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ORIGINAL ARTICLE

Identifying sincerity of effort by grip strength ratio of three wrist positions in individuals with upper extremity musculoskeletal disorders

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Abstract

Objectives: To evaluate whether the grip strength ratio of three wrist positions could determine sincerity of effort (SOE), by differentiating between maximal effort (ME) and submaximal effort (SE), in individuals with upper extremity musculoskeletal disorders (MSDs).

Methods: A total of 19 volunteers with unilateral upper extremity MSDs (9 males, 10 females) participated in this study. Participants performed grip strength tests in neutral, full flexion, and full extension wrist positions for both hands. In each wrist position, they exerted grip force with their ME and preferred SE for three times.

Results: Significant main effects of type of effort, wrist position ($P < .001$), and hand ($P = .005$) were observed. The results also showed significant interactions for type of effort × wrist position ($P < .001$) and wrist positions × hand ($P = .001$). Moreover, the grip strength ratios of neutral/flexion (N/F) and neutral/extension (N/E) between ME and SE differed significantly ($P < .001$).

Conclusion: This study suggests that the N/F and N/E grip strength ratios can discriminate between ME and SE in individuals with upper extremity MSDs. Thus, this test might be applicable to use for identifying SOE in clinical setting.

KEYWORDS

grip strength, maximal effort, musculoskeletal disorders, sincerity of effort, submaximal effort, wrist position

1 | INTRODUCTION

The most common work-related injury is musculoskeletal disorders (MSDs). It is the cause of continuous health problems and physical disability among workers worldwide.[1,2] MSDs generate additional costs and affect the quality of life.[3] Upper extremity MSDs are also commonly found in many professions.[4] In specific working populations, the prevalence of upper extremity MSDs has been reported to range from 22% to 40%.[5] In addition, it has been reported that there were greater cost and work disability related to upper extremity MSDs than to acute upper extremity injuries.[6] Moreover, the prevalence of symptom exaggeration or malingering could be approximately 30% of disability or worker's compensation case.[7]

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Sincerity of effort (SOE) is a condition of patient with motivation to perform the test with maximal or optimal effort. Insincere effort is a condition when patients give less than full effort during the test.[8] However, during evaluation and treatment, individuals with upper extremity MSDs may exert lower effort than a maximal voluntary contraction. Some people may put forth submaximal effort (SE) unintentionally.[9,10] On the other hand, some individuals may intentionally exert SE for other reasons such as receiving more compensation and avoiding return to work.[8,9,11,12]

Therefore, health care professionals need a method that is valid and reliable to identify if a client is malingering because without exerting sincere effort an individual cannot be effectively rehabilitated. Identifying the SOE is necessary for effective rehabilitation program. Some existing SOE methods such as electromyography, the force-time curve, and torque-velocity test are not simple to apply in the clinical setting because of their complexity and lengthiness to administer.[13–15] Grip strength test is one of the methods that can be used to determine upper extremity weakness.[16] The SOE tests that usually are applied in the clinical setting include five-handle position test, the coefficient of variation, and the rapid exchange grip test.[17,18]

Currently, there are no widely accepted methods for identifying the SOE. A recent study by Bhuanantanondh and colleagues suggested that the grip strength ratio of neutral/flexion (N/F) and neutral/extension (N/E) may also be used to identify the SOE in the clinic. However, in their study, they conducted the test in healthy participants.[19] Thus, the purpose of this study was to investigate whether the grip strength ratio of different wrist positions could discriminate between maximal effort (ME) and SE in individuals with upper extremity MSDs. Our hypotheses were that grip strength ratio of three wrist positions could detect SOE in individuals with upper extremity MSDs.

2 | METHOD

2.1 | Participants

Nineteen volunteers with unilateral upper extremity MSDs aged 20–40 years old were included in this study. Individuals with history of fracture or surgery of upper extremity, neurological problems, upper extremity deformity, and systemic inflammatory disease were excluded. All participants read and signed the informed consent that had been approved by the University where the research was conducted.

2.2 | Procedures

The methodology used in this study was adapted from a previous study.[19] This study was a within-subject research design comparing between ME and SE during performing grip strength tests in neutral, full flexion, and full extension wrist positions (Figure 1). In the ME condition, the participants applied force with 100% effort. In the SE condition, they exerted force with their preferred effort. All tests were performed with Jamar dynamometer (Sammons Preston, Bolingbrook, IL). Handle position was set at the second notch position. Participants performed practice trials for 1 min to familiarize themselves with the task prior to begin the test.

The order of the ME or SE condition was randomized for each participant. For all tests, the tested upper extremity of each participant was positioned with shoulder close to side of the body and neutrally rotated, elbow flexed in right angle, and forearm in a neutral position. The test started with the wrist in neutral position, followed by full flexion and full extension, respectively. In each wrist position, they exerted grip force with their ME and preferred SE for three repetitions. Each repetition lasted 3 s with a 5-s interval for interchanging between left and right hands. A one-minute rest period was provided between each test.[20] During the tests, the researcher provided standardized verbal instructions, but did not provide visual or auditory feedback to the participants.

2.3 | Statistical analysis

SPSS version 22.0 (IBM, Armonk, NY, USA) was used for data analysis. Descriptive statistics were reported as mean and standard deviation. The normality of the data was tested using Shapiro-Wilk test. A three-way repeated-measures analysis of variance (ANOVA) was used to compare differences in grip strength between ME and SE in

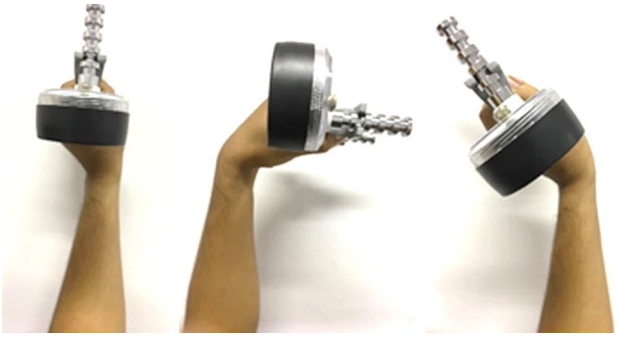

FIGURE 1 Three wrist positions (neutral, full flexion, and full extension)

three wrist positions of both hands. We used paired *t*-test to compare ratios of grip strength between ME and SE. Statistically significant was set at *P*-value <.05.

3 | RESULTS

There were 19 volunteers (9 males and 10 females) with unilateral upper extremity MSDs participated in this study (mean age of 24.32 ± 6.20 years). All participants were right-hand dominant and had MSDs at the right upper extremity with mild to moderate pain. Of all participants, three had scapular pain, four had shoulder pain, four had elbow pain, two had forearm pain, and six had wrist pain. Table 1 shows the demographic data of the participants.

The grip strengths of different wrist positions for ME and SE of the left and right hands are shown in Table 2. The results showed that there were significant main effects of type of effort ($F[1,18] = 149.225$, $P < .001$), wrist position ($F[2, 36)] = 56.684$, $P < .001$), and hand ($F[1, 18] = 10.315$, $P = .005$). Moreover, significant interactions were found for type of effort × wrist position ($F[2, 36] = 36.041$, $P < .001$) and wrist positions × hand ($F[2, 36) = 9.886$, $P \leq .001$).

The N/F and N/E ratios of grip strength of the ME and SE are shown in Table 3. Significant differences between ME and SE in the ratios of N/F and N/E of both hands were also observed ($P < .001$).

4 | DISCUSSION

The present study found that the grip strength ratios of N/F and N/E were substantially different between ME and SE. The ratios of N/F were greater than 1.7 in the ME condition and less than 1.3 in the SE. The ratios of N/E were greater than 1.4 in the ME condition, and less than 1.1 in the SE condition. The findings were in line with a previous study which was conducted in healthy participants.[19] This suggested that the grip strength ratios of N/F and N/E might be used to assess the SOE in people with upper extremity MSDs. The considerable lower grip strength and grip strength ratio found in the SE condition in comparison with ME condition may be explained by a model developed by Kroemer and Marras.[21] They postulated that repetitive feedback signals by adjusting the muscle fiber firing rates and the muscle fiber recruitments would require to control the muscle in the SE condition.

All grip strength tests in this study used the Jamar dynamometer. The handle of the dynamometer was set at the second notch position because at this position muscle would be in the optimal length to generate grip force and usually are used in clinical setting.[22] In addition, the method used in this study was adapted from a previous study.[19] In their study, 50% of ME was used in the SE condition. However, in this study, participants exerted self-adjusted effort in the SE condition. In addition, according to a study by Trossman and Li,[20] at least 1-min rest period should be provided between each grip strength test. Thus, a 1-min rest period between each test provided in this study should be an adequate time for muscle recovery. Therefore, the order of the test should not affect the findings in the present study.

It should be pointed out that all participants in this study were right-handed and had upper extremity MSDs on the right side. The finding of this study showed that in the ME condition, the dominant hand grip strength was still higher than the other hand. This finding is in agreement with the study by Noguchi and colleagues which asserted that the dominant hand is better in exerting maximum isometric contraction and controlling force exertion than the non-dominant hand.[23]

Moreover, the greatest grip strength was observed when performing the test with neutral position of the wrist in both effort conditions. The grip strength declined substantially during performing the tests with

TABLE 1 Mean and standard deviation of demographic data of the participants ($n = 19$)

Characteristics	Mean ± SD
Age (years)	24.32 ± 6.20
BMI (kg/m^2)	21.11 ± 2.15
Duration of pain (months)	8.58 ± 6.44
Pain scale	2.97 ± 1.33

TABLE 2 Mean and standard deviation of the grip strength in different wrist positions for maximal and submaximal efforts of the left and right hands

Hand	Type of effort	Mean (SD) Neutral wrist position	Mean (SD) Flexion wrist position	Mean (SD) Extension wrist position
Left	Maximal	29.09 (8.31)	17.30 (4.38)	20.91 (4.72)
	Submaximal	11.37 (3.77)	9.84 (2.56)	11.39 (2.89)
Right	Maximal	31.47 (8.06)	18.23 (4.41)	21.25 (3.96)
	Submaximal	12.72 (3.23)	10.00 (2.34)	11.56 (2.94)

TABLE 3 Mean ratios and standard deviation of neutral/flexion (N/F) and neutral/extension (N/E) of maximal and submaximal effort of left and right hands

		N/F ratio			N/E ratio		
Hand	**Type of effort**	**Mean (SD)**	***t***	***P*-value**	**Mean (SD)**	***t***	***P*-value**
Left	Maximal	1.71 (0.39)	5.291	<.001*	1.41 (0.22)	4.899	<.001*
	Submaximal	1.15 (0.23)			1.00 (0.24)		
Right	Maximal	1.75 (0.35)	6.129	<.001*	1.49 (0.33)	4.539	<.001*
	Submaximal	1.28 (0.20)			1.09 (0.16)		

**P*-value <.05.

wrist in full flexion and extension positions. The findings are in line with previous studies.[19] Pryce[24] in 1980 was reported that the maximal grip strength was observed at 15° of wrist extension with no deviation. Another study by Li[25] in 2002 also found that the deviation of finger forces with the wrist toward flexion had a greater effect on decreasing than deviation toward extension. The decreased of grip strength with the non-neutral position of the wrist might be associated with the muscle length-tension relationship.

This study has some limitations. One of the limitations is that the majority of the participants in this study were young adults with unilateral upper extremity MSDs. Therefore, the findings may not be applicable to other population. Another limitation is that each participant had different area of upper extremity MSDs. Thus, this might affect the interpretation of the results. Furthermore, participants perform SE based on the researcher's command which might not be the same situations that may occur in a clinic. Future studies are needed to run in clinical settings and find sensitivity and specificity of this protocol.

In conclusion, the results suggest that the N/F and N/E ratios of grip strength obtaining from three wrist positions can distinguish between ME and SE in individuals with upper extremity MSDs. It suggests that this protocol might be applicable to use in clinical setting by using the ratio greater than 1.7 (N/F) and 1.4 (N/E) for the ME condition and ratio less than 1.3 (N/F) and 1.1 (N/E) for the SE condition to detect or predict SOE.

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DISCLOSURES

Ethical approval: The Mahidol University Central Institutional Review Board reviewed and approved the protocol of this study (COA No. MU-CIRB 2016/127.2309). *Informed consent*: All participants signed a consent form, and anonymity and confidentiality were assured. *Registry and the registration no. of the study/trial*: N/A. *Animal studies*: N/A. *Conflict of interest*: N/A.

CONFLICT OF INTEREST

The authors declare no conflict of interests for this article.

AUTHOR CONTRIBUTIONS

Conceptualization: Nanta P. Methodology: Nanta P. Formal analysis: Nanta P., Bhuanantanondh P. Writing—original draft: Nanta P., Bhuanantanondh P. Writing—review and editing: Nanta P., Bhuanantanondh P. Approval of the final manuscript: Nanta P., Bhuanantanondh P.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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REFERENCES

1. Leigh J, Macaskill P, Kuosma E, Mandryk J. Global burden of disease and injury due to occupational factors. *Epidemiology*. 1999;10(5):626-631.
2. Leveille SG. Musculoskeletal aging. *Curr Opin Rheumatol*. 2004;16(2):114-118.
3. Picavet HS, Hoeymans N. Health related quality of life in multiple musculoskeletal diseases: SF-36 and EQ-5D in the DMC3 study. *Ann Rheum Dis*. 2004;63(6):723-729.
4. Rempel DM, Punnett L. Epidemiology of wrist and hand disorders. In: Nordin M, Andersson GB, Pope MH, eds. *Musculoskeletal Disorders in the Workplace: Principles and Practice*. Mosby-Year Book, Inc; 1997:421–430.
5. van Tulder M, Malmivaara A, Koes B. Repetitive strain injury. *The Lancet*. 2007;369:1815-1822.
6. Silverstein B, Welp E, Nelson N, Kalat J. Claims incidence of work-related disorders of the upper extremities: Washington state, 1987 through 1995. *Am J Public Health*. 1998;88(12):1827-1833.
7. Hashemi L, Webster BS, Clancy EA, Courtney TK. Length of disability and cost of work-related musculoskeletal disorders of the upper extremity. *J Occup Environ Med*. 1998;40(3):261-269.

8. Mittenberg W, Patton C, Canyock EM, Condit DC. Base rates of malingering and symptom exaggeration. *J Clin Exp Neuropsychol*. 2002;24(8):1094-1102.
9. Lechner DE, Bradbury SF, Bradley LA. Detecting sincerity of effort: a summary of methods and approaches. *Phys Ther*. 1998;78(8):867-888.
10. Pienimäki T, Tarvainen T, Siira P, Malmivaara A, Vanharanta H. Associations between pain, grip strength, and manual tests in the treatment evaluation of chronic tennis elbow. *Clin J Pain*. 2002;18(3):164-170.
11. Wilgen CP, Akkerman L, Wieringa J, Dijkstra P. Muscle strength in patients with chronic pain. *Clin Rehabil*. 2004;17:885-889.
12. Fishbain DA, Cutler R, Rosomoff HL, Rosomoff RS. Chronic pain disability exaggeration/malingering and submaximal effort research. *Clin J Pain*. 1999;15(4):244-274.
13. Sindhu BS, Shechtman O, Veazie PJ. Identifying sincerity of effort based on the combined predictive ability of multiple grip strength tests. *J Hand Ther*. 2012;25(3):308-318.
14. Sindhu B, Shechtman O. Using the surface electromyographic signal to identify maximal versus submaximal efforts in people with upper extremity injuries. *J Hand Ther*. 2009;22(4):385-386.
15. Sindhu BS, Shechtman O. Using the force-time curve to determine sincerity of effort in people with upper extremity injuries. *J Hand Ther*. 2011;24(1):22-29.
16. Shechtman O, Hope LM, Sindhu BS. Evaluation of the torque-velocity test of the BTE-Primus as a measure of sincerity of effort of grip strength. *J Hand Ther*. 2007;20(4):326-334.
17. King JW, Berryhill BH. Assessing maximum effort in upper extremity functional testing. *Work*. 1991;1:65-76.
18. Shechtman O, Gutierrez Z, Kokendofer E. Analysis of the statistical methods used to detect submaximal effort with the five-rung grip strength test. *J Hand Ther*. 2005;18(1):10-18.
19. Bhuanantanondh P, Nanta P, Mekhora K. Determining sincerity of effort based on grip strength test in three wrist positions. *Saf Health Work*. 2018;9(1):59-62.
20. Trossman PB, Li P-W. The effect of the duration of intertrial rest periods on isometric grip strength performance in young adults. *Occup Ther J Res*. 1989;9(6):362-378.
21. Kroemer KH, Marras WS. Towards an objective assessment of the "maximal voluntary contraction" component in routine muscle strength measurements. *Eur J Appl Physiol Occup Physiol*. 1980;45(1):1-9.
22. Firrell JC, Crain GM. Which setting of the dynamometer provides maximal grip strength? *J Hand Surg Am*. 1996;21(3):397-401.
23. Noguchi T, Demura S, Aoki H. Superiority of the dominant and nondominant hands in static strength and controlled force exertion. *Percept Mot Skills*. 2009;109(2):339-346.
24. Pryce JC. The wrist position between neutral and ulnar deviation that facilitates the maximum power grip strength. *J Biomech*. 1980;13(6):505-511.
25. Li Z-M. The influence of wrist position on individual finger forces during forceful grip. *J Hand Surg Am*. 2002;27:886-896.

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