Determining Changes in Electromyography Indices when Measuring Maximum Acceptable Weight of Lift in Iranian Male Students

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ABSTRACT

Background: In spite of the increasing degree of automation in industry, manual material handling (MMH) is still performed in many occupational settings. The aim of the current study was to determine the maximum acceptable weight of lift using psychophysical and electromyography indices.

Methods: This experimental study was conducted among 15 male students recruited from Tehran University of Medical Sciences. Each participant performed 18 different lifting tasks which involved three lifting frequencies, three lifting heights and two box sizes. Each set of experiments was conducted during the 20 min work period using free-style lifting technique and subjective as well as objective assessment methodologies. SPSS version 18 software was used for descriptive and analytical analyses by Friedman, Wilcoxon and Spearman correlation techniques.

Results: The results demonstrated that muscle activity increased with increasing frequency, height of lift and box size ($P<0.05$). Meanwhile, MAWLs obtained in this study are lower than those in Snook table ($P<0.05$). In this study, the level of muscle activity in percent MVC in relation to the erector spine muscles in L3 and T9 regions as well as left and right abdominal external oblique muscles were at 38.89%, 27.78%, 11.11% and 5.55% in terms of muscle activity is more than 70% MVC, respectively. The results of Wilcoxon test revealed that for both small and large boxes under all conditions, significant differences were detected between the beginning and end of the test values for MPF of erector spine in L3 and T9 regions, and left and right abdominal external oblique muscles ($P<0.05$). The results of Spearman correlation test showed that there was a significant relation between the MAWL, RMS and MPF of the muscles in all test conditions ($P<0.05$).

Conclusion: Based on the results of this study, it was concluded if muscle activity is more than 70% of MVC, the values of Snook tables should be revisited. Furthermore, the biomechanical perspective should receive special attention in determining the standards for MMH

Keywords
MMH, MAWL, EMG, Psychophysical Methodology

Introduction

Although many work activities are largely automated, many occupational settings still are using manual material handling (MMH) which can cause significant problems even with more recently developed industrial activities and technologies [1]. Manual handling is defined as any activity requiring the use of force exerted by

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a person to lift, lower, push, pull, carry, move, hold or restrain a person or an object [2].

One approach used to reduce LBP in the workplace is the psychophysical maximum acceptable weight of lift (MAWL) method [3, 4]. In this method, participants are instructed to imagine they are doing a task for a given period of time and then they have to perform the task for a fraction of the imagined time. Participants are typically given control over one task variable and allowed to adjust that variable to a desired comfort level [5]. Use of psychophysical method in determining MAWL in repetitive lifting jobs is well established [4, 6].

Snook et al., at the American Institute for Liberty Mutual, conducted several studies on workers in different industries and used psychophysical methods to determine the range of weights related to lifting, lowering and other manual handling tasks. Finally, the Institute for Liberty Mutual used the results of these studies and published some tables which are known as "Snook Tables". These tables determine the maximum weight limits for different percentages of male and female workers working in various conditions such as the frequency of lifting, the horizontal distance of load from the body, lifting height and the distance of carrying the load [3].

The basis for this table, on psychophysical and physiological variables such as heart rate, oxygen consumption and biomechanical approach, are not included in the design of these tables.

Although biomechanical variables have been shown to be important determinants of structural failure as well as of increases in risk of LBD, it is unclear if individuals are influenced by or react to biomechanical variables during a psychophysical determination of MAWL, or if in fact individuals can perceive biomechanical variables when changing the weight of the load.

Many developing countries do not define a limit on weights for lifting and carrying safely or they have some weight limits which are not determined based on scientific studies. Many studies related to manual handling of loads are based on the findings of studies which have been already conducted in Europe and North America, or based on the data collected from white populations [7]. In Iran, Snook Tables are used regardless of population and ethnic considerations. As a result, because of the differences in anthropometric factors and other differences between the American and Iranian people, it was necessary to conduct related studies in Iran and among Iranian population. Therefore, the aim of the current study was to determine the maximum acceptable weight of lift using psychophysical and electromyography indices.

Material and Methods

Participants

In the current study, fifteen young male students (20-30 years old) were recruited from Tehran University; sample size was consistent with those of previous studies [8, 9, 10, 11]. The students were examined to ensure that they had no serious cardiovascular problems and no previous history of significant low back pain or musculoskeletal problems in their extremities. They participated in training sessions and became familiar with experimental procedures before the commencement of the main session. For at least two hours prior to the main session and data collection, participants were instructed to avoid eating, smoking and drinking alcoholic beverages or carbonated liquids. They were trained to avoid taking part in any intense physical activity before the experiment and to maintain their normal sleeping patterns. All participants signed an informed consent form and were paid for their participation in the study. The summary of data on the subjects' age, height and weight are presented in Table 1.

Equipment

A height adjustable setup, which is shown in

Table 1: Demographic measurements

Variable	Mean	SD	Range
Age (years)	22.20	2.10	20–26
Weight (kg)	67.50	7.40	54.0–77.0
Height (cm)	177.70	5.30	169.0-187.0

Figure 1, similar to the device used by Snook (1978), was designed and constructed to simulate 18 different lifting conditions considered in this study. A stopwatch was used for time measurements and to instruct the subjects to start and end the test by examiner. Digital weighing equipment was used for measuring and adjusting the weights. Two plastic tote boxes with internal handles were used for putting the weights into and lifting purposes. Internal handles were 17.8 cm long and 4.2 cm thick, and they did not have any sharp edges. The small tote box typified a common small industrial carrying box with the following dimensions: "width: 33.4 cm, length: 56.2 cm, depth: 16.0 cm". The large tote box typified a very large industrial box with the following dimensions: "width: 76.1 cm, length: 56.5 cm, depth: 22.0 cm". The handles were placed midway in the width dimension. The dimensions of the box and handles were the same as those used in the Snook and Ciriello MMH lifting tables [3]. These boxes were rectangular in shape and are shown in Figure 1.

Surface electromyography was conducted using bio-signal g-tech (g.USB amp Austria) instrument. Myoelectric activities of thoracic and lumbar erector spine, as well as left and right abdominal external oblique muscles were recorded.

Electrode Orientation and Placement

In order to ensure the signal recording of studied muscle and to prevent cross-talk, the placement electrodes were conducted based on Europe Electrode Placement Systems (SENIAM) and bipolar method.

To optimize the electrical and mechanical connections before the placement of the electrodes, the surface of skin should be cleaned with alcohol. Thus, in order to reduce the Ohmic resistance of the surface of skin, the examiner first delicately removed a layer of skin by special abrasive sheet and then by ap-

Figure 1: Height-adjustable shelves and boxes for handling lift

plying alcohol, the particles of removed skin were removed.

Electrode wires were also tightly secured with adhesive tape and without internal tensions. Electrodes were placed on the lump, bulge or protrusion of bone and muscle with an inter-electrode distance (IED) of 2 cm. Moreover, the placement of the electrodes on the body is aligned with the orientation of muscle fibers.

The most appropriate spots for the recording of muscles' electromyographic activities were determined and based on the references, the electrode placement was performed on the basis of standard procedures. The electrode placement was conducted as follows:

For abdominal external oblique muscle (AEOM), the placement was done 15 cm from umbilical side at an angle of 45° on external fibers.

For the erector spine muscles (ESM), electrodes were placed around the waist on the right side of the spine parallel to the third lumbar vertebra L3 and within 3 cm from the midline of the back on the muscle ventricle. For the thoracic area, on the right side of the spine parallel to the ninth thoracic vertebrae T9 at a distance of 5 cm from the midline of the thorax chest on the muscle abdomen. Ground electrode was attached to the ulnar styloid process on the wrist.

Figure 2 shows the electrodes orientation and placement in the studied muscles.

Once electrode leads were installed in reference places and the placement of electrodes finished, they were tightly fixed and secured by adhesive tape and a special strap to minimize motion artefacts.

EMG Data Acquisition

In this study in order to obtain and record myoelectric activity, bio-signal g-tech (g.USB amp Austria) was employed. Using 16 silver-silver chloride surface electrodes, electromyography signals with a bandwidth of 5 to 500 Hz and sampling frequency of 1200 Hz from the four aforementioned muscles were collected.

As mentioned earlier, the electrodes were fixed and secured to the specified points aligned with muscle fibers, and ground electrode was attached to the ulnar styloid process.

Maximum Voluntary Contraction (MVC) Test

Biering-Sorensen muscle endurance (BSME) test was used in order to examine erector spine muscle MVC. To this end, subjects lay on their belly over the examination table, with their lower limb placed on the table and their anterior-superior iliac spine on its edge. Three straps were used to tie them to the table. In

Figure 2: electrode placement for erector spine muscles (ESM) in areas ofL3 and T9 and abdominal external oblique muscle (AEOM)

addition, subjects' upper limb and trunk rested on a chair before starting the experiment. Straps were tied in three areas (above the ankles, slightly above knees and slightly below the hip joint) to the extent that the subjects felt comfortable. Then, the subjects were asked to hold their body horizontally without any support. After a 10-minute contraction, the subjects were requested to rest on the bed for two minutes. The experiment was repeated three times, and the average value was recorded as the MVC index.

With respect to the right abdominal external oblique muscle, MVC was calculated through conducting crossed curl-up test; that is, lying in a supine position, subjects were asked to move their right shoulder toward their left leg while trying to exercise the maximum pressure on the right shoulder. By the same token, in order to measure MVC for the left abdominal external oblique muscle, the same method was applied in a mirror liked fashion (left shoulder approaching the right leg). This experiment was conducted three times, with each time lasting for 10 seconds and 2 minute intervals in between.

Experimental Design

A randomized, complete-block, factorial design was utilized to collect data. Three different variables were used in this study i.e., frequency of lifting, height of lifting and size of the box. These three variables are the major descriptors of manual lifting tasks. Three levels of lifting frequency (1 lift/min, 4.3 lifts/min and 6.67 lifts/min) were used. Three different lifting heights (floor to knuckle (F-K), knuckle to shoulder (K-S) and shoulder to arm reach (S-A) were specified. Two different box sizes were used (small and large). Thus, the levels of these three task variables (frequency/height/box size) provided 18 combinations of similar basic manual lifting tasks. Each participant performed lifting for all 18 tasks in random order. Each subject determined the maximum acceptable weight of lift. In a random order, subjects started with either a very light or a very heavy weight (according to 10th percentile and 90th percentile male based on Snook Tables [3], and they were allowed to adjust it to arrive at the maximum acceptable weight of lift. The adjustment took approximately 20 minutes. The final weight at the end of the period was considered as the MAWL of the combined task for that particular frequency.

During the electromyographic test of the studied muscles (including erector spine in L3 lumbar and T9 thoracic regions as well as the left and right abdominal external oblique muscles), MAWLs were simultaneously measured through a psychophysical method. Furthermore, MVC was calculated for each subject at the beginning and end of the test. In order to minimize the negative effects of fatigue, the entire test lasted for two months for each subject.

Study Procedure

Subjects first became familiar with the research methodology and were asked to fill in a demographic questionnaire. EMG electrodes were then installed, followed by conducting MVC test and MAWL test through a psychophysical method. Electromyographic signals for the studied muscles were recorded through the following procedure: during the first three minutes of the MAWL test, subjects were asked to increase/decrease the box weight in order to determine the weight they could lift. They were then asked to hold the lifted box for three minutes while electromyographic signals were recorded. This action was repeated three times with 10-minute intervals. Therefore, three MAWL values were recorded for each person at the beginning of the test. The same procedure was followed at the end of the test as well. Root mean square (RMS) amplitude and median power frequency (MPF) indices were extracted out of six records (three before and three after the test) and their mathematical averages were considered for data analysis.

Totally, each subject had to lift a load 36 times (18 conditions of weight lifting multiplied by the number of tests) during six working days. It should be noted that subjects were required to have only one working day in each week and, after each two weeks, they were asked to rest for a week. Hence, the entire experiment lasted for two months for each subject.

Data Analysis

The data obtained from the studied muscles through measuring variables and analyzing raw electromyographic signals were fed into SPSS (version 18) and subsequently underwent descriptive and interpretive data analyses. The results of Kolmogorov-Smirnov test revealed that the data were not normally distributed. Consequently, non-parametric tests were used in order to analyze the variables.

In this research, P-value of 0 .05 was considered as the criterion for accepting or rejecting the hypotheses.

Analyzing Recorded Signals and Extracting Features

Once electromyographic data were collected, preprocessing, artifact removal and feature extraction were conducted. The preprocessing stage involves filtering and removing artifacts. With the aim of SEMG signal frequency coverage, 500 and 5 Hz were selected as the low-pass and high-pass cut-off frequencies, respectively. At the same time, in order to remove the alternating current (AC) noise interference, a Notch filter with a 50 Hz frequency was used. Signals recorded for subjects at the beginning and end of each test were divided into 3-second periods (each of which was called an epoch) and their features were extracted. Then, the means of three epochs were calculated. All the analyses related to feature extraction were conducted through MATLAB R2013a.

Results

The mean and standard deviation of MAWL for the small box at a frequency of one lift/min at different heights of F-K height, K-S heights and S-A height were 30.00 (± 7.00), 22.00 (± 5.00) and 19.00 (±2.00) Kg. The obtained values for the same box at frequencies of 4.3 and 6.67 lift/min at the mentioned heights are presented in Table 2.

Tables 3 to 6 illustrate the means and standard deviations of studied muscles' RMSs and MPFs at the beginning and end of the test.

Muscles' RMS at the Beginning and End of the Test

The results of Wilcoxon test showed that,

Table 2: Maximum acceptable weights (kg) of lift for various boxes at different heights and frequencies

MAWL (Kg)	1 lift/min(F-K)	4.3 lift/min(F-K)	6.67 lift/min(F-K)	1 lift/min(K-S)	4.3 lift/min(K-S)	6.67 lift/min(K-S)	1 lift/min(S-A)	4.3 lift/min(S-A)	6.67 lift/min(S-A)
small	30.00 (7.00)	25.00 (4.00)	18.00 (4.00)	22.00 (5.00)	17.00 (2.00)	15.00 (1.00)	19.00 (2.00)	17.00 (4.00)	14.00 (2.00)
large	20.00 (4.00)	16.00 (3.00)	14.00 (3.00)	19.00 (2.00)	16.00 (2.00)	14.00 (1.00)	16.00 1.00)	14.00 (1.00)	12.00 (2.00)

Table 3: The mean (SD) of muscle activity (uv) before and after the test in a small box on a different frequency and height of lifting

SMALL BOX		1 lift/min(F-K)	4.3 lift/min(F-K)	6.67 lift/min(F-K)	1 lift/min(K-S)	4.3 lift/min(K-S)	6.67 lift/min(K-S)	1 lift/min(S-A)	4.3 lift/min(S-A)	6.67 lift/min(S-A)
Erector spine(L3)	Before	155.41 (40.10)	136.62 (34.88)	121.00 (36.21)	131.03 (30.33)	104.85 (22.85)	91.10 (18.81)	117.50 (30.04)	106.28 (18.38)	84.85 (25.47)
	after	169.58 (44.36)	148.58 (33.08)	133.07 (29.12)	139.85 (36.31)	111.61 (22.14)	102.06 (26.94)	130.30 (33.77)	124.95 (31.15)	102.02 (41.34)
Erector spine(T9)	Before	152.33 (42.97)	125.99 (33.41)	107.05 (26.14)	120.09 (41.64)	92.34 (22.67)	80.99 (18.26)	109.50 (29.98)	93.61 (15.84)	79.21 (20.27)
	after	143.45 (45.93)	145.48 (25.89)	117.93 (40.81)	123.73 (49.39)	104.71 (24.19)	91.50 (23.04)	119.60 (44.34)	105.10 (17.03)	98.93 (30.85)
Left external oblique	Before	64.26 (19.07)	57.62 (18.69)	50.63 (17.71)	48.80 (13.82)	42.22 (9.66)	38.10 (10.33)	42.65 (16.46)	39.36 (10.79)	33.36 (12.40)
	after	61.77 (17.96)	58.98 (22.32)	55.61 (22.44)	52.35 (18.45)	44.11 (10.68)	41.71 (16.70)	49.25 (18.55)	45.06 (13.53)	36.25 (10.80)
Right external oblique	Before	47.23 (16.14)	41.73 (14.07)	34.19 (8.81)	37.15 (14.06)	30.11 (9.22)	26.79 (7.40)	31.38 (12.38)	28.21 (8.64)	25.13 (7.71)
	after	45.57 (14.68)	43.82 (13.15)	35.62 (10.04)	39.55 (13.48)	32.25 (13.99)	29.81 (14.70)	38.03 (14.73)	30.37 (8.40)	30.34 (8.32)

with regard to both small and big boxes, there was a significant difference between the beginning and end of the test value of the RMS of erector spine in the L3 region irrespective of the conditions (various weight lifting heights and frequencies) ($P<0.05$). That is, the values were significantly larger at the end of the test.

The results further revealed a significant difference between the beginning and end of the test values of RMS of erector spine in the T9 region in almost all the conditions for the small box ($P<0.05$). In fact, knuckle height with the frequency of 1 lift/min was the only condition under which the difference was not statistically considerable. In significant conditions, RMS values were significantly higher at the end of the test. On the other hand, considering the large box, shoulder height condition with the frequency of 1 lift/min was the only condition under which the difference between the beginning and end of the test was not significant. In all other conditions, a significant difference was detected in RMS values of erector spine in the T9 region.

As for RMS values of left abdominal external oblique muscle, the difference between the beginning and the end of the test was significant for the small box under all conditions except for the maximum reach height ($P<0.05$), mediating that these values were bigger at the end of the test. Furthermore, considering the large box, knuckle heights with the frequency of 6.67 lift/min and maximum reach heights were the only conditions under which the dif-

Table 4: The mean (SD) of muscle activity (uv) before and after the test in a large box on a different frequency and height of lifting

LARGE BOX		1 lift/min(F-K)	4.3 lift/min(F-K)	6.67 lift/min(F-K)	1 lift/min(K-S)	4.3 lift/min(K-S)	6.67 lift/min(K-S)	1 lift/min(S-A)	4.3 lift/min(S-A)	6.67 lift/min(S-A)
Erector spine(L3)	Before	128.38 (41.04)	102.16 (27.61)	86.84 (31.26)	114.40 (24.36)	100.39 (28.09)	91.42 (30.07)	103.67 (25.44)	87.73 (29.73)	70.24 (24.94)
	after	135.28 (42.32)	111.19 (41.49)	100.83 (36.11)	121.94 (29.63)	111.30 (30.94)	102.67 (26.15)	114.42 (37.21)	103.58 (36.92)	86.52 (27.77)
Erector spine(T9)	Before	117.26 (46.76)	91.35 (25.37)	77.46 (21.21)	104.56 (23.80)	90.66 (28.46)	81.95 (32.57)	86.96 (18.39)	75.53 (16.21)	66.09 (17.15)
	after	128.88 (42.89)	104.85 (30.43)	90.17 (23.23)	112.46 (31.10)	96.56 (32.26)	85.48 (21.72)	99.70 (30.90)	96.97 (33.96)	76.51 (24.19)
Left external oblique	Before	50.14 (11.25)	40.86 (10.93)	34.66 (10.40)	46.49 (11.87)	39.34 (11.31)	36.23 (11.98)	39.26 (14.16)	32.74 (13.28)	30.19 (12.28)
	after	47.79 (14.94)	46.98 (16.96)	45.49 (16.15)	49.32 (13.52)	45.93 (14.79)	41.95 (16.52)	43.66 (11.57)	37.83 (16.72)	38.10 (14.33)
Right external oblique	Before	36.56 (10.19)	29.72 (7.70)	26.19 (7.12)	34.22 (11.11)	28.42 (8.08)	25.94 (7.85)	28.29 (9.30)	24.35 (8.83)	24.52 (8.03)
	after	38.42 (13.37)	34.55 (17.06)	29.29 (11.53)	36.22 (14.24)	28.66 (8.28)	31.27 (7.19)	34.02 (11.21)	28.34 (12.15)	28.31 (9.39)

ference in the abovementioned values were not significant. Significant differences were detected between the beginning and end of the test values in all other conditions.

Finally, the results of Wilcoxon test indicated that in the case of small box, there was a significant difference between the beginning and end of the test values of RMS for right abdominal external oblique muscle under the conditions of shoulder height with frequencies of 1 and 6.67 lift/min as well as all the frequencies of maximum reach height ($P<0.05$). At the end of the test, the values were much bigger. With regard to the large box, significant differences were detected between the beginning and end of the test values in the shoulder height condition with the frequency of 6.67 lift/min and that of maximum reach height.

Muscle Fatigue at the Beginning and End of the Test

The results of Wilcoxon test revealed that, for both small and large boxes under all conditions (various heights and lifting frequencies), significant differences were detected between the beginning and end of the test values of MPF of erector spine in the L3 region, erector spine in the T9 region and left and right abdominal external oblique muscles ($P<0.05$), that is, all values were significantly higher at the end of the test.

Amount of MAWL

With regard to the small box, the results showed that, save for the condition of knuckle height with the frequency of 4.3 lift/min, the obtained values of MAWL were smaller than those of Snook Tables. Wilcoxon test also in-

Table 5: The mean (SD) of muscle median power frequency (Hz) before and after the test in a small box on a different frequency and height of lifting

SMALL BOX		1 lift/min(F-K)	4.3 lift/min(F-K)	6.67 lift/min(F-K)	1 lift/min(K-S)	4.3 lift/min(K-S)	6.67 lift/min(K-S)	1 lift/min(S-A)	4.3 lift/min(S-A)	6.67 lift/min(S-A)
Erector spine(L3)	Before	53.74 (9.75)	50.17 (7.63)	46.56 (7.15)	50.16 (9.84)	46.01 (6.75)	42.14 (5.07)	47.38 (8.55)	45.30 (8.46)	39.96 (4.29)
	after	44.30 (7.63)	40.51 (5.26)	36.89 (4.11)	42.08 (7.73)	37.30 (6.20)	35.23 (5.59)	40.69 (8.98)	36.74 (7.86)	33.98 (6.38)
Erector spine(T9)	Before	50.04 (7.46)	45.10 (6.22)	42.92 (6.58)	44.91 (8.53)	48.86 (7.18)	39.18 (6.46)	42.78 (7.13)	42.49 (8.02)	40.15 (6.11)
	after	44.25 (7.40)	40.32 (7.40)	36.74 (5.19)	41.24 (8.30)	37.88 (8.07)	35.39 (7.02)	38.30 (9.23)	38.77 (8.79)	33.22 (8.55)
Left external oblique	Before	41.08 (7.94)	36.36 (7.89)	35.84 (7.24)	35.03 (6.43)	33.32 (5.63)	31.94 (6..39)	35.20 (6. 56)	36.14 (7.77)	33.74 (8.34)
	after	33.01 (9.78)	31.30 (6.06)	30.61 (5.67)	30.43 (9.17_)	29.05 (6.57)	28.19 (7.54)	31.52 (6.19)	31.15 (9.20)	29.05 (8.53)
Right external oblique	Before	42.85 (8.07)	41.89 (6.52)	38.04 (5.80)	39.12 (6.76)	36.60 (6.66)	35.19 (6..81)	39.05 (5. 99)	39.11 (7.59)	38.09 (7.94)
	after	35.85 (8.49)	35.62 (5.47)	33.09 (7.80)	31.85 (9.75_)	30.70 (7.14)	30.90 (8.01)	31.45 (8.71)	35.20 (8.80)	31.61 (8.78)

dicated that these differences were statistically significant (P<0.05). The same held true for the large box; that is, except for the knuckle height condition with the frequency of 6.67 lift/min, all other values of MAWL were smaller than those of Snook Tables, with the difference being significant (P<0.05). MAWL average for the present study ranged from 12.3 to 29.93 kg.

In addition, it was found that, during the process of determining MAWL, RMS in the L3 region covered a range of 28% to 93.35% of the MVC. In case of small box at maximum reach height, RMS amounted to over 70% of MVC in all frequencies. Also, with regard to the large box, in all the frequencies of 1 lift/min and 4.3 lift/min under the condition of shoulder height, RMS amounted to over 70% of MVC (Figures 3 and 4).

Furthermore, it was revealed that, during the process of determining MAWL, RMS in the T9 region covered a range of 36% to 168% of MVC.

Similar to the case of L3 region in small box, in all frequencies of lifting, RMS amounted to over 70% of the MVC. Considering the large box, in the frequency of 1 lift/min under the knuckle height condition as well as maximum reach, RMS exceeded 70% of MVC (Figures 3 and 4).

On the other hand, the results showed that, during the process of determining MAWL, RMS of left abdominal external oblique muscles covered a range of 12.38% to 105.48% of MVC.

Regarding the small box, in the frequencies of 1 and 4.3 liters per minute under the maximum reach condition, RMS was more than

Table 6: The mean (SD) of musclemedian power frequency (Hz) before and after the test in a large box on a different frequency and height of lifting

LARGE BOX		1 lift/min(F-K)	4.3 lift/min(F-K)	6.67 lift/min(F-K)	1 lift/min(K-S)	4.3 lift/min(K-S)	6.67 lift/min(K-S)	1 lift/min(S-A)	4.3 lift/min(S-A)	6.67 lift/min(S-A)
Erector spine(L3)	Before	47.15 (8.14)	43.14 (7.85)	39.11 (6.75)	46.97 (8.58)	42.36 (4.99)	40.32 (6.56)	43.44 (6.48)	42.02 (7.35)	39.88 (9.63)
	after	38.49 (4.97)	36.17 (3.92)	32.20 (4.45)	38.06 (8.22)	36.45 (5.21)	33.03 (5.51)	38.82 (6.40)	35.03 (8.44)	32.68 (9.53)
Erector spine(T9)	Before	45.73 (7.77)	44.53 (6.76)	40.93 (7.63)	43.43 (9.48)	39.10 (7.55)	37.69 (4.74)	38.36 (6.61)	39.54 (4.33)	37.33 (8.41)
	after	41.15 (6.41)	38.18 (4.14)	32.82 (7.85)	37.69(10.66)	33.91 (9.96)	31.77 (7.26)	35.80 (6.59)	33.29 (5.40)	31.93 (7.68)
Left external oblique	Before	36.90 (4.32)	34.05 (7.44)	33.04 (6.47)	33.57 (5.19)	33.19 (6.43)	33.09 (5.53)	33.95 (6.58)	36.23 (4.79)	31.83 (8.03)
	after	33.19 (4.79)	29.55 (7.98)	27.94 (7.11)	26.07(5.90)	27.61 (6.28)	28.19 (7.21)	32.74 (8.13)	31.26 (6.24)	27.14 (8.15)
Right external oblique	Before	41.84 (6.10)	37.06 (3.84)	36.48 (6.11)	37.67 (7.98)	35.36 (5.95)	34.79 (4.87)	36.83 (7.25)	37.81 (4.44)	34.93 (8.10)
	after	34.19 (5.77)	31.32 (5.44)	31.37 (8.39)	30.05 (9.89)	30.16 (7.32)	25.59 (7.39)	32.98 (7.91)	33.27 (7.69)	29.38 (7.20)

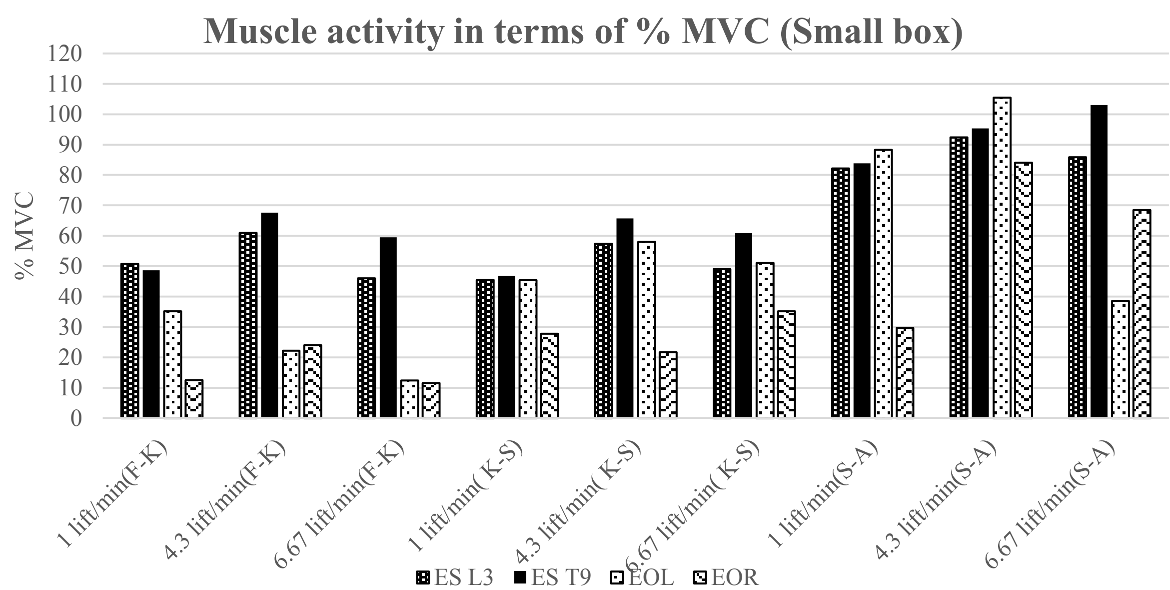

Figure 3: Muscle activity in terms of % MVC for small box at different heights and frequencies when determining the maximum acceptable weight of lift.

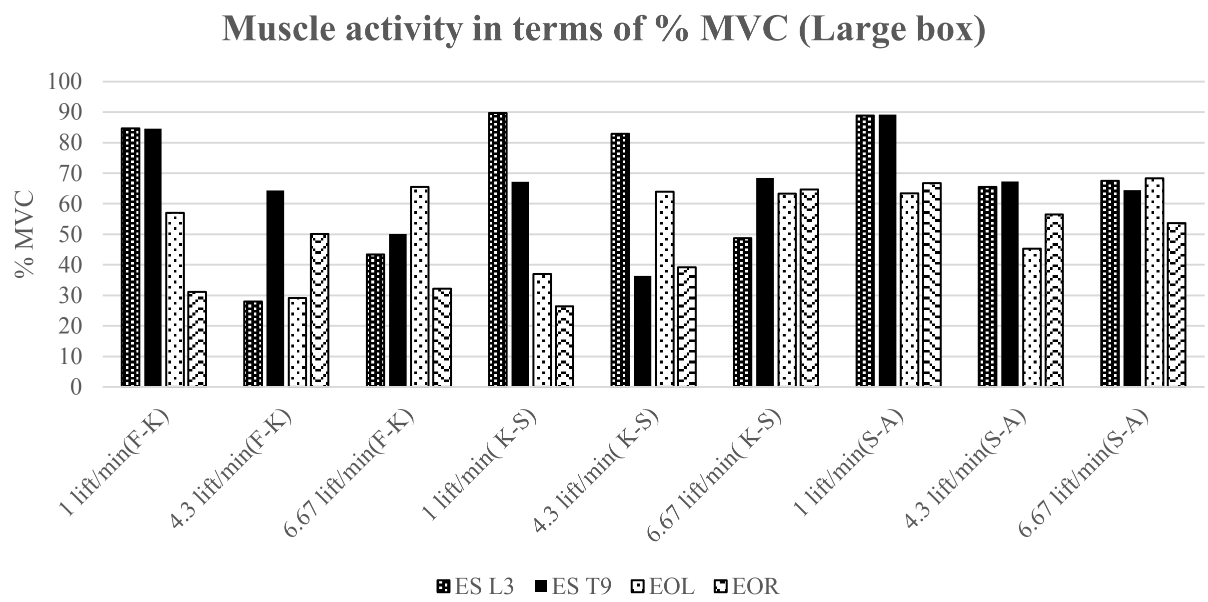

Figure 4: Muscle activity in terms of % MVC for large box at different heights and frequencies when determining the maximum acceptable weight of lift.

70% of MVC. Also, with respect to all conditions of the large box, RMS was less than 70% of MVC (Figures 3 and 4).

The results also indicated that, during the process of determining MAWL, RMS of right abdominal external oblique muscles covered a range of 11.53% to 84.08% of MVC.

When it comes to the small box, in the frequencies of 4.3 liters per minute under the maximum reach condition, RMS was more than 70% of MVC. Additionally, considering all the conditions of the large box, RMS was less than 70% of MVC (Figures 3 and 4).

In total, under the maximum reach condition and in 1 and 4.3 lift/min, RMS of all studied muscles was over 70% of MVC.

Correlation between Studied Muscles' RMS Variables/MPF and MAWL

The results of Spearman correlation showed that there was a significant correlation between the RMS of erector spine in the L3 region and MAWL at both the beginning and end of the test (P<0.05), mediating that an increase in MAWL would lead to the rise of RMS. Similarly, the RMS of the muscles of erector spine in the T9 region and right abdominal external oblique muscles had a significantly positive correlation with MAWL at both the beginning and end of the test (P<0.05). Thus, as the value of MAWL increased, the value of RMS rose as well.

The results of Spearman correlation also indicated a significant correlation between the MPF of erector spine in the L3 and T9 regions and MAWL at both the beginning and end of the test (P<0.05). This correlation was negative which means that an increase in MAWL would result in a decrease of MPF. In addition, the correlation between the MPF of right and left abdominal external oblique muscles and MAWL was statistically significant at both the beginning and end of the test (P<0.05), accordingly, as the value of MAWL increased, that of MPF declined.

Discussion

Amount of MAWL

The results revealed that the values obtained for MAWL in the current study were smaller than those of Snook Table. This discrepancy can be explained; in this study EMG index to determine the maximum acceptable weight lifting, unlike Snook Tables, used only physiological criteria which has a high sensitivity setting as for the selected weight. The difference can also be in the light of anthropometric and racial differences between American and Iranian societies; therefore, when it comes to the Iranian context, it is necessary to utilize the values obtained based on Iranian subjects (e.g. the present study) to determine the standard limits for carrying and lifting loads in industries and to reduce related risks.

In this study, the level of muscle activity in percent MVC is taken into account when determining the maximum acceptable weight lifting psychophysical methods in relation to the erector spine muscles in the L3 and T9 regions as well as left and right abdominal external oblique muscles at 38.89%, 27.78%, 11.11% and 5.55%, respectively in terms of muscle activity is more than 70% MVC.

Numerous studies have shown that if muscle activity is over 70% of MVC, spine muscles especially in the lumber area are likely to be hurt [12, 13 and 14]. Snook Tables have been constructed based on physiological and psychophysical indices without taking the biomechanical perspective into account. Based on the results of the current study, if muscle activity is more than 70% of MVC, the values of Snook Tables should be revisited. Furthermore, the biomechanical perspective should receive special attention in determining the standards for carrying loads by hand.

Muscle Fatigue and Muscle Activity

According to Panjabi (1992), three elements are essential in maintaining spine stability: passive, active and nervous systems. Disorder in any of these elements can disturb spine stability which in turn may lead to backache [15]. One of the factors that makes the spine unstable is changing its structure and using the muscles of this region in an incorrect and unsuitable way. The inappropriate use of these muscles may weaken them, causing disorder in their performance, leading to fatigue and, subsequently, backache. The main muscles that stabilize spine are para-spinal and abdominal muscles [16 and 17].

Evaluating the degree of fatigue for lumbar muscles can be used in scanning, ergonomics, rehabilitation and even prediction of prospective backaches. One of the most useful instruments for analyzing muscles' fatigue is surface electromyography (SEMG) signals. Due to their non-aggressive nature, they have received a lot of attention [18].

In fatigue-related studies via electromyography, the focus is on the changes of electromyographic domain and range. The typical parameter for studying domain changes in electromyography is Root Mean Square (RMS) or Electrical Activity, while frequently used parameters for studying the frequency range of electromyographic recorded signals are Median Frequency and Median Power Frequency.

As the degree of fatigue increases, the domain rises and the range of electromyographic recorded signals declines [19, 20]. Lin et al.'s study showed that, for analyzing muscle fatigue in dynamic and long contractions with low levels of power, frequency range is a more valid and suitable parameter than domain [21].

The results of the present study indicated that, in all muscles studied (including erector spine in the L3 and T9 regions and left and right abdominal external oblique muscles), there were significant differences in the RMS and MPF at the beginning and end of the test. More precisely, RMS increased at the end of the test, whereas MPF declined. This can be attributed to the MAUP recode and the increase of their firing frequency. The findings of this study in this regard are in line with those of similar research projects.

Tucker et al. (2009) studied the electrical activity of erector spine, while, some healthy subjects held a load for 6 minutes. They found that RMS index significantly increased during the load holding period, while MPF went down [22].

Kumar (1997) concentrated on the electromyographic behavior of trunk muscles among healthy men and women while they were holding a load for some time. The results showed that, in the course of time, the MPF of erector spine muscles dwindled [23].

The findings of this study illustrated that as MAWL increased, RMS significantly went up, a finding that is similar to that of other studies.

Arjmandi and Shirazi (2006) studied the effects of bending forward with and without holding loads in hands on muscle power and concluded that as the amount of external load increased, muscle power went up. They also showed that there was a significant correlation between eletromyographic RMS of back muscles and the amount of the load p24].

AbdoliErmaki et al. (2006) aimed at determining the electromyography in L3 and T9 erector spine muscles as well as external and right abdominal oblique muscles during the process of carrying a load by hands. They demonstrated that as the amount of load increased, the RMS of spine muscle increased too; this indicates a possible relationship between electromyography and lifted load [25].

Sonya Chan (2007) conducted a research on the electrical RMS of spine and upper limb muscles during the process of carrying loads by hand. The results showed that there was a significant relationship between the value of RMS and the amount of load in hands [26].

It is recommended that similar studies be conducted with females. This study was conducted only on students whose ages ranged from 20 to 30, because they were easily available; therefore, it is recommended that similar studies be conducted with workers with a wider age range in order to obtain more accurate standards for the maximum acceptable weight of lift and to reduce the risks of handling weights.

Conclusion

In Iran, Snook Tables are used regardless of population and ethnic considerations. Factors like eating habits, ethnicity, work culture etc. affect the variations in Iranians' physique and anthropometry Vis-a` -Vis the Americans. As a result, because of the differences in anthropometric factors between the American and Iranian people, it was necessary to conduct related studies among Iranian population.

The results also indicated that when RMS is over 70% of MVC, the values of Snook Table should be revised. Furthermore, the biomechanical perspective (e.g. electromyographic indices) must be taken into account for determining the legitimate limitation for carrying loads by hand.

In addition, the results showed that when MAWL increased, RMS and MPF went up and down, respectively.

According to the results presented in this study, the current approaches which are often employed during the design of manual materials for handling tasks (incorporating the loads that 95% of males could perform based on Snook and Ciriello Tables (1991) may not be sufficiently protective for Iranian male workers in the workplace.

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Conflict of Interest

None

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