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Effect of hand posture on maximum force grip and discomfort in tractor drivers

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Abstract

In designing work stations, maintaining best hand posture is particularly important in achieving the highest grip power. This study aims to assess the effect of hand posture on maximum force grip and discomfort in 24 tractor drivers in Sanandaj. maximum force grip in different postures using hydraulic dynamometer, and discomfort level using simulated 10-degree visual scale were measured and recorded. Significant relationships were observed between hand direction and also hand-shoulder distance and maximum force grip and discomfort level. The highest force grip was achieved at hand direction angles above 90 degrees. Maximum force grip was achieved at hand angle 135 degrees and hand-shoulder distance of 100 arm-reach (43.1 kg force). Also, the most discomfort was found at 45 degrees hand direction and hand-shoulder distance 50 of arm-reach (58.8 kg force).
Discomfort level and hand direction angle affect maximum force grip, and unless these ergonomic factors are taken into account in designing hand tools and controls, consequences such as increased accidents, fatigue, and musculoskeletal problems will inevitably follow.

Keywords: Discomfort, Posture, Tractor Drivers

Introduction

Force Hand grip is the force exerted by hand onto a specific position or instrument during work [1]. Manual work is part of most routine tasks such as industrial jobs, services, computer, driving, etc., in which force grip is directly and physically involved in the task. One of the problems considered by ergonomists, engineers, and healthcare professionals is the use of hand in performing physical tasks and its association with many harmful symptoms such as early fatigue, loss of occupational motivation, and high prevalence of musculoskeletal problems including carpal tunnel and Guyon tunnel syndromes in employees [2].
Fore grip is measured in ergonomics to assess the integrated function of muscles [3]. Ergonomists design and redesign work stations according to forced hand grip to eliminate or reduce workers' exposure to risk factors or non-ergonomic factors [4].

The prevalence of discomfort, pain, and musculoskeletal problems is substantially higher when work stations and tools are designed in such a way that workers are compelled to adopt non-neutral and stressful postures [5]. Computer and video terminal operatives that work in a non-neutral and non-ergonomic posture have reported numerous problems including carpal and Guyon tunnel syndromes and inflammation of tendons and ligaments [6]. More than 40% of computer operatives that worked in a non-ergonomic work station reported musculoskeletal problems and pain [7].

In developed countries, data obtained from population studies relating to the highest force grip and discomfort in different postures have been used in designing work stations and hand-held tools [8]. According to international studies, force grip is affected by posture of distal upper extremities (DUE) [9]. These studies have measured force grip in different postures of upper limbs, which were defined according to different angles of wrist, arm, and shoulder [10]. Workers use physical effort to grasp hand-held tools, machine controls or handles to perform their task [11]. Sengupta et al. confirmed the significant effect of hand posture on maximum force grip, and reported that the highest grip power can be achieved in standing position and at 90 degrees arm angle [12]. In a study on basketball players, Taghread et al. reported that fatigue and discomfort in the DUE significantly reduces all factors relating to force grip[13].

According to a standard protocol for measuring force grip, the person should be in sitting position, with straight shoulders, without rotation, elbow at 90 degrees, and forearm and wrist in neutral position [8]. However, workers perform their tasks using physical effort in different postures that are far from standard [9]. Force Grip depends on several factors, including hand angle and posture [14], wrist [15], arm [16], hand-arm distance [17], hand-shoulder distance [18], and also size and material of hand-held tool [19].

Studies should be conducted to identify the best postures for maximum force grip and least discomfort [20], and force grip [21] and discomfort [22] data should be used to design and redesign work stations and hand-held tools [22-24].

Specificity of mean data from every nation renders equipment designed and made in other countries useless. Thus, appropriate posture for maximum force grip and least musculoskeletal discomfort in DUE should be identified through ergonomic studies. The present study was conducted on tractor drivers with huge ergonomic problems caused by absence of national standards for appropriate design of agricultural machinery, and especially tractor driver's cabin. Review of literature showed a lack of a domestic study in this area and unavailability of data relating to maximum force grip and discomfort in different postures in Iranians. This study aims to measure the highest force grip and discomfort level in different hand positions in tractor drivers in Sanandaj city, west of Iran in 2013.

Method

This quasi-experimental study was conducted to assess the effect of hand posture on the maximum force grip and level of discomfort in tractor drivers. According to 5% first degree error and 80% power, sample size was found 16 drivers. However, to measure other postures as a secondary outcome, 24 drivers were selected by census. Study inclusion criteria were male drivers with more than 4 years of tractor driving history and no musculoskeletal diseases, and exclusion criteria involved drivers with any musculoskeletal problems, and those taking tranquilizers and sleeping pills. Accordingly, study population consisted of all tractor drivers with 4 years of experience (32 drivers) employed at the School of Agriculture, University of Kurdistan and Azad University of Sanadaj, of whom, 3 were excluded due to history of hand and forearm injuries, 3 due to musculoskeletal problems in hand, forearm, and arm, and 2 due to history of use of tranquilizers and sleeping pills, ultimately reducing samples size to 24 drivers. Drivers were informed of study method and objectives, and signed consent forms, and completed General Health Questionnaire (GHQ). Nordic questionnaire was used to assess their musculoskeletal status.

Then, anthropometric data, including height, weight and arm-reach were measured, followed by measurement of maximum force grip in one position (using dynamometer). Finally, using visual scale, discomfort level in different postures was assessed.

Before the main test, participants practiced a few times, held dynamometer in their hands, and reported level of discomfort.

In the main test, the designed hand position was established and subjects grasped dynamometer handle (different hand postures were defined according to distance and direction of hand from shoulder and arm). In this study, the test began with an alarm signal that continued throughout the 4-second test, during which subjects grasped dynamometer and exerted their maximum force grip, and stopped when the signal stopped. Afterward, discomfort level was assessed and recorded, and 7 minutes of rest was allowed until the next test in a different position. Subjects that required longer rest time were allowed to do so.

Hand position and posture:

Maximum force grip was measured in different hand positions, which were determined according to hand-shoulder distance and hand direction. Hand-shoulder distance is the distance between hand and shoulder joint, known as the percentage of arm-reach. The three hand-shoulder distances included 50%, 75% and 100% of arm-reach. At 100% arm-reach, dynamometer handle is grasped with fully stretched elbow and neutral wrist position. At 75% and 50% arm-reach, dynamometer handle was moved to maintain distance from shoulder equivalent to 75% and 50% of arm-reach respectively. Subjects were asked to grasp handle in a totally comfortable position.

Hand direction is determined by the line stretching from shoulder to hand, and is expressed as shoulder bending angle at 100% arm-reach of hand-shoulder distance. Five hand directions tested included 45, 90, 135, and 180 degrees. Thus, maximum force grip was measured in 15 hand positions (3 hand distances×5 hand-shoulder directions).

Discomfort level was measured for every hand position and maximum force grip. Subjects were asked about discomfort level in exerting maximum force grip. A vertical 10 cm line was used as the scale for measuring discomfort (from no discomfort=0, to maximum discomfort=10), and after every test, subjects marked their level of discomfort on this scale.

A hydraulic dynamometer (JAMAR) was used to measure maximum force grip in kg-force. Dynamometer was held by a bar that was easily adjusted according to height and direction.

A visual scale was used to rate discomfort level according to marks placed on the scale by subjects. Data obtained were analyzed in SPSS-19, using descriptive statistics for frequency of variables, and chi-squared and ANOVA tests for relationships between variable, at significance level $p<0.05$.

Results

Mean and standard deviation (SD) of drivers' age, height, weight, and BMI were 36.14±9.08 years, 1.74±0.79 meters, 77.66±12.18 kg, and 25.58±3.84 kg/m2 respectively.

According to Table 1, hand direction had a significant relationship with maximum force grip ($p=0.01$) and discomfort level ($p=0.0001$). Hand-shoulder distance had a significant relationship with maximum force grip ($p=0.001$) and discomfort level ($p=0.0001$). Furthermore, hand direction and hand-shoulder distance had a significant relationship with level of discomfort ($p=0.0001$).

According to Table 2, the highest force grip was achieved at hand angles above 90 degrees. The highest force grip (41.3 kg force) and the least discomfort (20.6 kg force) were achieved at hand-shoulder distance 75% of arm-reach.

According to Table 3, maximum force grip was achieved at 135 degrees hand direction and 100% arm-reach hand-shoulder distance (43.1 kg force), and minimum force grip at 45 degrees of hand direction and 50% arm-reach of hand-shoulder distance (37.5 kg force). The highest discomfort level was at 45 degree of hand direction and 50% arm reach of hand-shoulder distance (58.8), and the least discomfort at 90 degrees of hand direction and 100% ram-reach of hand-shoulder distance (30.8).

Table 1 *Force grip and level of discomfort data*

	Degree of freedom	Maximum force grip (kg force)		Degree of discomfort	
		F	p	F	p
Hand orientation	4	3.11	0.001	6.73	0.0001
Shoulder-hand distance	2	52.69	0.001	55.37	0.0001
Shoulder-hand distance × hand orientation	8	1.06	0.3	6.6	0.0001

Table 2 *Mean maximum force grip and level of discomfort in different hand postures of tractor drivers*

	Different levels	Maximum force grip (kg force)		Level of discomfort	
		Mean	SD (±)	Mean	SD (±)
Hand orientation	0	40.3	8.5	47.4	26.8
	45	40.4	8.6	44.8	24.1
	90	40.9	7.8	39.1	22.1
	135	41.6	8.4	43.3	22.2
	180	41.3	9.1	48.6	24.5
Hand-shoulder distance	50% arm reach	38.6	8.3	56.7	24.6
	75% arm reach	41.3	8.3	42.1	20.6
	100% arm reach	32.7	8.3	35.1	22.1

Table 3 *Mean and SD of maximum force grip and level of discomfort in different shoulder angles and hand-shoulder distances*

	Different angles	Hand-shoulder distances					
		100% arm reach		75% arm reach		50% arm reach	
		Mean	SD (±)	Mean	SD (±)	Mean	SD (±)
Maximum force grip (kg force)	0	42.5	8.8	40.3	7.8	38.2	8.4
	45	42.6	8.2	41	8.1	37.5	8.7
	90	42.5	7.9	41.6	7.9	38.5	7.2
	135	43.1	8.3	42.2	8.5	39.4	8.1
	180	42.7	8.8	41.5	9.4	39.7	9
Level of discomfort	0	31.1	19.2	42.7	21.7	68.4	24.5
	45	34.6	22.7	41.1	19.7	58.8	23.2
	90	30.8	20.2	36.5	19.5	50	22.3
	135	40.2	23.6	40.3	17.9	49.3	23.8
	180	38.9	23.7	49.9	22	56.9	24.6

Discussion

Results obtained showed that study population of 24 drivers was relatively young and tall, but according to BMI, mostly overweight. A significant relationship was observed between hand direction angle and maximum grip power (p=0.001), which agrees with several studies [7-9,19,22,24]. This relationship may be attributed to the fact that when hand angle is not neutral, muscles in this area are static and their coordination in uniform exertion of power is reduced, blood and energy supplies are also reduced, and thus less force is exerted [24].

Results also showed a significant relationship between hand direction angle and level of discomfort, which agrees with several studies [1,2,10,19,21]. This may be explained by the fact that in dynamic and neutral postures, all limbs are in full interaction, and there is no

stress or pressure, and thus no fatigue or pain is felt in any of them. By changing position and working in non-neutral postures, after a while, limbs involved become tired due to pressure points on nerves. Continued fatigue turns these symptoms into burn, inertia and pain, leading to loss of initial power in the limb [3,8,11,15].

A significant relationship was also observed between hand-shoulder distance and maximum grip power, which is supported by several studies [5-7,9]. This is explained by the fact that stress and pressure in muscles change with changing muscle length, thereby changing power exerted for the task [11,15].

According to results, there was a significant relationship between hand-shoulder distance and level of discomfort, which was also demonstrated in several studies [3,12,13]. This is due to increased force required to hold hand high due to changes in hand-shoulder distance, resulting in early tiredness of muscles, and feeling of discomfort, also leading to static state in some hand and shoulder muscles, which impairs blood supply to muscles, and energy is reduced due to accumulation of lactic acid, leading to early tiredness [2,4,6,7].

Results obtained showed no significant relationship between combined effect of hand direction with hand-shoulder and the highest grip power, which disagrees with several studies [2,10,19]. This may be due to use of a hand holder to change hand-shoulder distance and hand angle in the present study.

According to the results obtained, level of discomfort was significantly related to the combined effect of hand direction angle and hand-shoulder distance, which agrees with one study [13]. This is probably due to non-neutral posture of DUE that exerted huge pressure on hand and wrist muscles, tendons, and nerves and carpal and Guyon tunnels, resulting in increased discomfort [1,2,7,12].

The present study results also showed the lowest grip power at hand direction of 0 degrees angle, and the highest at 135 degrees, which agrees with several studies [6,7,16,19,22-24], and disagrees with one study [4] that reported the lowest grip power at hand direction 135 degrees and the highest at 0 degrees. This may be due to inadequately valid and reliable grip power measuring tools used in study [4].

The present study results showed the highest discomfort level at hand direction 0 degrees, and the lowest at 90 degrees, which agree with several studies [1,2,10,21]. This is due to changes in pressure exerted on muscles and also changes in dynamic/static status of muscles in the two directions [10,21].

The highest grip power (41.3 kg force) and the lowest discomfort level (20.6) were achieved at hand-shoulder distance 75% of arm-reach, and the lowest, and this was confirmed in several studies [9,13]. In this state, muscles were more coordinated and dynamic, creating more force and less discomfort [8,9].

Maximum grip power was achieved at 135 degrees hand direction and hand-shoulder distance 100% of arm-reach (43.1 kg force), and minimum [37.5 kg force) at 45 degrees hand direction and hand-shoulder distance 50% of arm-reach, which is supported by several studies [7,13,23].

The highest level of discomfort (58.8) was felt at 45 degrees hand direction and hand-shoulder distance 50% of arm-reach, and the lowest at 90 degrees hand direction and hand-shoulder distance 100% of arm-reach, which agrees with several studies [1,2,3,12].

Conclusion

Results of these kinds of studies can be used in designing work stations, and hand-held machinery and tools to increase operatives' comfort and reduce fatigue.

In the present study, there were no particular limitations, except in procuring dynamometer (due to economic hardships facing the country), which was resolved by cooperation of finance management of Kurdistan university of medical sciences.

The present study results can somewhat fill the gap in lack of studies in this area, and also showed significant relationships between hand posture and the highest grip power and level of discomfort. The grip power was higher at angles exceeding 90 degrees than other

postures. Given the importance of the subject, car manufacturers and production factories should design control levers and hand-held equipment in such a way to reduce high risk of hand injury and the prevalence of musculoskeletal problems in DUE, especially in hands, so that hand is positioned at angles above 90 degrees.

The present study results reveal the importance and the need for accounting ergonomic principles and human factors to match work stations and tools with dimensions of the body, which will play an obvious role in enhancing workers' motivation and morale, thereby increasing productivity.

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Contribution

Study design: FA
Data collection and analysis: FA, OG, MJ, KR
Manuscript preparation: FA, OG, MJ, KE, FB, FB

Conflict of Interests

"The authors declare that they have no competing interests."

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