La Medicina del Lavoro

Original article

Med. Lav. 2026; 117 (1): 17299
DOI: 10.23749/mdl.2026.17299

The Silent Strain: Grip Strength, and Wrist/Hand Musculoskeletal Disorders Among Meat Cutters

Hamid Jahangiri[1], Fatemeh Ghasemi[2], Mojgan Zoaktafi[3], Hamid Salmani Nodooshan[4], Mohebat Vali[5], Hadi Daneshmandi[6,*]

[1] Student Research Committee, Shiraz University of Medical Sciences, Shiraz, Iran
[2] Faculty of Information Technology and Communication Sciences, Tampere University, Tampere, Finland
[3] Department of Industrial and Enterprise Systems Engineering, University of Illinois at Urbana–Champaign, Urbana, IL, USA
[4] Department of Biomedical Engineering, University of Calgary, Calgary, AB, Canada
[5] Department of Epidemiology, School of Health, Shiraz University of Medical Sciences, Shiraz, Iran
[6,*] Research Center for Health Sciences, Institute of Health, Shiraz University of Medical Sciences, Shiraz, Iran

Keywords: Grip Strength; Meat Cutters; Musculoskeletal Symptoms

Abstract

Background: *Meat cutters are a working group that engages in awkward postures, repetitive motion, and forceful wrist/hand exertion. This study was conducted a) to examine the prevalence of musculoskeletal symptoms among Iranian meat cutters, b) to assess the wrist musculoskeletal disorders risk assessment and hand grip strength.* **Methods:** *Ninety-five male meat cutters in Iran (≥ 1 year tenure) completed a demographic/occupational questionnaire, the Nordic Musculoskeletal Questionnaire (NMQ), and the Boston Carpal Tunnel Syndrome Questionnaire (BCTQ). Ergonomic risk was assessed via the ACGIH-TLV® hand activity method, and maximum hand-grip force was measured.* **Results:** *With 69.5% reporting point prevalence and 70.5% reporting period prevalence of wrist/hand musculoskeletal symptoms, the study indicated that meat cutters had a significant prevalence of these symptoms. Most participants demonstrated mild to moderate severity in self-reported wrist symptoms while retaining asymptomatic functional status. The ACGIH-HAL assessment indicated most participants operated at or above the action level (AL), suggesting potential ergonomic risks. Moreover, The ACGIH-HAL ratio had a weak negative association with hand grip strength ($\beta = -0.0071$, $p = 0.12$).* **Conclusions:** *These findings highlight the ergonomic challenges associated with meat-cutting tasks.*

1. Introduction

Work-related musculoskeletal disorders (WMSDs) encompass a spectrum of arthritic and degenerative conditions that cause pain and functional impairment. These disorders are primarily caused or exacerbated by occupational activities or by conditions in the work environment [1-3]. Several epidemiological studies have shown a relationship between ergonomic risk factors in manual work, especially repetitive and forceful exertions, and musculoskeletal disorders (MSDs) [3-5].

Occupational exposure to high physical workloads, a prominent factor in MSD development, correlates significantly with higher prevalence of musculoskeletal disorders in affected populations [2, 6]. Meat-processing operations are linked to recognized ergonomic risk factors, including high work pace, strenuous knife use, and excessive grip force demands [7-11]. Meat-processing workers perform

Received 27.06.2025 – Accepted 12.01.2026
*Corresponding Author: Hadi Daneshmandi; E-mail: ha.daneshmandi@gmail.com

diverse, physically demanding tasks, such as lifting heavy carcasses and performing repetitive, forceful, and technically precise movements. These activities often involve awkward postures, limited recovery time, intensive tool use, and exposure to cold environments, all of which contribute to biomechanical strain [12]. Such factors significantly contribute to occupational health issues, notably MSDs [2, 13-15]. Kaka et al. [2] reported that low back pain was the most common WMSD among butchers. Numerous studies have shown that MSDs related to the workplace are complex and have a wide range of contributing factors, including those observed among meat cutters [5, 16-18].

Multiple occupations require excessive and/or sustained muscular exertion, which, when coupled with repetitive tasks, may lead to a high incidence of work-related wrist disorders [19, 20]. Meat cutters are more likely than other industrial workers to develop carpal tunnel syndrome (CTS) and trigger finger, which are believed to be induced by the use of handheld tools such as knives [21]. Musculoskeletal disorders (MSDs) affecting other upper-limb joints, such as tendinitis, neck and lower back pain, as well as epicondylitis and tenosynovitis, are problematic among meat-processing workers [22-26]. Hansson et al. identified rapid wrist kinematics and forceful exertions as critical contributors to the onset of musculoskeletal disorders (MSDs) in meat-cutting tasks. These risks are prevalent in both assembly line work and individual cutting stations [27, 28]. Accidents and disorders can be caused by the knife, which is the primary and frequently the only tool used by meat cutters [26, 29, 30]. The prevalence of CTS, a common hand disorder, ranges from 5.8% in females to 0.6% in males [31].

In recent years, research has advanced understanding of ergonomic risks and interventions in the meat-processing industry. Recent findings indicate that repetitive knife tasks, high physical workload, and insufficient recovery time remain major predictors of upper-limb musculoskeletal disorders in slaughterhouse environments, even after ergonomic training and awareness programs [32]. Organizational factors such as work rotation, task distribution, and production pace have also been shown to significantly influence the occurrence of these disorders [33]. Intervention studies in meat-processing plants have shown that applying ergonomic checkpoint tools, redesigning workstations, and adjusting knife-handling tasks can effectively reduce physical strain and improve postural alignment [32, 34]. Moreover, environmental factors—particularly cold exposure—have been found to exacerbate discomfort and muscle fatigue, highlighting the importance of proper thermal conditions and personal protective equipment [35]. Collectively, recent studies emphasize that modern ergonomic approaches combining workstation redesign, participatory ergonomics, and environmental control are essential for reducing biomechanical strain and mitigating long-term musculoskeletal risks in meat-processing occupations.

Most studies in the manual meat-cutting sector have focused primarily on tool and workstation design. These investigations have examined the impact of knife sharpness on the cutting force required to process animal carcasses, ergonomic modifications to hand tools and workspaces to minimize musculoskeletal strain, and the advantages of mechanization for butchers [10, 26]. Although mechanization and automation have significantly increased production in the poultry industry, knives remain essential for tasks such as cutting, trimming, skin or fat removal, and processing. Despite efforts to improve knife design, these tools still require forceful exertions and repetitive motions, which contribute to the development of MSDs [36]. In developing countries like Iran, occupational health and safety hazards, including MSDs, receive relatively little attention. Currently, no statistical data are available on injury rates, occupational health issues, or other ergonomic concerns specific to Iranian butchers.

Only a few studies have investigated the occupational health and safety of butchers [37]. However, no prior research has specifically examined the prevalence of WMSDs or evaluated hand force exertion among Iranian meat cutters. Hence, the current study was undertaken in this sector with the following objectives: a) To evaluate the occurrence of musculoskeletal disorders (MSDs) in Iranian meat-processing industry workers, and b) To assess the risk of wrist musculoskeletal disorders and hand grip strength. The results of this study provide a foundational framework for reducing the risk of biomechanical overload and for developing and deploying targeted ergonomic interventions in workplace settings. These actions are aimed at improving workers' well-being and the quality of professional life.

2. Methods

2.1. Participants

This study included 95 right-handed male meat cutters with at least one year of experience. The mean duration of job experience among participants was 15.03 ± 2.78 years. Individuals with pre-existing musculoskeletal conditions or prior illnesses affecting the musculoskeletal system were excluded from participation. Participants were selected from a slaughterhouse in Shiraz using simple random sampling from a random number table. All workers participated voluntarily after receiving full disclosure of the study's aims and procedures. Written informed consent was obtained from all participants prior to the study's initiation. The study was conducted in accordance with the Helsinki Declaration of 1964, as revised in 2008 [38].

2.2. Data Gathering

In this research, the required data were collected using standard methods/tools as detailed below.

2.2.1. Demographic/Occupational Questionnaire

This questionnaire included questions on age, weight, height, job experience, daily working hours, marital status, and level of education. Table 1 shows the personal profiles of the participants.

Table 1. Personal Profile of the Participants (n = 95.)

Quantitative variable	**Mean ± SD**[†]
Age (years)	36.62 ± 11.59
BMI* (kg.m^{-2})	25.65 ± 3.59
Job experience (years)	15.03 ± 2.78
Working time per day (hours)	11.14 ± 2.10
Qualitative variable	**No. (%)**
Marital status	
• Single	38 (40)
• Married	57 (60)
Education level	
• Diploma and lower	86 (90.5)
• Associate Diploma and higher	9 (9.5)

**Body Mass Index.*
†Standard Deviation.

2.2.2. Nordic Musculoskeletal Questionnaire (NMQ)

NMQ evaluates the self-reported prevalence of musculoskeletal symptoms across various anatomical regions within the studied demographic [39]. In this study, period prevalence (during the 12 months preceding the study) and point prevalence of musculoskeletal symptoms across various bodily regions among participants were reported. Participants completed the questionnaire in their respective work environments. The validity and reliability of the Persian version of NMQ were assessed by Choobineh et al. (Cronbach's alpha = 0.691) [40].

2.2.3. Boston Carpal Tunnel Syndrome Questionnaire (BCTQ)

The BCTQ is a measurement tool specifically designed to assess self-reported symptom severity and functional status associated with the disease. Symptom severity is scored on a scale of 11 (no symptoms) to 55 (most severe symptoms), and functional status is measured on a scale of 8 (normal function) to 40 (total functional impairment) [41]. The Persian version of the BCTQ has demonstrated good reliability and validity in the study by Rezazadeh et al. (Cronbach's alpha = 0.90) [42].

2.2.4. American Conference of Governmental Industrial Hygienists Threshold Limit Value (ACGIH-TLV) for Hand Activity Level (HAL)

The ACGIH TLV for hand activity was used to assess job risk factors for MSDs of the hand and wrist. Hand activity was rated on a scale from 0 to 10, and the level of effort was measured as normalized peak force (NPF) on a similar scale. NPF was assessed using three methods: quantified as a percentage of maximal voluntary contraction (MVC), self-assessed ratings of perceived exertion (RPE), and observational assessments derived from the Moore-Garg Strain Index protocol. The combination of HAL and NPF was then plotted on a TLV graph to determine the risk level, with a TLV of 0.78 and an action limit (AL) of 0.56 [43].

2.2.5. Jamar Hand Dynamometer

The Jamar hand dynamometer (Sammons Preston Model: 563213) was used to measure peak grip strength. This dynamometer uses precision load cell technology, enhancing measurement sensitivity and accuracy, even for very low grip strengths. By adhering to the industry-standard Jamar design, researchers can easily compare their findings with existing standardized normative data.

2.3. Implementation of the Study

In this study, individuals completed demographic/occupational, NMQ, and BCTQ questionnaires at their workplace. Peak hand grip strength was assessed using the Jamar Hand Dynamometer. Participants were seated in a standardized posture with adducted, neutrally rotated shoulders, 90° elbow flexion, and neutral anatomical alignment of the forearms and wrists. They held the dynamometer in their hand, with a wrist safety strap securing it and gentle support at the base to prevent accidental dropping. Grip force was applied smoothly, avoiding rapid or jerking motions. A 0-30° wrist extension was permitted to achieve maximal grip. Any wrist position other than extension or exceeding 30° of extension was noted.

Hand activity levels were assessed using the ACGIH-HAL method while workers performed their regular job tasks at the workstations. The force component (Normalized Peak Force) was determined using self-assessed ratings of perceived exertion embedded in the ACGIH-HAL method. Workers rated the effort required to perform their cutting tasks on a 0-10 scale, with 0 indicating 'no exertion' and 10 indicating 'extremely strong exertion'. This perceived exertion score was then used to derive the NPF value for placement on the ACGIH TLV graph.

2.4. Statistical Analysis

Data were analyzed using the Statistical Package for Social Sciences 16 (SPSS Inc, Chicago, IL, USA). Descriptive statistics (mean, standard deviation, number, and percent) and the Spearman correlation coefficient were used to analyze the collected data. A p-value less than 0.05 was considered statistically significant. To test the normality of the data, the Kolmogorov-Smirnov, Shapiro-Wilk, and Skewness & Kurtosis tests were used. A multivariable linear regression model was used to assess the association between the ACGIH-HAL ratio and maximum hand grip strength (measured using a Jamar hand dynamometer), while controlling for potential confounders including age, body mass index (BMI), and daily work hours.

3. Results

3.1. Prevalence of Musculoskeletal Symptoms

Table 2 presents the point and 12-month period prevalence of musculoskeletal symptoms across different anatomical regions among the participants. The highest point and period prevalence of musculoskeletal symptoms among the participants were related to the wrists/hands, reported by 66 workers (69.5%) and 67 workers (70.5%), respectively.

3.2. Self-Reported Wrist Symptom and Functional Status Derived from the P-BCTQ

Table 3 demonstrates self-reported wrist symptom severity and functional status of the meat cutters derived from the P-BCTQ. As shown in Table 3, the majority of participants fell within the mild and moderate severity levels concerning disease severity. However, regarding functional status, most participants were asymptomatic.

Table 2. Point and period prevalence of musculoskeletal symptoms in different body regions of the participants (n = 95).

Body region	Point prevalence No. (%)	Period prevalence No. (%)
Neck	34 (35.8)	36 (37.9)
Shoulders	46 (48.4)	46 (48.4)
Elbows	16 (16.8)	18 (18.9)
Wrists/ hands	66 (69.5)	67 (70.5)
Upper Back	31 (32.6)	32 (33.7)
Lower Back	54 (56.8)	54 (56.8)
Thighs	8 (8.4)	8 (8.4)
Knees	56 (58.9)	56 (58.9)
Ankles/feet	60 (63.2)	61 (64.2)

Table 3. Self-reported wrist symptom and functional status of the meat cutters (n = 95).

BCTQ* Subscale	No. (%)
Severity level	19 (20)
• Asymptotic	40 (42.1)
• Mild	26 (27.4)
• Moderate	10 (10.5)
• Severe	-
• Very severe	
Functional status level	65 (68.4)
• Asymptotic	28 (29.5)
• Mild	1 (1.1)
• Moderate	1 (1.1)
• Severe	-
• Very severe	

**Boston Carpal Tunnel Syndrome Questionnaire.*

3.3. Assessment of Hand Activity Level by ACGIH-HAL Technique

As described in the methods section, participants' hand activity was assessed using the ACGIH-HAL technique. The final result, the "NPF / (10-HAL)" ratio, was then calculated. The mean ± SD of the subjects' ratios was 0.61 ± 0.29.

Finally, this ratio was evaluated based on the action levels of "< AL (0.56)", "AL to TLV (0.78)", and "> TLV". Table 4 shows the frequency of subjects in the different action levels. As indicated, most subjects were in Action Level (AL) 1, followed by AL 2.

Table 4. Frequency of the subjects in the different action levels of the ACGIH-HAL (n = 95).

ACGIH-HAL* action level	No. (%)
1. (<AL† (0.56))	46 (48.4)
2. (AL to TLV (0.78))	28 (29.5)
3. (>TLV)	21 (22.1)

** American Conference of Governmental Industrial Hygienists Threshold Limit Value.*
† Action Level.

3.4. Assessment of the Maximum Hand Grip Strength

Mean ± SD of the "maximum hand grip strength" of the subjects derived from the Jamar hand dynamometer was 423.16 ± 83.51 N.

3.5. Correlation Between the ACGIH-HAL Ratio and Maximum Hand Grip Strength derived from the Jamar Hand Dynamometer

The multivariable linear regression analysis, adjusted for age, BMI, and daily work hours, showed an inverse association between the ACGIH-HAL ratio and maximum hand grip strength (measured with a Jamar Hand Dynamometer) in the study population (β = − 0.0071, p = 0.12). The negative beta coefficient indicates an inverse relationship. This means that for every one-unit increase in hand grip strength (measured in newtons), the ACGIH-HAL ratio tends to decrease by 0.0071 units.

4. Discussion

The present study was conducted among male meat cutters in a slaughterhouse. The results showed that the participants had an average age of approximately 37 years and an average of 15 years of work experience. Their average BMI was 25.65 kg/m^2, and they worked an average of 13 hours daily. Most participants reported MSD symptoms in the hand/wrist region, followed by the lower limbs, lower back, and shoulders. An evaluation of hand activity using the ACGIH-HAL showed an average hand activity level of approximately 0.6, falling within the range between the AL and the TLV. Although all participants worked in the same slaughterhouse, notable differences were observed in the ACGIH-HAL action levels: 46 workers were below the Action Limit (AL), 28 workers operated between AL and TLV, and 21 workers exceeded the TLV. The variation in HAL action levels among workers is primarily explained by differences in workstation tasks (e.g., carcass breakdown vs. trimming), required cutting force, tool handling technique, and individual anthropometric characteristics. Maximum grip strength was approximately 423 Newtons. However, participants reported applying a moderate amount of force during their work.

Butchers and meat cutters frequently experience pain and discomfort in various body parts due to WMSDs. Among meat-processing professionals, lower back pain is a frequent site of work-related musculoskeletal complaints, with prevalence rates ranging from 42% to 66.7%. Shoulder, wrist, and hand pain are also prevalent, often linked to repetitive and overhead manual tasks [2, 44]. Butchering involves repetitive motions, leading to conditions such as lateral epicondylitis. Moreover, butchers working over 9 hours daily have shown a higher prevalence of musculoskeletal issues [45]. The results obtained in this study are consistent with prior research findings. According to the results of the BCTQ questionnaire, while most of the butchers participating in this study reported experiencing mild to moderate symptoms related to wrist issues, 68 percent remained functionally asymptomatic. A number of studies have demonstrated a relationship between wrist symptoms and hand function. Wrist conditions can adversely affect hand performance. In CTS patients, symptoms such as pain, numbness, and tingling significantly impair hand function, affecting daily activities like grasping, writing, and carrying objects. The severity of symptoms correlates with functional limitations in patients' hand performance [46]. However, a previous study showed that pain interference is the strongest predictor of self-reported disability in individuals with wrist and hand pain. Pain interference is defined as the degree to which pain compromises an individual's capacity to perform daily tasks and diminishes their overall quality of life [47]. Addressing pain interference is crucial in improving outcomes for individuals experiencing chronic pain.

The trend toward a weak, negative association between the ACGIH-HAL ratio and maximum handgrip strength (β = − 0.0071, p = 0.12) indicates that workers with higher grip strength may be slightly less likely to exceed the ACGIH-HAL threshold; however, this association was not statistically significant, suggesting that handgrip strength alone may not be a reliable predictor of compliance with ACGIH-HAL guidelines.

The ACGIH-HAL TLV is designed to assess the risk of upper extremity MSDs by evaluating hand activity and force during occupational tasks. Studies have shown that the HAL TLV can be a useful tool for identifying jobs with higher risks of disorders such as CTS. For instance, according to a study, the HAL was an independent predictor of CTS, with higher HAL scores associated with increased risk [48]. While hand grip strength reflects an individual's maximum voluntary contraction and overall hand function, it does not directly measure the repetitive hand activities and force exertions that contribute to musculoskeletal strain in occupational settings. Physiologically, fatigue can reduce the capacity to sustain force over time without necessarily affecting maximal grip. measured at a single point. This means that individuals with high maximal strength may still experience strain when performing repetitive tasks [49]. Therefore, relying solely on hand grip strength to assess the risk of exceeding ACGIH-HAL thresholds may overlook critical factors related to task-specific hand activities.

To create a safer, more comfortable work environment for butchers, it's important to focus on their ergonomic needs and minimize the risk of injuries, particularly to the wrists and hands. Here are thoughtful strategies to consider:

- Designing an appropriate workstation: Workstations should be adjusted to each user's height to minimize wrist strain. This adjustment reduces excessive wrist flexion or extension, lowering biomechanical load and the risk of cumulative strain injuries.

- Ergonomic tools: Ensure that knife and hand-tool design is optimized for the individual user: handles sized to the operator's hand, non-slip coatings, angled grips to maintain neutral wrist posture, and minimal force required. Implement a systematic tool maintenance and sharpening program to preserve cutting efficiency and prevent increases in required hand force. Regular knife sharpening and timely replacement of worn-out items are essential to maintain optimal performance and minimize physical strain on workers [32, 50, 51].
- The workplace temperature must not fall below 12 degrees Celsius. Meat cutters who perform tasks in cold environments and feel cold are more likely to experience bodily discomfort [52, 35].
- Training in techniques: Offering training sessions on how to use tools correctly can empower butchers with the skills they need to work safely. Learning the right techniques can significantly lower the risk of developing MSDs.
- Regular breaks: Although ergonomic design can partially correct awkward postures, implementing proper work–rest schedules is essential to further mitigate the effects of repetitive motions and sustained exertion. Short breaks of 5-10 minutes after every 30 minutes of continuous work allow soft tissues adequate time to recover from micro-trauma and fatigue. Moreover, each work period should not exceed 1.5 hours between breaks, and tasks involving knife use should be limited to a maximum of 6 hours per day to prevent cumulative musculoskeletal strain [50, 52].
- Strengthening exercises: Providing simple exercises for the hands and wrists can be beneficial. Strengthening these muscles not only helps prevent injuries but also improves grip and overall performance.
- Assistive devices: Using handy tools or devices that lighten the load can greatly reduce strain on the wrists and hands. These could be anything from holders to specialized cutting aids that make tasks easier. Where feasible, integrate powered aids or mechanized material handling to reduce repetitive, forceful exertions and cycle times [10].
- Ongoing support: It's essential to regularly check the ergonomic setup of the workplace and the well-being of the butchers. By assessing their needs and any potential issues, we can find effective solutions together.

4.1. Limitations

Most assessments of hand activity and symptoms in individuals were conducted using subjective methods, which are not error-free. This study was conducted among right-handed male meat cutters, so the findings might not apply to female or left-hand-dominant individuals. Data were also collected from a single slaughterhouse, which might not represent other settings or meat-processing methods. In this study, information on participants' sports or strength training activities and psychosocial factors was not collected. These factors may influence perceived exertion ratings and could therefore affect the estimation of force within the ACGIH-HAL assessment. Future studies should include such variables to better account for individual differences in physical capacity and subjective effort perception. In addition, the study's design limits causal inferences about the relationship between risk factors and outcomes.

4.2. Recommendations for Future Studies

Future studies should include female and left-handed participants to enhance the generalizability of findings. Longitudinal research is recommended to establish causal relationships between risk factors and MSDs. Future research should also assess workers' physical conditioning (e.g., participation in sports or strength training) and psychosocial factors, as these may influence perceived exertion ratings and ergonomic risk assessment outcomes. Incorporating objective tools, such as motion analysis and wearable sensors, can provide validation for self-reported data. Additionally, interventional studies should assess the effectiveness of ergonomic modifications, such as adjustable workstations, improved tool designs, and task rotations, in reducing musculoskeletal risks. Finally, conducting multisite analyses across various slaughterhouses will account for variability in practices and tools, offering a more comprehensive understanding of occupational hazards in the meat-cutting industry.

5. Conclusion

This study highlighted the high prevalence of MSDs, particularly in the wrist and hand, among meat cutters, emphasizing the physically demanding nature of their tasks. The findings demonstrated a strong association between hand activity levels and perceived exertion, underscoring the ergonomic risks inherent in repetitive and forceful hand tasks. Although hand grip strength showed a weak correlation with risk levels, the overall results indicated the need for targeted ergonomic interventions. Implementing workplace redesigns, improving tool ergonomics, and adopting preventive strategies can help mitigate these risks. Addressing these occupational challenges is essential for enhancing employee productivity and well-being in the meat processing sector.

Funding: This work was supported by the Shiraz University of Medical Sciences under Grant 31693.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and was approved by the ethics committee of Shiraz University of Medical Sciences (Ethics Code: IR.SUMS. SCHEANUT.REC.1403.107).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Acknowledgments: The authors would like to thank meat cutters who participated in the study.

Author Contribution Statement: HD was involved in the study design, interpretation of the data, and drafting of the manuscript. HJ, FG and MZ were involved in the study design, data collection, interpretation of the data, drafting of the manuscript. HSN and MV were involved in the analysis and interpretation of the data and drafting of the manuscript. All authors have read and approved the final manuscript.

Declaration of Interests: The authors declare no conflict of interests.

Data Availability: The de-identified raw data and analysis code are available from the corresponding author upon reasonable request.

References

1. Collins R, Janse Van Rensburg D, Patricios J. Common work-related musculoskeletal strains and injuries. *South African Family Practice*. 2011.53(3):240-246. Doi: org/10.1080/20786204.2011.10874091
2. Kaka B, Idowu OA, Fawole HO, Adeniyi AF, Ogwumike OO, Toryila MT. An Analysis of Work-Related Musculoskeletal Disorders Among Butchers in Kano Metropolis, Nigeria. *Saf Health Work*. 2016;7(3):218-24. Doi: 10.1016/j.shaw.2016.01.001
3. Punnett L, Wegman DH. Work-related musculoskeletal disorders: the epidemiologic evidence and the debate. *J Electromyogr Kinesiol*. 2004;14(1):13-23. Doi: 10.1016/j.jelekin.2003.09.015
4. Barcenilla A, March LM, Chen JS, Sambrook PN. Carpal tunnel syndrome and its relationship to occupation: a meta-analysis. *Rheumatology (Oxford)*. 2012;51(2): 250-61. Doi: 10.1093/rheumatology/ker108
5. National Research Council. Work-related musculoskeletal disorders: a review of the evidence. *National Academies Press*. Washington, DC. 1998.
6. Idowu PA, Adedoyin RA, Adagunodo RE. Computer-related repetitive strain injuries. *J Nig Soc Physiother*. 2005;15(1):13-18.
7. Grant KA, Habes DJ. An electromyographic study of strength and upper extremity muscle activity in simulated meat cutting tasks. *Appl Ergon*. 1997;28(2): 129-37. Doi: 10.1016/s0003-6870(96)00049-x
8. Dempsey PG, McGorry RW. Investigation of a pork shoulder deboning operation. *J Occup Environ Hyg*. 2004;1(3):167-72. Doi: 10.1080/15459620490424465
9. McGorry RW, Dowd PC, Dempsey PG. The effect of blade finish and blade edge angle on forces used in meat cutting operations. *Appl Ergon*. 2005;36(1):71-7. Doi: 10.1016/j.apergo.2004.08.002
10. Arvidsson I, Balogh I, Hansson GÅ, Ohlsson K, Akesson I, Nordander C. Rationalization in meat cutting - consequences on physical workload. *Appl Ergon*. 2012;43(6):1026-32. Doi: 10.1016/j.apergo.2012.03.001
11. Christensen H, Søgaard K, Pilegaard M, Olsen HB. The importance of the work/rest pattern as a risk factor in repetitive monotonous work. *Int J Ind Ergon*. 2000;25(4): 367-373. Doi:10.1016/S0169-8141(99)00025-6
12. Caso MA, Ravaioli M, Veneri L. Esposizione a sovraccarico biomeccanico degli arti superiori: la valutazione del rischio lavorativo nei macelli avicoli. *Prevenzione Oggi*. 2007;3(4):9-21.

13. Botti L, Mora C, Regattieri A. Improving ergonomics in the meat industry: a case study of an Italian ham processing company. *IFAC-PapersOnLine*. 2015;48(3): 598-603.
14. Omokhodion FO, Adebayo A. Occupational hazards and self-reported health problems of butchers in Ibadan, southwest Nigeria. *J Public Health*. 2013;21(2):131-134.
15. Corbin M, McLean D, Mannetje A', et al. Lung cancer and occupation: A New Zealand cancer registry-based case-control study. *Am J Ind Med*. 2011;54(2):89-101. Doi: 10.1002/ajim.20906
16. Johansson B, Rask K, Stenberg M. Piece rates and their effects on health and safety - a literature review. *Appl Ergon*. 2010;41(4):607-14. Doi: 10.1016/j.apergo.2009.12.020
17. Karsh BT, Moro FB, Smith MJ. The efficacy of workplace ergonomic interventions to control musculoskeletal disorders: a critical analysis of the peer-reviewed literature. *Theor Issues Ergon Sci*. 2001;2(1)23-96. Doi: 10.1080/14639220152644533
18. Tappin DC, Bentley TA, Vitalis A. The role of contextual factors for musculoskeletal disorders in the New Zealand meat processing industry. *Ergonomics*. 2008;51(10): 1576-93. Doi: 10.1080/00140130802238630
19. Harris C, Eisen EA, Goldberg R, Krause N, Rempel D. 1st place, PREMUS best paper competition: workplace and individual factors in wrist tendinosis among blue-collar workers--the San Francisco study. *Scand J Work Environ Health*. 2011;37(2):85-98. Doi: 10.5271/sjweh.3147
20. Nordander C, Ohlsson K, Akesson I, et al. Exposure-response relationships in work-related musculoskeletal disorders in elbows and hands - A synthesis of group-level data on exposure and response obtained using uniform methods of data collection. *Appl Ergon*. 2013;44(2):241-53. Doi: 10.1016/j.apergo.2012.07.009
21. Gorsche RG, Wiley JP, Renger RF, Brant RF, Gemer TY, Sasyniuk TM. Prevalence and incidence of carpal tunnel syndrome in a meat packing plant. *Occup Environ Med*. 1999;56(6):417-22. Doi: 10.1136/oem.56.6.417
22. Kurppa K, Viikari-Juntura E, Kuosma E, Huuskonen M, Kivi P. Incidence of tenosynovitis or peritendinitis and epicondylitis in a meat-processing factory. *Scand J Work Environ Health*. 1991;17(1):32-7. Doi: 10.5271/sjweh.1737
23. Viikari-Juntura E, Kurppa K, Kuosma E, et al. Prevalence of epicondylitis and elbow pain in the meat-processing industry. *Scand J Work Environ Health*. 1991;17(1):38-45. Doi: 10.5271/sjweh.1736
24. Yassi A, Sprout J, Tate R. Upper limb repetitive strain injuries in Manitoba. *Am J Ind Med*. 1996;30(4):461-72. Doi: 10.1002/(SICI)1097-0274(199610)30:4<461::AID-AJIM12>3.0.CO;2-2
25. Magnusson M, Ortengren R, Andersson GB, Petersén I, Sabel B. An ergonomic study of work methods and physical disorders among professional butchers. *Appl Ergon*. 1987;18(1):43-50. Doi: 10.1016/0003-6870(87)90069-x
26. Vogel K, Karltun J, Eklund J, Engkvist IL. Improving meat cutters' work: changes and effects following an intervention. *Appl Ergon*. 2013;44(6):996-1003. Doi: 10.1016/j.apergo.2013.03.016
27. Hansson GA, Balogh I, Ohlsson K, et al. Physical workload in various types of work: Part I. Wrist and forearm. *Int J Ind Ergon*. 2009;39(1):221-233. Doi: 10.1016/j.ergon.2008.04.003
28. Hansson GA, Balogh I, Ohlsson K, et al. Physical workload in various types of work: Part II. Neck, shoulder and upper arm. *Int J Ind Ergon*. 2010;40(3):267-281. Doi: 10.1016/j.ergon.2009.11.002
29. Fogleman MT, Freivalds A, Goldberg JH. An ergonomic evaluation of knives for two poultry cutting tasks. *Int J Ind Ergon*. 1993;11(3)257-265. Doi: 10.1016/0169-8141(93)90114-S
30. Szabo RL, Radwin RG, Henderson CJ. The influence of knife dullness on poultry processing operator exertions and the effectiveness of periodic knife steeling. *AIHAJ*. 2001;62(4):428-33. Doi: 10.1080/15298660108984644
31. Gay RE, Amadio PC, Johnson JC. Comparative responsiveness of the disabilities of the arm, shoulder, and hand, the carpal tunnel questionnaire, and the SF-36 to clinical change after carpal tunnel release. *J Hand Surg Am*. 2003;28(2):250-4. Doi: 10.1053/jhsu.2003.50043
32. Tirloni AS, Dos Reis DC, Tirloni SF, Moro ARP. Exertion Perception When Performing Cutting Tasks in Poultry Slaughterhouses: Risk Assessment of Developing Musculoskeletal Disorders. *Int J Environ Res Public Health*. 2020;17(24):9534. Doi: 10.3390/ijerph17249534
33. Dias NF, Tirloni AS, dos Reis DC, Moro ARP. Risk of slaughterhouse workers developing work-related musculoskeletal disorders in different organizational working conditions. *Int J Ind Ergon*. 2020;76:102929. Doi: 10.1016/j.ergon.2020.102929
34. Pérez E, Rodríguez Y, Salazar MC, Trujillo MA. Improving Working Conditions Using the Ergonomic Checkpoints Tool: Application in a Colombian Meat Processing Plant. *IISE Trans Occup Ergon Hum Factors*. 2021;9(2):72-77. Doi: 10.1080/24725838.2021.1962622
35. Tirloni AS, Dos Reis DC, Dias NF, Moro ARP. The Use of Personal Protective Equipment: Finger Temperatures and Thermal Sensation of Workers' Exposure to Cold Environment. *Int J Environ Res Public Health*. 2018;15(11):2583. Doi: 10.3390/ijerph15112583
36. Szabo RL, Radwin RG, Henderson CJ. The influence of knife sharpness on poultry processing operator exertions and the effectiveness of re-sharpening. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*. SAGE Publications. Los Angeles, CA. 1998.
37. Hesam G, Motamedzade M, Khakbaz G, Moradpour Z. Ergonomic intervention in poultry slaughter industry and evaluation of effectiveness by key indicators method (KIM). *Journal of Ergonomics*. 2014;2(2):9-19.
38. World Medical Association. World Medical Association Declaration of Helsinki: ethical principles for

medical research involving human subjects. *JAMA*. 2013;310(20):2191-4. Doi: 10.1001/jama.2013.281053
39. Kuorinka I, Jonsson B, Kilbom A, et al. Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. *Appl Ergon*. 1987;18(3):233-7. Doi: 10.1016/0003-6870(87)90010-x
40. Choobineh A, Dortaj E, Razeghi M, Ghaem H, Daneshmandi H. Assessment of Load Manual Lifting among Shelf-Stoking Workers in Chain Stores: A Cross-Sectional Study. *Appl Bionics Biomech*. 2024:2324416. Doi: 10.1155/2024/2324416
41. Levine DW, Simmons BP, Koris MJ, et al. A self-administered questionnaire for the assessment of severity of symptoms and functional status in carpal tunnel syndrome. *J Bone Joint Surg Am*. 1993;75(11):1585-92. Doi: 10.2106/00004623-199311000-00002
42. Rezazadeh A, Bakhtiary A H, Moghimi J, Samaei A. Validity and reliability of the Persian Boston questionnaire in Iranian patients with carpal tunnel syndrome. *Koomesh*. 2014;15(2):e152626.
43. American Conference of Governmental Industrial Hygienists, Threshold limit values for chemical substances and physical agents and biological exposure indices. *ACGIH*. Cincinnati, OH. 1995.
44. Saleem Z, Waqas S, Ahmad M, Javaid A. Frequency of work-related musculoskeletal problems among butchers. *J Riphah Coll Rehabili Sci*. 2020;8(2):61-63.
45. Kalair MFI, Khattak Z, Saeed A, Asif S. Assessment of lateral epicondylitis in butchers in Islamabad. *J Health Rehabil Res*. 2024;4(3):1-5.
46. Anwar I, Ameer A, Azam S, Khalid M, Asim H. Hand Function among Patients with Carpal Tunnel Syndrome. *Open J Ther Rehabil*. 2019;7:170-177. Doi: 10.4236/ojtr.2019.74012
47. Pelletier R, Bourbonnais D, Higgins J, Mireault M, Harris PG, Danino MA. Pain interference may be an important link between pain severity, impairment, and self-reported disability in participants with wrist /hand pain. *J Hand Ther*. 2020;33(4):562-570.e1. Doi: 10.1016/j.jht.2019.06.001
48. Kozak A, Schedlbauer G, Wirth T, Euler U, Westermann C, Nienhaus A. Association between work-related biomechanical risk factors and the occurrence of carpal tunnel syndrome: an overview of systematic reviews and a meta-analysis of current research. *BMC Musculoskelet Disord*. 2015;16:231. Doi: 10.1186/s12891-015-0685-0
49. Pageaux B, Lepers R. Fatigue Induced by Physical and Mental Exertion Increases Perception of Effort and Impairs Subsequent Endurance Performance. *Front Physiol*. 2016;7:587. Doi: 10.3389/fphys.2016.00587
50. Mukhopadhyay P, Khan A. The evaluation of ergonomic risk factors among meat cutters working in Jabalpur, India. *Int J Occup Environ Health*. 2015;21(3):192-8. Doi: 10.1179/2049396714Y.0000000064
51. Vogel K, Karltun J, Eklund J, Engkvist IL. Improving meat cutters' work: changes and effects following an intervention. *Appl Ergon*. 2013;44(6):996-1003. Doi: 10.1016/j.apergo.2013.03.016
52. Van Eerd D, Cole D, Irvin E, et al. Process and implementation of participatory ergonomic interventions: a systematic review. *Ergon*. 2010;53(10):1153-66. Doi: 10.1080/00140139.2010.513452