and maintaining window air conditioner units on perceived fatigue as well as the impact of shift work. The relationships among objective and subjective measures of perceived physical demand and fatigue in an actual heavy workload task setting were analyzed. The study considered 88 skilled male workers (aged 26 – 40) employed in window air-conditioner maintenance workshops. In this study, two objective measures were used, heart rate (HR) and energy expenditure (EE), to evaluate the levels of energy required and fatigue. Subjective assessment tools were used, with the Swedish Occupational Fatigue Inventory (SOFI) employed to rate perceived fatigue. The NASA-TLX subjective tool was used to evaluate the overall demand, whereas Borg-CR10 was used to measure the perceived physical demand. The results indicate that the HR and EE significantly increased when the workers lifted air-conditioner units, and the subjective assessment scores increased as well. Workers perceived the highest overall workload and fatigue levels during the night work shift, as reflected in the higher scores for the SOFI parameters during that shift. The correlations among objective and subjective measures were significant. The SOFI parameters (lack of energy and lack of exertion) and the NASA-TLX and Borg-CR10 measures were positively correlated with HR. EE was positively correlated with the SOFI parameters, except for the lack of motivation parameter, and the NASA-TLX and Borg-CR10 scales. Significant relationships among the subjective tools of the SOFI, NASA-TLX and Borg-CR10 scales were found. Therefore, the SOFI technique is a useful and valid method to evaluate fatigue levels in tasks performed in occupational work.

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1. Introduction

Generally, a correlation exists between physical activities and fatigue levels, and a relationship exists between physical demand and stress in the workplace (Barker and Nussbaum, 2011). Fatigue is considered a primary factor leading to unsafe performance, accidents and injuries in various occupations (Williamson et al., 2011). Williamson et al. (2011) stated that fatigue could lead to reduced attention, unacceptable response, and poor strategic thinking while performing a task. However, occupational fatigue is a multidimensional issue and occurs in the workplace due to various factors (Barker and Nussbaum, 2011; Bosch et al., 2011). These factors include the task demands (physical and mental), environmental factors (e.g., noise and heat), and psychological factors (Barker and Nussbaum, 2011; Albers et al., 2005). Fatigue is the result of multidimensional factors because it can occur due to mental demands and/or physical demands (Young et al., 2015; Åhsberg et al., 2000). Relationships exist between fatigue and physical and mental stress in the workplace, and these stress factors are affected significantly by the task demands (Guastello et al., 2012; Macdonald, 2003). Lifting heavy loads leads to physiological stress, which causes a reduction in muscle capacity; it also leads to objective fatigue, which refers to productivity reduction (González Gutiérrez et al., 2005). According to Maconald (2003), increasing levels of physical and cognitive loads lead to fatigue (i.e., muscle and information process fatigues), which is associated with a decline in performance. Thus, the correlation among lifting heavy objects, fatigue and stress in real work environments is worthy of further investigation.

Many of the tasks in real work require physical and cognitive efforts, and increasing levels of these efforts negatively affect individual responses. Manual material handling (MMH) tasks are common in industrial sectors, such as construction, manufacturing, and maintenance workshops (Albers et al., 2005; Leung et al., 2004). Task demands can be divided into two main types: physical demands and cognitive demands (Sluiter, 2006). Task demands refer to the task difficulty, time pressure, and effort required to meet the task workload (Nixon et al., 2011). Task demands are one of the major factors that can increase the level of physiological stress in the workplace, and there is a significant correlation between an increased level of task workload fatigue and individual errors (Guastello et al., 2012; Dorrian et al., 2011). Additionally, task workload is one of the primary factors in the workplace that leads to mental and physical capacity failure (i.e., mind and muscle fatigue) (Nixon et al., 2011). Additionally, Dorrian et al. (2011) mentioned that the physical factors of tasks, such as using a high level of force in lifting, holding heavy objects and repetitiveness, contribute significantly to reducing the capacity level of muscles. Srinivasan et al. (2016) stated that a high level of physical activity negatively affects cognitive performance, causing the levels of concentration and attention to decrease, resulting in an increase in human errors. Numerous studies have focused on the effect of awkward postures and lifting task factors on musculoskeletal symptoms; however, the correlations among these factors and individual fatigue and task demands have been overlooked (Macdonald, 2003). However, attentional resources and cognitive processes, as well as muscle strength, are affected by the physical fatigue that results from manual work, such as lifting and pulling heavy loads (Åhsberg et al., 2000; Guastello et al., 2012). Dorrian et al. (2011) mentioned that the correlation among task demands, fatigue, and stress has not received intense investigation. Few studies have been conducted examining the effect of lifting heavy materials on fatigue and physiological stress in a real-world environment, such as an industrial environment.

Albers et al. (2005) stated that the process of mechanical installation and fitting, such as plumbing, air-conditioning fitting, and pipe setting in commercial, industrial, and residential sectors, requires high levels of manual effort. Workers performing these tasks are exposed to a high risk of ergonomic hazards, such as musculoskeletal problems and fatigue (Moriguchi et al., 2013), because they must perform a high level of physical activities, experience static load, and often have poor working postures (Albers et al., 2005; Moriguchi et al., 2013). Workers in electrical task installation, for example, must carry objects and equipment to a work location, place and align an object in a fixed position, and connect electrical wires (Albers et al., 2005). Lifting heavy objects while moving can negatively influence the worker’s attention and increase the number of errors (Rugelj and Sevšek, 2011). Young et al. (2015) stated that physical task demands can lead to muscle strain and fatigue and increased levels of physiological stress, whereas high cognitive loads lead to information process fatigue; both lead to performance deterioration. Furthermore, numerous studies have linked fatigue, physical activities, and decreased performance (Barker and Nussbaum, 2011). In addition to ergonomic hazards such as musculoskeletal disorders (e.g., low back pain), slipping, and falling (Kroemer, 2009), lifting heavy objects can reduce a worker’s alertness so that performance deterioration occurs (Williamson et al., 2011). As a result, the potential for experiencing high physiological stress and fatigue is increased when lifting heavy objects (e.g., window air-conditioner units).

In addition to a high level of physical demands, another important factor that can increase fatigue is shift work (Young et al., 2015). It has been stated that different types of shift work significantly affect a worker’s performance and fatigue levels (Åkerstedt and Wright, 2009). For example, working the night shift leads to a high level of subjective sleepiness, physical fatigue and sluggishness (Young et al., 2015). Most studies reported the occurrence of impaired performance associated with working the night shift rather than the day shift (Folkard and Akerstedt, 2004). Low values of physiological parameters, such as heart rate and blood pressure, have been associated with day shift work compared with night shift work (Ohira et al., 2000). According to Wakui et al. (2002), high levels of energy expenditure among healthcare workers have been observed during the night shift compared with the day shift. There is a significant relationship between shift work and fatigue, and the resting period between day shift and night shift is short (Åkerstedt and Wright, 2009). However, most of the previous studies used objective and subjective measures of fatigue separately (Wakui et al., 2002).

In Saudi Arabia, the major requirement in electrical maintenance workshops is the physical demand because most of the tasks require manual activities. For example, to clean a window air-conditioner unit, two workers must lift it manually. Additionally, one worker must lift the unit on his back and move with it to reach the required location; then, they must install the unit in the wall of the building. The weight of an air-conditioning unit ranges from 55 to 75 kg, depending on the size and type of unit. According to Visser et al. (2014), loads greater than 25 kg should be lifted via ergonomic mechanical aids. Consequently, workers involved in these tasks experience different physical ergonomic hazards, such as lifting heavy objects and awkward postures, that can increase the potential level of these hazards. Increasing levels of physical activity affect workers’ performance and attention; thus, the potential of other hazards—such as fatigue and slipping while lifting—is high. It is believed that overlooking ergonomic rules and guidelines in manual lifting causes physical and mental stress, which leads to fatigue and unacceptable performance (Shikdar and Al-Hadhrami, 2012).

Developing countries do not consider the importance of safety or the idea of ergonomic interventions to eliminate and reduce ergonomic hazards (Shikdar and Al-Hadhrami, 2012). However, many authors have noted that a high level of physical exertion leads to a decrease in cognitive performance, mental fatigue and individual attention reduction (Mehta et al., 2012; Jung and Jung, 2001). The implementation of ergonomic methods, guidelines, and interventions (e.g., engineering and administrative interventions) in these types of tasks significantly contributes to reducing the risk of musculoskeletal hazards, energy expenditure, and fatigue; thus, productivity increases, and the percentage of accidents decreases (Choobineh et al., 2011). Therefore, the examination of the correlation between heavy physical loads and fatigue among workers lifting window air-conditioning units is the aim of the current study. The potential for experiencing high physiological stress and fatigue is higher when lifting heavy objects (e.g., window air-conditioner units).

Many objective measures have been used to evaluate physical load levels and fatigue while performing tasks (Nur et al., 2015). Physiological measures (objective measures) such as heart rate (HR), energy expenditure (EE) and blood pressure (BP) were used to evaluate the levels of energy, physical activity and physiological stress. Many researchers have mentioned that HR and EE are sensitive to changes in physical activity levels (Visser et al., 2014; Nur et al., 2015). An increasing level of HR and EE indicates that the demands of a task exceed the worker’s physical limitations, which are considered indicators of fatigue (Nur et al., 2015). Subjective measures are also used to evaluate the level of a task workload, such as the NASA-TLX scale (Hart and Staveland, 1988), the Subjective Workload Assessment Technique (SWAT) and the Overall Workload Level (OWL) (Jung and Jung, 2001). According to Mehta and Agnew (2015), the NASA-TLX scale has been widely used to evaluate the overall demand of a task as well as the mental workload. In addition, it has six subscales: mental demand (MD), physical demand (PD), temporal demand (TD), performance (P), effort (E) and frustration (F) (Hart, 2006). Therefore, the current study used the NASA-TLX scale to evaluate the overall demand of a lifting task. Borg-CR10 (Category Ratio) is a scale that has been extensively used to evaluate work-related fatigue and the physical demand level of a task (Arellano et al., 2015). Furthermore, many studies have used the Borg-CR10 scale to measure the changes in perceived exertion and the level of energy required for an activity with different numbers of tasks (Borg, 1982; Kee and Lee, 2012). The Swedish Occupational Fatigue Inventory (SOFI) scale is one of the most often used scales to assess occupational fatigue in different task settings (Arellano et al., 2015). The scale includes five dimensions: lack of energy, physical exertion, physical discomfort, lack of motivation and sleepiness. Lack of energy (LE) includes three variables: worn out, exhausted and drained. Physical exertion (PE) involves the variables of heavy breathing, palpitation and warmth, while physical discomfort (PD) refers to stiff joints, numbness and aching that were reflected in the physical fatigue that occurred due to the task. Cognitive fatigue was reflected in a lack of motivation (LM; variables: listless, passive and indifferent) and sleepiness (SL; variables: sleepy, falling asleep and yawning). The SOFI scale has been commonly used in many studies to measure occupational overall fatigue in different sectors, such as the healthcare and industrial fields (Young et al., 2015; Leung et al., 2004). According to Barker and Nussbaum (2011), the reliability of the SOFI scale has been shown, and it has been considered a useful subjective method to distinguish between physical and mental fatigue in an occupational setting. Arellano et al. (2015) concluded that the internal consistency between the NASA-TLX and SOFI scales is significantly high in assembly tasks. However, the correlation between the objective and subjective measures of fatigue and physical demands is lacking in a heavy-load occupational task setting (González Gutiérrez et al., 2005). Furthermore, the number of studies concerning industrial and maintenance workers is limited, particularly in developing countries such as Saudi Arabia. Consequently, the goal of the current study was to determine the relationships among objective and subjective measures of evaluating the physical demand and fatigue levels involved in tasks with a heavy-load physical activity (i.e., lifting window air-conditioner units).

2. Methods

Study Sample Size

Thirty-two window air-conditioning workshops were used in the current study, and 88 male workers participated. All of the participants are experts at their job, and their ages range from 25-37 years. The participants' demographic information such as age, height, BMI, heart rate (resting HR), education level, smoker or non-smoker and number of years in their current job is presented in Table 1. All of the workshops operated with two work shifts: the day shift from 08:00 am to 03:00 pm and the night shift from 5:00 pm to 10:00 pm. An informed consent was submitted by all of the participants.

Table 1. Participants' Variables for Age, Height, Body Mass, Heart Rate (Resting HR), Energy Expenditure (EE), Mean (±SD), n(%) of Education Level, Smoker or Non-Smoker and Number of Years in Current Job (N=88)

Parameters, Mean (±SD)	**Total**
Age (years)	32.2 (±6.7)
Height (cm)	171.2 (±5.9)
Body mass (Kg)	77.9 (±11.2)
HR (rest level; beats/min)	81.4 (±7.3)
Energy expenditure (kcal/min)	0.78 (±0.21)
Number of years in current job	6.80 (±4.8)
Parameters, n(%)	**N (%)**
Education level	
- No education	3 (3.6)
-Primary school	21 (25.6)
-Middle School	44 (53.7)
- Secondary school	14 (17.1)
Smokers	34 (41.5)

Outcome Measures

The current study aimed to investigate the perceived physical demand, stress and fatigue variables that are associated with lifting window air-conditioning units. The current study obtained many measurements to evaluate these variables. Physiological measures (objective measures) such as heart rate (HR) and energy expenditure (EE) were used to evaluate the levels of energy, physical activity and physiological stress. An Actiheart monitor (320569, Cam Ntech Ltd, UK) device was used in this study to measure HR and EE. This device has been widely used to measure heart rate and energy expenditure in many task conditions (Nur et al., 2015). The subjective assessment tools (subjective measures) used were the Borg-CR10 scale and the NASA-TLX scale (six subscales: mental demand-MD, physical demand-PD, temporal demand-TD, performance-P, effort-E and frustration-F) to evaluate the physical load level and the overall workload of a lifting task, respectively. The overall workload level (OWL) was obtained based on the sum of the NASA-TLX score (i.e., sum of six subscales). Each sub scale score ranged from 1 (low demand) to 5 (very high demand). The Generalitat Valenciana classification used to categorize the OWL depends on the NASA-TLX final score (Valenciana, 2004). The classifications are as follows: 1-25% is a low workload level, 26-50% is a moderate level, 51-75% is a high level and 76-100% is a very high level. Additionally, the Swedish Occupational Fatigue Inventory (SOFI) scale was used to evaluate the total fatigue involved in lifting a window air-conditioning unit. As mentioned previously, this involves five subscales: lack of energy, physical exertion, physical discomfort, lack of motivation and sleepiness. The scale includes twenty items that are numerically ranked from "0", meaning "not at all", to 10, meaning "to a very high degree".

Lifting Task and Data Collection

In Saudi Arabia, the majority of window air-conditioning workshops depends on manual activities and requires a heavy physical workload. The tasks in the workshops vary from cleaning the air-conditioning units to lifting them and transferring them to the end users. Particularly, the workers perceived a heavy physical load while they were lifting the units. The procedures of repairing an air-conditioning unit include the following: first, two workers are required to perform these procedures. The first worker (technician) disconnects the unit's electrical wires then pulls the unit from the wall. Then, the technician assists his co-worker (second worker) to lift and place the unit on his back, as illustrated in Figure 1. Then, the worker carries the unit to the utility truck that belongs to the workshop to transfer the unit to a maintenance workshop. The required maintenance of the unit is performed in the workshop; then, the two workers return the unit to its original location using the same procedures as those for the lifting steps. However, the average number of units that need repairs is 6 units/day, and one of the two workers must lift the unit two times (Figure 1). Therefore, the worker responsible for lifting the unit is required to carry it 12 times per day, thus perceiving a heavy physical load due to the lifting task.

Figure 1. A Worker Lifting a Window Air-Conditioner Unit.

The data collection procedures began with a brief introduction to the study's goal, and then, the resting HR for each participant was recorded. Then, the Actiheart monitor was fixed to the participant's chest to continuously record the EE and HR during the lifting of an air-conditioning unit. The participants were asked to record the NASA-TLX and Borg-CR10 scores directly after completing the lifting task.

Additionally, the participants completed the SOFI questionnaire that contained four categories.

Data Analysis

One-way repeated measures analysis was used to evaluate the effect of lifting window air-conditioning units and the effect of two work shift conditions on the HR, EE, SOFI scores, and the NASA-TLX and Borg-CR10 scales. The Bonferroni test was used to determine the difference between the outcome measures in terms of the work shift factor. The correlation among physiological variables (HR and EE), SOFI subscales, NASA-TLX subscales and Borg-CR10 was obtained by Pearson's product-moment correlation. Cronbach's alpha (α) test was used in the current study to examine the internal consistency and reliability of all subscales of the SOFI scale. The Kayser-Meyer- Olkin (KMO) test was used to verify the sample adequacy, which was found to be at levels greater than 0.7. All of the out measures were statistically normal according to Shapiro-Wilk's test. Except for the subscales LE and PE in SOFI and the frustration subscale in NASA-TLX, a non-normal distribution was found. Therefore, transformations were performed for these measures using SPSS (version 22). The current study applied a 95% confidence level and α = 0.05.

3. Results

The one-way ANOVA test showed that lifting an air-conditioning unit significantly affected the HR ($F_{(1,87)} = 48.68$, $p<0.01$) and EE ($F_{(1,87)} = 12.03$, $p<0.05$). The heart rate while lifting the unit was significantly higher than the resting heart rate ($p<0.05$), and the difference between the EE while lifting and at rest was significant ($p<0.05$). The results presented by the day shift workers were significantly higher regarding the HR level, whereas the EE was higher in the night shift workers ($p<0.05$), as illustrated in Table 2. In terms of the SOFI scale, lifting the unit very significantly affected the lack of energy parameter ($F_{(1,87)} = 41.95$, $p<0.01$). Additionally, physical exertion, physical discomfort and sleepiness were significantly affected, with values of ($F_{(1,87)} = 21.17$, $p<0.05$), ($F_{(1,87)} = 36.72$, $p<0.05$) and ($F_{(1,87)} = 13.84$, $p<0.05$), respectively. The physical discomfort and lack of motivation parameters were not affected by the lifting task ($p>0.05$). Overall, the NASA-TLX and Borg-CR10 scores increased significantly while the workers were performing the lifting task under both work shift conditions (($F_{(1,87)} = 18.04$, $p<0.05$) and ($F_{(1,87)} = 26.31$, $p<0.01$)). The physical demand subscale obtained the highest score (4.49) compared with the other subscales ($p<0.05$), as illustrated in Table 2. According to the OWL classification as mentioned previously, 3% of workers scored this task as a moderate workload level, 43% scored it as a high workload and 53% scored it as a very high workload level.

The findings demonstrated that the workers had a higher HR value ($p<0.05$) in the day shift as well as a higher EE ($p<0.05$), as illustrated in Table 2. Furthermore, the lack of energy, physical exertion and sleepiness parameters were significantly higher ($p<0.05$) in the night work shift. In contrast, the differences in the parameters of physical discomfort and lack of motivation between the day shift and night shift were not significant, with values of $p=0.109$ and $p=0.213$, respectively. The workers had a higher level of fatigue during the night shift.

The results showed that the Bor-CR10 score significantly increased during the night shift ($p<0.05$). Additionally, the night shift workers gave an overall higher score for NASA-TLX ($p<0.05$). In the TLX subscales, mental demand, physical demand and effort had higher scores in the night shift (Table 3). No significant differences were found between day and night work shifts in the frustration subscale ($p=0.124$).

Pearson's correlation analysis showed that most of the fatigue-related SOFI parameters, such as lack of energy and physical exertion, were significantly positively correlated to the physiological measure of HR (($r = 0.41$) and ($r = 0.61$), respectively). Additionally, an increased level of EE was associated with an increased score for lack of energy ($r = 0.33$), physical exertion ($r = 0.54$), physical discomfort ($r = 0.22$) and sleepiness ($r = 0.26$). As expected, an increased level in the physiological variables (HR and EE) was positively correlated with a high overall TLX score, as presented in Table 3. As shown in Table 3, a lack of motivation was not significantly correlated to HR, EE, the overall TLX score or the Borg-CR10 scale. However, the correlation between Borg-CR10 and the other parameters of the SOFI scale, such as lack of energy, physical exertion and physical discomfort, was highly significant with values of $r = 0.55$, $r = 0.74$ and $r = 0.57$, respectively. The CR-10 and TLX scales were significantly positively correlated to HR and EE. The physical demand subscale in TLX was highly correlated to HR, EE, physical exertion-SOFI and the Borg-CR10 scale. However, a low correlation between the mental demand-TLX subscale and HR, EE, physical exertion-SOFI and sleepiness-SOFI was found. The frustration subscale in NASA-TLX was highly correlated with some of the SOFI parameters, such as lack of motivation ($r = 0.45$), physical discomfort ($r = 0.42$) and physical exertion ($r = 0.38$).

Table 2. Summary of the Outcome Measures for Day and Night Shifts; Mean (±SD) for (N=88)

Outcome measures, Mean (±SD)	**Day shift**	**Night shift**	**Total**
HR (beats/min)	124.7 (±8.9)	118.4 (±9.6)	121.60 (±9.1)
EE (kcal/min)	3.27 (±0.86)	4.84 (±0.64)	4.06 (±0.17)
SOFI scale			
- Lack of energy	5.08 (±1.12)	6.08 (±1.24)	5.94 (±0.86)
- Physical exertion	4.11 (±2.38)	5.71 (±2.11)	4.91 (±1.01)
- Physical discomfort	4.91 (±1.28)	5.87 (±1.14)	5.39 (±0.92)
- Lack of motivation	1.59 (±0.94)	1.66 (±0.81)	1.63 (±0.21)
- Sleepiness	4.31 (±2.10)	5.17 (±1.29)	4.74 (±0.97)
Borg-CR10	5.87 (±1.17)	7.58 (±1.04)	6.73 (±0.86)
NASA-TLX			
-Mental demand	2.94 (±5.89)	3.24 (±6.13)	3.09 (±4.21)
-Physical demand	4.08 (±4.56)	4.89 (±5.08)	4.49 (±3.56)
-Effort	3.58 (±3.19)	4.29 (±3.95)	3.94 (±4.17)
-Frustration	3.16 (±4.38)	3.59 (±4.81)	3.29 (±3.28)
Overall NASA-TLX	3.62 (±5.63)	4.12 (±5.21)	3.87 (±4.54)

Table 3. Pearson's Correlation (r) for the Objective and Subjective Variables of Physical Load and Fatigue for Lifting a Window Air-Conditioner Unit (N=88)

Outcome measures	**HR**	**EE**	**LE**	**PE**	**PD**	**LM**	**SL**	**Borg-CR10**	**Overall NASA-TLX**	**MD-TLX**	**PD-TLX**	**E-TLX**
HR	-											
EE	0.54**	-										
Lack of energy (LE)	0.41**	0.33**	-									
Physical exertion (PE)	0.61**	0.54**	0.73**	-								
Physical discomfort (PD)	0.13	0.22*	0.40**	0.34**	-							
Lack of motivation (LM)	0.07	0.02	0.20*	0.29**	0.36**	-						
Sleepiness (SL)	0.12	0.26*	0.43**	0.54**	0.29**	0.38**	-					
Borg-CR10	0.71**	0.60**	0.55**	0.74**	0.57**	0.07	0.26*	-				
Overall NASA-TLX	0.54**	0.40**	0.32**	0.38**	0.22*	0.11	0.27*	0.34**	-			
Mental demand (MD-TLX)	0.23*	0.17*	0.10	0.20*	0.09	0.12	0.22*	0.13	0.51**	-		
Physical demand (PD-TLX)	0.51**	0.44**	0.38**	0.56**	0.35**	0.13	0.31**	0.73**	0.69**	0.36**	-	
Effort (E-TLX)	0.48**	0.41**	0.49**	0.57**	0.34**	0.09	0.35**	0.52**	0.56**	0.38**	0.61**	-
Frustration (F-TLX)	0.33**	0.17*	0.12	0.38**	0.42**	0.45**	0.29**	0.46**	0.71**	0.37**	0.43**	0.35**

Table 4. Summary of Cronbach's Alpha and KMO Test Results of the Subjective Outcome Measures of SOFI, NASA-TLX and Borg-CR10 Scales, (N=88)

Outcome measures	**Cronbach alpha**	**KMO**
SOFI scale	-	-
- Lack of energy	0.942	0.724
- Physical exertion	0.838	0.733
- Physical discomfort	0.764	0.697
- Lack of motivation	0.757	0.687
- Sleepiness	0.812	0.751
Borg-CR10	0.772	0.799
NASA-TLX	0.829	0.735

Cronbach's alpha (α) test was used to evaluate the internal consistency between SOFI's five dimensions, NASA-TLX and Borg-CR10. The current study's results showed a high internal consistency. In the SOFI measures, the highest Cronbache alpha value was observed with a lack of energy (0.942). Alpha values of the SOFI scale parameters ranged from 0.764 to 0.942 (Table 4). The NASA-TLX and Borg-CR10 scales showed alpha values of 0.829 and 0.772, respectively. The sum of the items from the SOFI parameters and the NASA-TLX subscales was 0.873 for Cronbach's alpha value and 0.863 for KMO.

4. Discussion

Outcome Measures

The findings from this study showed that the physiological parameters of HR and EE were sensitive to the heavy physical load associated with lifting window air-conditioner units. The heart rate and energy expenditure for lifting the units increased significantly compared with the resting level. The heart rate increased from 77.0 beats/min (baseline) to 121.60 beats/min while a worker lifted the unit. Additionally, the findings indicated that the energy expenditure significantly increased while the worker lifted the unit (4.06 kcal/min) compared with the resting level (0.74 kcal/min). The results are consistent with the previously mentioned studies in which an increase in the physical load of a task and an increase in frequency lead to a significantly increased energy expenditure (Nur et al., 2015). The work shift factor had a significant effect on the physiological measures of HR and EE. Heart rate and energy expenditure differences were observed between day and night shifts in which the day shift had higher heart rate values, whereas the energy expenditure in the night shift was higher. This may be because the duration of the day shift was longer than that of the night shift, therefore increasing the effect on the heart rate. These results are similar to a previous study that showed an increased heart rate among healthcare workers during the day shift and an increased energy consumption during the night shift (Wakui et al., 2002). According to the literature (Ohira et al., 2000), the time of the work shift significantly affected the physiological stress levels of Japanese nuclear plant operation workers because the heart rate increased in the day shift, whereas the energy expenditure increased in the night shift.

Generally, the lifting of window air-conditioner units had a significantly effect on the worker's fatigue level. The results of the current study showed that all of the SOFI scale parameters were sensitive to fatigue. This result agrees with those of Arellano *et al.* (2015) who noted that increasing scores of SOFI parameters were associated with an increasing load level in assembly tasks. In particular, the lack of energy had the highest score followed by physical exertion and physical discomfort scores because the assembly task evaluated in that study was dependent on manual activity (Arellano et al., 2015). In the current study, the workers perceived a higher physical fatigue level in the air-conditioner lifting task than mental fatigue. The physical exertion and physical discomfort (physical fatigue) parameters had a higher score than the lack of motivation parameter (this parameter indicates mental fatigue). Note that the score of physical fatigue may be affected by the physical and force loads (i.e., weight of the unit) that were required to bear to lift the unit. However, the shift work factor significantly influences the SOFI parameters. The scores for lack of energy, physical exertion and sleepiness increased in the night shift, possibly because the overall task load characteristics in the night shift are high. The lack of motivation parameter obtained the lowest score among all the parameters; in contrast, the lack of energy had the highest score. According to Barker and Nussbaum (2011), SOFI subscales have been observed to have higher scores among healthcare workers in the evening shift.

Furthermore, the current results are consistent with those of Leung et al. (2004) who showed that the SOFI questionnaire is sensitive to total occupational fatigue and shows the fatigue difference levels between task work shifts among Visual Display Terminal (VDT) Chinese workers. Åkerstedt and Wright (2009) stated that the effect of shift time on sleepiness in a subjective assessment was verified. According to the current study results, a lack of energy and physical discomfort obtained high scores, highlighting the high potential for ergonomic hazards and occupational injuries among workers that perform the task of lifting window air-conditioner units.

Generally, the NASA-TLX score was sensitive to the demand of the window air-conditioner lifting task. Most workers (53%) considered the task to have a very high workload level, and 43% of the workers perceived a high workload. The physical demand subscale obtained the highest score followed by the effort subscale, indicating that the workers required a high level of physical activity to lift the air-conditioner unit, and they needed to supply a high level of effort to complete the task. Arellano et al. (2015) evaluated the assembly task workload among Mexican workers and concluded that the TLX score was sensitive to the assembly task demand. They stated that 47% of workers perceived a high assembly demand, and 52% reported a very high assembly load level. Many studies concluded that NASA-TLX is a useful assessment tool to evaluate the overall workload in different sectors, such as the healthcare (Barker and Nussbaum, 2011; González Gutiérrez et al., 2005) and industrial fields (Macdonald, 2003). However, during night shifts, the workers perceived a higher task workload compared with the day shift. All subscale scores were significantly higher in the night shift, which may be due to the sleepiness factor that affected the workers' judgment, thus increasing the job demand characteristics during the night shift. As expected, the workers perceived a high level of physical activity while lifting the unit, giving it a high score on the Borg-CR10 assessment. Similar to the NASA-TLX scale, the night shift had a high score for CR10. The Borg-CR10 assessment tool has been shown to be sensitive to physical workload changes in experimental and actual settings and is a common, reliable subjective method (Borg, 1982; Kee and Lee, 2012).

Correlation Between Outcome Measures

A correlation between the objective and subjective measures of task workload and fatigue was found among workers that lift window air-conditioner units. The correlation among all of the outcome measures was positive. Heart rate and energy expenditure, which represent the objective measures, were significantly correlated with the SOFI parameters of lack of energy and physical exertion. The correlation between energy expenditure vs. lack of energy, physical exertion, physical discomfort and sleepiness was significant. These results are supported by a previous study that showed the validity of the SOFI parameters and found a significant correlation among heart rate and physical exertion and lack of energy (Åhsberg and Gamberale, 1998). As expected, the correlation between the objective measures HR and EE with Borg-CR10 was significantly positive. Previous findings showed that an increased CR-10 score is associated with increasing HR and EE values (Borg, 1998). Furthermore, the overall NASA-TLX score was linearly correlated with HR and EE. Lee and Liu (2003) reported a strong relationship between an increase in HR and the overall NASA-TLX score in a driving task setting. The results of the current study reveal that the physical demand and effort subscales were highly correlated to HR. This may partially explain the force and level of physical activity that are required to lift air-conditioner units. The relationships among the subjective assessment tools (SOFI, NASA-TLX and Borg-CR10) were determined.

All SOFI parameters were correlated with the overall TLX scale, except for lack of motivation. The physical demand (PD) subscale in NASA-TLX was especially correlated to physical exertion, physical discomfort and lack of energy. These results were consistent with a previous study reporting a significant correlation between lack of energy and physical demand (NASA-TLX) (Arellano et al., 2015). Furthermore, the effort subscale (NASA-TLX) showed a significant positive relationship with physical fatigue in the SOFI scale (physical exertion and physical discomfort) and lack of energy and sleepiness. As previously stated, the weight of air-conditioner units ranges from 55 to 75 kg; thus, the lifting of this heavy weight on a worker's back significantly contributes to a lack of energy. In addition, with this heavy weight, the workers engaged in a difficult physical activity with awkward postures to complete the task, which may affect their judgment in the physical fatigue parameters. Frustration in NASA-TLX was correlated with the SOFI parameters of physical exertion, physical discomfort, lack of motivation and sleepiness. This is consistent with the findings of Gonzalez Gutierrez et al. (2005) who concluded that the relationships between frustration (NASA-TLX) and SOFI subscales (physical exertion, physical discomfort, lack of motivation and sleepiness) were significant. Note that according to the current results, certain relationship patterns were observed between objective and subjective measures as well as among the subjective measures, which supports the differentiations among the subjective subscales that were used in this study. The numerical Borg-CR10 score increased considerably as the overall NASA-TLX score increased, and all of the SOFI parameters increased, except for the lack of motivation parameter.

Generally, NASA-TLX subscales, Borg-CR10 and SOFI parameters had a high internal consistency. According to the present study results, the range of Cronbach alpha was from 0.757 to 0.942, which was a satisfactory level and was consistent with previous studies (Arellano et al., 2015; Arellano et al., 2012). The KMO test values ranged from 0.687 to 0.799.

5. Conclusions

The present findings clarify the negative effect (i.e., workload and fatigue) associated with lifting window air-conditioner units. Lifting air-conditioner units exposes workers to a heavy physical demand, as the heart rate and energy expenditure significantly increased. Objective and subjective measures were influenced by shift work. Night shift work was more demanding than day shift work. Significant differences in the objective measures (i.e., heart rate and energy expenditure) between shifts were found. The scores for the SOFI parameters of lack of energy, physical exertion, physical discomfort and sleepiness were affected by lifting the unit and shift work. Workers perceived a high level of physical demand during the night shift, as the total scores of the NASA-TLX and Borg-CR10 assessment tools increased. The current study indicates that the SOFI technique is a useful method for assessing fatigue in an actual occupational setting, such as lifting air-conditioner units. The correlation between objective and subjective measures of the physical demand and fatigue, assessed among workers performing an air-conditioner lifting task, was determined. Using the SOFI subjective tool, fatigue levels representing a heavy physical load could be directly and easily obtained. The heart rate was positively correlated with the lack of energy and physical exertion parameters in the SOFI method and was significantly correlated to NASA-TLX and Borg-CR10. In contrast, lack of energy, physical exertion, physical discomfort and sleepiness were positively correlated with energy expenditure. Subjective measures also had significant relationships. In the present study, an internal consistency among the SOFI dimensions and the NASA-TLX subscales was obtained, indicating the validity of the SOFI method and the TLX scale in evaluating a heavy physical load task.

Future study is required to determine the correlation between awkward postures, performance and fatigue in these tasks. Other factors, such as shift duration and number of sleep hours per day, could contribute to the perceived fatigue level in this type of task. Finally, an evaluation of the acute and chronic fatigue levels while lifting air-conditioner units is required in the future.

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