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Ergonomics Study on the Handle Orientation of Shovel

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Abstract The paper intends ergonomic modification of the existing shovel for manual material handling tasks. A preliminary assessment of subjective discomfort and posture was conducted at the brick construction site in Rampur (UP), India. The survey conducted on 16 workers (age: mean = 35.8 years; SD = 3.1 years) revealed a REBA score of 17. With the help of computer-aided ergonomics, four different orientations of the shovel handles, namely H75, H80, H85, and H90 (measured relative to the base of the shovel), were tested. It was revealed that the orientation of the shovel handle had a significant effect on the right shoulder, left wrist, left shoulder, and C0-C1 vertebral joint. Minimum joint torques were obtained for shovel with H80 handle.

Keywords Manual material handling · Shovel · Computer-aided ergonomics

1 Introduction

Nearly every sector and industries involves manual material handling (MMH) tasks. These tasks generally involve holding, lifting, lowering, turning, push–pull, and carrying of weights through a distance [1]. MMH tasks are susceptible to forceful exertions, awkward posture, and repetitive motions, which if kept unnoticed may lead to work-related musculoskeletal disorders in workers and loss of work days [2, 3].

Shovelling is one important MMH task that is being exhaustively performed in construction and agriculture sector, involving plowing, digging, and conveying of loose material. The physical work load associated with manual shovelling is exceptionally high. Shovelling task is physically intensive and requires excessive trunk flexion/extension, trunk rotation, and shoulder rotation. Literatures have reported

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shovelling being associated with lower back, shoulder, and cardiovascular problems [4]. Earlier studies on the ergonomics of shovelling tasks were predominately related to the physiological response with lifted weight, throw distance, and throw height [5]. It's only recently that researchers have eagerly looked in the design aspects of shovels [6, 7]. While the orientation of handles have been studied as a simple ergonomic adjustment for existing design of different tools [8, 9], studies relating to the orientation of shovel handles are not reported.

Apart from objective and subjective assessments, human modeling (HM) and computer-aided ergonomics (CAEr) provides an alternative approach for design evaluation. Researchers have shown the usability of CAEr in evaluation of design ergonomics [10–12]. The advantage of CAEr is that it provides a simulation environment that integrates information about human tools, tasks, and operators while satisfying design constraints. [13].

In this study, the design modification is sought in existing shovels to reduce the biomechanical loads during shovelling. The study was conducted in two parts. First, a field survey was conducted for the postural assessment of workers engaged in shovelling and, second, different orientations of shovel handle were tested in digital human modeling interface, HumanCAD (HCAD),with the aim to reduce the postural load involved in shovelling. Figure 1a) shows the existing dimensions for the shovel commonly available in Indian market. It consists of a cast iron blade attached to a wooden shaft. The weight of the shovel averages approximately 3.5 kg, while the average inclination of the handle to the blade is generally kept 75°.

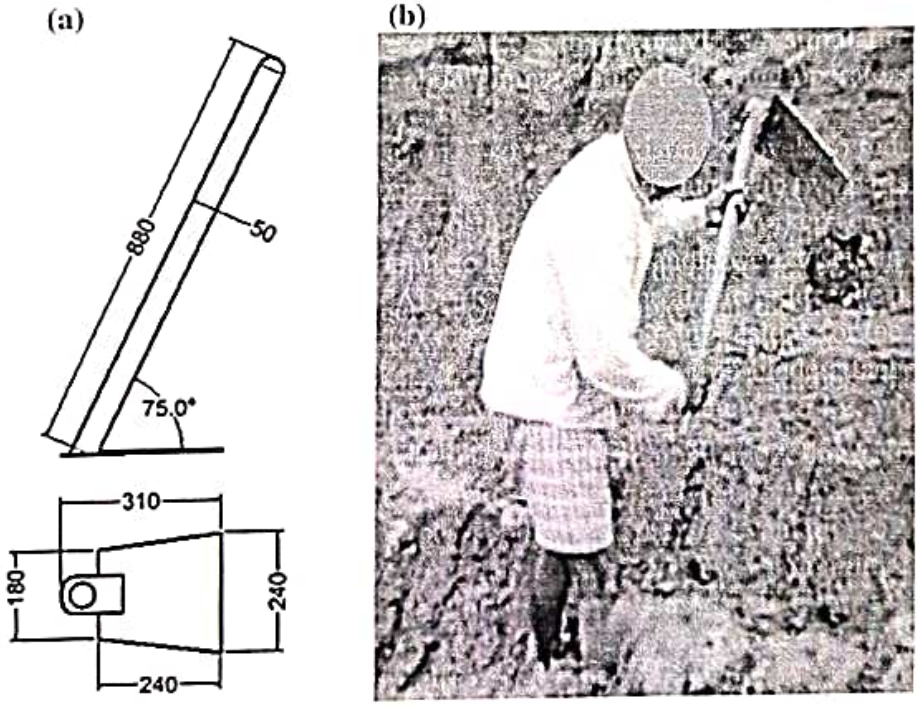

Fig. 1 **a** Dimension of the existing shovel and **b** worker performing shovelling task

2 Field Survey

2.1 Participants

Survey was conducted at brick construction sites in Rampur (UP), India. Sixteen workers (age = 35.8 ± 3.1 years, weight = 63.6 ± 6.6 kg, height = 168.3 ± 2.9 cm, and work experience = 11.2 ± 2.54 years) were assessed for discomfort and posture analysis.

2.2 Survey Assessment

The Corlett and Bishop discomfort map [14] along with 100 mm visual analog scale was used to access the discomfort site and discomfort level in the workers [15]. Figure 1(b) shows the worker engaged in shovelling task.

2.3 Post-survey Analysis/Results

Figure 2 shows the frequency of discomfort site and level of discomfort (VAS rating) as reported by the workers. The trunk was the most frequently reported site of discomfort by the workers, followed by the lower arm and shoulders. Also, VAS discomfort rating was higher for lower back and mid back (mean score of 6 out of 10). Joint angles for REBA were approximated through SolidWorks CAD package [16]. From post-processing of photographs, it was found that the average trunk flexion in stooping posture (ground position) while using shovel was 69.8°. Also, the shovelling requires

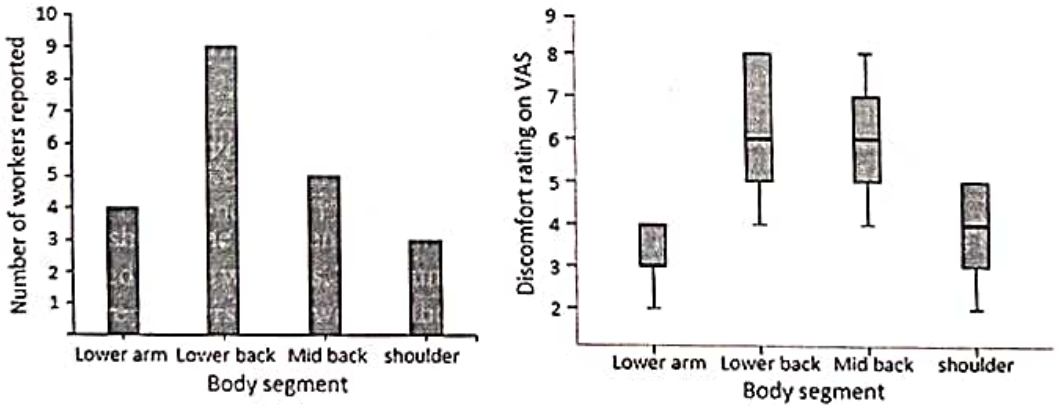

Fig. 2 Discomfort reported by workers

continuous wrist movements, and the average maximum wrist deviation during shovelling was 145.87°. The REBA score evaluated for each worker was greater than 14, indicating immediate action and modification of the task/tool.

3 Shovel Design Modification

Form the survey, it was evident that shoveling requires excessive trunk flexion and wrist deviation from neutral position. A high REBA score demands improvements in the existing design of shovel. For the present study, shovelling task was divided into three distinct postural adaptations (handling positions) as encountered by the worker. Up position—when the worker moves the shovel over his head, to provide him with the necessary force to dig or plow. Ground position—when the worker begins to plough or fill material placing the shovel on the ground. Throw position—when the worker throw or convey the material to other place.

3.1 Shovel Handle Orientations

In the present study, four different shovel handle orientations were tested for their effect on the human biomechanics for the three handling positions (up position, ground position, and throw position). Separate CAD models for shovel with four different handle orientations viz 75° (H75), 80° (H80), 85° (H85), and 90° (H90) were developed in SolidWorks as shown in Fig. 3. Dimensions other than handle orientation were kept same as of the existing shovel.

Fig. 3 CAD design for shovel showing different handle orientation

Fig. 4 HCAD simulations (95 percentile male) for H80 handle in different handling positions

3.2 *HCAD Modeling*

For testing and comparing the efficacy of handle orientation on body biomechanics during shovelling, the designed handles were evaluated in a digital human modeling interface. The CAD designs for the shovels were imported in HCAD (NexGen Ergonomics, Canada) for calculating force and torque at the body joints for different handling positions. The mannequins pertaining to Indian anthropometric data representing 5 percentile female and 95 percentile male population were simulated for all the three positions (Fig. 4).

4 Results and Discussions

Load and torque at the right ankle, right knee, right hip, left ankle, left hip, right wrist, right elbow, right shoulder, left wrist, left elbow, left shoulder, L5-S1, T12-L1, and C0-C1 were evaluated. Figure 5 shows the joint torque at C0-C1 vertebrate for 5 percentile female and 95 percentile male population.

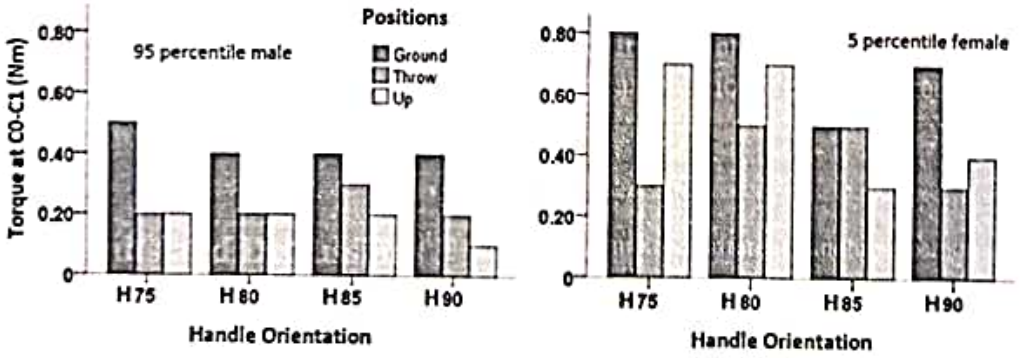

Fig. 5 Torque obtained at C0-C1 vertebrae for ground, throw, and up positions

A two-factor ANOVA was conducted for each of the following dependent variables: torque on right ankle, right knee, right hip, left ankle, left hip, right wrist, right elbow, right shoulder, left wrist, left elbow, left shoulder, L5-S1, T12-L1, and C0-C1. For each of the significant factors, multiple comparisons between the four shovel handle orientations and the two population percentile (95% male and % Female) were made. The results from ANOVA found no significant effect of population percentile on the left wrist and right wrist. However, orientation had significant effect on torque at right shoulder ($p = 0.025$), left wrist ($p = 0.008$), left shoulder ($p = 0.010$), and C0-C1 ($p = 0.021$). Further, minimum torque was obtained at right shoulder, left shoulder, and C0-C1 for H80 handle, while torque on left wrist was minimum for H90 handle. Also, the torque in right shoulder, left shoulder, and left wrist was greatest at throw position. Significantly lower joint torques were reported in case of 5 percentile female population as compare to 95 percentile male population. This may be attributed to shortening of moment arm as the limb length reduces.

5 Conclusions

Shovelling tasks are accompanied by a high REBA score, which urges for immediate modification in conventional shoveling task. The study focuses on the orientations of the shovel handle and its affect on the joint biomechanics at different shovel handling positions. From the simulations carried out in HCAD, it was found that the orientation of shovel handle has significant effect on right shoulder, left wrist, left shoulder, and C0-C1. Also, for all the shovel handle orientations tested, H80 handle produced minimum torque at right shoulder, left shoulder, and C0-C1, while the minimum torque at left wrist was observed found for H90 handle orientation. No single handle among H75, H80, H85, and H90 was able to reduce torque at all the body segments. However, H80 produces least torque at the majority of body segments and could be recommended as the simplest design modification to improve the shovel ergonomics.

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