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ORIGINAL ARTICLE

PSYCHOPHYSICAL AND PHYSIOLOGICAL STUDY OF ASYMMETRIC LIFTING AND LOWERING TASK FOR MALAYSIAN MALES

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ABSTRACT

Extensive research has been carried out over the years to determine the maximum acceptable weight that a worker is capable of lifting in a given situation among the Occidental populations in the Europe and US. At present, there is a scarcity of studies in which lifting frequency is used as the measuring variable, especially in developing countries such as Malaysia. Therefore, the objective of this study is to determine the effects of lifting loads on the maximum acceptable frequency limit (MAFL), physiological response (muscle activity) and rating of perceived exertion (RPE) for asymmetric lifting and lowering tasks of Malaysian males.Ten male subjects are recruited in this study and they perform asymmetric lifting and lowering tasks repetitively for 30 minutes. Two lifting loads are considered (1) 1 kg and (2) 5 kg. Each of the subjects adjusts his frequency of lifting using a psychophysical approach. The subjects are instructed to perform the lifting and lowering task as fast as they could over duration of 30 minutes without exhausting themselves or becoming overheated. Electromyography (EMG) signals are recorded from four muscles (Right Erector Spinae (RES), Left Erector Spinae (LES), Right Trapezius p Descendenz (RTD) and Left Trapezius p Descendenz (LTD) and analysed in terms of the normalized MVC during asymmetric lifting and lowering tasks. The ratings of perceived exertion (RPE) for four body parts (arms, lower back, shoulders and entire body) are also collected after the subjects have completed the lifting and lowering task. The mean frequency of the lifting and lowering task obtained from the experiment is 13.41 and 9.66 times/minute for a lifting load of 1 and 5 kg, respectively. The results of the independent sample t-test show that load has a statistically significant effect on the maximum acceptable frequency limit ($p < 0.05$). However, it is found that even though there is an increase in muscle activity and RPE with an increase in lifting load, there is no significant difference in the overall mean muscle activity and RPE ($p > 0.05$). The percentage decrease in the maximum acceptable frequency for Malaysian males is higher than the Occidental populations for both of the loads investigated in this study.

Keywords: *Lifting and lowering task; load; frequency; psychophysical; physiological Malaysian male*

INTRODUCTION

Lifting is one of the major health and safety hazards in the automotive industry[1]. It is also the most disabling and costly of all workplace injuries and is now one of the serious issues in various industries which need to be addressed[2]. Extensive research has been carried out over the years to develop guidelines and determine the safe limits in which a worker can operate. Previous studies[3,4,5,6,7,8] have been conducted to determine the maximum acceptable weight limit (MAWL) and the effect of frequency of a manual material handling (MMH) task. Frequency is used as the control variable in these studies. However, there is evidence that most of the workers involved in MMH tasks in the automotive industry are required to lift light loads (which may be parts or materials) at relatively high frequencies in order to maintain their pace with machines and/or conveyors. It is also known that the weight of a material cannot be changed, but the frequency of the lifting task can be adjusted to suit the working conditions. Hence, frequency is one of the important characteristics which influences an operator's capability to perform lifting tasks[9]. At present, there is a scarcity of studies available in the literature in which frequency is used as the measuring variable for asymmetric lifting and lowering task, particularly for light loads. Among the notable works in this subject are those by Snook and Irvine[10], and Fox and Smith[11]. In the former study, a heavy load tote box is used to determine the maximum acceptable frequency limit (MAFL), whereas the latter study involves the use of a light load box for the same purpose.

Most of the studies related to lifting tasks are carried out in Europe and North America and therefore, the data presented in these studies are for Occidental populations[7,12]. More importantly, the differences in the physique of populations from various ethnicities have never been considered, and this limits the applicability of the safe limits obtained in such studies[13]. Even more alarming, lifting task problems are more severe in developing countries such as China, Taiwan, India and Malaysia – however, only a couple of studies have been conducted[7,14] in order to establish manual lifting guidelines in China and India, and the results may be irrelevant to the Malaysian population. This leads to the following question: 'What is the lifting capacity of the Malaysian population?'

To the authors' knowledge, there are no studies which have proven that the lifting capacity of the Malaysian population is the same as that for the Occidental population. In addition, the limitations of the workload for manual lifting tasks must be known in order to increase work productivity and prevent workers from being exposed to musculoskeletal disorders (MSD), specifically in Malaysia. For these reasons, it is necessary to determine the lifting capacity of manual lifting tasks using data for the Malaysian population. In line with this motivation, the objective of this study is to determine the effects of lifting loads on the maximum acceptable frequency, physiological response (muscle activity) and rating of perceived exertion of Malaysian males for two-handed asymmetric lifting and lowering task over a duration of 30 minutes.

METHODS

Subjects

Ten healthy Malaysian males without historical records of musculoskeletal problems volunteered to participate in the experiment. The subjects were first briefed on the purpose of the study and they signed the written consent form, indicating that they fully agreed to take part in the experiment. The subjects were also assured on the confidentiality of their data and therefore, their names and personal information will not be disclosed in any form of presentation or publication. Prior to the experiment, the subjects were given a practical session in order to enable them to familiarize themselves with the experimental procedure. The methodology used in this study was approved by the University of Malaya Research Ethics Committee (UMREC) (UM.TNC2/RCH/UMREC). The mean and standard deviation values of the anthropometric dimensions (height, knuckle height, waist height and sternum height) along with back static strength and shoulder static strength are summarized in Table 1.

Experimental design and data analysis

The experimental task was designed based on the lifting and lowering tasks observed in the automotive industry as well as those reported in previous[11,15,16]. The subjects were instructed to lift and lower a load on their right side from knuckle height position to sternum height position at 90° of asymmetry, as shown in Figure 2. The experiment was specially designed to accommodate the anthropometric characteristics of each subject, whereby the lifting height was adjusted for each subject and the table was also adjusted to suit the subject's knuckle height and sternum height. The variables and conditions of the experiment are summarized in Table 2. Statistical analysis was performed using SPSS (version 21.0) software. The independent sample *t*-test was carried out to compare the mean difference on MAFL, muscle activity and RPE between two loads (1 kg and 5 kg).

Table 1 – Anthropometric dimension and strength measurements of the subjects (N = 10)

Variable	Mean	SD	Range
Age (years)	29.60	6.11	23-28
Weight (kg)	70.40	19.60	47-103
Height (cm)	170.75	4.87	163-181
Knuckle height (cm)	72.50	2.17	70-77
Waist height (cm)	95.60	6.96	87-109
Sternum height (cm)	128.30	6.60	120-142
Back strength (N)	305.17	111.18	197.9-524.9
Shoulder strength (N)	226.55	99.66	112-378.1

Table 2 – Variables and conditions of the experiment

	Variable	Levels or conditions
Independent variable	Load	1 kg and 5 kg
Dependent variable	Maximum acceptable frequency limit (MAFL) (times/min)	
	Muscle activity (%MVC)	
	Rating perceived exertion (RPE)	
Controlled variable	Simulated automotive parts (Figure 1)	1kg = car body interior (81 cm × 15.5 cm × 2.5 cm) 5 kg = bumper (125 cm × 22 cm × 5 cm)
	Task duration	30 minutes
	Temperature	23°C

Experimental procedure

The subjects were briefed on the objective and procedure prior to the commencement of the experiment. The subjects used the psychophysical method to determine their MAFL for the lifting and lowering task. The instructions given to the subjects were the same as those used by Fox and Smith[11]. Each subject was required to lift the given load from knuckle height followed by twisting his trunk to the left in order to place the load on the table. The motions were reversed for the lowering task. The subjects performed the lifting and lowering task for two loads, and they were instructed to adjust the frequency of lifting until it represents the maximum frequency that they can sustain for the given load over a duration of 30 minutes. The number of lifts per minute performed by each subject was counted every 5 minutes throughout the 30-minute session. The subjects were instructed to work on an incentive basis – they were encouraged to perform the lifting and lowering task to the best of their capability without straining or exhausting themselves, or becoming weakened, overheated or out of breath[10]. Each subject's muscle activity were recorded during the lifting and lowering task. Each subject was asked to rate the perceived exertion (RPE) of the lower back, shoulders, arms and whole body at the end of each lifting and lowering task[17]. The Borg-RPE Scale was used for this purpose, having a range of 1 to 10.

Equipment

An electromyography (EMG) system (Noraxon USA, Inc.) was used to record the activity of lower back muscle in the erector spinae (ES) and upper limb muscle in trapezius p. descendens (TPD) on the right and left sides. This study only focuses on these muscles since it has been frequently reported that low back injuries and shoulder pain are due to problems with the erector spinae and trapezius muscles. Ag/Ag Cl/solid adhesive pre-gelled disposable surface electrodes were attached to the skin of the subjects in order to detect muscle activity. The raw EMG signals were sampled during test contraction with a sample frequency of 1,500 Hz and the signals were then band-pass filtered (20–400 Hz). The data were recorded continuously using Telemyo 2400T G2 Telemetry EMG System. The RMS value corresponds to the square root of the average power of the raw EMG signals over a given time period. The subjects were instructed to perform the maximum voluntary contraction (MVC) task as soon as the signals from all sensors were stable. The subjects performed the MVC task three times, in which the duration of each task was approximately 5 seconds, with 30 seconds of rest in between contractions. The 30 seconds of rest serves as recovery time after each task. The MVC measurement procedure used in this study was based on the procedure outlined in[18]. MVC refers to the highest EMG amplitude obtained from three recordings and is expressed as the percentage of MVC (%MVC). The MVC was used to normalize the surface EMG signals that were recorded during the series of experimental tasks. The normalized EMG RMS (%MVC) obtained during the experimental tasks was analysed and is used to represent muscle activity.

RESULTS

Effects of lifting load

The MAFL, muscle activity and RPE obtained from the mean difference analysis of *t-test* are summarized in Table 3. It can be observed that the MAFL decreases with an increase in asymmetric lifting load. The independent sample *t*-test reveals that load has a statistically significant effect on the MAFL ($p < 0.05$). It is found that the MAFL for the 5-kg load (9.66 ± 3.93) is significantly lower than the MAFL for the 1-kg load (13.41 ± 2.54), ($p = 0.02$), with a difference of 3.76 (95% CI, 0.65 to 6.86). It can also be observed that the muscle activity and RPE at different body parts increases when the load is increased. Even though there is a significant decrease in the MAFL, there is no significant difference in the overall mean muscle activity and RPE ($p > 0.05$) between the two loads. Table 3 also shows that the lower back is rated as the most stressed body part, followed by the shoulder, arm and entire body. However, the analysis of mean difference shows that the lifting load has an insignificant effect on the overall RPE ($p > 0.05$).

Table 3 - Independent t-test results, whereby the maximum acceptable frequency limit, muscle activity and rating of perceived exertion are the dependent variables

Dependent variable	Load				Sig. (2-tailed)
	1 kg		5 kg		
	Mean	SD	Mean	SD	
Maximum acceptable frequency limit (times /min)	13.41	2.54	9.66	3.93	0.020*
Right erector spinae (RES) (%MVC)	2.22	0.28	3.72	1.01	0.750
Left erector spinae (LES) (%MVC)	1.55	0.13	2.00	0.37	0.276
Right trapezius p. descendens (RTD) (%MVC)	1.79	0.16	2.76	0.42	0.314
Left trapezius p. descendens (LTD) (%MVC)	0.70	0.04	0.84	0.09	0.777
RPE at lower back	1.2	1.11	2.2	1.69	0.135
RPE at arm	1.1	0.97	1.75	1.18	0.195
RPE at shoulder	1.4	1.05	1.95	1.09	0.266
RPE for entire body	1.3	1.03	1.65	0.97	0.446

* $p < 0.05$ = statistically significant at 5% level

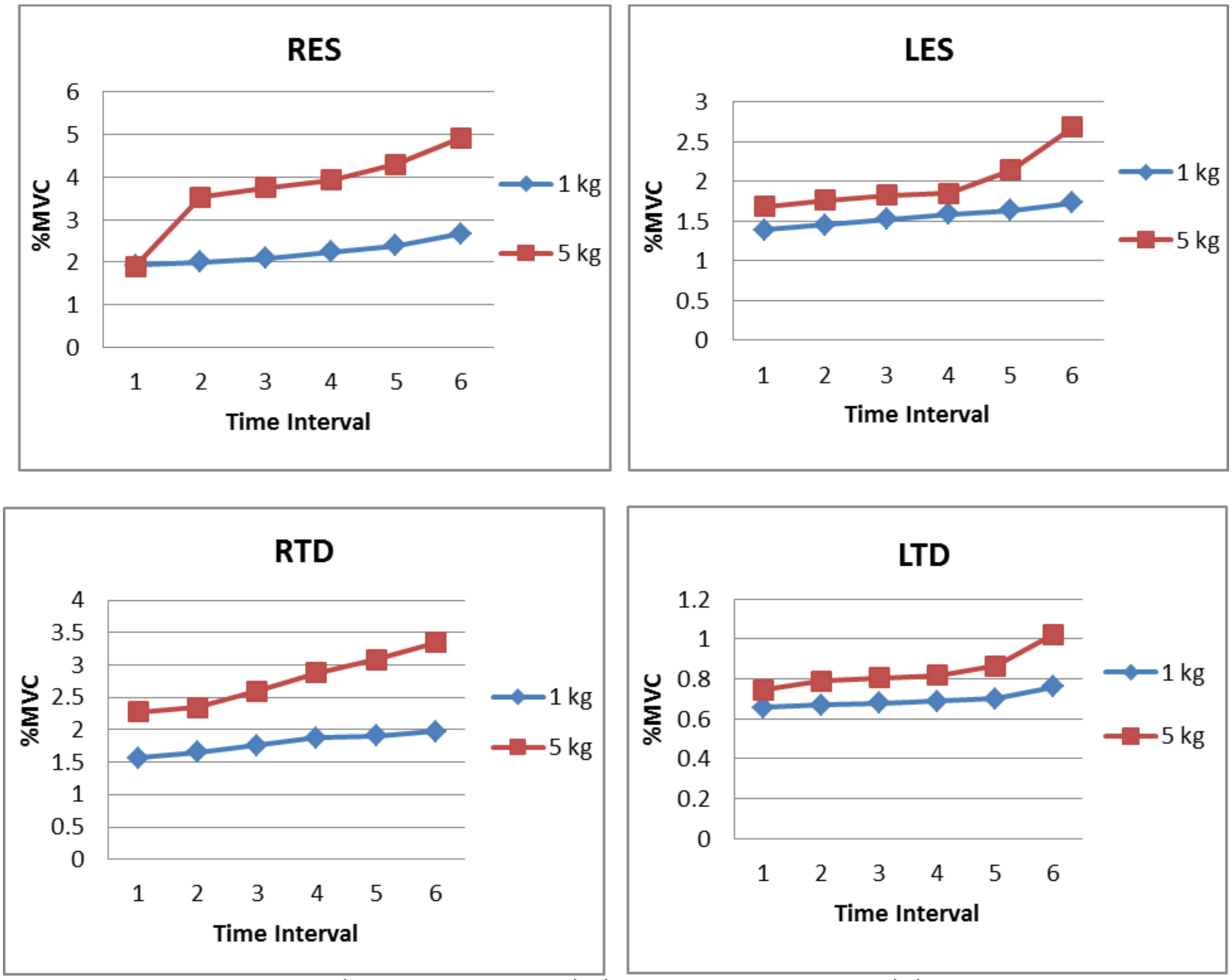

Figure1 - Effect of lifting loads on muscle activity

Muscle activity for different loads

Figure 3 shows the variations of muscle activity with respect to time for the right erector spinae, left erector spinae, right trapezius pars descendens and left trapezius pars descendens muscles for 1-kg and 5-kg loads. The data are divided into six time intervals. The one-way ANOVA reveals that there is no significant difference in the %MVC between each time interval (p> 0.05) for all muscles and lifting loads. Even though there is no significant difference in the %MVC between each time interval, the plots show that the %MVC tends to increase with respect to time for the four muscles investigated in this study.

DISCUSSION

Psychophysical responses

The key finding of this study is concerned with the psychophysical determination of the lifting frequency of light loads. The results of this study confirm the findings of Foxet al.[11], whereby the MAFL is significantly influenced by the lifting load. In this study, it is observed that the MAFL decreases with an increase in lifting load. The mean lifting frequency is found to be 13.41 and 9 times/minute for the 1-kg and 5-kg load, respectively. These frequencies are significantly lower than those typically observed in psychophysical research related to MMH tasks[4,5,11]. In this study, the decrease in MAFL is found to be 27.96% whereas Fox and Smith [11] obtained a value of 24.7%. The difference in the values may be due to variations in physique (specifically anthropometric dimensions) of different populations. In general, the Malaysian population has a smaller average body size compared to Occidental populations and therefore, it is perfectly understandable that they will find it more difficult to lift asymmetrically loadfrom knuckle to sternum height. It is evident that even though the subjects worked harder to lift the 5-kg load, the frequency of lifting is lower than that for the 1-kg load.

Physiological responses

The results show that the highest %MVC is measured for the right erector spinae compared to other muscles. This observation agrees well with the findings of previous studies[15,19], in which there is an increase in muscle activity in the shoulder muscles (trapezius pars descendens) and lower back muscles (erector spinae) during lifting tasks. Rohmert[20] recommended a force exposure limit of 15 %MVC in order to prevent fatigue. In this study, it is found that the %MVC for all muscles is below 15 %MVC, which indicates that the muscle activity for all muscles during lifting/lowering tasks is below the force exposure limit prescribed by Rohmert[20]. The significant activity of the right erector spinae may be due to contraction as the muscle deals with the imbalance caused by the extreme angle of asymmetry at 90°. It has been reported in Oliveira[21] that an individual will change the response of the trunk muscles depending on the weight of the object that is lifted in order to control the trunk's stability. It has also been stated inWu[13] that asymmetric lifting leads to greater intra-abdominal pressure, increased electromyographic activity and higher spinal capability. Hence, in order to cope with the excessive physical stress generated from asymmetric lifting, the subjects in this study would have to reduce their maximum acceptable lifting frequency and thus, there are no variations in the physiological response. The second highest muscle activity is measured for the right trapezius pars descendens, which may be attributed to the fact that the subjects adopted an upper limb posture (lifting from knuckle height to sternum height) owing to repetitive lifting and lowering of automotive parts with irregular shapes. This result is consistent with the results of James[22] who observed that repetitive lifting of irregular-shaped vehicle panels such as car doors increases the occurrences of upper limb problems. It is indeed expected that the subjects will experience higher muscle activity when lifting and lowering the automotive parts to the designated location.

Rating of perceived exertion

The results of this study reveal that the perceived stress levels of the subjects increase with an increase in lifting load. However, the average RPE of all muscles during the lifting and lowering task is close to 'scale 2' (weak) for both 1-kg and 5-kg loads. This finding indicates that the subjects perceived that the given task is not really stressful and the task is still within their lifting capacity. In other words, the subjects performed the lifting and lowering task as quickly as possible without exhausting themselves or becoming overheated. In contrast, the RPE is higher for Occidental populations even though they have larger body sizes compared with the Malaysian population. The body parts with the highest stress level are also different between these populations. For instance, Fox and Smith[11] found that the body parts with the highest stress level are the lower back and legs. However, the results of this study indicate that the body parts with the highest stress level are the shoulders and lower back, which is in agreement with the findings of Wu[13].
It is worth to note that the subjects recruited in this study do not have any experience in lifting and lowering tasks. Hence, it is recommended that subjects with experience in lifting and lowering tasks should be recruited in future studies, preferably workers who are involved in manual material handling in the automotive industry. This is important in order to obtain a clearer picture on the crucial parameters involved in lifting and lowering tasks which can then be used to design lifting and lowering tasks which incorporate safety considerations. This, in turn, will help boost work productivity and minimize the risk of work-related musculoskeletal disorders.

CONCLUSION

In this study, the effects of lifting load on the maximum acceptable frequency limit, physiological response (muscle activity) and rating of perceived exertion of two-handed asymmetric lifting and lowering tasks for Malaysian males have been investigated by means of a psychophysical approach. Two lifting loads are considered in this study: 1 kg and 5 kg. The results reveal that the MAFL is significantly influenced by the lifting load. The MAFL decreases with the lifting load is increased from 1 to 5 kg – however, the muscle activity and RPE both increase. In addition, there is no significant difference in the muscle activity and RPE between the two loads investigated in this study. More importantly, there is a significant difference in the MAFL between the Malaysian and Occidental populations for the 1-kg and 5-kg loads. The decrease in MAFL is higher with an increase in lifting load for the Malaysian population compared with the Occidental population.

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COMPETING INTERESTS

There is no conflict of interest.

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