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Reliability of isometric neck and shoulder muscle strength measurements between symptomatic and asymptomatic female office workers using a hand-held dynamometer

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Abstract

In order to evaluate neck/shoulder muscle function in asymptomatic and symptomatic office workers, it is necessary to develop clinical tests that can be applied in the clinical settings without using complicated instruments and the workers can be tolerate for the resistance. However, there was a lack of evidence in the reliability of isometric maximal strength by using the method of hand-held dynamometer (HHD) specifically in the female office workers. The objective of this study was to determine the intra- and inter-tester reliability of neck/shoulder strength measurement using a HHD among asymptomatic and symptomatic office workers. A HHD was used to evaluate neck and shoulder strength in 15 asymptomatic and 15 symptomatic office workers. The maximal isometric strength was tested in cervical flexor, extensor, and lateral flexor; and the right shoulder muscles as upper trapezius, lower trapezius and anterior deltoid, using both hands to apply isometric resistance for 5 seconds for each. The test was taken twice for 3-7 days. The maximal force of 3 trials for each test position was used for statistical analysis. The intraclass correlation coefficients (ICCs) for intra-tester reliability ($ICC_{3,1}$) showed moderate to high reliability ranging from 0.70 to 0.94 for all test directions from trial 1 to trial 2. High inter-tester reliability ($ICC_{2,1}$) between 2 assessors with intraclass correlation coefficient (ICC), ranging from 0.84 to 0.96. The result indicated that a HHD is a reliable tool for assessing the maximal isometric test of the neck and shoulder muscles in office workers with and without neck/shoulder symptoms.

Keywords**:** *hand-held dynamometer, neck and shoulder muscle, office workers, reliability, strength measurement, symptomatic*

1. Introduction

The prevalence of work related to musculoskeletal disorders has been increasing in industrialized countries (Delp & Wang, 2013; Kaliniene, Ustinaviciene, Skemiene, & Januskevicius, 2013; Robertson, Huang, & Larson 2016), industrially developing countries (Maakip, Keegel, & Oakman, 2016; Celik, Celik, Dirimese, Taşdemir, Arik, & Büyükkara, 2018).including Thailand (Montakarn, & Nuttika, 2016). The symptoms in the neck and shoulder are the highest prevalence rates in office workers (Chen, O'Leary, & Johnston, 2018; Shariat et al., 2018; Bau, Chia, Wei, Li, & Kuo, 2017). Furthermore, female office workers are at higher risk of having musculoskeletal disorders in the neck and shoulder area (Bau et al., 2017; Sadeghian, Raei, & Amiri, 2014). Neck pain is associated with exposure to sustained abnormal posture such as prolonged sitting and neck held in prolonged flexion (Muñoz-García, Gil-Martínez, López-López, Lopez-de-Uralde-Villanueva, La Touche, & Fernández-Carnero, 2016; Nejati, Lotfian, Moezy, & Nejati, 2015). As with shoulder pain, the predictive factor among office workers with shoulder pain is the exposure to monotonous work (Bruls, Bastiaenen, & de Bie, 2015). Thus, the office workers are usually working in a monotonous muscular work. Being in awkward posture has been considered as an important factor to develop the musculoskeletal disorders especially in the neck and shoulder areas. The limitation of a functional activity such as decreasing in strength and mobility may result in cervical pain (Chen et al., 2018; Jun, Zoe, Johnston, & O'Leary, 2017).

As an important role of the neck and shoulder muscle strength, neck muscle strength has been used as an indicator of impairment of muscle function (Jun et al. 2017). Neck muscle strength in females is only about half of that of males (Eckner, Oh, Joshi, Richardson, & Ashton-Miller, 2014). Consequently, the relative weak neck muscles may result in a higher incidence of neck pain. It is needed

to evaluate the strength of neck and shoulder muscles in the symptomatic and asymptomatic female office workers. Therefore, the evaluation of neck and shoulder muscle strength is important for the clinicians and researchers to provide objective information to diagnose the impairment of muscle functions and to monitor the rehabilitation progression.

In clinical practice, the MMT is often used but it is not a recommended for neck strength above grade 3 (Dvir, & Prushansky, 2008). The level of strength in the MMT has been considered as an interval scale. The MMT is also considered as a low validity and low reliability method for strength measurement (Dvir, & Prushansky, 2008). Handheld dynamometry (HHD) is the quantitative apparatus to test isometric strength. It can display the static force in units of Newton. The application of HHD for muscle strength testing is similar to MMT as described by Kendall and colleges (Kendall, McCreary, Provance, Rodgers, & Romani, 2005). The examiner will apply the dynamometer on a subject and provide the resistive force that subjects can exert force by the muscle under consideration. In order to evaluate neck and shoulder muscle function in asymptomatic and symptomatic office workers, it is necessary to develop clinical tests that can be applied in the clinical settings without complex instruments and the office workers can be tolerate for the resistance. Furthermore, there was a lack of evidence in the reliability of isometric maximal strength by using the method of HHD specifically in the female office workers. We expected the stability of the estimation of isometric maximal contraction force of cervical and shoulder musculature applied by using the handheld dynamometry in symptomatic and asymptomatic office workers.

2. Objectives

The purpose of this study was to assess the intra-, and inter-rater reliability of the maximal isometric strength test of neck and shoulder muscles by using a hand-held dynamometer in office workers with and without neck/shoulder symptom.

3. Materials and methods

3.1 Participants

Thirty female office workers who had neck/shoulder pain and asymptomatic volunteered to participate in this study. The sample size for intra-tester reliability was calculated based on the method described by Walter, Eliasziw, & Donner (1998), so that a sample size was 15 participants for each group. Volunteers were eligible for inclusion if they were office workers aged between 18 and 40 years; work on a visual display unit (VDU) more than 4 hours a day; work in the current position for a minimum of 2 years; and had a dominant right hand. Potential participants were excluded if they had reports of the following experience: pregnant or on maternity leave; a history of trauma in the neck and shoulder areas, any history of previous neck and shoulder surgery; severe disorder of cervical spine such as disc prolapse, spinal stenosis, and nerve entrapment; shoulder disease such as tendinitis, capsulitis, and bursitis; fibromyalgia; rheumatoid conditions; idiopathic scoliosis; bone cancer; spasmodic torticollis; neurological disorder; or disease of the central nervous system.

The symptomatic group included 15 participants with a primary complaint of the neck or shoulder or both areas for at least 3 months prior to enrolment and had been presented in the past 7 days. Participants identified pain area on the body chart. The complaint of discomfort at the neck/shoulder areas was 3 and above of the visual analog scale (VAS) as 0 = nothing at all, and 10 = extremely strong. Fifteen participants who report no history of neck and shoulder areas illustrated by a Modified Nordic Questionnaire in the last year or had discomfort less than 3 on VAS were addressed in the healthy group (asymptomatic). The symptomatic and healthy groups were matched based on age, level of working experience, and body mass index. All participants provided written informed consent prior to enrolment, and this study was approved by the Rangsit University Research Ethical Review Board.

3.2 Examiners

Two licensed physical therapists served as the examiners. Examiner 1, a physical therapist who had 10 years of clinical experience in orthopedic physical therapy and the examiner 2 had 3 years of clinical experience. Both examiners practiced the testing protocol for 2 hours training to standardize the examination procedure before the experiment. They tested the protocol together and tested with a volunteer who was not included in the study.

3.3 Procedure

A repeated measure design was used to determine the intra- and inter-tester reliability of neck and shoulder strength in female office workers

with and without neck/shoulder symptom. The next visit was conducted within 3-7 days. The experimental testing was carried out in a musculoskeletal research laboratory of the physical therapy faculty. Qualified participants measured their neck and shoulder strength in the morning between 8.00-12.00 a.m. of 2 separated days. A digital handheld dynamometer (FPIX 100 kg load cell, Wagner Instruments, Greenwich, CT) was used as an instrument to measure isometric contraction force. The maximal voluntary isometric contraction test was conducted twice in the same procedure on two different days with an interval between 3 and 7 days.

The examiners were not blinded to the participant's group assignment as a safety precaution. Any symptoms were monitored all the time during the strength testing. Just in case, they have the onset of any symptoms of pain or worsening of pain during the test, the test would stop immediately. Participants were instructed to stop the test at any point during testing, if they got pain or dizziness. However, the examiners were blinded to the other rater's findings between examinations. The order of testing positions of neck and shoulder maximal voluntary isometric contractions was random.

Before testing, the participants were instructed about the detail of the testing protocol. They had an opportunity to practice the movement testing positions with minimal resistance to assist familiarization with the test. All participants performed a gentle stretching of each testing muscle to prevent the injury prior to the testing. The participants performed the maximal isometric contraction for 3 times of each testing position with a 30-60 second rest interval. The examiners applied the manual resistant by both hands on the participants to determine the maximal isometric strength by the HHD of cervical flexor, extensor, and lateral flexor; and the right shoulder muscles as upper trapezius, lower trapezius and anterior deltoid. The participants maintained the isometric contraction of each position for 5 seconds. They were given verbal encouragement during the test to facilitate the highest force of isometric contraction. They had a 3-minute break between each changing position. During a break, they rested comfortably in a supportive chair.

Neck lateral flexor strengths was measured bilaterally. Shoulder muscle strength was measured on the right side. The three maximal effort trials were well tolerated by participants without an increase in muscular symptom. Thus, each participant performed a total of 21 contractions per one examiner and the testing session lasted approximately 30 minutes. The highest force of the three maximal effort trials was analyzed. To determine inter-tester reliability, the other examiner repeated all strength testing positions after a 30-minute rest break of the first session. Finally, participants retested within 3-7 days after the initial test. The highest force data of each static position from 2-day separately testing was used to evaluate intra-tester reliability. The details of strength testing procedure of neck and shoulder muscle are shown in Table 1.

3.4 Data analysis

Recorded strength data (newtons) was transferred to SPSS statistical program for subsequent analysis. All anthropometric and strength values were initially tested for normality of distribution according to the Kolmogorov-Smirnov test, then parametric tests were used.

For analysis of intra- and inter-tester reliability, we used repeated-measure analysis of variance (ANOVA). The intra-class correlation coefficients model 3, 1 ($ICC_{3,1}$) was used to determine intra-tester reliability, and we choose the intra-class correlation coefficient model 2, 1 ($ICC_{2,1}$) for inter-tester study.

We also calculated the standard error of measurement (SEM), the relative standard error of measurement (%SEM) and the minimal detectable change (MDC) (Hopkins, 2000). MDC values were calculated separately for the healthy and the neck/shoulder symptom groups.

The SEM was obtained using the following formula:

$$SEM = S_x\sqrt{1 - ICC}$$

where S_x was the pooled standard deviation. The SEM was used to calculated %SEM as follows:

$$\%SEM = \frac{SEM}{\bar{x}\, i} * 100$$

where $\bar{x}\, i$ was the pooled mean.

$$MDC = 1.96\ \sqrt{2} * SEM$$

The ICC ranges from 0.00 to 1.00. It was calculated using variance estimates obtained through an analysis of variance. It reflected both degree of correlation and agreement among ratings. The difference was significant at the 0.05 level. The ICC values were interpreted as follows: > 0.90 = high reliability; 0.80-0.89 = good reliability; 0.70-0.79 = fair reliability; and < 0.70 = poor reliability (44).

Table 1 Procedure of strength testing of neck and shoulder muscle

	Testing procedure
Neck muscle	
Neck flexor 	Participants were positioned in supine with crossing arms to prevent thoracic movement. A Velcro strap (4 inches width) was use to stabilize at the shoulders to prevent a compensatory movement from trunk while performing the test. The examiner put the hand held dynamometer at the center of forehead. The examiner applied a force in the direction of the extension. Participants were asked to tuck their chin and hold their head in a maximal contraction at 30 degree of flexion against the dynamometer (Kendall et al., 2005).
Neck extensor 	Participants were positioned in prone with the arms at side, the shoulders supported at the edge of the examination table, and the head was beyond the edge of the table. The Velcro strap was placed across the upper back for stabilization. Participants performed a static neck extension in a neutral position against the hand held dynamometer placed behind the head at the center (McLean, 2005).
Neck lateral flexor 	Participants were positioned in supine with the arms at side. A Velcro strap was used to stabilize at the shoulders to prevent a compensatory movement from trunk while performing the test. Participants were asked to tuck their chin and hold their head to side bend in a maximal contraction in a neutral position against the dynamometer (Kendall et al., 2005).
Shoulder muscle	
Upper trapezius 	Participants sat on a chair. The dynamometer was placed over the arm above the elbow. A horizontal strap is fixed to the trunk of subjects and the chair to prevent unwanted movement. Participants performed unilateral maximal isometric contraction of the shoulder abduction at 90° in frontal plane with their palms facing downwards (Mathiassen, Winkel, & Hägg, 1995).
Lower trapezius 	Participants were in a prone lying position and the dynamometer was placed one inch proximal to the lateral epicondyle of the elbow. The Velcro straps was placed across the pelvis at the level of superior iliac spine and on the thighs proximal to the knees. (Kendall et al., 2005).
Anterior deltoid 	Participants sat on a chair, shoulder in a 30° forward flexion, and elbow in a 75° flexion. Participants performed a static forward flexion at their shoulder. Resistance was provided in the extension direction with the dynamometer placed one inch proximal to the elbow. (Szeto, Straker, & O'Sullivan, 2005).

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4. Results

4.1 Participants

Thirty females who were healthy and had neck/shoulder symptom were participated in this study. There were fifteen participants for each group. They had experience in using computer for 9.13 years. Baseline characteristics of participants were presented in Table 2. Continuous variables were compared with unpaired t-test. No statistically significant baseline differences were observed.

Table 2 Baseline characteristics of participants (Mean ± SD)

	Healthy	Neck/shoulder symptom	p-value
Age (yr)	24.80 ± 4.63	24.93 ± 3.73	0.931
Weight (kg)	56.77 ± 9.65	52.55 ± 6.53	0.173
Height (cm)	160.67 ± 3.44	159.67 ± 4.42	0.495
BMI (kg/m^2)	22.01 ± 3.81	20.59 ± 2.23	0.225

4.2 Neck and shoulder muscle strength

Neck and shoulder muscle strength testing of each participant group and assessor are shown in Table 3

4.3 Intra-tester reliability of neck and shoulder strength

Intra-tester reliability of neck and shoulder strength in a healthy group and a neck/shoulder symptom group are shown in Table 4 and Table 5, respectively. When testing with the healthy group, the assessors 1 showed moderate to high intra-tester reliability with intra-class correlation coefficient (ICC) 0.71-0.88. Whilst, the assessor 2 almost demonstrated moderate to high reliability except for neck extensor muscle test which got poor reliability. When testing with the neck/shoulder symptom group, the assessor 1 showed moderate to high reliability with intra-class correlation coefficient (ICC) 0.72-0.94. Whereas, the assessor 2 demonstrated moderate to high reliability except for lower trapezius muscle test with poor reliability.

4.4 Inter-tester reliability

High inter-tester reliability with the intraclass correlation coefficient (ICC) 0.88-0.95 in the healthy group between the 2 assessors was found. In addition, there was also high inter-tester reliability between the 2 assessors in the symptomatic group with the intraclass correlation coefficient (ICC) 0.84-0.96.

Table 3 Neck and shoulder muscle strength of both groups

Strength measurement	**Healthy** (N=15)				**Neck/shoulder symptom** (N=15)			
	Assessor 1 (mean ± SD)		**Assessor 2** (mean ± SD)		**Assessor 1** (mean ± SD)		**Assessor 2** (mean ± SD)	
	Session1	Session2	Session1	Session2	Session1	Session2	Session1	Session2
Neck muscle strength (N)								
Flexion	60.84 ± 13.74	61.63 ± 11.08	59.71 ± 11.56	57.73 ± 10.44	56.38 ± 11.49	60.87 ± 10.35	52.85 ± 9.83	56.37 ± 10.39
Extension	85.30 ± 18.88	84.59 ± 12.68	85.99 ± 12.20	82.17 ± 12.79	83.08 ± 20.08	84.99 ± 15.62	79.85 ± 19.52	80.32 ± 13.15
Rt.lateral flexion	66.44 ± 19.53	70.13 ± 15.42	68.13 ± 18.28	66.63 ± 11.74	65.24 ± 14.74	65.07 ± 13.27	65.46 ± 17.23	65.93 ± 14.37
Lt.lateral flexion	69.34 ± 17.49	71.38 ± 16.11	65.08 ± 18.06	67.35 ± 13.94	66.73 ± 14.58	65.17 ± 12.19	65.61 ± 15.69	63.59 ± 12.07
Shoulder muscle strength (N)								
Upper trapezius	98.90 ± 18.05	99.87 ± 17.60	97.81 ± 17.42	97.16 ± 18.24	92.86 ± 15.02	94.48 ± 15.20	91.84 ± 18.33	91.54 ± 14.46
Lower trapezius	69.42 ± 11.48	72.03 ± 14.26	69.63 ± 11.44	71.17 ± 11.93	72.83 ± 10.44	74.91 ± 13.15	69.65 ± 9.33	73.21 ± 10.76
Anterior deltoid	101.43 ± 23.78	105.87 ± 22.54	104.47 ± 24.29	99.60 ± 25.07	94.06 ± 19.25	100.11 ± 23.34	95.81 ± 17.41	98.58 ± 22.12

Table 4 Intra-tester reliability of neck and shoulder strength in a healthy group

Strength measurement	Assessor 1			Assessor 2		
	SEM	MDC	ICC (95% CI)	SEM	MDC	ICC (95% CI)
Neck muscle strength						
Flexion	5.59	15.48	0.800 (0.503 – 0.928)	3.65	10.12	0.890 (0.704 – 0.962)
Extension	8.67	24.03	0.709 (0.327 – 0.892)	8.42	23.33	0.546 (0.067 – 0.820)
Rt. lateral flexion	8.29	22.97	0.778 (0.459 – 0.920)	7.45	20.63	0.765 (0.432 – 0.915)
Lt. lateral flexion	8.66	24.00	0.734 (0.372 – 0.902)	6.08	16.84	0.858 (0.629 – 0.950)
Shoulder muscle strength						
Upper trapezius	6.10	16.88	0.883 (0.688 – 0.959)	4.22	11.69	0.944 (0.842 – 0.981)
Lower trapezius	4.07	11.28	0.901 (0.731 – 0.966)	4.82	13.35	0.830 (0.567 – 0.940)
Anterior deltoid	9.69	26.85	0.825 (0.555 – 0.938)	12.42	34.39	0.747 (0.397 – 0,907)

Table 5 Intra-tester reliability of neck and shoulder strength in a neck/shoulder symptom group

Strength measurement	Assessor 1			Assessor 2		
	SEM	MDC	ICC (95% CI)	SEM	MDC	ICC (95% CI)
Neck muscle strength						
Flexion	5.20	14.40	0.774 (0.451 – 0.918)	5.06	14.01	0.750 (0.404 – 0.909)
Extension	10.45	28.93	0.709 (0.328 – 0.892)	7.95	22.01	0.772 (0.446 – 0.917)
Rt. lateral flexion	3.52	9.75	0.749 (0.402 – 0.908)	6.93	19.21	0.809 (0.521 – 0.931)
Lt. lateral flexion	5.36	14.84	0.841 (0.591 – 0.944)	6.40	17.73	0.791 (0.485 – 0.925)
Shoulder muscle strength						
Upper trapezius	3.58	9.90	0.944 (0.842 – 0.981)	5.14	14.24	0.903 (0.736 – 0.966)
Lower trapezius	6.27	17.37	0.721 (0.348 – 0.897)	6.81	18.86	0.543 (0.062 – 0.819)
Anterior deltoid	9.54	26.43	0.801 (0.506 – 0.929)	9.67	26.79	0.764 (0.429 – 0.914)

Table 6 Inter-tester reliability of both groups

Strength measurement	Healthy				Neck/shoulder symptom			
	SEM	%SEM	MDC	ICC (95% CI)	SEM	%SEM	MDC	ICC (95% CI)
Neck muscle strength								
Flexion	4.06	6.73	11.23	0.898 (0.723 – 0.964)	3.17	5.81	8.79	0.912 (0.760 – 0.970)
Extension	4.90	5.72	13.57	0.905 (0.741 – 0.967)	6.26	7.69	17.35	0.900 (0.729 – 0.965)
Rt. lateral flexion	3.74	5.55	10.35	0.961 (0.888 – 0.987)	3.17	4.85	8.77	0.961 (0.887 – 0.987)
Lt. lateral flexion	3.94	5.86	10.90	0.951 (0.861 - 0.983)	2.95	4.46	8.18	0.962 (0.891 – 0.987)
Shoulder muscle strength								
Upper trapezius	3.72	3.78	10.30	0.956 (0.874 – 0.985)	4.47	4.84	12.37	0.929 (0.803 – 0.976)
Lower trapezius	3.87	5.57	10.72	0.886 (0.694 – 0.960)	3.92	5.51	10.87	0.843 (0.595 – 0.944)
Anterior deltoid	6.31	6.14	17.49	0.931 (0.807 – 0.976)	6.14	6.47	17.01	0.888 (0.699 – 0.961)

5. Discussion

5.1 Intra-tester reliability of neck and shoulder strength

The intra-tester reliability of the assessor 1 were ranged from moderate to high in both healthy and symptomatic groups. We found that the intra-tester reliability of the assessors 2 was poor when testing the neck extension of the healthy group and poor when testing the lower trapezius muscle of the symptomatic group. In accordance with poor reliability of these tests, the high MDC values are limited in use to detect clinically meaningful change across time. Our intra-tester reliability coefficient and MDC values are generally in agreement with previous reports (Baschung Pfister, de Bruin, Sterkele, Maurer,de Bie, & Knols, 2018; Vannebo, Iversen, Fimland , & Mork, 2018; Segarra, Dueñas, Torres, Falla, Jull, & Lluch, 2015; Jørgensen, Ris, Falla, & Juul-Kristensen, 2014; Geary, Green, & Delahunt, 2013; Juul, Langberg, Enoch, & Søgaard, 2013).

5.2 Inter-tester reliability

The inter-tester reliability for neck and shoulder muscles strengths was high in both healthy and symptomatic groups. These findings are consistent with previous reports of substantial reliability of neck muscles in healthy and neck pain populations (Juul et al. 2013; Baldwin, Paratz, & Bersten, 2013; Jørgensen et al. 2014; Segarra et al., 2015; Baschung Pfister et al., 2018).

5.3 The clinically use of hand-held dynamometer in neck and shoulder assessment

The intra and inter-tester reliability for neck and shoulder muscle strength assessed by using hand-held dynamometer has been described as "doubtful" due to limited number of existing studied. To date, to the authors' knowledge, the present study is the first to investigate the intra and inter-tester reliability of isometric neck and shoulder muscle strength using a commercial hand-held dynamometer in office workers. However, the laboratory-based and custom-developed neck and shoulder strength testing protocol has been reported by several researchers (Almosnino, Pelland, Stevenson, 2010; Westrick, Duffey, Cameron, Gerber, & Owens, 2013; Davies, Moore, Moran, Mathema, & Ranson, 2016; Kubas et al., 2017). Thus, the results of the present study provide ICC values similar to those reports in previous literatures. Moreover, the results of the present study have established that a commercial available hand-held dynamometer can be used in clinical settings to quantify neck and shoulder muscle strength in healthy and symptomatic office workers.

5.4 Statistical parameters

The present study has included overall isometric neck/shoulder strength values and reporting the ICC values as well, we have also included values relating to SEM, %SEM and MDC in line with the recommendation of Dvir and Prushansky (2008). Such statistical parameters have yet to be reported in the studies relating to isometric strength testing. Furthermore, the MDC is clinical importance as it refers to the amount by which the subjects' score need to change to be sure that the change is greater than measurement error. Therefore, the calculation and reporting of MDC values are relevant for day-today clinical decision making and measurement of training adaptation, consequently increasing the clinical applicability of the particular test (Geary et al., 2013).

5.5 Study limitations

In this study, the assessors were not blinded to group status. Since any worsen of symptom that may have occurred during the test could be monitored as a safety precaution. A lack of blinding could have biased the results; however, this treatment was minimized by the use of standardized and objective measurement techniques. In addition, the study population comprised young to middle-aged female office workers with mild to moderate levels of neck/shoulder symptom. Therefore, our finding may not generalize to older populations, or the other group of workers.

6. Conclusion

The result showed that a hand-held dynamometer is a reliable tool for assessing the maximal isometric test of the neck and shoulder muscles in office workers with and without neck/shoulder symptoms.

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