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Determination of lifting capabilities of workers of different heights under symmetric and asymmetric lifting based on psychological and physiological criteria

Ravi Bansal*, Sanjay Srivastava

Industrial Kinesiology Lab., Faculty of Engineering, Dayalbagh Educational Institute (DEI), Dayalbagh, Agra-282005, India.

Corresponding author: *Ravi Bansal, Research Scholar, Department of Mechanical Engineering, Faculty of Engineering, Dayalbagh Educational Institute, Dayalbagh, Agra-282005, India.

Abstract

Twelve young Indian male subjects participated in this study to examine the maximum acceptable weight limit (MAWL) and maximum weight limit (MWL) for symmetric lifting in sagittal plane as well as for 90^o trunk rotation (asymmetric lifting). Change in MAWL and MWL was observed with respect to changes in height of subjects. This study involved lifting a container to 74 cm height at 4 lifts/min for 4 hours. The participants were grouped into three height categories namely small height (150 cm to 170 cm), medium height (170 cm to 180 cm) and large height (180 and above). The results showed that MAWL and MWL decreased for asymmetric lifting under each category of height significantly. The mean MAWL decreased by 21.5%, 17.2 % and 17.2% for small, medium and large height participants respectively and mean MWL also decreased by 36.7 %, 33.8 % and 33.2 % for small, medium and large height participants respectively. The change in resting heart rate and working heart rate increased by 12%, 17.1% and 11.7% for small, medium and large height participants respectively. For a particular mode of lifting the MAWL and MWL increased from small height participants to large height participants. Change in heart rate is also increased with increase in lifting height ($p<0.5$).

Keywords: Maximum acceptable weight limit, Maximum weight limit, Physiological measurements, Asymmetric lifting

Introduction

Lifting a load to a destination off the mid-sagittal plane is referred to as an asymmetric lifting. An asymmetric lifting task usually requires a lifter to twist the trunk to some degrees off the sagittal plane while lifting. Several studies have demonstrated the potential disadvantages for twisting trunk while lifting. For example, an asymmetric lifting would increase the shear and compression loading on the intervertebral discs and the muscle activities of the trunk [9, 1, 10, 7]. Second, an asymmetric lifting would decrease maximum isometric trunk strength [5], peak lifting force, velocity and average upward acceleration [8] or human lifting capability [12, 6, 4, 13, 18, 19]. Third, an asymmetric lifting can cause poor posture stability and asymmetric muscular loads on the spine [5]. In 1991, Snook and Ciriello developed manual materials handling guidelines, maximum acceptable weights and forces that derived from studies conducted in a 27-year time span before 1991 [14]. Newly, Ciriello, Dempsey, Maikala, et al. revealed secular changes, a drop in absolute psychophysically determined maximum acceptable weights and forces, over 20 years, though the effects of task variables were similar to earlier results [3]. This study aimed to observe maximum acceptable weight limit (MAWL) for symmetric and asymmetric lifting tasks (asymmetric lifting with trunk rotation), and for three different categories of height of participants for a 4 hours work period. A further objective was to examine the percentage of participants' MAWL to their maximum weight of lifting (MWL). The effects of lifting mode and frequency on psychophysically established maximum acceptable weight of lift for 4 hr. of work on 10 undergraduate men. The heart rate and rate of perceived exertion (RPE) of the individuals while lifting the maximum acceptable weight of lift were measured. When performing a 90° asymmetric lifting, subjects lifted approximately 10% less weight than lifted in symmetric lifting. Non-significant differences in maximum acceptable weight of lift, heart rate, and RPE values were found between asymmetric lifting with trunk rotation and asymmetric lifting with leg rotation. The lifting frequency significantly affected the maximum acceptable weight of lift, heart rate, and RPE. Heart rate and RPE increased with lifting frequency. The maximum acceptable weight of lift at 2 lifts/min. and 4 lifts/min. were approximately 91.5% and 82.5% of that of 1 lift/min., respectively. [16]

The effects of 3 lifting ranges and 3 lifting modes on maximum lifting capability and total lifting time is examined by Tzu-Hsien Lee. [17]According to results, the maximum lifting capability for FK (from floor to knuckle height) was greater than that for KS (from knuckle height to shoulder height) or FS (from floor to shoulder height). Moreover, asymmetric lifting with initial trunk rotation decreased maximum lifting capability compared with symmetric lifting or asymmetric lifting with final trunk rotation.

Demands at work are associated with an increased risk of cardio vascular diseases, but little is known about its underlying connection. The purpose of this study was to evaluate the effects of physical and mental tasks that induced stress, on Heart Rate Variability (HRV). Another aim was to observe the trends in subjective workload ratings in conjunction with the physiological response of the heart and also to assess the comfort level of the participants while wearing the heart rate monitor and performing tasks.

Cardiovascular diseases are the highest cause of death in the industrialized world and many of these deaths may be work related. Stress at work is associated with an increased risk of cardiovascular disease but little is known about the mechanisms that underlie this connection.

Therefore the goals of this study were:

(a) To find out the variation of Heart Rate during lifting by different subjects height.

(b) To find out the variation in MAWL & MWL for different subjects height in different position of lifting.

Materials and methods

This study examined participants' MAWL for lifting a container from the floor onto a 74-cm high table at a frequency of 4lifts/min for a 4 hours work period. Participants were tested over two lifting modes and a container dimensions. The two lifting modes were symmetric lifting and 90° asymmetric lifting with trunk rotation. For symmetric lifting, participants lifted the container sagittally from the floor onto a 74-cm-high table. For 90° asymmetric lifting with trunk rotation, participants first twisted their trunk and held a container initially located at their right side, and then lifted the container onto a table in front of them. Figure 1 presents the schematic top view of the two lifting modes. For both the lifting modes, the participants were permitted to take one or two steps as needed for body stability while placing the container onto the table. The horizontal distance fromthe table edge to the middle of the initial location of the ankles was 90 cm. The container dimensions(length × width × height) in this study were 53 × 36 × 26cm. The container had grooves on the upper middle half of the container width sides.

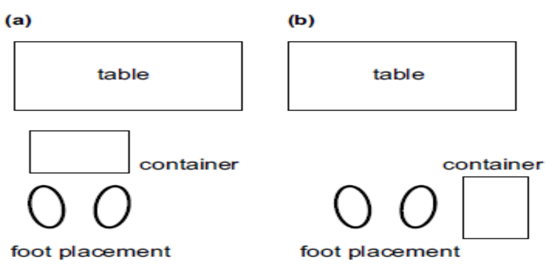

Figure 1: Top schematic view for (a) symmetric lifting and (b) 90° asymmetric lifting with trunk rotation.

Twelve young male university participants, experienced in manual materials handling tasks, were recruited for this experiment. Their mean anthropometric data were, age 21 years, body weight 67.8 kg, height 174.7 cm and BMI 22.4 (table 1, figure 2). All participants were in good physical health and medically fit. The participants were divided into three groups based on their heights namely:

1. Small height (150cm to 170 cm)
2. Medium height (170cm to 180 cm)
3. Large height (>180cm).

Before formal experiments, each participant had a necessary training to become familiar with the psychophysical weight adjustment procedure. The participants didn't wear shoes during the experiments. Before theexperiment, the participants were asked to rest for at least 10 min on a seat before his resting heart rate was taken with a Biopac-bioharness heart rate monitor. Then, the participant stretched to warm up. Next, the participant performed one of experimental conditions. The initial weight inside the container was randomly assigned, 5–25 kg. The participant was asked to lift the container using a free-stylelifting posture at a frequency of 4 lifts/min.

Table 1: BMI Details of the participants.

	Small Height (cm)	Medium Height (cm)	Large Height (cm)
Average Height	167.62	175.18	22.85
Average BMI	21.63	181.81	22.87

Figure 2: BMI measurement of participant before experiment.

Subjects were motivated to adjust the weight (by adding or subtracting smaller weights) inside the container to the maximum that he could accept at a frequency of 4 lifts/min for 4-h work without strain or discomfort, without feeling tired, weakened, overheated or out-of breath. Psychophysical weight adjustment lasted for 10 min. After the participant confirmed that he had adjusted the weight to his MAWL, he was asked to perform the lifting task for another 5 min to reach a steady heart rate and then the test ended. The participant's heart rate was recorded right after the end of each test. Before formal experiments, each participant had a necessary training to become familiar with the psychophysical weight adjustment procedure. This study also measured each participant's MWL capacity from the floor onto the 74-cm high table for both experimental conditions (figure 3 and figure 4). The lifting posture for MWL measurements was identical to that for MAWL. To obtain the participant's MWL capacity for a given condition, he was initially asked to lift a container loaded with some weights from the floor onto a 74-cm-high table. If the participant could lift the container onto the table, he was asked to increase the load by adding more lead shots, in increments of 2–10 kg, until he could not perform the task. Initial load increments were large but they were reduced as the participant approached his estimated MWL capacity. At least 2 min of rest were provided between two consecutive progressive tests. The participant's MWL capability could normally be obtained after several progressive tests.

Figure 3: Symmetric Lifting Task

Figure 4: Asymmetric Lifting Task

Equipment and instruments

Heart rate was taken with a Biopac-bioharness heart rate monitor. BioHarness with AcqKnowledge software is a state-of-the-art lightweight portable biological data logger and telemetry system. It monitors, analyzes and records a variety of physiological parameters including ECG, respiration, temperature, posture, and acceleration. The BioHarness operates in Bluetooth transmitting mode for live viewing of data or data logging mode. A specially licensed version of AcqKnowledge is included and required when used with BioHarness. The system is ideal for exercise physiology, sports conditioning, human factors, public health, and psychological studies. BioHarness Data Channels are ECG – Raw, Breathing, RR Interval, Heart Rate, and Respiration Rate. Live data viewing features include a variety of selectable waveforms and trend data including ECG, Heart Rate, RR values, Respiration. It consists of smart, adjustable and Velcro fabric chest strap which is elastic and webbing incorporating Zephyr Smart Fabric sensors of Width 50 mm and Weight 50 grams. BioHarness transmitter /Logger frequency (Bluetooth) is 2.4 to 2.835 GHz, Sample Rate 250 Hz Max., Memory Capacity 480 hours and transmitter range up to 100 m. Its battery life is 12-28 hours transmitting 35 hours logging.

Results and analysis

Table 2: Comparison between Symmetrical and Asymmetrical lifting for MAWL, MWL and ΔHR for all small, medium and large height categories

MODE	HT CAT	AVG HT	MAWL	MWL	REST HR	WHR	Δ HR
		Mean ±SD	Mean ±SD	Mean ±SD	Mean ±SD	Mean ±SD	Mean ±SD
SYM	SMALL	167.75±2.61	14.11±0.47	41.61±1.01	76.8±11.03	101.875±10.03	25.02±7.40
	MEDIUM	175.15±2.7	14.55±0.77	42.86±1.93	73.85±9.98	100.12±12.21	26.28±6.43
	LARGE	181.18±1.09	15.6±0.98	44.8±1.65	78.71±11.82	106.42±9.44	27.73±6.96
ASYM	SMALL	167.75±2.61	11.03±0.95	26.31±0.88	76.86±11.03	104.83±8.72	27.97±7.28
	MEDIUM	175.15±2.7	11.97±0.64	28.43±1.13	75.18±10.59	105.98±8.8	30.77±8.17
	LARGE	181.18±1.09	12.88±0.91	29.86±1.71	78.71±11.82	109.13±7.75	30.45±7.89

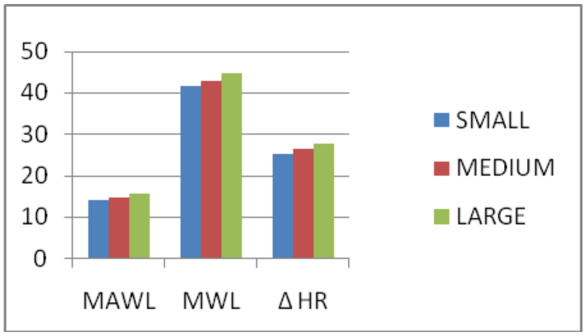

Figure 5: Relation between MAWL, MWL and ΔHR for Symmetrical Lifting

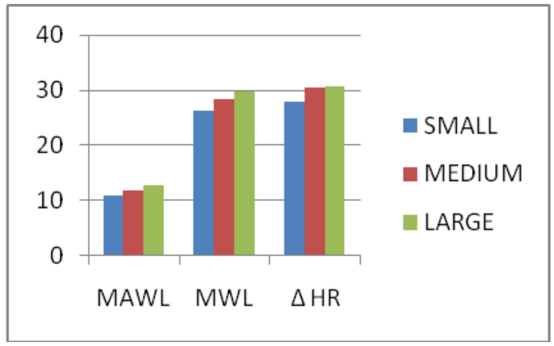

Figure 6: Relation between MAWL, MWL and ΔHR for Asymmetrical Lifting

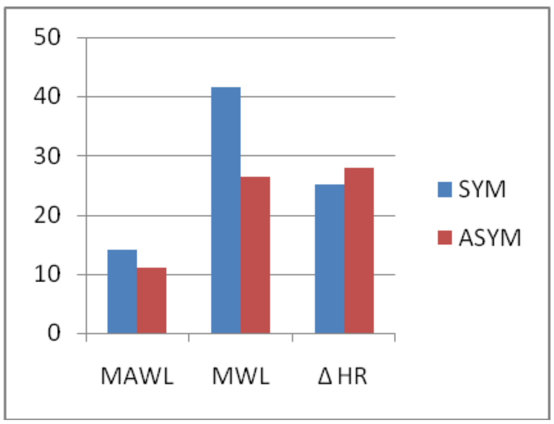

Figure 7: Relation between MAWL, MWL and ΔHR for Symmetrical and Asymmetric Lifting for small height category

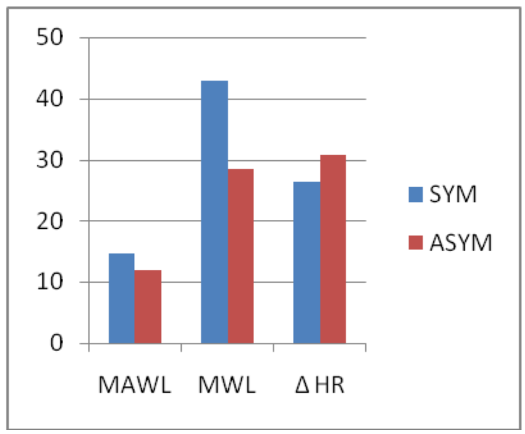

Figure 8: Relation between MAWL, MWL and ΔHR for Symmetrical and Asymmetric Liftingfor medium height category

Table 3: ANOVA Results for three heights

Group	ANOVA parameters	S.S.	M.S.	d.f.	F value	F crit	p value
Symmetric Lifting	MAWL & MWL at different heights	116.12	2.524	46	3817.35	4.05	7E-46
	Resting heart rate and Working hear rate	5000	108.7	46	70.84	4.05	7.2E-11
	MAWL, MWL and ΔHR	1158.1	16.78	69	290.2	3.12	2.55E-34
Asymmetric Lifting	MAWL & MWL at different heights	114.5	2.48	46	1271	4.05	3.69E-35
	Resting heart rate and Working hear rate	4159	90.4	46	134	4.05	2.94E-15
	MAWL, MWL and ΔHR	1426	20.7	69	112	3.12	1.9E-22
Symmetrical and Asymmetrical Lifting	MAWL	51.2	1.14	46	83.6	4.05	6.39E-12
Symmetrical and Asymmetrical Lifting	MWL	179	3.89	46	682	4.05	3.12E-19
Symmetrical and Asymmetrical Lifting	Heart Rate	3912	85	46	5.89	4.05	0.0183
Symmetrical and Asymmetrical Lifting	Change in Heart Rate	1989	43.2	46	7.07	4.05	0.017

Figure 9: Relation between MAWL, MWL and ΔHR for Symmetrical and Asymmetric Lifting for large height category

According to the procedure described we found the MWL and MAWL for all the participants and also monitored their heart rates. After all the observations we calculated the means of MAWL and MWL, MAWL to MWL percentages, difference between working heart rate and resting heart rate (Δ heart rate) and relative percentage for all experimental conditions (table 2). Statistical analysis (table 3) (one way ANOVA) is done for all results calculated as above.

Discussion

Our data demonstrated that for symmetrical lifting, the MAWL increases with participants height from small height to large height category (10.5%) and MWL also increases with participants height from small height to large height category (7.7%) ($p<0.05$).The change in Heart Rate ΔHR also increases with participants height from small height to large height category (10.8%) ($p<0.05$). For asymmetrical lifting, the results show that, MAWL increases with participants height from small height to large height category (16.7%) and MWL also increases with participants height from small height to large height category (4.3%) ($p<0.05$).The change in Heart Rate ΔHR also increases with participants height from small height to large height category (8.8%) ($p<0.05$). For short height category, the results show that, MAWL decreases from symmetrical lifting to asymmetrical lifting (27.9%) while MWL decreases (7.6%) ($p<0.05$). The change in Heart Rate ΔHR also increases from symmetrical lifting to asymmetrical lifting (10.8%) ($p<0.05$). For medium height category, the results show that, MAWL decreases from symmetrical lifting to asymmetrical lifting (8.3%) while MWL decreases (33 %) ($p<0.05$). The change in Heart Rate ΔHR also increases from symmetrical lifting to asymmetrical lifting (17%) ($p<0.05$). For large height category, the results show that, MAWL decreases from symmetrical lifting to asymmetrical lifting (17.9%) while MWL decreases (33.4%) ($p<0.05$). The change in Heart Rate ΔHR also increases from symmetrical lifting to asymmetrical lifting (9.8%) ($p<0.05$). (figure7, 8 & 9)

In terms of physiological, asymmetric lifting elevates heart rate during lifting due to trunk rotation. This implies that a practitioner should avoid asymmetric lifting task. Asymmetric lifting decreased MAWL and MWL as compared to symmetric lifting (figure 5). Additional body movement and longer travel distance of the container in asymmetric lifting may also be responsible for lower MAWL and MWL. This study revealed that asymmetric lifting led to lower MAWL while heart rate also increased as compared to symmetric lifting (figure 6),though Garg and Banaag [8] reported heart rate increased with an increase in the angle of asymmetry. It seems that participants adjusted their MAWL psychophysically to achieve a near equal circulatory load for both symmetric and asymmetric lifting. Previous studies confirmed that asymmetric lifting resulted in lower MAWL. However, the decrease in MAWL of 90° asymmetric lifting with trunk rotation to that of symmetric lifting differed among studies due to different experimental conditions, such as lifting frequency, container, lifting range, participants and work duration.

The asymmetric lifting with body turn has an apparent biomechanical advantage over asymmetric lifting with trunk rotation due to lesser trunk twist, which might be safer for the trunk. However, asymmetric lifting with body turn also requires one or two more foot steps in the lifting process. By analyzing MWL data, we found that the difference in MWL between asymmetric lifting with trunk rotation and body turn was more considerable than the difference in MAWL.

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