The evaluation of ergonomic risk factors among meat cutters working in Jabalpur, India

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Background: Manual meat cutters in India are at high risk of work-related musculoskeletal disorders (WMSDs) for a variety of reasons including holding awkward postures, repetitive forceful exertions, and inadequate rest. This is the first study of its kind to investigate the nature and magnitude of WMSDs among manual meat cutters in India.

Objective: The aim of this study was to measure the ergonomic risk factors for WMSDs among adult male manual meat cutters working in Jabalpur, India.

Methods: We used direct observation, activity analysis, questionnaires, interviews, photography, and video to measure the quantitative ergonomic risk factors.

Results: Ovako working posture analysis indicated high scores (four for the back in peeling, six for the arms in cutting, and six for the arms during mincing tasks). Rapid entire body assessment method (REBA) scores were also high at 10/10 for deboning and mincing tasks, all associated with repetitive movements of the arms and awkward posture of the upper part of the body.

Conclusions: The study indicates that most tasks for meat cutters fall in the high-risk category for occupational injury. Results suggest that ergonomic interventions that address retooling and workstation and process redesign would be useful in reducing the number of injuries.

Keywords: Ergonomics, Injury, Discomfort, Risk, Design, Biomechanics, Posture, Pain

Background

Work-related musculoskeletal disorders (WMSDs) are a well-documented health concern among workers worldwide.^{1,2} Previous research has identified poor work space layout and/or hand tool design, which force workers to adopt awkward postures over long periods of time, as risk factors for the occurrence of WMSDs.^{2,3} It is therefore important that these risk factors, including awkward postures, repetitive movements, and forceful exertions, be identified before workers develop WMSDs, as they can result in decreased productivity and decreased quality of work. Work-related musculoskeletal disorders have been found to be especially prevalent in unorganized occupational sectors, since risk factors and control measures are less well understood in the informal economy.^{4,5}

Manual meat cutting is an important means of livelihood for many people throughout India and because it is completely dependent on human labor, there is a huge potential for ergonomic intervention.⁶ Meat cutters are part of the informal economy in India and therefore employment is not secure and

employees are not covered by insurance or social security services. Statistical data on injury rates, occupational health, and other ergonomic issues does not currently exist for this vulnerable population. Previous research in the manual meat cutting industry has focused exclusively on tool or workstation design, including investigating the relationship between knife blade sharpness and the amount of force required to cut animal carcasses, alteration of hand tool, and workspaces designs to reduce musculoskeletal stress, and the benefits of the mechanization process for butchers.^{7–10}

A literature review revealed few studies describing the prevalence of WMSDs in the meat cutting sector and the importance of controlling injuries through hand tool and workstation design. However, all of these studies were carried out in the context of the Western world, which differs greatly from the working conditions in India.^{11,12} In the Indian context, meat cutting is considered taboo, because it involves handling the blood and flesh of animals. As a result of this marginalization, no standard workplace or hand tools for butchers exist. In India, mechanization has not yet been adopted in this profession and most Indian meat cutters run their businesses from either small unsanitary rooms or in open-air workshops.

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The aim of this study is to gain insight on the different ergonomic risk factors for employees in this profession in the context of India. This is the first study of its kind to investigate the nature and magnitude of WMSDs among manual meat cutters in India. Non-profit organizations, policy makers, and health and human rights stakeholders can use the results from this study to advocate for improved working conditions for butchers in India.

Methods

Overview

Participants for this research were recruited from different meat cutting units by advertisement in the local newspaper. There were no cash payments for the volunteers, but they were given a small packet of sweets for participating in the study. The purpose of the study was explained and participants provided consent to participate and to be photographed. The local butchers association approved this study. Oral consent was obtained from all participants.

Direct observation and activity analysis

We used direct observation and activity analysis, which were modified for meat cutters.¹³ These modifications were essential, as the activities in this sector contrast greatly with the manufacturing and banking sectors for which these methods were originally devised. Subjects were observed in their normal work conditions. Their postures, number of repetitive movements of the dominant hand, and the path of travel of the hands and legs were studied. Data from these observations were then used for postural analysis in assessing risk factors for WMSDs. This methodology was adopted from previous work done from the manual brick manufacturing sector.¹⁴

Questionnaire and interview technique

The first step was to identify the list of relevant measures.¹⁵ In the second stage, open and closed ended questions were framed around each measure. In the third stage, questions were ordered based on relevance. Three versions of the questionnaires were drafted and piloted with butchers. The final questionnaire included questions about participant demographics, hours worked, the prevalence of body pain and injury, and workplace and hand tool design problems.

Photography

Photography and videos were used to document the different process involved in the work of the meat cutters, with special attention paid to postures such as bending, twisting, and repetitive movements that have previously been found to lead to injury.¹⁶

Measurement of psychophysical parameters

A 10 cm visual analog scale (VAS) was used to measure the level of discomfort experienced by meat cutters in the shoulder–arm system after 30 minutes of work. Subjects were shown a 10 cm scale and asked to indicate their level of discomfort by marking the scale with a vertical line. A Borg's scale for rated perceived exertion (RPE) was used to measure the effort involved in a particular task and was also administered at the end of 30 minutes of work.^{17,18} The RPE scale includes verbal anchors and an accompanying scale ranging from 0 to 10. Subjects were asked to identify the number and description that best represented their level of exertion and were able to express their level of effort using fractions and values greater than 10. Similar methodology has been used in past studies.^{17,18}

Postural analysis for musculoskeletal risk factors

Multiple measurements¹⁹ were used to assess postural analysis of work-related musculoskeletal risk factors, including the Ovako working posture analyzing system, the rapid entire body assessment method (REBA), and the rapid upper limb assessment method (RULA).^{20,21} The Ovako working posture analysis identifies common work postures. Each body posture is assigned a code between 0 and 6, with a code of 0 indicating a safe limit and a code of 6 indicating the need for immediate intervention. A posture code of 2 is used to indicate a need for less urgent intervention. Rapid entire body assessment method is an ergonomic assessment tool used to evaluate musculoskeletal disorders (MSDs) and the risks associated with occupation tasks. Posture codes range from 0 to 4 for different activities and body parts. A code of 0 is considered safe and a code of 4 is considered high risk. A code of 2 or more denotes the need for immediate intervention.²² Cumulative REBA scores calculated by summing the individual ergonomic risk attributes for a particular activity, including posture, weight, movement, duration, and rest. Therefore cumulative scores may be greater than 12. The RULA method is similar to REBA but is limited to the upper body. Posture codes range from 0 to 4 with 0 considered to be safe and 4 vulnerable to injury.

The strain index (SI) and occupational repetitive action (OCRA) were also used.²³ The OCRA and SI methods analyze different postures and the number of repetitive activities during particular tasks for the entire body. Separate codes are assigned to each body part and for each repetitive activity to indicate the vulnerability of the particular task. The normal limits for OCRA and SI are 7 and 4 (respectively). Similar to the RULA, OCRA scores are calculated separately for the right and left side of the body.

Figure 1 Animal skin being peeled off.

Figure 2 Cleaning of the viscera.

Results

Physical characteristics of the subjects

Fifteen healthy right-handed adult males were included in the study. Participants had a mean age of 33.1 years, a mean height of 159.7 cm, and a mean weight of 66.9 kg (Table 1).

Direct observation and activity analysis

Work process

Eight stages were identified in the manual meat cutting process, all of which required a significant amount of physical and/or cognitive effort (Figs. 1–3). The first stage is the sacrifice, performed by slitting

the animal's throat and allowing the blood to drain. More than physical effort, this step requires a significant amount of mental workload. The second stage is the separation of the head from the torso, typically performed on the floor and requiring effort

Table 1 Physical characteristics of the butchers ($n=15$)

	Age (years)	Height (cm)	Weight (kg)
Mean	33.1	159.7	66.9
SD	12.2	10.4	14.1
Maximum	61	182	90
Minimum	20	145	44

Figure 3 Tools used for meat cutting.

with both the hands and maintaining an odd posture. The third stage is peeling off the animal's skin with a sharp knife, which requires precision, since the entire skin must be separated as a single piece in order to retain its value in the leather market. The fourth stage involves the torso being slit open to expose the viscera, and in the fifth stage the organs are removed from the body. The sixth, seventh, and eighth stages all involve removing the meat from the animal. The majority of buyers preferred meat with bones, although boneless meat, requiring the manual separation of the meat from the bone, and minced meat are also in demand. All of these process required manual labor, strenuous activities to be performed in awkward postures, repetitive motions, and forceful exertions with very little recovery time in between movements.

Activity analysis (repetitive movement of the forearm and wrist)

The mean hand movement per minute of the dominant hand ranged from 3.7 to 47.6 (Table 2); with the lower bound of this range being observed during Step 2 (separating the torso from the head),

and the upper bound being observed during mincing of the meat.

Questionnaire and interview

The butchers normally worked between 8 and 10 hours a day, taking breaks during periods with no customers. All butchers who participated in this study reported working 7 days a week with an occasional day off. Participants identified their neck, shoulder, and lower back were the areas most affected by pain at the end of the day. Older butchers (≥ 60 years) and new butchers (working 2–3 years) were most affected. The most commonly impacted areas of the body were: upper back (30%), lower back (25%), upper arm (15%), forearm (15%), shoulder (10%), and neck (5%).

Photography

This revealed that awkward postures, such as bending forward, twisting of the torso and the neck as well as improper gripping of the different tools, were prevalent.

Psychophysical parameters (RPE and VAS)

The RPE scores (Table 3) were 11.7 for mincing, 11.1 for cutting, and 10.2 for deboning tasks. The VAS scores were 9.0 for mincing, 8.9 for cutting, and 8.1 for torso separation activities.

Postural analysis for musculoskeletal risk factors

Ovako working posture analysis

Ovako working posture analysis revealed that none of the postures were within the safe limit. For example, the risk of injury to the arm was high for cutting and mincing tasks (Ovako score of 6) (Table 4). Similarly, there was a very high risk of force/weight application for tasks such as cutting, deboning, and mincing (again with an Ovako score of 6).

REBA and RULA working posture analysis

Cumulative REBA scores were high at 12/12 for the task of slaughtering and 10/10 for deboning and

Table 2 Mean hand movement per minute of the dominant hand in different tasks

	Slaughter	Torso separation	Peeling	Cleaning	Segregation	Cutting	Deboning	Mincing
Mean	8.9	3.7	6.5	5.4	9.5	17.8	3.9	47.6
Range	(5–12)	(2–6)	(4–10)	(1–10)	(5–22)	(2–31)	(2–9)	(22–63)
SD	2.0	2.0	2.0	2.0	4.1	7.4	2.2	13.5

Table 3 Mean scores on rated perceived exertion (RPE) and visual analog scale (VAS) in different tasks

	Slaughter	Torso separation	Peeling	Cleaning	Segregation	Cutting	Deboning	Mincing
RPE								
Mean	9.4	10.0	6.2	4.3	5.3	11.1	10.2	11.7
Range	(8–14)	(8–12)	(4–8)	(3–5)	(5–6)	(9–14)	(6–14)	(10–14)
SD	1.7	1.3	1.3	0.6	0.5	1.5	2.7	1.3
VAS								
Mean	7.7	8.1	5.9	3.7	1.9	8.9	7.6	9.0
Range	(5.8–9.5)	(5.8–10)	(4.5–8.7)	(3–4.2)	(1–3)	(6.3–10.3)	(5.9–9.4)	(5.9–10)
SD	1.1	1.4	1.1	0.4	0.7	1.3	1.0	1.0

Table 4 Postural analysis scores for different tasks

Tasks	Ovako working posture scores				
	Head	Back	Arms	Legs	Force/weight
Slaughter	2	3	2	3	4
Torso separation	3	2	3	2	2
Peeling	3	4	4	2	2
Cleaning	2	2	3	2	2
Segregation	2	3	2	3	2
Cutting	4	4	6	4	6
Deboning	4	5	5	4	6
Mincing	4	5	6	4	5

mincing, indicating a need for immediate intervention (Table 5). Similarly, the cumulative RULA scores were high (7/7) for all tasks, also demanding immediate intervention.

Occupational repetitive action index (OCRA) and strain index (SI)

Occupational repetitive action index scores were high at 200/333.3 (Table 5) for the task of slaughtering and also dangerously high for mincing tasks at 11.9/10.6, again warranting immediate ergonomic intervention. The subsequent SI scores were also high for cutting at 30.4.

Discussion

This study found that there are multiple ergonomic risk factors in the meat-cutting sector, which may lead to the development of WMSDs and in turn affect productivity and quality of work. The risk factors are predominantly related to awkward postures and repetitive movement of the limbs accompanied by insufficient rest between activities.

Findings revealed that the majority of the tasks performed by meat-cutters involve awkward postures and repetitive activities, making the body vulnerable to WMSDs and soft tissue injury. Meat-cutters identified the back as the area of the body most affected by discomfort due to performing tasks that require bending and twisting of the torso.

Rated perceived exertion scores indicated that the amount of effort required for most activities was either light or very light, although tasks such as

Table 5 Postural analysis and repetitiveness scores for different tasks

	REBA	RULA	OCRA	SI
Slaughter	12/12	8/8	200/333.3	1.1
Torso separation	7/7	7/7	10/5.71	1.1
Peeling	9/9	7/7	6.35/6.35	0.8
Cleaning	8/8	7/6	4.4/3.7	0.8
Segregation	7/7	7/7	5.7/5.7	0.8
Cutting	9/9	7/7	10.6/10.6	30.4
Deboning	10/10	7/7	18.5/8.2	6.8
Mincing	10/10	7/7	11.9/10.6	5.1

REBA: rapid entire body assessment; RULA: rapid upper limb assessment; OCRA: occupational repetitive action index; SI: strain index.

cutting, mincing, and deboning required the most effort. Interestingly, the VAS scores were high for cutting, deboning, mincing, and torso separation tasks. The RPE scores were relatively low but the corresponding VAS score were higher than the normal limit of 5. This was mainly due to the involvement of more muscles of the upper arm. As the perception of pain was set at a higher level for these subjects acclimated to the profession, the exact RPE scores were not reflected. In almost all the tasks, the repetitive movements of the forearm were coupled with prone and supine movement of the forearm. Such movements of the forearm in deviated wrist postures set the stage for WMSDs and ultimately lead to lateral epicondylitis.²⁴

Postural analysis for musculoskeletal risk factors Postural risk factors

Postural analyses found that many of the postures associated with meat cutting tasks were high risk and require immediate intervention to prevent and treat WMSDs. Particularly vulnerable postures such as forward flexion and upper arm abduction with forearm prone or supine could increase the chances of WMSDs. Forward flexion and abduction of the upper arm stresses the glenohumeral capsule and renders it vulnerable to injury.²⁵ Similarly, repeated prone and supine movement of the forearm increases the chances of lateral epicondylitis.²⁴ This was mainly due to static muscular load and postures deviating from the neutral position for long durations. Such findings have been reported in similar field studies on manual brick workers and also in a controlled environment.^{6,25,26} Previous studies have found that these work conditions impact the quality of work, productivity, and occupational health and safety of the workers, increasing their risk of developing WMSDs. Such risk factors for WMSDs also exist for tasks such as slaughtering, deboning, mincing, cutting, and peeling of the skin.

Repetitive activities as risk factors

On the basis of repetitions only (number of hand movements per minute), three tasks were found to be hazardous and vulnerable to injury.²⁷ These three tasks were mincing, cutting and segregation, with mincing being the most vulnerable as it had a very high repetition rate. The permissible limit for the forearm/wrist was 10 repetitions per minute and that of the fingers were 100 repetitions per minute.²⁷ In all the three tasks mentioned above, the forearm and wrist were used to a great extent and were therefore vulnerable to injury. Occupational repetitive action scores were above normal in all the three tasks, indicating that repetitive activities did not give the body parts enough time to recover. This results in a build up of micro traumas in the soft tissues of the

body and sets the stage for many major disorders or injuries in the future.^{3,27} High SI scores for the corresponding tasks substantiated this finding. Investigations in a controlled environment on the mathematical modeling of risk factors for WMSDs at different articulations of the upper and lower limbs and at different grip and torque forces of the forearm revealed that repetitive twisting, bending forward, and even light load lifting were significant factors in the genesis of WMSDs and injury, and such postures impose a tremendous amount of force at the lumbosacral segment of the vertebral column.^{25,26}

Implications

There is still a paucity of data on risk factors for musculoskeletal disorders for different articulations typical of the manual meat cutting industry. Tasks in this sector involving awkward postures of the body have a strong association with injury as workers most often maintain static positions for certain limbs or are involved in repetitive activities while performing tasks for long durations. This study presents the different risk factors and their level of risk in such work. Knowledge of these risk factors can be used to identify and control high risk tasks before they develop into musculoskeletal disorders, especially in the design stage (for hand tools and workstations) when using biomechanical models.

Study strength and limitations

The strength of the study is that it was carried out on participants in actual working conditions. Hence, the risk factors identified both in terms of their nature and degree are reliable indicators for future ergonomic intervention. In the future, such studies could be substantiated by more objective analysis like electromyography of the different skeletal muscles of the body or measurement of the energy expenditure of the participants while performing different tasks, which would give further insight into other ergonomic issues affecting performance in these types of tasks.

Future directions

Work-related musculoskeletal disorders among meat cutters involved complicated processes and interventions in this sector will be most successful if they combine both design intervention (including changes in tool and workstation design) and changes in non-design issues (including the work/rest cycle, rest pauses, correct postures, exercises, and proper training). A re-design of the tools and workstations to meet the anthropometric dimensions of the Indian male populations is needed. Currently, such designs have been done with no reference to anthropometric dimensions, resulting in people of different anthropometric dimensions having to work in awkward postures. Injuries resulting from

postures including abduction, forward flexion of the upper arm, and pronation and supination of the forearm cannot be corrected exclusively through modifications in physical design. The anthropometric dimension of their different body parts should also be taken into account when selecting workers. For example, a worker with a stature in the 95th percentile category is better suited for work involving abduction and forward flexion of the upper arm along with pronation and supination of the forearm. In this case, the abduction of the upper arm is automatically minimized because the work surface is at elbow height. Other tasks require a pinch grip and deviated wrist postures for long durations accompanied by repetitive activities. Although such postures may be corrected to a limited extent through design, proper work/rest regimens could further reduce the impact of repetitive activities and awkward postures by giving the soft tissues of the body enough time to repair as they undergo micro wear and tear. Workers should be advised to take a short break of 5–10 minutes after every 30 minutes of continuous work.⁵

In particularly vulnerable postures, such as deboning, where the work demands pronation of the right forearm, it may be preferential to utilize left-handed workers who can perform the same task using a relatively safer supination movement.²⁸

We also recommend that workers could be trained to perform aerobic exercise in order to increase the tone of their musculature to prevent injury.^{5,6,29} Finally, workers should be trained on the proper usage of tools and workstations to promote occupational health and safety, and thereby improving productivity and quality of work in this sector.

Work-related musculoskeletal disorders are a major threat to employees in the meat cutting sector and make work less lucrative. Any design intervention that does not take into account making the work humane will not be sustainable. The findings of this research indicate that this informal sector in India requires ergonomic design intervention to reduce and prevent the risk factors for WMSDs. The correct diagnosis of these problems would pave the way for proper design solutions in terms of tools, workstations, and work process design.

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