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Abstract. Manual material handling (MMH) is the most common cause of occupational fatigue and low back pain. This study aimed to determine the maximum acceptable weight of lift (MAWL) and rating of perceived exertion (RPE) among young workers using the psychophysical approach. Sixty healthy Thai youth aged 18-24 years old performed at five different lifting frequencies (1, 2, 4, 6, and 12 lifts/min) in the sagittal plane as followed the NIOSH lifting technique. The results indicated that the MAWL at five different lifting frequencies (12, 6, 4, 2, and 1 lifts/min) were 2.0, 2.29, 3.00, 4.50, and 5.50 Kilograms, respectively. The RPE of participants with 12 lifts/min of lifting frequency revealed that men and women had the highest means of RPE at 5.63 and 5.17, respectively. The reference mass of this study can be used as a guide to safe manual handling at work.

Keywords: Psychophysics; Thai youth; Manual material handling

1 Introduction

The manual material handling or MMH (lifting-lowering, pushing pulling, and carrying by a person) is one of the ergonomics risk factors and can develop to musculoskeletal disorders (MSDs) that affected to muscle and tendons pain on body such as hands, wrists, arms, shoulders and especially lower-back. Main cause of this problem are improper lifting postures, prolonged, and repetitive lifting. Health and Safety Executive [1] reported that 473,000 workers suffered from work-related MSDs in 2022/23, resulting in 6.6 million working days lost due to work-related MSDs. Manual material-handling tasks were the main cause and heavy lifting was the main attributed task of work-related MSDs. The report found that the highest prevalence of MSDs was back and upper limbs or neck area, accounting for 41% of back and upper limbs and 17% of lower limbs. Furthermore, the report identified that workers in industries administrative and support service activities, construction, and human health and social work activities were particularly

prone to MSDs. The Workmen's Compensation Fund in Thailand for the years 2018 to 2022, it was reported that the primary disease resulting from work characteristics, work conditions, or occupation is work related-MSDs. During 2018-2022, 4,760 workers experienced work-related-MSDs, with 1.13% per year, 68.69% of cases resulted in absences from work for less than 3 days, followed by 29.51%of cases that led to absences from work for more than 3 days. The age group most affected by MSDs from 2018 to 2022 was individuals aged 25 to 29 years old, followed by 20 to 24 years old because of lacking experience and poor lifting technique. Furthermore, young workers have significantly higher rates of work-related injuries than older workers. According to the latest European data, the incidence of non-fatal workplace injuries is 40 percent higher among youth workers aged 18 to 24 than among adult workers [2]. Nevertheless, this age group does not have legal recognition or protection by the law like workers under 18 years old.

Lifting and moving heavy objects are required force exerted of worker who might be use over physical ability and expose other risk factors which are potential to cause to injury in the same time [3]. If workers must work in inappropriate conditions for a long time, it can affect body functions and lead to injury and fatigue [4]. According to the studies [5] recommend that the maximum acceptable weight of lifting should not exceed 23 kilograms, and the weight must be reduced when other risk factors are involved such as vertical heigh, horizontal distance, lifting posture, frequency, duration and gripping quality. This scenario may cause the maximum acceptable weight of lifting is only 4-5 kilograms. In 2004, Thailand has issued a Minitrial Regulation Prescribing Weight for Employees to perform as Employer Required which defined the maximum weight limit of lifting at 55 kilograms for males and 25 kilograms for females regardless of other risk factors that might cause injury when workers perform lifting and moving the objects.

For this reason, Thailand must study the maximum acceptable wight of lift among young workers. This study aimed to determine the maximum acceptable weight of lift (MAWL) and determine the rating of perceived exertion (RPE) for five different lifting frequencies among Thai youth age group between 18-24 years using the psychophysical approach. The findings of this study will be used as a guideline for lifting tasks with physical exertion and as a guide for improving the ministerial regulation on determining and improving the rate of weightlifting in Thailand.

2 Methodology

2.1 Psychophysical approach

To determine the maximum acceptable weight of lift in this study, the psychophysical approach was applied. Previous studies [6, 7] applied psychophysical approach to find the MAWLs in manual material handling tasks. It was considered that these values were perceived from the sensation of the musculoskeletal and cardiovascular systems as a whole [8]. Determining the maximum acceptable weight of lift for safe is based on the percentage of population acceptance, at least 75% of the female group, not less than 99% of male, and 90% of all workers' acceptation which the population consist of 50% male and 50% female [9]

2.2 Participants

Sixty healthy participants of this study were male and female with the average of 20.59±1.33 and 20.63±1.45 years old, respectively. They did not have congenital disease and neurological and musculoskeletal abnormality. The participants signed an informed consent before study participa-

tion. The participants were interviewed the readiness of the subjects to do the physical activity followed by PAR-Q+2019 Thai version (Physical Activity Readiness Questionnaire) and measured resting heart rate and blood pressure before experimenting. In addition, the participants were instructed to do the physical fitness test, including leg dynamometer test, arm lift test, and handgrip – endurance test. The research protocol was approved by the Human Research Ethics Committee of Thammasat University (Science) (code: 66PU037).

2.3 Experimental design and equipment

This study conducted a psychophysical approach to study reference mass considered for determining the recommended weight limit in manual lifting of one person among Thai youth (18-24 years old). The workstation used in the lifting test could be adjusted following the height of the subjects to avoid stoop posture while lifting. The horizontal distance and the handle level were according to NIOSH recommendations and based on ISO 11228, Ergonomics-Manual Handling-Part 1(2003).

The container was plastic (25 x 33 x 14 cm.). Inside the basket contained metal pellets in bags of 0.5 kilograms per bag. In experiment, there was a predetermined frequency to be a signal for lift. The work characteristic was only lifting from the lifting point (origin) to the lower point (destination). Five different lifting frequencies (1, 2, 4, 6, and 12 lifts/min) were investigated. Each participant performed lifting for all five experimental conditions in a random sequence. The participants were required to lift the object using both hands from the knuckle height to elbow height level without moving their feet. The environmental conditions in the laboratory while doing an experiment was 25ºC (dry temperature, 55%-65% humidity, and air velocity less than 0.2 m/s).

2.4 Experimental procedure

The participants were asked to lift the object for 20 minutes in each five different lifting frequencies. The initial weight of the object was obtained from the recommended weight of lift which was calculated from NIOSH Lifting Equation (NLE). During 20 minutes, the participants had to project that they performed the lifting task 8 working times in each lifting frequency trial and they had to decide to increase or decrease the weight inside the basket until the weight reaches the appropriate weight (maximum acceptable weight of lift) using their perception of lifting capability. The maximum weight would not cause subjects to be unusually tired, overheated, or out of breath. At the end of each lifting task, the participant was asked to RPE using the Borg Category Ratio-10 (CR-10) scale. Afterwards, analyzed the maximum acceptable weight of lift of subjects using statistic within acceptable lifting capacity of about 99% of male subjects, 75% of female subjects and 90% of all subjects [10].

2.5 Data analysis

The researcher established dummy table, validated data and recorded data on statistical package and then analyzed data using descriptive statistic, including number, percent, percentiles, mean and standard deviation (SD) to describe subject characteristics, lifting weight decision, reference mass, and rating of perceived exertion.

3 Results

3.1 Maximum acceptable weight of lift (MAWL)

The results of the study on lifting tasks to determine the Maximum Acceptable Weight of Lift (MAWL) for a group of Thai youth under appropriate working conditions using psychophysical approach revealed that at five different lifting frequencies (12, 6, 4, 2, and 1 lifts/ min) , the MAWLs were 1.50, 2.22, 3.00, 4.50, and 5.45 Kilograms, respectively. On the other hand, females could lift a maximum average weight of 3.02, 3.73, 4.67, 5.70, and 6.85 kilograms, respectively. Details were shown in Table 1. It is evident that the MAWL for male is higher than female at every frequency.

Table 1. Maximum acceptable weight of lift (MAWL) categorized by frequency and gender (n=60)

Frequency (lifts/min)	MAWL (kilograms)							
	Male (n=30)				Female (n=30)			
	Min	Max	Mean	SD	Min	Max	Mean	SD
12	2.0	14.0	6.10	2.87	1.50	6.50	3.02	1.39
6	2.0	16.50	7.23	3.59	1.50	8.50	3.73	1.55
4	3.0	18.0	8.38	3.54	2.0	8.50	4.67	1.64
2	4.50	19.50	9.95	3.94	3.0	10.0	5.70	1.53
1	6.0	25.50	11.88	4.74	4.0	11.50	6.85	1.73

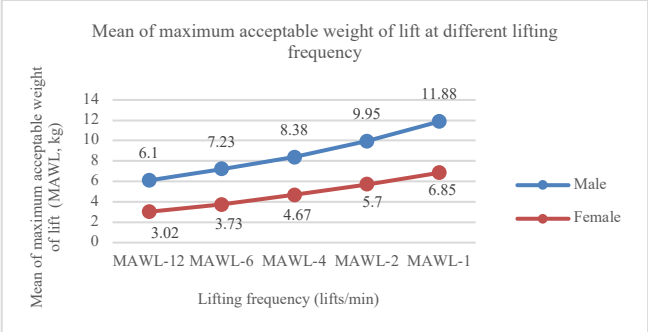

Fig. 1. The mean of MAWL at different lifting frequencies, separated by gender.

3.2 The percentile of maximum acceptable weight of lift.

Psychophysical approach considered the percentage of population acceptance, at least 75% of the female group, not less than 99% of male, and 90% of all workers' acceptation (males and females are equal). Selecting the lowest value to be the maximum acceptable weight of lift from three criteria. Therefore, the maximum acceptable weight of lift of this study classified by five different lifting frequencies (12, 6, 4, 2, and 1 lifts/min) were 2, 2.29, 3, 4.5, and 5.5 kilograms, respectively. Details are shown in Table 2.

Table 2. Maximum acceptable weight of lift (MAWL) using psychophysical approach categorized by frequency (kilogram)

Frequency (lifts/min)	MAWL of about 99% of male subjects	MAWL of about 75% of female subjects	MAWL of about 90% of both male and female subjects	MAWL of Thai youth (18-24 years old)
12	2.0	2.0	2.0	2.0
6	2.29	3.5	2.5	2.29
4	3.29	3.5	3.0	3.0
2	4.65	5.0	4.5	4.5
1	6.0	5.63	5.5	5.5

3.3 Rating of perceived exertion from lifting task

In this study, it was found that the rating of perceived exertion from lifting task of subjects found frequency at 5 seconds/lift, male and female subjects reported the highest rating of perceived exertion, with averages of 5.63 and 5.17, respectively, as shown in Fig. 2.

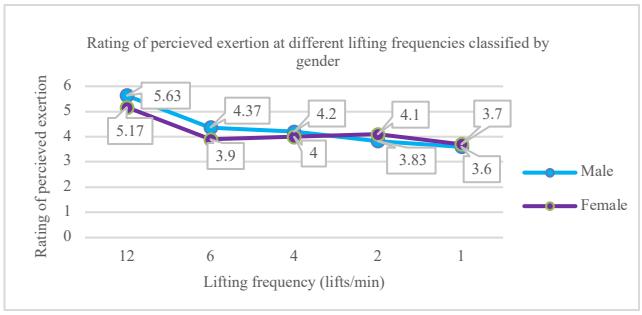

Fig. 2. Rating of perceived exertion categorized by lifting frequency and gender (n=60).

4 Discussion

The results of this study found that the mean MAWL decreased when increased lifting frequency corresponded with studying the maximum acceptable weight of lift in adolescents aged 15 to less than 18 years old [11] found that the MAWL of 90% both male and female adolescence classified by lifting frequency at 12, 6, 4, 2, and 1 lifts/minwas 5.5 6 7.5 6 and 10.5 kilograms, respectively. This is in agreement with the results of the previous studies [12, 13]. For the reason that when increased lifting frequency, subjects need to lift rapidly result of heart rate and metabolic energy expenditure increased [7,13] so subjects were easier fatigued or out of breath than low lifting frequency, including when high lifting frequency, subjects must use their muscles continuously for repetitive tasks, with intervals for rest and muscle recovery getting shorter. These might lead to a reduction in muscle endurance, resulting in a decreased ability to lift heavy objects. The reason for the difference in the MAWL value between the current study and the previous studies was due to the difference in the participants' characteristics, such as age group, BMI, and strength, the difference in the experimental conditions, such as lifting frequencies, lifting posture, and lifting duration

and the difference in the environmental conditions, such as the temperature, air velocity, and the humidity.

Comparing the MAWLs for Thai youth of this study with the mean recommended weight limits (RWLs) which were calculated from the NIOSH lifting equation (1991) and were used to be the beginning weight of lifting at each lifting frequency, found that at high lifting frequencies (6 and 12 lifts/min) the MAWLs were higher than the mean RWLs and at lower lifting frequency (1, 2, and 4 lifts/min) the MAWLs were less than the mean RWLs since this study applied solely the psychophysical criterion to find the MAWL. The participants were instructed to lift with the beginning weight (RWL), they had to project that they performed the lifting task 8 working times in each lifting frequency trial and they had to decide to increase or decrease the weight inside the basket until the weight reaches the appropriate weight (maximum acceptable weight of lift) using their perception of lifting capability. This approach differs from the NIOSH methodology, which used physiological, biomechanical, and psychophysical criteria to create an equation for RWL calculation. As a result, the mean RWLs and the MAWLs for Thai youth are not equal. In addition, using the NIOSH equations to assess the risk of manual lifting at high frequencies may be an underestimate. On the other hand, low frequencies may be overestimated. Because the variables in NIOSH equations are about task and material characteristics, the personal characteristics like gender or physical strengths are not considered so caution must be taken in using the RWLs at low-frequency lifting. It can be concluded that the NIOSH equations to assess the risk of manual lifting can be used by Thai youth for high lifting frequency more than low frequency. However, applying the MAWLs of this study to use, should consider the other variables apart from the lifting frequency such as horizontal distance, vertical distance and asymmetric angle.

The mean MAWL of male participants were higher than females at every lifting frequency, which corresponded with previous research of [11] they found that the MAWL of male children were significantly higher than female children at every lifting frequency. This may be explained that since males and females have different body structures, with males having larger and more numerous muscles, males are generally able to generate more energy for various activities compared to females. In cases where they receive the same training for muscle usage, females can produce only approximately 70% of the force generated by males, due to the relatively smaller muscle size in females. In addition, males being stronger than women because of physical differences, the culture of Thai also makes men have to be stronger than women since Thai culture which has existed for a long time teaches men to work or exert more energy than women since childhood, for example, boys must help their father carry things while girls must help their mother wash the dishes, boys must be Thai Reserve Officer Training Corps Students (TROTCS) when they were 16 years old, which requires intense training to pass the exam, result in boys have to be strong all times while girls do not have to be like that. Therefore, it is not surprising that boys grow up to be able to lift heavier objects than girls. Thai law also specified the lifting weight of men higher than women because there is a belief that men are stronger than women. Psychosocial factors may influence lifting capacity that is the men who help the women lift the heavy objects are called ‘gentlemen’ and are complimented by the women resulting in giving men a sense of satisfaction and self-esteem for being able to help others who are less strong. Therefore, the current study reported that regular the mean MAWL of male participants were higher than females.

The rating of perceived exertion in this study investigated that the mean of rating of perceived exertion tended to increase both males and females, although MAWL were lower. The frequency of 5 seconds per lift (12 lifts per minute) resulted in the highest level of perceived exertion. These results aligned with the research conducted by [11] and were consistent with international studies [12, 14]. The study's outcomes suggested that the lifting frequency significantly impacts the body's

fatigue levels, even when the weight being lifted is relatively low. This may be attributed to the limited time available for the muscle fibers involved in the lifting process to recover and prepare for the next lifting frequency trial. Additionally, the body requires oxygen for energy production, which necessitates increased breathing frequency. Consequently, this might lead the participants to feel more fatigued when lifting at higher frequencies.

The maximum of recommended weight limit of Thai regulation (55 kg for males and 25 kg for females over 18 years old) is higher than the MAWLs of this study for both males and females so the weight limits should be considered to improve since they are not suitable for performing lifting tasks of Thai youth and cannot prevent the MSD injuries. These findings suggest that should consider the recommended weight limits using the NIOSH lifting equation (NLE) in order to work safety and well-being among Thai youth.

5 Conclusion

This study found that increasing lifting frequency, decreasing the maximum acceptable weight of lift. On the other hand, increasing lifting frequency, increasing the rating of perceived exertion. Further study should consider the MAWL using biomechanical and physiological approaches to comprehensively address all ergonomic issues.

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