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Long-term assessment of upper arm posture and motion and their association with discomfort perceived symptoms among bakery workers

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Abstract

Background The highest prevalence of work-related musculoskeletal disorders (MSDs) among bakery workers is reported in the shoulder region. Awkward shoulder postures have been suggested to be a cause of shoulder discomfort in bakery workers. This study aimed at long-term assessment of upper arm posture and motion and their association with discomfort perceived symptoms among bakery workers. The results of this study are expected to have an effective role in identifying risk factors in order to provide appropriate strategies for preventing shoulder disorders in bakery workers. Methods In this study, fifty seven bakers of the three types of bread baking systems (sangak, taftoon and tanoori baking systems), were randomly selected. The self-reported severity and frequency of shoulder discomfort perceived by workers were recorded. Working postures and movements of the shoulders during work were continuously recorded with inclinometry measurements during three hours. Results Results suggest bakery workers, especially sangak bakers, may be exposed to high physical exposure levels. A significant correlation were found between perceived discomfort intensity on VAS scales for the right and left shoulder angles (50th) among bakers in sangak baking system ($p \leq 0.005$). Percentage of time spent with the upper arm right elevated more than 60° was significantly correlated with perception of shoulder discomfort for all bakery workers ($p \leq 0.05$). Angular velocity was significantly negatively correlated with perceived discomfort intensity for both upper arms ($p \leq 0.005$). Conclusions Study findings suggest, in addition to high physical exposure level, poor workstation design and inappropriate hand tools may be the main risk factors for developing disorders in the shoulder regions among bakers. Our results can provide more informed decisions with respect to both engineering (e.g. ergonomic workstation and equipment design) and administrative (e.g. work organization) control strategies.

Background

Bread is an essential food in human nutrition.The world’s total bread consumption is estimated at 86 million tons annually. Asia and the Pacific are the largest markets in the world(1). In most countries, the bakeries are either fully or partially automated and the bread production is carried out in small and medium industrial units. Bread is considered as the first food of the Iranian people and its consumption in the daily diet is very common(2). In cities of Iran, bread is produced in a number of different types of traditional bakeries The Crop Research Center of the Ministry of Industry and Mining has announced that about 62,980 bakeries with more than 100,000 workers are active in the country in 2011(3).

In 2000 in Europe, the number of injures in the industrial bakery was reported to be 1750, which is slightly lower than other food industries. Manual lifting and awkward posture are the main causes of disorders and injures resulting in “absenteeism more than 3 days” and accounts for 32% of these injures(4). Since bread baking systems are fully mechanized in the industrial bakeries, it seems that bakers are less exposed to ergonomic problems than the traditional bakery. In industrial bakeries, most of the injuries are due to manual material handling tasks, so that 66% of musculoskeletal disorders are reported to be related to this issue. (4). Traditional bread baking is one of the most tedious professions; requiring long hours of static work. According to categorization of hard and hazardous jobs by the ministry of

cooperatives labour in 2014, bakers are subject to the hard and hazardous jobs act(5) .The production of bread in the traditional way requires more involvement of the upper limbs to complete the baking process. Bakers are exposed to a number of recognized risk factors, such as manual lifting, poor workstation design, repetitive movements and awkward postures in the upper limbs.The highest prevalence of work-related musculoskeletal disorders (MSDs) among traditional bakers is reported in the shoulder region(6, 7).

Qualitative studies have shown that musculoskeletal disorders in the workplace of bakers are associated with a variety of occupational risk factors, including individual, physical workload (posture-force-movement), and psychosocial factors(6, 7). Bakers perform their tasks through repetitive movements of the upper arms with different speed and force at non-ergonomic workstations. Among the ergonomic risk factors, awkward postures in the shoulder region of the bakers are recognized as the most important one for development of musculoskeletal disorders(8).

In this regard, a limited number of studies are carried out to evaluate the ergonomics risk factors in traditional bakeries, and the performed evaluations are qualitative and self-reporting. In the present study, in order to accurately evaluate the shoulder postures among bakers, the direct measurements technique was used for a long period of time. In addition, the relationship between awkward postures and shoulder discomfort was investigated among bakery workers. The results of this study are expected to have an effective role in identifying risk factors in order to provide appropriate strategies for preventing musculoskeletal disorders among traditional bakers.

Methods

2.1. Describing Workstations based on types of bread baking system

Mostly three types of bread baking systems are now commonly used in Iran: The sangak system, the tanoori system and the taftoon system.

2.1.1 Sangak Baking System

The oven of the sangak baking system is a 4×5 m dome-shaped space whose floor is covered with small stones. The height of these ovens is about 1 meter from the ground. The oven can be heated with kerosene, mazut, diesel fuel, and recently natural gas. A firebrick wall is made in front of the direct flame, with an approximate height of 50 cm. The wall is built to prevent the spreading of fine particles of diesel fuel or mazut and to convert direct into indirect heat. In this type of bakery, a special oar is used to spread the dough inside the oven. The oar has a 20- to 50-cm blade and a 3-meter handle, made of wood or steel. The oar with the dough on its blade weights about 3.5 kg.

2.2.2 Tanoori baking system

The oven in this type of bakery is made of tile and in two forms of ground and air. The oven opening is 80-90 cm diameter and the oven inside diameter and depth are 1 m and 1.20 m, respectively. The edge of the oven is at the floor level and usually the baker stands in a trench next to the oven or sits down and imprints the dough on the oven's wall. In this type of bakery, a device called saruj is used for spreading the dough and putting it inside the oven. Saruj consists of a cushion that is usually made up of a round or oval-shaped board coated with canvas. It is 70-80 cm length and 2 kg total weight with the dough.

2.2.3 Taftoon baking system

In taftoon baking system, the oven is roughly industrialized, consisting of a baking plate rotated by a conventional rotary machine. In this machine, the heat required for baking is supplied by two torches with direct or indirect flame from beneath and over of the baking plate, and thus the final product (bread) is produced. The tool used to put the dough inside the oven is the saruj used in tanoori baking system, but it is rectangular (80×90 cm) and weights totally 2-2.2 kg with the dough.

2.3. Participants

This study was carried out in mid-May 2015 in Ahvaz, SW Iran. In this study, of the three types of bread baking systems mentioned (sangak,taftoon and tanoori baking systems),57 bakers were randomly selected in Ahwaz city. Table 1 shows the characteristics of the participants. All participants were right hand dominant, with a mean age of 30 years. Mean height was 173 cm and mean weight was 77.3 kg. On average, bakers had 6 years of bread baking experience.

Study equipment

In this study, the self-reported severity and frequency of shoulder discomfort experienced by workers were recorded. The frequency of shoulder discomfort were assessed during an interview with the standardized nordic musculoskeletal questionnaire (SNMQ)(9). The questionnaire included two sections: the first addressed demographic characteristics, and the second included questions about shoulder discomfort experienced during the past year. Self-reported severity pain or discomfort in the shoulder regions using a body map was estimated on a 100 mm visual analogue scale (VAS), with 0 = no pain and 100 = extreme pain. The VAS score was measured in millimeters from the left zero point of the scale to the point at which the workers marked the line. Before taking part in the experiment, all bakers were told about the aims of the study and were required to complete an informed consent form.

Shoulder elevation angles were recorded using a triaxial accelerometer (inclinometer) called the Virtual Corset (VC) (Microstrain, Williston, VT, USA). The VC is a wireless, battery-operated, lightweight (6.8 × 4.8 × 1.8 cm, 72 g), portable logger with 2 MB of onboard memory. Tri-axial accelerometers were validated in vitro for measuring velocity and postural data under static and dynamic conditions for use at the

shoulder. One VC was mounted using elastic athletic tape to each posterior upper arm half the distance between the lateral epicondyle of the humerus and the acromioclavicular joint.

Prior to data collection, a reference upright standing position was recorded with participants instructed to stand upright with the arms hanging along the side of the body, while holding a 2-lb weight in each hand. Upper arm elevation angles were recorded continuously over a 3-h period while bakers performed their normal assigned tasks. Throughout sampling, signals were recorded using a portable logger with 2 MB of onboard memory at a sample rate of 7.5 Hz. Prior to data processing, VC signals were filtered with a low pass filter of 3 Hz and a fourth order Butterworth filter. The upper arm elevation angles were calculated for the amplitude probability distribution for median (APDF 50%) and peak (APDF 90%) values(10). All signal processing and parameters calculations were completed using custom-written programs developed in Matlab R2007B (The Math Works Inc., Natick, MA, USA).

2.4. Statistical analysis

All statistical analyses were performed using the SPSS version 22.0 at 0.05 levels. The Kolmogorov–Smirnov statistical test was used to examine the normality of the distribution of data. All data were tested to be normally distributed, so the paired t- test was used for comparing the kinematic parameters between the right and left upper arm elevation. Analyses for associations between VAS scores of shoulder pain and inclination data were measured by Pearson correlations.

Results

The highest prevalence of musculoskeletal symptoms among bakers was reported in the right and left shoulders (%66 and %64, respectively) in the past 12 months. The prevalence of shoulder symptoms was higher on the right side, which was the dominant side of all bakers.

Table 2 represents the mean visual analogue scale (VAS) scores of the bakers for all bread baking systems. Mean (CI 95%) VAS for the right and left upper arm was 6.2 (5.1-7.2) and 4.7 (3.4-5.6), respectively.

Table 3 shows posture and movement of the upper arms for each type of baking systems. On average, the right upper arm was more elevated than the left one for all bakers in baking systems. Sangak bakers had higher 50th and 90th percentile posture bilaterally as compared to taftoon and tanoori bakers. For example, Median upper arm elevation among sangak bakery workers was 46° and 36° for the right and left upper arms, respectively.On average, bakers worked with the right and left arms elevated in extreme postures (greater than 45°) for %31 and %18 of the work shift (3 hours) with the right and left arms, respectively. Sangak bakery workers had the highest percent times spent in extreme posture bilaterally as compared to taftoon and tanoori bakery workers (Table 3).

Taftoon bakery workers had higher percent times spent in neutral postures, and lower percent times spent in extreme postures bilaterally as compared to sangak and tanoori bakery workers (Table 3).The average

MPF for the right and left upper arm was 0.72 Hz and 0.66 Hz, respectively. Tanoori bakery workers had lower levels of repetitiveness than sangak and taftoon bakery workers (Table3).

Correlations between kinematics data and VAS scores are shown in Table 4. Significant correlations were found with the perception of perceived discomfort for the right and left shoulder angles (50^{th}) among bakers in sangak baking ($p \leq 0.005$). Percentage of time spent with the upper arm right elevated more than 60° was significantly correlated with perception of shoulder discomfort for all bakers in baking systems ($p \leq 0.05$) (Table 4).

Median angular velocity among all bakers was 30°/s and 25°/s for the right and left arms, respectively, which correlates significantly negatively with perception of shoulder discomfort for all bakers in baking systems ($p \leq 0.005$) (Table 4).

Discussion

To our knowledge, this is the first study to evaluate biomechanical exposures to the shoulders among traditional bakers. An important strength of this study was the use of a long-term sampling strategy, which is rare in field-based ergonomics research(11) .Direct measurements of the posture provide accurate quantitative measurements suitable for estimating exposure to work-related physical risk factors(12) . Direct measurement methods enable the most precise measurements of prolonged exposure to postures, movements and repetitions as compared to observational or self-report methods (13-15).In this study, we used the inclinometers to assess the shoulder kinematics. It's demonstrated that inertial measurement units including of accelerometers, gyroscopes and magnetometers utilized to measure upper limb posture can accurately estimate shoulder positions during work(16).

The results of the present study showed that the right shoulder was significantly more elevated during baking tasks than the left for all baking systems. This difference may be due to use the right, or dominant, hand to perform the baking operation. In such situations, workers have to endure more external force in addition to awkward postures in the right shoulder area. Several studies have shown that a combination of awkward posture, external force, and the frequency and duration of high-risk tasks may represent the most significant mechanical loads on the upper extremities during work.Results suggest the sangak bakery workers were exposed to higher extreme postures, higher angular velocities and higher levels of repetition as compared to bakery workers of taftoon and tanoori. Compared to other jobs, our findings suggest that bakers may experience higher proportions of time spent in extreme right shoulder posture than parlor workers(17), car disassembly workers(18), hairdressers(19), dentists(20) . This higher proportion may be due to the work nature and task demands of the bakery job compared with other jobs.

The results of the statistical analyses revealed a significant correlation between right and left shoulder angles (50^{th}) and perception of pain among bakers in sangak baking system ($p \leq 0.005$).

In fact, given the nature of the tasks in the sangak baking operation, bakers have to use both hands to perform the task. One of the high risk tasks in this baking system is to put dough inside the oven and to remove the baked bread from the oven using an oar with long handle (3 to 3.5 m) and an approximate weight of 3.5 kg. For performing this task, the dominant hand (right hand) is forced to endure more loads. Also, the oar control requires more force during working, especially when the baker needs to put the dough in the deeper parts of the oven. It might lead to an increase in muscle loads in the shoulder areas.

One of the injuries, which might occur in the shoulder area for bakers, is the rotator cuff tendon syndrome. One of the important factors, causing this injury is the occupational activities of individual. Work with elevated arms may lead to degenerative changes in the rotator cuff tendons and thus predispose to tears. Physical exposure factors at work such as increasing percent time spent with shoulder extreme posture and high hand loads, particularly grip strengths, increase the odds of rotator cuff tendon syndrome. It is unclear how high and for what period of time the upper arms must be elevated for these adverse effects happen. Silverstein (2008) reported that a significant relationship between shoulder flexion more than 45° for 15% of time combined with forceful exertions and the development of rotator cuff syndrome.

The angular velocity of the right upper arm among bakery workers was high. Compared to other studies, bakery workers have higher extreme angular velocities than parlor workers (17), car disassembly workers (18), hairdressers (19), dentists (20).The high angular velocities in the present study are related with dynamic positions of the upper arms. A more dynamic pattern of motion is believed to be related with a lower prevalence of MSD development (21). Activities including more variable motor strategy (i.e., greater angular velocity) may protect workers from WMSD(22).

According to the survey conducted in this study, suggest that the workstations design and hand tools for traditional baking systems are not based on ergonomic and anthropometric principles. It is believed that poor workstation design, in particular, design inappropriate for the anthropometric dimensions of individual, can be one of the main risk factors for developing fatigue and disorders in the shoulder area. The bakers' distance from the oven and the high depth of the oven might increase the forward reach distance to put the dough using the oar inside the oven. These situations might cause stressful postures in the shoulder area. Some studies have shown that postures and movements of shoulder may depend partly on workers anthropometric measurements(17).The mismatch between anthropometric measures of the bakers and the workstation dimensions, such as forward reach distance or oven height, might be one of the main reasons for high physical exposure in shoulders area among the bakers. For example, bakers with shorter arm lengths or lower stature might experience higher levels of stress postures on shoulders while reaching forward during putting the dough inside the oven than bakers with longer arms or higher stature. The lack of proper handle on saruj and the mismatch between the handle diameter and grip strength of the bakers might be involved in development of musculoskeletal disorders. Studies have shown that physical exposure factors at work such as increasing percent time spent with shoulder extreme and high hand loads, particularly grip strengths, increase the odds of rotator cuff syndrome

In this study, there were no significant differences between discomfort perceived symptoms with some physical exposures in the shoulder regions. These results are probably not related to increased risk of disorders, but they might represent differences in variability of motor performance(23).
Further studies are needed to investigate muscle activity of the shoulders symptomatic and healthy bakers.

Bakery work organizational factors such as increased speed of working and inadequate rest in combination with the biomechanical factors for the upper arms may have a significant influence on muscular tension in the shoulder region. In addition to, worker fatigue may affect product quality and productivity. Experts and ergonomics should consider work organization factors and their impact on baker performance and productivity. Further research is needed to investigate the role of baker health and workload on performance, product quality and productivity.

Limitation

There were some limitations in this study. The sample size was considered small and this may have contributed to the lack of statistically significant relationships. The second limitation is the sensitivity of accelerometers to linear acceleration resulting from non-zero angular velocities and accelerations. Previous studies demonstrate that these errors are small and predictable(24).

Conclusions

Our study, which employed continuous assessment of shoulder posture by long-term inclinometry among traditional bakery workers, revealed that the bakery workers may be exposed to high physical exposure levels. In addition, significant correlations were found between physical exposure levels and discomfort perceived responses in the shoulder region.

In generally, our results can enable more aware decisions with respect to both engineering (e.g. workstation and tools design) and administrative (e.g. work organization) control strategies.

Abbreviations

WMSD: Work-related musculoskeletal disorders; SNMQ: Standardized nordic musculoskeletal questionnaire; VAS: Visual analogue scale; APDF: Amplitude probability distribution for median.

Declarations

Ethics approval and consent to participate:

After meeting criteria, the study was explained and bakery workers were asked to sign an informed consent and the study protocol was approved by the Jundishapur University of Medical Sciences Ethics Committee.

Consent for publication: Not applicable.

Availability of data and materials:

The dataset used for analysis during the current study are available from the corresponding author on reasonable request

Competing interests: The authors declare that they have no competing interests.

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Authors' contributions:

DA and LJ carried out the data collection and analysis and were major contributors in writing the manuscript. ID and MN were contributors in writing and reviewing the manuscript and all authors read and approved the final manuscript.

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Tables

Table 1 .Demographic characteristics of the bakers (N=57)

Mean(SD)			variable
Tanoori (N=20)	Sngak (N=18)	Taftoon (N=19)	
31(5)	28(3.5)	31(4)	Age (years)
172(5)	175(3)	172(6.5)	Height (cm)
78(3)	76(6)	78(5)	Weight (kg)
7(2.5)	5(3)	7(2)	Work experience (years)

Table 2 .Mean and CI 95% (in brackets) for VAS scores of shoulders discomfort

	Right		Left	
bread baking systems	Mean	(CI 95%)	Mean	(CI 95%)
Tanoori(N=19)	5.8	(4.8-6.8)	4.7	(3.7-5.7)
Sangak(N=18)	6.2	(5.1-7.3)	5.0	(4.1-5.8)
Taftoon(N=20)	6.6	(5.6-7.6)	4.4	(3.5-5.4)
Total	6.2	(5.1-7.2)	4.7	(3.4-5.6)

Table 3. Posture and movement exposure metrics of the shoulders in bakers (N=57).

Exposure variables	Bread baking systems					
	Tanoori(N=19)		Sangak(N=18)		Taftoon(N=20)	
Shoulders inclination angle	Right	Left	Right	Left	Right	Left
APDF 10th	-7(4.9)	-2(1.3)	-9(2.8)	-7(2)	-2(4.6)	-5(2.1)
APDF 50th	38(3.2)	14(2.7)	42(3.2)	36(4.7)	27(4.8)	25(4.2)
APDF 90th	77(7)	64(6)	97(5.3)	72(5.9)	67(5.3)	59(5.1)
APDF 10th -90th	69(9)	66(6)	86(6)	65(6)	64(8)	54(5)
Time spent in flexion (%)						
neutral (<20º)	66(6.8)	85(3)	57(7)	58(7)	59(5.1)	78(4)
extreme (>45º)	24(4)	12(2.5)	28(4)	28(5)	27(4)	14(2.4)
extreme (>60º)	4(4.6)	3.5(2.6)	13(3)	12(5)	12(3.7)	4(2)
Movement velocities (°/s)						
APDF 10^{th}	6(1.7)	6(1.4)	5 (1.1)	5(1.8)	6(1.7)	6.5(1.9)
APDF 50^{th}	27(5.1)	25(3.7)	32(6.8)	29(4)	32(3.7)	23(5.4)
APDF 90^{th}	150(11)	121(8.6)	175(5.1)	166(6.3)	165(9)	161(9.9)
APDF 10th -90^{th}	136(6.5)	115(8.7)	169(4.9)	161(5.7)	159(10)	154(10)
Mean Power Frequency (Hz)						
10^{th}	.2 (0.05)	.2 (0.03)	.2 (0.05)	.2 (0.04)	.1 (0.06)	.1 (0.03)
50^{th}	.9(0.04)	.6 (0.05)	.7 (0.07)	.7 (0.08)	.5 (0.07)	.5 (0.07)
90^{th}	1.4(2)	1.2(.2)	1.3(.3)	1 (.24)	.9 (.1)	1(.2)
APDF 10th -90^{th}	1.1(2)	1(.2)	1(.3)	.9(.2)	.8(.1)	.9(.2)

Negative values denote postures in extension and left bend, positive values in flexion and right.

Table 4 .Correlation between VAS scores of shoulder discomfort and inclination data

Exposure variables	Bread baking systems					
	Tanoori(N=19)		Sangak(N=18)		Taftoon(N=20)	
	r	p	r	p	r	p
Right Shoulders						
inclination angle(50th)	.27	.26	.68	.002*	.36	.11
Time spent in flexion (%)						
neutral (<20º)	.13	-.35	-.32	.18	-.57	.01
extreme (>45º)	.27	.26	.33	.24	.17	.31
extreme (>60º)	.50	.02*	.63	.005*	.48	.03*
Movement velocities (°/s)	-.63	.004	-.87	.000*	-.60	.005*
Mean Power Frequency (Hz)	.03	.87	.02	.88	.10	.66
Left Shoulders						
inclination angle(50th)	.32	.18	.02	.54	.07	.41
Time spent in flexion (%)						
neutral (<20º)	-.24	.31	-.36	.14	-.10	.67
extreme (>45º)	.39	.09	.38	.12	.11	.64
extreme (>60º)	.29	.23	.20	.42	.27	.25
Movement velocities (°/s)	-.41	.08	-.61	.007*	-.30	.19
Mean Power Frequency (Hz)	.11	.64	.10	.7	.24	.31