DETERMINATION OF THE OPTIMAL DURATION OF WORK EXPOSURE WHILE SITTING IN A SQUATTING POSITION TO AVOID LOW BACK PAIN: A SIMULATION STUDY

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Abstract
The objective of this study was to determine the optimal duration of work exposure while sitting in a squatting posture. A simulation study was formulated on work similar to the traditional jewellery manufacturing activity. The task of metal setting was simulated in a controlled environment. Fifteen young adult males participated in this study. The results of 12 participants were included as others discontinued the study for their personal reasons. The study continued for 2 hours. Trunk muscle strength and body part discomfort (BPD) were measured before and after completion of the task. BPD ratings in CR 10 scale were also collected after each 15 minutes of work. The mean age (year), height (cm), weight (kg) and BMI (kg/m²) of the subject were 24.25 ± 2.14, 172.47 ± 3.88, 65.08 ± 4.52 and 21.88 ± 1.33, respectively. Using inferential statistics, a predictive equation was developed to determine the optimal duration of exposure in a squatting position similar to traditional jewellery manufacturing activity. An hour of work with a small break was suggested after considering the study result for the workers who worked in a squatting posture like traditional jewellery manufacturing.

Key words: Low back pain; jewellery manufacturing; squatting; optimal duration

INTRODUCTION

Musculoskeletal health of any working population is a challenging area of research in the field of ergonomics. To improve musculoskeletal health and minimize feeling of subjective fatigue, it is required to reduce the risk factors which are involved in the development of musculoskeletal discomfort or pain.

Literature had shown that the duration of exposure is an important factor which affects the development of musculoskeletal disorders apart from working posture. Colombini et al. (2007) suggested in their study for upper extremity job demands, the optimum duration of exposure at a stretch would be 50 min with a 10 minute break. A report published by ILO (1989) mentioned that the maximum similar exposure would not be more than two hours. A guideline by Occupational Safety and Health Administration (OSHA, 1997) also suggested a maximum exposure of two hours.

As previously reported in literature, daily duration of work exposure has an impact on the development of low back trouble, the nature of the level of back discomfort and duration of work exposure is important for understanding the causation of back-related problems (Gerr et al., 2002; Metgud et al., 2008). Various physiological responses, for example, the level of blood lactate and incremental exercise showed a non linear relationship with the onset of blood lactate accumulation (OBLA) as a point, whereas there are studies which revealed that the discomfort level has a linear relation with the duration of exposure, when it is studied in dynamic shoulder muscle groups. But there is a scarcity of literature reporting the relation-
ship between discomfort sensation and duration of exposure for static work especially for trunk muscles.

This study aims at finding out the nature of increment of the discomfort level of the trunk muscles which is majorly responsible for holding the posture, when exposed to static loading and finding out optimum duration of exposure which will minimize the generation of discomfort or pain at the back (major affected body part) in a squatting posture.

METHODS

Study population

Fifteen young adult males participated in this study with signed informed consent. The aims and modalities of the study were explained before participation. The result of 12 subjects included for the analysis as rest of them discontinued the study for different reasons. All the participants were from similar working background (jewellery manufacturing) with similar years (5-7 years) of experience.

Inclusion criteria

The subjects without any discomfort or pain in any body part, any systemic health problems and any medication were included in the study. Participants were asked not to participate in any heavy physical activity and prolonged sitting and any other activity that may lead to the body discomfort or any other injuries.

Ethical declaration

The study was duly approved by the Institutional Human Ethics Committee, Department of Physiology, University of Calcutta, Kolkata, India.

Work desk

A work desk was prepared almost similar to the work desk used in the traditional jewellery manufacturing activity. The length, height and width of the work desk were 41.1 cm, 37.5 cm and 42.2 cm, respectively, which were the mean values of the work desk measured during the field study (Fig. 1). All the subjects who participated in this study had approximately similar stature and BMI which helped them adopt a similar kind of working posture at this simulated work desk. There was a hole of 5 mm in diameter at the centre of the top of the work desk.

Category Ratio 10 (CR10) Scale

The CR 10 scale was used to obtain the subjective response of the low-back in this part of the study.

Fig. 1. Sample work desk.
(Table 1) as it is a well known and widely used scale (Borg, 1982) for assessing the pain or various symptoms of various groups of patients with musculoskeletal disorders and experimentally on healthy subjects. The CR10 scale is a general intensity scale developed by Gunner Borg. It is used in the fields of physiology, psychology, and ergonomics to rate pain, fatigue, physical exertion and discomfort due to its reliability. This scale presents a non-linear growth of pain in different body parts when it is being used for assessing the musculoskeletal pain. This scale is a one dimensional scale from 0 and 10 with verbal anchors. In 1997, Shen and Parsons (1997) reported that Borg CR 10 scale has a fair reliability in reporting seated pressure discomfort. Studies have shown that there is a good correlation between the CR10 scale and Visual Analogue Scale (VAS) (Neely et al., 1992; Capodaglio, 2001).

<table>
<thead>
<tr>
<th>CR10 Scale</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Nothing at all</td>
</tr>
<tr>
<td>0.3</td>
<td>Extremely weak</td>
</tr>
<tr>
<td>0.5</td>
<td>Very weak</td>
</tr>
<tr>
<td>0.7</td>
<td>Weak</td>
</tr>
<tr>
<td>1</td>
<td>Moderate</td>
</tr>
<tr>
<td>1.5</td>
<td>Strong</td>
</tr>
<tr>
<td>2</td>
<td>Very strong</td>
</tr>
<tr>
<td>2.5</td>
<td>Extremely strong</td>
</tr>
<tr>
<td>3</td>
<td>Absolutely maximum</td>
</tr>
</tbody>
</table>

**Back strength dynamometer**

A digital back strength dynamometer (TKK 5402, Takei Scientific Instruments, Japan) was used to measure back strength of individuals.

**Simulation activity**

The subjects were asked to sit in a cross legged position (squatting) on the floor (same as adopted by jewellery manufacturing workers), asked to put the metal balls having a diameter of 2 mm through the hole.
at the work desk using a metal forceps for continuous 2 hours without taking any break. The reason to choose such an activity was due to following reasons.

1. The workers engaged in traditional jewellery manufacturing use a similar kind of metal forceps while doing the metal setting. They pick up a single piece of metal (balls, designed pieces) with the metal forceps and put them according to the design required. While doing so they sit in a cross legged (squatting) posture. They do this activity continuously for a stretch of 2.5 to 3.5 hours.
2. The work desks were prepared with the similar kind of height, width and length used by the workers engaged in jewellery manufacturing.

**Experimental procedure**

Subjects were asked to report to the laboratory one hour before the schedule of the actual experiment. During this time the subjects were asked to take a rest and they were explained about the objective and modalities of the experiment. Signed informed consents were obtained. Room temperature and the relative humidity level of the laboratory were maintained at 25°C to 27°C and at 50% to 60%, respectively (simulated laboratory condition to avoid other effect on discomfort). Illumination level at the work desk was controlled at 450 lux by using a controlled task light.

The trunk muscle strength was measured with a dynamometer before the subjects started the simulation activity. Subjective discomfort at the low-back was rated by using a body discomfort map along with CR 10 scale. Then the subjects were asked to sit on the floor and start the activity. After each 15 minutes the body discomfort rating was collected by using a blank (fresh) body discomfort map to avoid any biases of the previous ratings. The activity continued for two hours. Just after completion of two hours of the job the back strength was measured again.

**RESULTS**

The demographic data of the subjects are presented in Table 2. Mean age (year), height (cm), weight (kg) and BMI (kg/m²) of the subject were 24.25 ± 2.14, 172.47 ± 3.88, 65.08 ± 4.52 and 21.88 ± 1.33, respectively.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Age (Years)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>BMI (kg/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (± SD)</td>
<td>24.25 ± 2.14</td>
<td>172.47 ± 3.88</td>
<td>65.08 ± 4.52</td>
<td>21.88 ± 1.33</td>
</tr>
</tbody>
</table>

The results of the discomfort rating at the low-back of each subjects were present in Fig.3. The figures showed that at the beginning of the work, all the subjects had no discomfort (Rating at CR 10 scale 0-0.3) at the low-back region. After they started working, the discomfort level started increasing as time went on. The result also revealed a specific nature of each graph. It is shown that there is a sudden rise in the level of discomfort after approximately 30 minutes of exposure. The mean value of this duration was 36.25 ± 11.89 minutes with a range of 15 to 60 minutes.

The graphs also revealed that the level 3 of discomfort at Borg’s CR 10 scale reached after 61.66 ± 19.92 minutes with a range of 40 to 90 minutes.

The performances of the subjects were measured using error (missed to put the metal ball in the hole) count. It has been noticed that error count increased apparently at the end of two hours of work.

The mean body comfort level was plotted against the duration and presented in Fig. 4. The recovery data of the low-back was not obtained in this part of the study which may put light on the designing of the rest period of such activities. It also revealed a similar kind of nature (presented in graph) as individual responses of discomfort. Curve fitting was done with the mean value of discomfort level and it showed that the best matching curve was Cubic in nature with R value of 0.999. The result of curve fitting along with the model summary and ANOVA are presented in Tables 3-6 and Fig. 4.

Using the above model, the following predictive equation was developed.

Predicted body discomfort = 0.009 × time duration +0.001 × (time duration)² + 0.0000063 × (time duration)³ + 0.062
Fig. 3. Subjectwise increment of low back discomfort ratings.
Comparison of back strength

The back strength data were collected before the start of the experiment and just after the completion of the experiment. The results of back strength before and just after the completion of the experiment were compared using paired $t$-test, and the statistical result showed that the back strength reduced significantly ($t=5.860$, $p<0.001$) after two hours of exposure. The discomfort level of the low-back was also compared by using paired $t$-test. The result showed that the level of discomfort at the low-back region increased significantly ($t=9.222$, $p<0.001$). The result is presented in Table 7.
DISCUSSION

In the present study, it has been observed that the level of discomfort at the back region reached 3 at Borg’s CR 10 scale after 61.66 min (± 19.92). The verbal anchoring of the Borg’s CR 10 scale depicts that level 3 Borg’s CR scale (CR3) is moderate in feature, whereas CR2 is weak and CR4 is strong in nature. Further CR3 indicates, the effort that is noticeable (Moore and Garg, 1995), and it can be possible that the fatigue start accumulating after this time of exposure. In exercise physiology, OBLA phenomena is well known. OBLA generally occurs when the concentration of blood lactate reaches about 4 mmol/L (Sjodin and Jacobs, 1981; Tanaka et al., 1983).

Similar to OBLA phenomenon, the development of low-back discomfort, measured by Borg’s CR 10 Scale is non-linear in nature. Whereas, literature reported that rating of perceived discomfort for the shoulder muscle in a dynamic job had a linear relationship with time (Hager, 2008). The present study revealed that the growth of low-back discomfort was cubic in nature and reached level 3 at Borg’s CR 10 scale after 61.66 min (±19.92). Therefore, it is suggested that ‘a break after one hour’ is required when the activity is performed for a long duration with low exertion similar to the activities at the jewellery manufacturing.

From the above discussion, it may be concluded that sensation of body discomfort is not linear in nature. Further, sensation of body discomfort follows the cubic fashion where sudden increment of body discomfort is at 36.25 ± 11.89 minutes and the level of body discomfit reaches at level 3 at Borg’s CR 10 after 61.66 ± 19.92 minutes. As the study has been carried out only on 12 subjects, further study with larger sample size is recommended for generalizing the phenomena. Apart from the above findings it is recommended that the workers engaged in jewellery manufacturing need to take a micro-break after an hour while working continuously. But the detailed rest period design needs more research on recovery period.

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REFERENCES


