◈ Research Paper

A Study on the Maximum Torque Exertion Capabilities of Korean

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Abstract

A laboratory experiment was conducted to investigate the effects of body posture and of different types of common non-powered hand tools on maximum volitional torque exertion capabilities of Korean. Fifteen males and 15 females were participated in the experiment. Each subject exerted maximum volitional torque in 15 different body postures while using five different common non-powered hand tools. Results of the data analysis showed that, for both males and females, the magnitude of torque exertion is significantly affected by the type of tool and posture. Also the result indicated that females exerted only about 51.5% of torque when compared to that of males. This result is different with the general findings in the field of ergonomics that the muscular strength of female is usually 65% to 75% of male. It suggests that application of same profile of muscular strength of female as in the western population should be carefully considered in oriental countries since females in this region may possess less physical capability compare to that of western females in terms of percentage muscular strength of males. Profiles of maximum torque capabilities of Koreans are provided.

1. Introduction

Although the technological developments and automations in modern industrial society have contributed in the improvement of work efficiency and the ease of work method, there still are a lot of jobs that require physical strength of human being as the major source of power. Especially in the assembly and manufacturing industries, many jobs are still in the form of labor-intensive which involve the use of upper body of workers while using non-powered hand tools. Improper selection of hand tool and use of the tools in awkward postures can lead to the onset of musculoskeletal disorders (Kim, 1991, Aghazadeh and Mital, 1987). Hence, it is important to investigate physical capacity and characteristics of workers, and the relationship between operators and their hand tools in order to establish safe workload and design safe and efficient hand tools. However, there have not been many studies conducted to investigate physical capability of the Korean population. Therefore, the main objectives of this study were to examine and compare maximum volitional torque capability profiles of Korean, and to investigate the effects of posture and type of hand tools on human torque exertion capability.

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2. Method and Procedure

2.1 Subjects

Fifteen healthy male and 15 female university students were participated in the experiment. They were interviewed prior to the experiment so as to screen the subject with any physical ailment especially in upper body and low back area. Descriptive statistics and some of the important physical characteristics of the subjects are presented in table 1.

2.2 Equipments

A Work Simulator (BTE PRIMUS Model) and attached 5 tools were used to measure torque exertion values in the experiment. Also a GPM type Anthropometer and Lafayette 78010 Hand Dynamometer were used for the anthropometric and grip strength measures.

Table 1. Descriptive statistics of subjects

Characteristics	male(n=15)	female(n=15)
	Mean(S.D)	Mean(S.D)
Age(years)	24.67(2.72)	20.87(1.85)
Weight(kg)	69.13(9.66)	53.89(8.01)
Upper arm length(cm)	34.30(2.31)	31.84(1.19)
Forearm length(cm)	26.17(1.46)	26.73(5.14)
Arm length	78.41(4.24)	70.50(3.86)
Shoulder width	45.81(3.13)	40.05(2.70)
Forearm grip distance	35.72(1.64)	32.79(1.57)
Stature	172.01(5.34)	160.83(5.54)
Eye height	160.17(5.27)	149.77(5.60)
Shoulder height	139.18(4.17)	130.71(4.60)
Elbow height	104.87(3.41)	98.70(3.79)
Knuckle height	65.20(2.44)	61.27(2.01)
Sitting height	89.53(2.88)	81.77(4.17)
Sitting eye height	78.41(2.77)	69.58(5.51)
Sitting shoulder height	58.00(2.27)	53.60(1.34)
Sitting elbow height	23.06(1.85)	19.62(3.38)
Knee height	52.47(1.74)	47.39(2.05)
Arm strength at elbow 90° (N·m)	79.09(12.91)	32.77(6.56)
Grip strength at elbow 90° (kg)	47.93(4.99)	27.33(3.89)
Grip strength at elbow 180° (kg)	44.33(4.81)	25.13(3.72)

2.3 Experimental Procedures

Using five different tools, each subject exerted maximum volitional torque in each of the 15 postures. Each subject performed total of 75 torque measurement sessions in random order. Subjects were asked to build up to the maximum torque gradually, without jerking; over 3 second period and then hold it at the maximum for about 1second. All the test were performed on the dominant side of hand and arm except the wheel test which used both hand. Each combination of tool and posture was replicated twice. If the two replicated values were within 10% each other in term of the measured value, the higher value was chosen for analysis. Otherwise, the same replication and selection procedure was repeated until the proper value was found. Thus each subject performed at least 150 volitional torque exertions. At least five minutes break after thirty minutes of data collection were provided to avoid build-up of static muscle fatigue. This was in addition to the built-in rest break (at least one minute) resulting from the time to change equipment setting for different treatment combinations. Fifteen different body postures and five different non-powered hand tools used in the experiment are described in table 2. The PRIMUS Work Simulator and 5 tools used in the experiment are depicted in figure 1 and some of fifteen working postures are presented in figure 2, respectively.

Table 2. Description of tools and postures

No.	Posture	Tool specification
1	Standing, elbow height, tool axis horizontal (outward)	1. Screw driver 12.3 cm long * 2.7 cm diameter 2. Socket wrench 22.9 cm long * 1.8 cm diameter 3. Cylindrical handle 12.2 cm long * 3.4 cm diameter 4. Rotating knob 1.8 cm high * 3.8 cm diameter 5. Steering wheel 45.8 cm diameter * 1.8 cm rim diameter
2	Standing, shoulder height, tool axis horizontal	
3	Standing, eye height, tool axis horizontal	
4	Standing, overhead, tool axis vertical (upward)	
5	Sitting, elbow height, tool axis horizontal	
6	Sitting, shoulder height, tool axis horizontal	
7	Sitting, eye height, tool axis horizontal	
8	Sitting, overhead, tool axis vertical	
9	Kneeling on one knee, elbow height, tool axis horizontal	
10	Kneeling on one knee, shoulder height, tool axis horizontal	
11	Kneeling on one knee, eye height, tool axis horizontal	
12	Kneeling on one knee, overhead, tool axis vertical	
13	Lying on the back, elbow height, tool axis vertical (upward)	
14	Lying on the back, shoulder height, tool axis vertical	
15	Lying on the back, eye height, tool axis vertical	

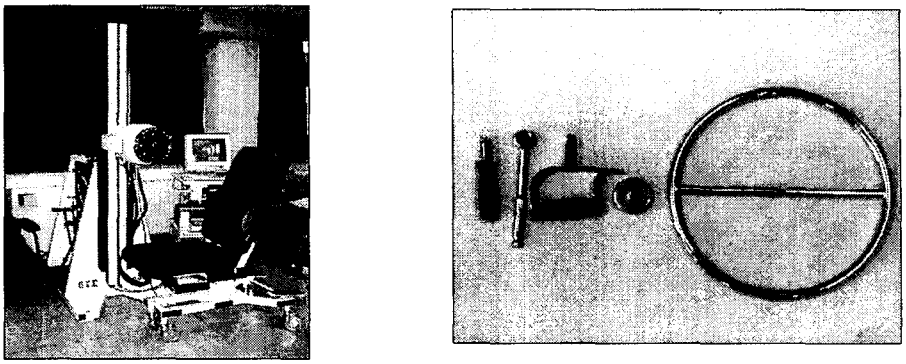
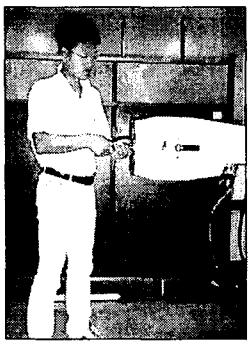
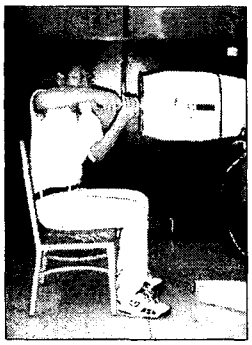


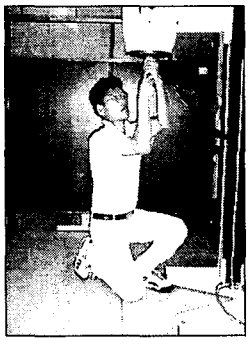
Figure 1. Pictures of Work Simulator and 5 Hand Tools



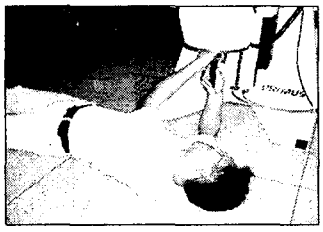
Posture 1



Posture 6



Posture 12



Posture 14

Figure 2. Photograph of working postures

3. Results

Analysis of variance (ANOVA) was performed for the data analysis. In the initial ANOVA including all data, all 3 main factors, gender, posture, tool type and interaction between posture and tool type had significant effects ($p<0.001$). Since the gender differences, as expected, were highly significant, a separate ANOVA for males and females was performed. For both males and females, the effect of tool type was more profound compared with the effect of posture on torque. Also for those task factors that had more than two levels, Duncun's multiple range test was carried out to separate a set of significantly different means into subsets of homogeneous means (Wapole and Myers, 1985).

3.1 Gender Effect

On the average, females exerted only 51.5% of the torque exerted by males. The average torque value of males was approximately 34.9N · m, whereas, the average torque of females was 17.9N · m. Also the ratio of the torque value of female over male in Korean population showed different pattern compared to the western population. In many previous researches, females usually showed about 2/3 of muscular strength compared with males (Mital, 1986, Mital and Sanghavi, 1986). However, in this study, Korean females only exerted 51.5% of torque value compared to the Korean males. This result may not agree with previous findings in many studies, however, it shows similar results in some other study. Astrand and Rodahl (1986) mentioned that the maximal leg muscle strength of the females is, on the average, 65 to 75 % of men's maximum. Also, for trunk muscles, the percentages are 60 to 70, but in elbow flexion and extension, females can attain only about 50 percent of the male maximum.

3.2 Effect of Tool Type

The effect of tool type was statistically significant at the 1% level. For further analysis, Duncan's multiple range test was conducted to separate a set of significantly different means into subsets of homogeneous means. The results showed the homogeneity only between screwdriver and knob. And both male and female exerted more torque values in the order of steering wheel, socket wrench, cylindrical handle, and rotary knob and screwdriver. Females exerted 65% of male torque with screwdriver, 59% with rotary knob, 57% with cylindrical handle, 47% with socket wrench, and 52% with steering wheel. Table 3 shows the results of Duncan's multiple range test on type of the tools.

Table 3. Duncan's multiple range test on tool type

(uint: N · m)

Male	
Tool type	Mean
Screwdriver	6.20
Knob	7.33
Handle	12.67
Wrench	53.42
Wheel	94.86

Female	
Tool type	Mean
Screwdriver	4.03
Knob	4.31
Handle	7.23
Wrench	25.37
Wheel	49.00

3.3 Effect of Posture

The effect of posture also was statistically significant at the 1% level. Also, Duncan's multiple range test was conducted to find homogeneous means among the torque value using different tools. The result showed that on the average, both male and female exerted the most torque in posture No.3 (standing, eye height, tool axis horizontal), whereas, males showed the least value in posture No.4 (standing, overhead, tool axis vertical) and females exerted the least torque in posture No.12 (Kneeling on one knee, overhead, tool axis vertical), respectively. The results also revealed that relatively higher torque were exerted at shoulder and eye height, whereas, relatively less torque were found at elbow and overhead height. Table 4 shows results of Duncan's multiple range test on posture.

Table 4. Duncan's multiple range test on posture

(unit: N · m)

Male	
Posture	Mean
4	28.33
8	28.48
12	28.49
13	28.64
5	29.31
1	30.94
9	31.86
14	35.22
6	35.56
15	37.33
7	38.42
10	40.64
11	42.13
2	42.56
3	45.69

Female	
Posture	Mean
12	13.82
4	13.89
8	14.05
5	14.92
13	15.03
9	16.03
1	16.62
14	17.21
6	18.28
15	19.61
7	19.93
10	22.17
2	22.25
11	22.78
3	23.18

3.4 Comparison with Other Studies

The results of present study were compared with previous researches conducted by Mital(1986), and Mital and Sanghavi(1986) in America. It was not possible to find exactly same studies in terms of experimental conditions unless they are duplicated and these two studies were the latest in terms of date and the closest in experimental conditions from the literature review. And only minimal comparison was performed in terms of percentage of torque value exerted by female over male to avoid meaningless or improper comparison. Mital(1986) conducted an experiment with 36 males and 14 females at 21 postures using 9 different tools. Mital and Sanghavi(1986) studied with 30 males and 25 females at 108 postural·combinations with 5 types of tools. The results from both studies showed that type of tool and posture had significant effect on maximum torque exertion. The present study showed same results. However, both studies with western population showed that maximum volitional torque of females was about 66% of males, whereas, in the present study, Korean females only exerted 51.5% torque value when theyare compared with Korean male on the average. Results of comparison are shown in table 5 and maximum volitional torque exertion profiles of Korean are given in table 6, respectively.

Table 5. Comparison with other studies

	Gender	Age(yrs)	Torque (N·m)	% (Female /Male)
Mital (1986)	Male	22.4	20.3	66.0%
	Female	23.3	13.4	
Sanghavi (1983)	Male	22.7	19.3	66.0%
	Female	21.6	12.8	
Present study	Male	24.7	34.9	51.5%
	Female	20.9	17.9	

Table 6. Average torque(N · m) at varying postures and different hand tools

(Male, n=15, uint: N · m)

Posture	Screwdriver			Wrench			Handle			Knob			Wheel		
	Mean	S.D	Range	Mean	S.D	Range	Mean	S.D	Range	Mean	S.D	Range	Mean	S.D	Range
1	6.53	1.22	5.2-9.8	43.85	8.90	28.0-62.1	12.66	1.73	9.7-15.8	7.24	1.52	4.9-9.9	84.41	13.84	51.8-108.8
2	6.44	1.50	3.2-9.4	73.85	19.70	34.6-127.0	13.71	3.74	8.1-20.3	8.02	2.60	5.0-14.5	110.76	21.27	65.8-141.3
3	6.14	1.38	4.1-8.8	79.44	12.36	47.6-98.9	12.88	2.81	6.3-16.8	7.64	1.30	5.0-9.5	122.34	23.50	71.9-155.0
4	6.79	1.50	4.3-8.8	39.30	13.35	25.0-60.2	13.61	4.37	7.5-23.9	7.70	2.33	4.3-11.6	74.24	14.07	43.8-107.9
5	5.90	1.44	4.0-9.7	39.46	8.52	25.6-53.9	11.40	1.52	7.6-13.1	6.31	1.39	3.8-8.9	83.50	14.40	51.0-108.7
6	5.89	1.60	3.6-9.9	57.73	12.29	32.4-75.9	11.83	1.70	9.3-15.5	6.95	1.32	4.1-8.6	94.41	17.74	50.4-126.2
7	5.55	1.53	3.1-8.1	61.05	12.30	32.6-80.4	11.00	3.47	4.8-17.7	6.85	1.78	4.1-9.4	107.64	24.24	59.7-142.7
8	5.83	1.00	4.2-7.8	39.01	11.17	25.1-71.0	12.64	2.25	6.0-15.6	6.51	1.78	4.1-11.0	78.40	17.97	45.3-115.9
9	7.26	1.48	5.3-10.5	43.39	9.35	28.7-61.0	13.86	2.86	9.8-19.1	7.36	2.11	4.0-10.7	87.43	16.06	51.3-107.8
10	6.68	1.86	4.0-10.5	65.59	12.31	35.7-82.1	12.85	2.76	8.5-16.7	8.17	2.21	5.0-12.8	109.92	17.50	66.0-133.5
11	6.01	1.36	4.3-9.6	73.48	13.54	34.3-83.6	12.74	3.19	6.4-17.9	7.45	2.0	3.6-10.6	110.96	19.72	74.9-146.7
12	7.12	1.49	5.4-9.5	38.58	8.36	21.5-50.7	13.50	3.66	8.0-20.7	7.37	2.09	3.8-9.9	75.91	15.25	45.7-103.5
13	5.82	1.38	3.5-8.5	40.38	8.44	23.3-57.7	11.84	2.99	6.0-16.2	7.02	2.32	3.8-12.1	78.14	11.69	50.1-96.6
14	5.60	1.42	3.5-8.2	49.34	10.69	24.5-71.4	12.81	3.46	6.9-18.8	7.69	2.63	4.3-13.3	100.66	18.95	55.9-138.7
15	5.36	1.29	3.4-8.5	56.80	10.74	32.9-70.7	12.72	3.57	8.2-20.6	7.66	2.17	4.4-11.8	104.13	20.13	57.2-133.7

Table 6. Average torque(N · m) at varying postures and different hand tools(continued)

(Female, n=15, uint: N · m)

Posture	Screwdriver			Wrench			Handle			Knob			Wheel		
	Mean	S.D	Range	Mean	S.D	Range	Mean	S.D	Range	Mean	S.D	Range	Mean	S.D	Range
1	4.48	1.68	1.9-7.6	21.24	5.45	12.9-31.9	6.94	2.08	3.4-9.5	4.71	1.89	2.3-9.3	45.72	11.71	31.3-79.1
2	4.15	1.47	1.9-7.9	33.79	9.13	20.8-49.7	8.78	3.43	4.3-15.5	5.01	2.00	2.4-9.6	59.51	13.37	35.4-85.3
3	3.67	1.70	1.3-7.2	35.54	6.06	27.6-47.1	8.76	2.65	5.4-12.9	4.97	2.20	2.5-9.9	62.92	15.98	38.5-87.9
4	4.45	1.81	1.8-8.1	18.41	3.86	13.8-25.6	5.88	2.58	3.1-12.0	4.62	1.94	1.4-8.1	36.11	5.65	28.9-46.4
5	3.85	1.51	1.8-7.6	20.15	5.75	13.4-36.4	5.96	2.23	2.6-11.3	3.76	1.20	1.6-5.8	40.90	8.67	26.1-53.3
6	3.80	1.78	1.1-7.6	26.77	6.58	19.1-43.7	7.34	2.35	2.8-11.3	4.47	2.00	1.9-9.0	49.02	12.63	29.8-86.0
7	3.61	1.66	0.9-7.5	30.24	8.63	19.8-52.9	6.90	2.76	3.2-12.1	3.87	1.45	2.0-7.0	55.00	14.00	33.2-85.4
8	4.44	2.06	2.0-9.5	19.45	6.97	10.8-38.0	5.50	1.47	3.7-8.2	3.11	0.79	1.5-5.0	37.76	12.46	20.9-68.9
9	4.53	2.11	1.0-8.8	21.55	6.75	13.8-37.5	7.21	2.77	2.5-11.8	4.53	1.77	2.1-7.2	42.32	7.24	29.8-58.2
10	4.02	1.54	1.5-6.7	32.03	6.06	24.0-44.3	7.91	2.57	4.9-15.5	4.74	1.20	2.6-7.1	60.78	12.86	35.6-79.5
11	3.98	1.82	1.9-8.5	35.18	7.71	22.5-49.7	8.88	3.88	4.5-18.1	4.42	1.28	1.8-6.8	61.41	14.70	31.9-83.8
12	4.68	2.04	2.4-9.4	18.48	3.55	13.0-25.1	6.19	2.19	3.2-10.3	3.84	1.90	1.4-8.6	35.78	10.72	21.6-55.4
13	3.70	1.71	1.6-8.2	18.99	4.09	13.4-27.1	5.84	2.59	2.5-10.4	4.15	2.10	0.9-9.7	42.48	8.79	28.0-62.9
14	3.66	1.62	1.1-7.6	22.31	5.18	14.6-34.6	7.52	2.71	4.5-13.6	3.96	1.03	2.4-6.7	48.55	9.61	32.9-64.3
15	3.35	1.63	1.1-7.2	26.32	6.7	13.7-41.6	7.42	1.66	5.1-10.7	4.28	1.83	1.6-8.2	56.66	11.71	40.2-81.5

4. Conclusions and Remarks

The results of this study leads to following conclusions.

1. The maximum volitional torque exertion profiles of Korean have been investigated at varying postures with different non-powered hand tools. The results of ANOVA indicated that both the posture and tool type had significant effects on the maximum torque capability.
2. Korean females, on the average, exerted only about 51.5% of male torques. This is quite different pattern of torque exertion compared with western population. Further investigation with more oriental population is proposed to establish proper work guide for oriental females that might be different with that of western populations.
3. Relatively higher torque were exerted in the order of steering wheel, wrench, handle, knob, and screwdriver as one may speculate that torque exertion was affected by lever arm of the tools. Also both males and females exerted relatively higher torque value at shoulder and eye height, whereas, relatively less torque were found at elbow and overhead height.
4. The maximum volitional torque exertion data and other findings from this study can be applied in the establishment of safe workload in manual work and also in designing of more safe and efficient hand tools.

The results of this study could be used in establishing a database for physical strength of Koreans and also in design of more safe and efficient hand tools. However, limited scopes of population in this study leaves many research topics for further studies. Hence, more studies for different age groups are needed to establish extensive database. Also, a joint research program with other oriental countries can be performed to find if there is any racial differences in physical strength profile between male and female.

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