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Short Communication

Association of Hand Anthropometric Dimensions and Pushing and Pulling Muscular Strength

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ABSTRACT

Background: Pushing and pulling are common actions while using hand tools in workplaces and homes. Such repetitive actions by operators require high torque generation, resulting in musculoskeletal complaints of the lower back and upper extremities. Repetitive forceful exertions in long duration works leads to increased risk of musculoskeletal disorders and injuries. Anthropometric dimensions, such as weight, stature, hand length, hand breadth may affect the maximum push-pull force exertion.
Materials and Methods: The present study was conducted on male subjects (N=100) of 18-60 years age group. The study quantified the hand-arm-shoulder complex strength (isometric strength) testing of the dominant hand during pushing and pulling tasks. Anthropometric dimensions of the hand were measures and correlated with the strength parameters.
Results: Pulling strength generated recorded higher (~14% to 17%) than the pushing strength in both short and long duration test. Short duration activity could generate higher strength (~17% to 19%) as compared to the endurance tasks. For both pushing and pulling operations, peak strength was achieved within first few seconds, and thereafter a sharp decline was observed till the end of the bout at 60 seconds. The weight ($p<0.01$) and hand breadth at metacarpal III ($p<0.05$) were correlated with pushing and pulling strength, which implies that pushing and pulling tasks were dependent on weight of an individual, as well as breadth of the hand across metacarpal III.
Conclusion: The strength data generated would help in work schedule design and assist in developing engineering guidelines in the design of tools at workplace.

Keywords: Push-pull tasks, strength, anthropometry, work design, musculoskeletal disorders.

INTRODUCTION

Pushing and pulling activities are common tasks at workplaces, which require variable allowance of shoulder, arm and whole hand manipulations. Incessant or frequent maneuvering of such types of activities requires high torque generation by the upper extremity. More than half of the manual materials handling tasks necessitate pushing as well as pulling forces. [1] Particularly for pushing and pulling type of activities in dynamic postures, musculoskeletal system gets overexerted as well as there remains an elevated accidental risk, which might be due to tripping or slipping, while applying forward or backward straight translational inertial movement. [2]

Anthropometric dimensions, such as weight, stature, hand length, hand breadth

affect the maximum pushing and pulling force exertion, and may be relevant to protect the individual from musculoskeletal injury or muscular overloading. In 2011, Hendriske [3] reported correlation between height and weight and the generation of pushing and pulling strength with both hands in dynamic postures. Some other studies reported also found correlation between hand dimensions with hand grip strength of the workers. [4,5] However, literature also reports some studies which observed that hand anthropometric parameters did not significantly influence upper extremity strength. [6, 7]

It is understood that pushing and pulling actions may bring about fatigue, injury and musculoskeletal disorders in various areas of the body, predominantly the upper extremities. Therefore, the present study was conducted to understand the relationship between anthropometric dimensions of the hand and the pushing and pulling strength in short duration and long duration operations.

MATERIALS & METHODS

The study was conducted on 100 healthy male working subjects in the age group of 18-60 years. The ethical approval for the study was obtained from the Institutional Ethical Committee of the Institute. A written consent was also obtained from each subject after explaining the objectives, outcomes and ethical issues involved in the study.

Height was measured on a stadiometer and weight was measured on a weighing scale. Four anthropometric parameters of the hand namely, hand length, hand breadth, hand breadth at metacarpal III and hand breadth across thumb were measured using a vernier caliper.

The strength measurement experiment was carried out in Humac Norm Testing and Rehabilitation System, Humac Norm-770, CSMi, USA. The pushing and pulling strength was measured as torque (in Nm) in erect seated posture. The handle diameter of the pushing and pulling coupler was 32 mm and the handle length was 125 mm. The handle was kept at the knee height parallel to the plane of the thigh, while the subject was sitting. The strength measurement tests were performed by the subjects with their dominant hand for short duration (7 seconds) and long duration (1 minute) tests in isometric mode.

Statistical Analysis

The statistical analysis was carried out in SPSS version 16.0. The data were expressed as mean and standard deviation. For the anthropometric and strength parameters, 5^{th} and 95^{th} percentiles were calculated. The correlation between strength parameters and anthropometric variables were measured though two-tailed bivariate correlation with Pearson correlation coefficient.

RESULTS

The characteristics of the subjects and their anthropometric attributes are depicted in Table 1. The mean age of the volunteers was 35 years (range of 18-60 years). The mean values of the parameters revealed that the subjects were homologous in terms of the parameters measured. The coefficient of variation explained that the variation was consistent (except age and weight), suggesting extremely constant anthropometric variability relative to the mean for all of the measured variables.

Table 1. Anthropometric profile of the study population.

	Mean (SD)	COV (%)	Range	Percentiles	
				5^{th}	95^{th}
Age (yrs)	35.0 (11.5)	32.9	19-59	20.1	58.0
Height	170.9 (7.1)	4.2	152-187	159.0	183.0
Weight (Kg)	69.1 (13.3)	19.2	37-98.0	49.0	93.7
Hand length	18.6 (1.0)	5.3	16-21.0	17.0	20.1
Palm length	11.0 (0.7)	6.4	10-12.0	10.0	12.0
Hand breadth across metacarpal III	8.3 (0.5)	6.0	7.0-10.0	8.0	9.0
Hand breadth across thumb	10.0 (0.5)	5.0	9.0-11.0	9.0	11.0

SD = Standard deviation; COV = Coefficient of variation; all values in cm, unless otherwise mentioned.

The observed strength data during the pushing and pulling activities in short duration and long duration tests are depicted in Table 2. Pulling strength was ~14% to 17% higher than the pushing strength in both short duration and long duration tests. Short duration activity could generate ~17% to 19% higher torque as compared to the long duration activity. Consistent coefficients of variation (32.4% to 41.7%) suggested that there was moderately constant strength variability relative to the mean for both pushing and pulling conditions. Further, for the 1-minute test for both pushing and pulling operations, the subjects achieved their peak strength within the first few seconds of strength application. However, a sharp decline from the peak strength was observed thereafter, which continued till the end of the test at 60th second.

Table 2. Pushing and pulling strength (Nm) during short duration and long duration tests.

Condition	Mean (SD)	COV (%)	Min-Max	5th-95th Percentile
Pull 7 sec	28.99 (12.1)	41.7	10.4 - 73.6	13.84 - 48.42
Push 7 sec	23.96 (8.6)	37.1	9.0 - 50.8	11.49 - 39.72
Pull 1 min	23.27 (9.6)	41.2	7.4 - 43.2	9.44 - 39.2
Push 1 min	19.88 (6.4)	32.4	6.0 - 37.6	10.16 - 29.97

Table 3 depicts the association between anthropometric parameters and pushing and pulling strength parameters for the studied subjects. The weight was highly correlated with the pushing activity ($p<0.01$). Hand breadth at metacarpal III was correlated with pushing and pulling strength ($p<0.05$). This implies that the pushing task was dependent on weight of an individual, whereas the breadth of the hand across metacarpal III influenced both type of activities. This implied that grip size of the handle of the pushing and pulling tool plays important role in the strength generation.

Table 3. Correlation between anthropometric parameters and pushing and pulling strength parameters.

Condition	Height	Weight	Hand length	Palm length	Hand breadth across metacarpal III	Hand breadth across thumb
Pull 7 sec	.009	.154	.095	.148	.167	-.007
Push 7 sec	.027	.279**	.078	.124	.204*	.004
Pull 1 min	-.041	.146	.106	.105	.221*	.002
Push 1 min	.137	.323**	.143	.108	.231*	.048

* Significant correlation at 0.05 level (2-tailed); ** Significant correlation at 0.01 level (2-tailed).

DISCUSSION

Continuous or frequent use of pushing and pulling tasks in repetitive forceful exertions are associated with elevated risk to muscular discomfort, fatigue and injury to workers. [8] It is imperative to comprehend the maximum capacity of muscular strength, as a step towards controlling the occurrence of injury and musculoskeletal disorders. Further, as any pushing and pulling activity would require grip of the hand while holding on the tool, hand dimensions may play a pivotal role in generation and sustaining the strength produced.

In the present study, weight and hand breadth at metacarpal III were observed to be correlated with pushing and pulling tasks. Several studies earlier have demonstrated that height, weight and BMI influence strength generation. [3, 9] In a study on push and pull strength, the researchers reported that height and weight of the subjects significantly influenced generation of pushing and pulling strength with both hands in dynamic postures. [3] However, in our study, height did not influence the strength generation. This might be because the earlier studies considered both hands strength in specified dynamic postures, while the present study considered static condition in sitting position, restricting the allowance of muscle groups other than the upper extremity. The present study corroborates in fraction with the earlier studies of Kumar *et al.* [10] and Hendriske, [3] wherein weight was observed to be significantly influencing the push-pull

strength. The reason could be that pushing and pulling activities demand exertion of heterogeneous groups of muscles of the body other than the upper extremity and a participant can generate strength against the weight of their body, even if the posture is restricted. Thus, in the present study, although height did not show significant effect on strength generation, body weight of the subjects impacted to the torque generated during the pushing and pulling tasks.

In the present study, some hand anthropometric parameters namely palm length, hand breadth at metacarpal III were significantly correlated with pushing and pulling strength. The results corroborate with the earlier findings which also witnessed that dimensions of the hand are correlated well with hand grip strength of the working population. [4, 5] However, a study on the push/pull handle for vertical ladder attributed the decreases in strength because of friction of the hand with the handle. [11] The present study results may not have influenced by handle friction, as both pushing and pulling tasks were performed on horizontal plane. Further, a study from India also reported that on an optimum handle diameter of 31-35 mm, major forces of thumb and fingertips can be applied simultaneously against the palm, resulting in high reaction force and maximum strength generation. [12] Corroborating with these earlier studies, the results of the present study with 32 mm handle diameter revealed some association of hand dimensions with the strength generated.

CONCLUSION

Association of weight and hand breadth at metacarpal III with the pushing and pulling tasks was observed in the study. This implied that pushing and pulling strength during short duration and long duration efforts are influenced by the weight of an individual, in addition to the breadth of the hand which holds the grip of the tool. This would assist in developing suitable engineering design guidelines, as a steady action towards control of repetitive strain injuries and musculoskeletal disorders through the reduction in overloading of muscles.

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