Determination of maximum acceptable weight of lift by adult Indian female workers

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Abstract

A study on maximum acceptable weight limit (MAWL) was conducted on ten adult Indian female building construction workers (CW) and eight household workers (HW), following the psychophysical methodology. All these workers were in the age group of 28–32 years. In this study, three different body heights (i.e. knee, waist and maximum reach) in sagittal plane were considered. The lifting frequency was fixed at 1 lift min$^{-1}$. The subjects were instructed to lift the load from the ground. Each set of experiments was conducted for 45 min work period using free-style lifting technique. Subjects were using a load container with no handle, which is typically used in the field. Both the working heart rates (WHR) and pause heart rates (with 4.4 s interval) were collected for the entire duration. The subjects were requested to rate their perceived exertion level after each load adjustment. The average MAWL working heart rates of CW group are 106.2(±8.3), 108.7(±9.3) and 106.8(±11.0) beats min$^{-1}$ for knee, waist and maximum reach heights, where the load levels were estimated as 18.2(±0.8), 17.4(±1.4) and 16.3(±1.2) kg, respectively. For HW group, the MAWL working heart rates obtained were 101.3(±8.0), 99.6(±6.2) and 105.2(±6.1) beats min$^{-1}$ for knee, waist and maximum reach heights and the corresponding load levels were 15.4(±0.5), 14.4(±0.7) and 13.9(±1.2) kg, respectively. Both the groups psychophysically rated the work in moderate to heavy category. A best-fit curve was obtained from average normalized baseline pause heart rates with work duration ($t$) as Avg. N.H.R$_{\text{base}} = k.t^n$. It has been observed that with extrapolation of the work duration to 8 h from 45 min experimental observation, the heart rate would increase to about 6–8 beats min$^{-1}$ for both the groups of workers. This equation can be used to approximate the effect of work-duration on heart rate.

Relevance to industry

MAWL study was performed on industrial female workers, which is rarely reported in the literature. Moreover, earlier studies were mainly conducted on the Americans. This study is focused on Indian population to compare the
applicability of NIOSH guidelines in Indian context.

Keywords: MAWL; Indian female workers; Work duration; Heart rate; Psychophysical rating

1. Introduction

Maximum acceptable weight limit (MAWL) is determined by the workers, as the highest acceptable workload, which can be lifted comfortably based on their perceived exhaustion level (Gambarale, 1985). Use of psychophysical method in determining MAWL in repetitive lifting jobs is well established (Snook, 1978; Legg and Myles, 1981). Snook (1978) first introduced the term MAWL for the industrial workers engaged in different types of repetitive lifting tasks. In his report, Snook (1978) proposed a methodology to determine MAWL, where the subjects are asked to select the maximum acceptable load effectively of their own choice that they can lift under a specific condition for 8-h workday ‘without straining themselves or without becoming unusually tired, overheated, weakened or out of breath’. Many authors (Legg and Myles, 1981; Mital and Manivasagan, 1983; Aghazadeh and Ayoub, 1985; Karwowski and Yates, 1986; Ciriello et al., 1990; Fernandez et al., 1991) suggested that the psychophysical approach is a reliable method in assessing the perceived exertion during manual material handling (MMH) task in low and moderate frequencies ($4 \text{ lifts min}^{-1}$). However, it is also reported that this method overestimates the workers’ capacity for high lifting frequency ($>6 \text{ lifts min}^{-1}$) conditions (Ciriello and Snook, 1983; Asfour et al., 1985; Karwowski and Yates, 1986). In 1991, NIOSH committee selected this psychophysical criterion as an alternative determinant for estimating the safe load limit. In this criterion, it is mentioned that the estimated load will be accepted by 99% of male workers and 75% of female workers, or 90% of the whole working population (i.e. in a population of equal number of males and females). In a study on rate of perceived exertion (RPE), Karwowski (1991) showed that while selecting the maximum acceptable weight for 8-h job, the female subjects rated the load as moderate or heavy weight, whereas most of the male subjects rated the load as either heavy or very heavy. Therefore, the authors concluded that the female subjects were more realistic with respect to subjective perception of load heaviness in selecting MAWL value. Kelsey et al. (1984) also reported similar results.

Regarding the selection of the duration of simulated experiment which should reflect the 8 h job criteria in industry, Mital (1983) reported that at the end of 8 h females were lifting only 85% of the load that they had selected at the beginning of the psychophysical experiment. This is because with the advancement of work time the work-efficiency decreases. Ciriello et al. (1990) suggested that 40 min work is sufficient to select the acceptable load. Several studies (Ayoub et al., 1978; Snook, 1978; Mital, 1984) mention that 20–30 min experimental work duration is adequate to estimate the appropriate workload for an 8 h or 12 h workday. Ayoub and Mital (1989) categorically mentioned that 40–45 min work period is sufficient to determine the weight, which the subject can lift for 12 h duration even if it includes 4 h overtime about which they have no prior warning.

In psychophysical experiment, the task is generally initialized with a random load weight and the subject is asked to adjust the load based on their choice such that the load will be acceptable for 8 h for repetitive handling operation. Snook (1978) provided a 40 min adjustment period to allow the participants to monitor their own feelings and adjust the load weight. A significant difference of this adjustment period is found in earlier studies. Some authors (Garg and Saxena, 1982; Garg and Beller, 1994) used a longer adjustment period (i.e. 45, 50, or 60 min). Again, in other studies (Mital, 1983, 1984; Karwowski and Yates, 1986; Mital and Aghazadeh, 1987; Zhu and Zhang, 1990; Chen et al., 1992), it is mentioned that participants could determine the
MAWL load weight within shorter adjustment period. In these studies, the authors identified many factors affecting this perceived subjective response such as, workers and load characteristics, type of task, work environment etc. and also the load weight factor.

In 1981, National Institute for Occupational Safety and Health (NIOSH) recognized the growing problem of work-related back injuries and published a summary of lifting-related literature. It also provided a lifting equation for calculating a recommended weight for specified two-handed, symmetrical lifting tasks, an approach for controlling the hazards of low back injury from manual lifting (NIOSH, 1981). In 1991, a revised lifting equation was developed with more number of lifting parameters (Waters et al., 1993). In Europe and North America, this NIOSH equation is well established, but the applicability of NIOSH equation across different countries is under question (Zhu and Zhang, 1990; Evans, 1990; Lee et al., 1995; Wu, 1997). In fact, manual handling problem is more severe in developing and underdeveloped countries. For example, in India, the laborers are continuously over-exhausted without the protection of any constraint law. These workers are employed temporarily by the labor contractors on daily wage basis, not as the direct payee of the organization. No records are maintained on their health or industrial accidents. The Factory Act, 1948, does not indicate the safe load limit for Indian population. In Maharashtra (one of the developing state in India) the Maharashtra Factory Act (Rule no. 66) specified the maximum limit of weight handled by an adult female worker as 30 kg (Dwivedi, 2000), which seems to be heavy for the workers. According to Joshi et al. (2001), the existing Indian Factory rule inadvertently created the occupational health hazard conditions in industries. Most of the literature reported in this area, the studies were carried out on college students (not on industrial workers) who were not habituated to the task. Moreover, this type of study on Indian female workers is not available in literature.

In this context, a laboratory simulation study was carried out for the first time on adult Indian women workers for estimating maximum acceptable load limit for manual lifting. In this experiment, two different groups of workers participated; (1) building construction workers (CW) and (2) household workers (HW). The objectives of this study are (1) to estimate the MAWL level for these two groups of Indian adult female workers following psychophysical criteria, (2) to evaluate the difference of MAWL levels due to a particular job-habit, (3) to study the psychophysical rating responses against the lifted load, (4) to study the group difference in their predicted load and the actual load weight, and lastly (5) to find the effect of work-duration on heart rate.

2. Methods

Ten female workers having at-least 7 years of work experience as building construction laborers and eight household workers participated in this study. The household workers had at-least 4–5 years of experience. The construction workers (CW) generally work in the field daily from 9.00 to 18.30 with 30 min lunch break. On some days, they work even more. On the other hand, the household workers (HW) used to work 7–9 h in 3–4 houses daily. Actually, their job mainly consists of cleaning the utensils and houses, manually washing the cloths, mopping the floor, cutting the vegetables, making food, bringing water, etc. Both the groups were categorized within age group of 28–32 years, with no history of chronic or acute illness, no record of hypertension or acute rheumatic problem, not currently under any medications and not pregnant. They were instructed not to take any stimulant for at-least 2 h prior to their participation and throughout the experiment. Both the groups were belonged to same economic group and were slum dwellers. The demographic details of the subjects are given in Table 1.

Before starting the experiment, the subjects were thoroughly instructed to make them understand properly about the aim of this study. Thereafter their consents were taken. A minimum amount of token money (equivalent to 1.5 days wages i.e. ~2.0 USD) was given as a reimbursement of their daily wage, as there was a high chance of loosing their on-going temporary job. The subject was
asked to select the maximum amount of load according to their choice, which they could continue for 8 h, as per the conditions defined by Snook (1978). Before starting our laboratory experiment, one arbitrary base load was provided, and the subjects were asked to adjust the suitable load weight by themselves during the experiment. Since the industrial workers were participated in this study and they were well experienced with this type of load handling, therefore, the shorter load adjustment time was allotted. This load adjustment was performed at 4 different points in time, at the beginning, after 5, 10 and 20 min of the work, respectively. While adjusting the load, they were verbally encouraged to take maximum amount of load, which they could carry without straining themselves. After each load adjustment, the subjects were also asked to guess the amount of load and then their psychophysical ratings on this lifting job were collected based on 5-point scale (Varghese et al., 1994) as I. very light—1, II. light—2, III. moderate—3, IV. heavy—4, and V. extremely heavy—5. The final MAWL load weight was estimated at the end of experiment (45 min duration) from base load and adjusted load weights. The subjects were not having any knowledge about base load, adjusted load even the final MAWL load weights.

The lifting duration was 45 min with lifting frequency of 1 lift min⁻¹ and the origin of lift was set at the ground level. Three vertical lifting distances in saggital plane were selected, i.e. knee, waist and maximum reach. The maximum reach point was identified as where the subject could handle the load at a maximum height without hyper-flexing the body, and generally it was near the eye–ear line level. Each subject completed three sets of experiments. These three sets of experiments on each subject were distributed in such a way that the effect of maximum reach height was studied in one day and two other sets of experiments on different vertical height levels were studied on another day with sufficient rest pause. The whole study was completed within two months period.

It was observed that in the construction industries, specially for handling the concrete mixture, a half-oval shaped with round-opening container, called “Ghamela” was used. This container was made of steel plate, without any handle. Same type of container was used in this study (Diameter: 35.2 ± 2.53 cm and Depth: 8.30 ± 1.27 cm). These construction workers generally handle pebbles, sands, concrete mixtures, etc. in the actual field. Therefore, in this study, pebbles were selected as load and there was no problem related to the discriminability of load heaviness. The subjects were instructed to adjust the load weight, on their own, as per their comfort. One male worker was engaged to manually lower the load. The after-lunch session was generally started 2–3 h after the lunch break. The workers wore their usual daily cloth as they did in the field. During this experiment, the laboratory room temperature was 28 ± 1.3 °C as compared to the actual field condition observed in the months of April, May and June, where wet-bulb temperature 26.8 ± 0.65 °C, dry-bulb temperature 33.3 ± 1.6 °C, globe temperature 46.7 ± 5.0 °C (under Sun) and 33.3 ± 2.8 °C (under shade).

An experimental rig was made in-house by using slotted angles with a wooden platform. A periodic sound was generated from a computer to control the frequency of lifting. The vertical lifting distances were set according to the subjects’ anthropometry. Subject stood on load cell platform of a weighing machine during the experiment. An amplifier was made in house to amplify the load-cell output. Two Ag–AgCl electrode were attached on Manubrium-Xyphoid body line to

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (Yrs)</th>
<th>Height (cm)</th>
<th>Body weight (kg)</th>
<th>Knee height (cm)</th>
<th>Waist height (cm)</th>
<th>Eye height (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CW</td>
<td>29.5 ± 2.8</td>
<td>148.3 ± 4.4</td>
<td>37.5 ± 5.4</td>
<td>47.0 ± 1.9</td>
<td>86.2 ± 3.4</td>
<td>131.2 ± 4.1</td>
</tr>
<tr>
<td>HW</td>
<td>29.6 ± 1.6</td>
<td>145.1 ± 5.6</td>
<td>45.6 ± 4.9</td>
<td>42.5 ± 4.6</td>
<td>84.9 ± 3.6</td>
<td>127.7 ± 4.2</td>
</tr>
</tbody>
</table>

Table 1
Demographic description of the subjects (both CW and HW group)
collect ECG signal with skin resistance of $<5$ k$\Omega$. Both these ECG and amplified load cell output were fed to a computer via A/D conversion process, with a sampling rate of 1100 samples $s^{-1}$. The side view of the subject was recorded by a video camera. Just before the A/D conversion (40 $\mu$s), two $+5$ V D/A signals were generated. One of them was used to micro-switch a video pointer, which in turn helped to print a cross mark on a corner of the video image. The other one was used to lit a LED, focused towards the camera. These were acting as synchronizing signals for the video recording. The video images were stored into a cassette. The experimental set-up is outlined in Fig. 1.

The resting body weight of the subject was offset to zero of the load-cell response just before starting the actual work. Later, while lifting, the dynamic change of body weight was reflected in the load cell output response. The change of load-cell output from a steady line response indicated the precise onset and duration of the actual lifting (Fig. 2(A)). The postural images were digitized offline with sampling rate of 25 frames $s^{-1}$. The video output data of the lifting duration were used to indicate the lifting posture. The joint co-ordinates of the lifting postures were identified with respect to a particular reference-point. From those co-ordinates the joint angles were calculated and the stick diagrams were drawn (as shown in Fig. 2(C)) using their original body-lengths, collected in anthropometric study.

The experimental heart rates were taken as the average of two successive heart rates. The individual heart rate was calculated from digitized ECG signals as follows:

$$
H.R. \text{ (beats min}^{-1}) = \frac{\text{Sampling rate}}{\text{No. of samples between R–R waves}} \times 60.
$$

The working heart rate was considered as the heart rate just after the lifting, as typically depicted in Fig. 2(B), where two successive heart rates were taken after the position marked as ‘S’. After the working heart rate, the pause heart rates were sampled with an interval of 4.4 s. Eleven pause heart rates were collected from each pause period of around 1 min, in between two successive lifts. To reduce the inter-subject variation effect, the heart rates were normalized. As the baseline heart rates fluctuated quite a bit, the normalization was done with individual’s maximum heart rate as follows:

$$
\text{Normalized Heart Rate \left[ N.H.R. \right]} = \frac{\text{Max. H.R. – Working (or Pause H.R.)}}{\text{Max. H.R.}}.
$$

The maximum heart rates from these subjects were recorded separately during maximum aerobic power measurement by treadmill exercise (Maiti, 2001). After normalization of individuals’ heart rate, the average was taken across the subjects within a particular group and was termed as Average Normalized Heart Rate (Avg. N.H.R.).

3. Results

3.1. Maximum Acceptable Weight Limit (MAWL)

A comparative result of MAWL of lifting between the CW and HW groups is plotted in Fig. 3. As evident from this figure, the CW group could lift more amount of load than HW group. The ANOVA result (Table 2) shows an increase in vertical lifting distance caused a significant decrease in load-weight for both the groups ($p<0.001$). In case of CW group, when the vertical lifting distance changed from knee to waist height, the MAWL decreased by 4.4%. A further 6.4% decrease of MAWL was noted while lifting from waist to maximum reach height. In case of HW group, these decreases of MAWL level were obtained as 6.4% and 3.9%, respectively. It was also observed that the CW had an overall higher ($p<0.001$) lifting capacity than their counterpart, i.e. HW group. The subjective ratings, collected at the end of the experiment are presented briefly in Table 3.

3.2. Difference between the perceived load and actual load weight

For CW group, the mean difference between the perceived load weights (i.e. what the subject
assumed after each time adjustment) and the actual load weights was obtained as $1.4 \pm 2.8 \text{ kg}$, whereas the same for HW group was $2.3 \pm 3.7 \text{ kg}$. From this result, it is inferred that the CW group was much more experienced with the amount of lifted load than HW group.

### 3.3. Effect on working heart rate

The variations in mean and standard deviation of the MAWL working heart rates are shown in Fig. 4. One-way ANOVA result (Table 4) shows that the mean working heart rates were significantly different at 3 vertical lifting distance conditions (i.e. knee, waist and maximum reach heights). This result also indicated that these working heart rate levels were significantly different between CW and HW groups.

### 3.4. Effect of work duration on heart rate

The typical pattern of average normalized heart rate with lifting time is shown in Fig. 5. In this figure, the heart rate data were collected from CW group for knee height response. In this figure, the working heart rates are marked as solid circles. However, during the pause time, after each lifting, the subjects were only standing. They claimed that they felt tired because of merely standing for a long time without movement. As a result, along with the workload, the fatigue also may occur from this constrain working posture for a long period. However, Fig. 5 shows that there are high
fluctuations in working heart rates (marked as solid circles), as the frequency of lifting was low. It is also showed that first 2 normalized pause heart rates were even less than the normalized working heart rate (Fig. 5). Then, the normalized pause heart rates increases towards the baseline level and fluctuates before it settled down. Therefore, a baseline zone was selected excluding first 2 higher normalized pause heart rates. To calculate the effect of work duration, the best-fit equation was developed based on the selected zone of Avg. N.H.R. not on all the Avg. N.H.R. data and was termed as Avg.N.H.R\_base. Changes in Avg.N.H.R\_base levels with working time ($t$) followed a power equation as:

\begin{equation}
\text{Avg.N.H.R}_{\text{base}} = k \cdot t^a.
\end{equation}

Here $t$ represents working time in minute. The fitted parameters $k = 0.529$ and $a = -0.0376$ were obtained from CW group for knee height response. Similar kind of power-fit was performed

**Table 2**
ANOVA results for evaluating MAWL at different lifting distances for both CW and HW group

<table>
<thead>
<tr>
<th>Target group</th>
<th>ANOVA parameters</th>
<th>S.S.</th>
<th>M.S.</th>
<th>d.f.</th>
<th>F-ratio</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CW</td>
<td>MAWL at different heights</td>
<td>21.352</td>
<td>10.676</td>
<td>2</td>
<td>8.385</td>
<td>0.00147</td>
</tr>
<tr>
<td>HW</td>
<td>MAWL at different heights</td>
<td>7.454</td>
<td>3.727</td>
<td>2</td>
<td>5.346</td>
<td>0.01766</td>
</tr>
<tr>
<td>CW vs HW</td>
<td>MAWL (knee height)</td>
<td>32.36</td>
<td>32.36</td>
<td>1</td>
<td>64.46</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>CW vs HW</td>
<td>MAWL (waist height)</td>
<td>33.07</td>
<td>33.07</td>
<td>1</td>
<td>24.71</td>
<td>0.000204</td>
</tr>
<tr>
<td>CW vs HW</td>
<td>MAWL (Max. reach height)</td>
<td>22.17</td>
<td>22.17</td>
<td>1</td>
<td>16.27</td>
<td>0.00123</td>
</tr>
</tbody>
</table>

**Table 3**
Mean ± SD results of psychophysical rating response, collected from the subjects, at the end of each set of experiment of 45 min duration

<table>
<thead>
<tr>
<th>Target group</th>
<th>Knee height</th>
<th>Waist height</th>
<th>Max. reach height</th>
</tr>
</thead>
<tbody>
<tr>
<td>CW</td>
<td>3.4 ± 0.52</td>
<td>3.5 ± 0.53</td>
<td>3.5 ± 0.53</td>
</tr>
<tr>
<td>HW</td>
<td>3</td>
<td>3.17 ± 0.41</td>
<td>3</td>
</tr>
</tbody>
</table>

Fig. 3. Graphical representation of average MAWL levels at 3 different vertical lifting distances, were estimated by HW and CW groups. The error bars are represented the SD of the heart rate response.
Fig. 4. Average working heart rate responses obtained from HW and CW group during MAWL study. The error bars are represented the SD of the heart rate response.

Table 4
ANOVA results on the working heart rates at different lifting distances are presented for both CW and HW group

<table>
<thead>
<tr>
<th>Target group</th>
<th>ANOVA parameters</th>
<th>S.S.</th>
<th>M.S.</th>
<th>d.f.</th>
<th>F-ratio</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CW</td>
<td>Working HR at different heights</td>
<td>153.88</td>
<td>76.94</td>
<td>2</td>
<td>10.45</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>HW</td>
<td>Working HR at different heights</td>
<td>255.19</td>
<td>127.59</td>
<td>2</td>
<td>14.90</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>CW vs HW</td>
<td>Working HR (knee height)</td>
<td>496.31</td>
<td>496.31</td>
<td>1</td>
<td>105.62</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>CW vs HW</td>
<td>Working HR (waist height)</td>
<td>1922.20</td>
<td>1922.20</td>
<td>1</td>
<td>175.35</td>
<td>0.00001</td>
</tr>
<tr>
<td>CW vs HW</td>
<td>Working HR (Max. reach height)</td>
<td>1671.31</td>
<td>1671.31</td>
<td>1</td>
<td>202.68</td>
<td>0.00001</td>
</tr>
</tbody>
</table>

on Avg.N.H.R.\textsubscript{base} for other vertical lifting distances and also for HW group responses. From these equations, the Avg.N.H.R.\textsubscript{base} level was extrapolated to 8h work duration. For easy interpretation, the Avg.N.H.R.\textsubscript{base} was again converted to normal heart rate by using average maximum heart rate and was termed as Base Heart Rate (HR\textsubscript{base}). For CW group, after 8h of work, the calculated HR\textsubscript{base} were obtained as 109.9, 112.1 and 106.8 beats min\textsuperscript{-1} for knee, waist and maximum reach height, respectively. For HW group, these heart rates were obtained as 105.7, 103.2 and 103.7 beats min\textsuperscript{-1}. Therefore, in combination of different vertical lifting distances, for CW group, after 8h of work, the HR\textsubscript{base} would increase by an average of (7.8 ± 1.4) beats min\textsuperscript{-1} from 45 min work level in case of CW group; whereas, for HW group, the increased heart rate was calculated as (5.9 ± 2.1) beats min\textsuperscript{-1}.

3.5. Effect of load adjustment period

In this study, the load adjustment was performed at 4 different points in time, (1) just
before starting of the work, (2) after 5 min, (3) after 10 min, and (4) after 20 min of work. From Table 5, it is observed that the maximum amount of load was adjusted at 5 min of job whereas at 20 min almost no load adjustment was performed.

4. Discussion

NIOSH lifting equation is generally used by health practitioners and ergonomists to analyze the work stress factors in the work environment. This, in turn, helps to reduce the Low Back Disorder (LBD) among the industrial workers. This equation was developed based on the studies on American population and the applicability of this NIOSH equation in different racial population is doubtful as the Occidentals have different physique, body anthropometry, etc. as compared to other ethnic communities. Zhu and Zhang (1990) and Wu (1997) reported that MAWL for Chinese subjects were less than that observed for the Western population. Evans (1990) and Lee et al. (1995) have mentioned that the NIOSH limit might not be applicable for non-Western population. However, no study is reported on the applicability of this NIOSH equation on the Indian Women workers till date. The calculated RWL (using 1991 revised NIOSH lifting equation) is obtained as 15.34 kg, in case of lifting from floor to the knee height with lifting frequency of 1 lift min\(^{-1}\) and for 1 h duration of work, which is comparable as observed in present study. However, it is reported that these Indian workers have lower aerobic power than the Americans (Maiti, 2001) and poor physique status. Moreover, factors like food habits, ethnic group, work culture etc. also affect the variations in Indians' physique, antropometry, brawn and faculty vis-à-vis the Americans. Mital et al. (1997) estimated the
recommended load weight for the industrial female workers (based on physiological criterion) and suggested that for two-handed symmetrical lifting with lifting frequency of 1 lift min\(^{-1}\) and the box size of 34 cm for 8 h job the load weight should be 12 kg (75th percentile)–14 kg (50th percentile). This load weight is slightly lower than the present study result, as physiological approach might have overestimated the actual physiological stress factor in lower lifting frequency conditions, because according to Ayoub (1992), in case of lower lifting frequencies (less than 2 lifts min\(^{-1}\)), metabolic fatigue is unlikely to occur. In this low lifting frequency (1 lift min\(^{-1}\)) condition, the biomechanical restriction is more dominant than physiological limitation. Recently, Wu (2003) studied on Chinese female college students and reported that MAWL for Chinese females for 1 h lifting from floor to the knuckle height level obtained as 24.80 kg with an overall average RPE (Rating of Perceived Exertion) response was “somewhat hard”. In India, existing Maharashtra Factory Rule suggested that 30 kg load should be the acceptable load limit for Indian Female workers (Dwivedi, 2000), which is just double of this estimated MAWL value. Therefore, acceptable load limit for Indian female workers needs to be modified.

In the present study, it is found that both the CW and HW groups lifted more load in case of lower vertical lifting distance (from ground to the knee level). This MAWL level was gradually decreased with the increase in vertical lifting distance. These results are consistent with the results reported by Snook (1978). It is also observed that CW group could lift more weight than the HW group. This was because the CW group was more habituated to weight lifting than their counterpart. A comparable result was obtained in case of Chinese male workers, reported by Wu (1997). As the present study was conducted on the industrial workers the findings of this study can be directly applied to the industrial population. It is very important to report that the load limit value for adult female workers, mentioned in existing Maharashtra Factory Rule i.e. 30 kg (Dwivedi, 2000), is abnormally higher than this estimated MAWL value. This could be due to the

<table>
<thead>
<tr>
<th>Table 5</th>
<th>The amount of subject-wise adjusted loads at different load adjustment periods</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>CW</td>
<td>1.22, 0.81, 0.44, 0.63</td>
</tr>
<tr>
<td>HW</td>
<td>1.11, 0.54, 0.75, 0.82</td>
</tr>
</tbody>
</table>
fact that this 30 kg limit was set earlier (i.e. in 1975), just by following some other country’s data. There is no scientific study available to support this load weight limit. From the psychophysical rating response towards the MAWL level (Table 3), it is found that both the CW and HW groups rated the selected load as moderate to heavy categories. Similar kind of result was observed in earlier studies (Karwowski et al., 1991; Kelsey et al., 1984).

According to Maritz et al. (1961) the working heart rate of 105 beats min\(^{-1}\), with a range of 95 to 115 beats min\(^{-1}\) would be accepted for 8 h industrial work shift. Brouha (1967) re-stated that the working heart rate should not exceed 110 beats min\(^{-1}\) otherwise there is a chance of cumulative fatigue. From Fig. 4, it is clear that for both CW and HW groups, the mean working heart rates are < 110 beats min\(^{-1}\). Maximum aerobic capacity measurement study on these workers was separately reported (Maiti, 2001). The average maximum heart rates for CW and HW groups were obtained as 189.3 and 189.75 beats min\(^{-1}\), respectively. In present study, the mean heart rates for knee, waist and maximum reach were equivalent to 32.6%, 34.6% and 33.1%, of the \(V_{\text{O2}}\) max, respectively, whereas, for HW workers, the average heart rates for knee, waist and maximum reach were obtained as 34%, 32.7% and 31.5%, respectively. Moreover, if the working period was extended for 8 h work duration using Eq. (3), the average increase in heart rate was obtained as 7.8–5.9 beats min\(^{-1}\) in both CW and HW groups.

In case of knee height lifting, both CW and HW groups lifted maximum amount of load. The amount of lifted load decreased further with the increase in vertical lifting distance. As a result, the mean working heart rate did not vary too much in different lifting conditions. In case of knee height response, trunk flexion was very rare and lifting was mainly done by knee flexion. So, the workers lifted the load in a constrained posture. In case of waist height response, the mean working heart rate was slightly higher than the other heights response. This could be due to the fact that while lifting up-to waist height level, the body could adopt upright position. Therefore, a sequential change in posture takes place. As a result, though the overall stress is more, but due to dynamic change in posture, subjects could accommodate more physical load with lesser discomfort feelings. In case of maximum reach height response, above the waist height level the load was mainly transferred by hands. This arm lifting is more stressful than lifting by trunk motion. Therefore, while lifting the load up to the maximum reach height level, due to the dynamic trunk motion, the workers could lift the MAWL load with slightly higher heart rates (i.e. metabolic stress level indicator) than that of knee level lifting response but less than the waist level lifting response. This kind of response was not observed in case of HW group, as they were not habituated to continuous heavy load lifting at different body height levels as CW group. Therefore, for HW group the contribution of the postural dynamic changes was not observed and the mean working heart rate decreased with increase in vertical lifting distance.

In a recent study (Wu and Chen, 2003), it was mentioned that MAWL level further decreased by about 11% when the adjustment period was increased from 20 to 40 min, and the MAWL percentage remained unchanged with the change in adjustment period from 40 to 50 min. From Table 5, it is observed that at 20 min almost no load adjustment is made. The present study deals with the workers who are habituated with load lifting operation; hence they could select the preferred load earlier unlike the inexperienced college students. Wu (1997) showed that the experienced Chinese male subjects had higher MAWL level than the inexperienced subjects. This study potentially supports that the MAWL study need to be experimented on the actual load handlers and not on the college students to obtain a better results towards the occupational health of industrial workers.

5. Conclusion

This study was done on adult female construction workers and household workers (having age of 28–32 years), who were regularly over-exerted in their working places. From this study, MAWL is
estimated as around 15 kg, which is consistent with earlier results. In existing Maharashtra Factory rules (1975), the safe load limit for adult female workers is mentioned as 30 kg, which is exactly double of this estimated MAWL load level. In present study, the effect of work duration on heart rate is also mentioned. This will help to estimate the MAWL level for variable work duration. This study strongly suggests that the existing factory rule needed to be modified for the welfare of the workers’ health.

References


