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Maximal isometric muscle strength of the cervical spine in healthy volunteers

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Objective: To describe the maximal isometric neck muscle strength in healthy Chinese volunteers, in six different directions, as measured by a Multi Cervical Rehabilitation Unit.
Design: A standardized cross-sectional observational study.
Setting: A university rehabilitation unit.
Subjects: Ninety-one healthy volunteers aged 20–84.
Methods: During the measurement the subject was instructed to do three consecutive steady contractions as hard as possible, with a 10-second rest in between each contraction and a 2-minute rest between different directions. The peak isometric strength for each of the six directions (flexion, extension, lateral flexions, protraction and retraction) was calculated.
Results: No significant difference was found in muscle strength between different age groups. Isometric muscle strength in the direction of right lateral flexion was significantly greater than that to the left in men ($p = 0.030$), but no difference was found in women ($p = 0.297$). Isometric strength in all directions in men was 1.2–1.7 times that in women (all $p < 0.028$). Correlations between physical measurements (height and weight) and strength values were all insignificant in both genders.
Conclusion: Men have approximately 20–70% greater isometric neck muscle strength than women. Both men and women can maintain high levels of cervical muscle strength in six different directions up to their seventh decade. There is no significant correlation between physical measurements and isometric neck muscle strength.

Introduction

Neck pain is extremely common in the general population. It constitutes approximately 30% of the population of individuals suffering from chronic pain.[1] Hasvold[2] reported that the lifetime prevalence of neck pain was 26% in Finland. In a study of neck and shoulder discomfort in medical secretaries, 63% reported neck pain in the previous year while 51% of the subjects noted low back pain.[3] In a recent population-based cross-sectional mailed survey in Saskatchewan, Cote[4] reported the age-standardized lifetime prevalence of neck pain to be 66.7% and the point prevalence as 22.2%. Neck pain is costly in

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terms of treatment, individual suffering, and time lost due to work absenteeism.[5]

Objective assessment of neck pain in the clinical field usually includes measurement of the range of movement, palpation and X-ray findings which according to van der Donk *et al.*,[6] are inadequate. Barton and Hayes[7] compared neck muscle strength, efficiency and relaxation times in normal subjects and those with neck pain. They found that all force values were significantly lower in those with neck pain. Several studies[8–10] demonstrated that the isometric strength measurement of neck muscles is an objective and practical method for estimating functional improvement in response to rehabilitation. In recent clinical studies intensive strength training of the neck muscles was used as the primary treatment for patients with chronic neck pain, results demonstrated reduced pain intensity and increased in neck muscle strength.[8,11]

Mayer *et al.*[12] suggested that normative data regarding the strength of the cervical musculature in healthy individuals are required for comparative evaluation of patients with neck pain. Staudte[13] studied the strength values of the flexors and extensors using handheld dynamometers, but the reliability of this procedure was questionable and the strength of the assessor might affect the outcome of measurement.[14] Several studies[7,15,16] investigated the cervical muscle strength with different types of apparatus. However, these authors only reported the isometric strength of flexors and extensors. There is no report on the isometric strength of other directions: protraction and retraction. Weakness in these directions may go undetected, resulting in muscle imbalance and a substantial decrease in support to the cervical spine. The purpose of this study was therefore to describe the maximal isometric strength of the cervical musculature measured by a Multi Cervical Rehabilitation Unit, in different directions in healthy volunteers.

Materials and methods

Subjects

Ninety-one volunteers, 45 men aged 20–84 (mean 46.8) and 46 women aged 20–80 (mean 46.2) were recruited by notices posted in the Hong Kong Polytechnic University and a geriatric social centre. The mean exertion rate of their occupation and their leisure activities as measured by a five-point scale question (1=minimal, 5=extra heavy), was light to medium (2.25/5). They were regarded as normally active. None of the participants had experienced neck pain for the past year before testing and none of them had engaged in training of the neck and shoulder muscles for at least nine months before testing. Documented consent was obtained from each volunteer and the project was approved by the university's Review Board for Health Sciences Research Involving Human Subjects.

Multi Cervical Rehabilitation Unit

The unit was designed to measure the active range of motion of the neck and isometric strength of neck muscles (Figure 1). Isometric muscle strength measurements can be carried out in the direction of flexion, extension, left and right lateral flexions, protraction and retraction and even in combined directions. The machine has a locking device that can be activated at 20°, 40° and 60° flexion or extension before testing of maximal isometric strength measurements. The unit is equipped with an armchair that rotates 90°, for measurement of lateral flexions, with adjustable seat height, lumbar support and armrests, and a shoulder restraint system, which helps to isolate cervical from thoracic motion to minimize procedural error. It also contains a unique head assembly system (movable inner and outer head brace) designed to safely control the subject's head to move in different planes. Within the inner head brace a load cell can be inserted to measure isometric strength. The load cell is connected to the computer so that information is collected and the peak isometric muscle strength is calculated automatically. Previous study[17] demonstrated that the machine has very good to excellent reliability in isometric measurement for all directions for both patients with neck pain and for healthy volunteers (intraclass correlation coefficient ranged from 0.92 to 0.99).

Isometric strength measurement

Three measurements were taken for each of the six directions (flexion, extension, left and right lateral flexions, protraction and retraction)

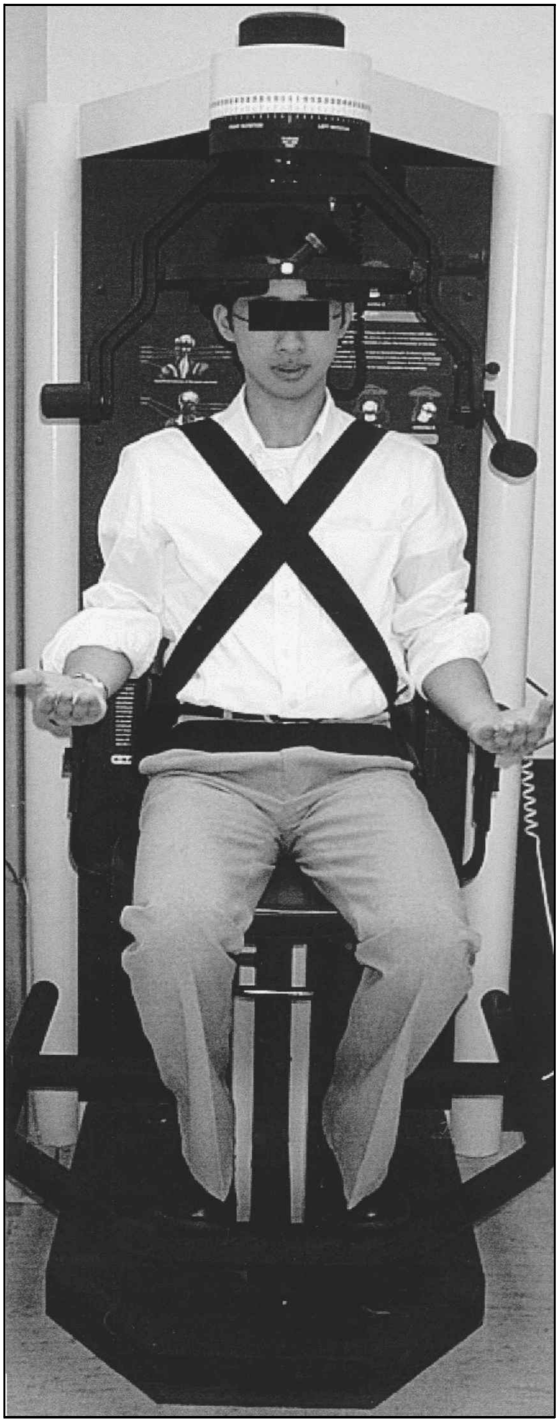

Figure 1 Multi Cervical Rehabilitation Unit (Hanoun Medical Inc., Ontario, Canada).

for each volunteer. During the measurement the subject sat comfortably upright in the adjustable chair, while the trunk was secured with the shoulder restraint system. Both the seat height and the position of the armrest were recorded to ensure a standardized position for repeated testings. An adjustable head brace was secured comfortably around the head of the subject. A load cell fitted into the brace was used to measure the isometric force applied by the subject in each of the six directions. The subject was instructed to perform two to three practice trials to become familiar with the movements. After that, the subject was instructed to do three consecutive steady contractions (in different directions to test different muscle groups) as hard as possible, with a 10-second rest in between each contraction and a 2-minute rest between different directions. The load cell was connected to the MRC unit with an objective documentation and evaluation system through direct system interface. The peak isometric strength (PIS) in different directions was calculated in Newtons (N).

Data management

Paired *t*-test was used to study the difference in isometric muscle strength between side flexion to the right and left side within the same subjects. Correlation analysis was used to determine the relationship between age and maximal isometric strength in each of the different directions for both men and women. Independent sample *t*-test was used to investigate the differences in isometric muscle strength in each of the different directions between men and women. Repeated measures ANOVA was used to determine whether there was any difference in isometric neck muscle strength between different angles of flexion and extension and between men and women. Correlation coefficients were calculated between isometric muscle strength, and both weight and height in men and women respectively. The Sharpened Bonferroni method[18] was applied to adjust for the alpha level when multiple testings were performed.

Results

Physical characteristics of the participants are presented in Table 1. The maximal isometric strength values and standard deviations (SD) of all tested groups for the six different directions are shown in Table 2. Measurements are given using the values obtained at 20° of flexion, extension and lateral flexions for men and at 40° of flexion, extension and 20° of lateral flexions for women, which were higher than those measured in the other position. The participants in this study were able to maintain a very good level of isometric neck muscle strength in all the six directions until their seventh decade. For example isometric strength in the direction of flexion for men was 90.6 N in the younger age group (20–39 years) and was 85.3 N in the older age group (60-84 years). Further analysis with paired *t*-test showed that isometric muscle strength in the direction of lateral flexion to the right side was significantly greater than that to the left in men ($p = 0.03$), but no difference was found in women ($p = 0.30$). No significant difference was found in isometric muscle strength between different age groups for men (p up to 0.71) and for women ($p = 0.22$–1.0) (Table 3). Maximum isometric muscle strength for flexion was observed at 20° flexion for men and at 40° flexion for women. There was a significant difference in muscle

Table 1 Physical characteristics of the 91 subjects. Mean values are given (with ranges in parentheses)

Age (years)	Number of subjects	Mean age (years)	Mean height (m)	Mean weight (kg)
All	91	46.49 (19–84)	1.62 (1.41–1.81)	60.16 (38.5–97.27)
Male	45	46.78 (20–84)	1.67 (1.51–1.81)	64.53 (50–85)
Female	46	46.22 (19–80)	1.57 (1.41–17.0)	55.88 (38.5–97.27)
19–39, all	34	27.56 (19–39)	1.65 (1.52–1.81)	57.88 (38.5–85)
Male	17	27.65 (20–39)	1.71 (1.64–1.81)	64.86 (53.64–85)
Female	17	27.47 (19–39)	1.59 (1.52–1.64)	50.89 (38.5–70)
40–59, all	36	50.44 (40–59)	1.61 (1.49–1.80)	60.74 (47.05–81)
Male	17	51.35 (40–59)	1.65 (1.51–1.80)	63.70 (50–81)
Female	19	49.63 (40–59)	1.58 (1.49–1.70)	58.09 (47.05–80)
60–84, all	21	70.38 (60–84)	1.58 (1.41–1.72)	62.85 (50.45–97.27)
Male	11	69.27 (62–84)	1.63 (1.55–1.72)	65.30 (54.55–76.07)
Female	10	71.60 (60–80)	1.51 (1.41–1.63)	60.15 (50.45–97.27)

Table 2 The mean values (N) and standard deviation (SD) of maximal voluntary isometric strength measured for different age groups in different directions of the neck musculature in 91 healthy subjects

Age (years)	Flex 20 (N)	Ext 20 (N)	Latl 20 (N)	Latr 20 (N)	Pro (N)	Ret (N)
Male						
20–39	90.61 (35.86)	96.17 (48.38)	63.66 (25.79)	68.91 (30.20)	72.07 (25.12)	66.28 (26.42)
40–59	90.52 (23.97)	98.09 (24.90)	68.69 (23.74)	76.48 (25.70)	75.95 (24.37)	79.38 (21.83)
60–84	85.26 (22.27)	54.79 (22.90)	45.75 (18.44)	52.25 (20.13)	81.70 (26.10)	45.97 (17.91)
Female	Flex 40	Ext 40				
19–39	68.64 (19.87)	74.08 (23.39)	44.55 (17.60)	47.93 (19.78)	46.77 (16.57)	54.12 (19.33)
40–59	59.74 (15.86)	70.56 (35.73)	53.90 (16.97)	51.72 (18.71)	43.61 (13.99)	59.11 (28.06)
60–84	54.39 (13.94)	53.81 (24.50)	38.80 (19.78)	49.67 (21.52)	40.54 (13.68)	40.22 (13.63)

Flex 20, flexion at 20°; Flex 40, flexion at 40°; Ext 20, extension at 20°; Ext 40, extension at 40°; Latl 20, left lateral flexion at 20°; Latr 20, right lateral flexion at 20°; Pro, protraction; Ret, retraction.

Table 3 Correlation between age and maximal isometric neck muscle strength in different directions in each gender

	Male age		Female age	
	r	*p*-value	*r*	*p*-value
Flexion at 0°	–0.056	0.713	–0.124	0.412
Flexion at 20°	–0.057	0.710	–0.058	0.703
Flexion at 40°	–0.163	0.284	–0.267	0.073
Extension at 0°	–0.214	0.159	0.009	0.951
Extension at 20°	–0.296	0.049	–0.120	0.427
Extension at 40°	–0.257	0.089	–0.185	0.218
Left lateral flexion at 0°	–0.162	0.287	0.005	0.973
Left lateral flexion at 20°	–0.140	0.358	–0.104	0.490
Right lateral flexion at 0°	–0.165	0.278	0.000	0.998
Right lateral flexion at 20°	–0.146	0.338	0.049	0.748
Protraction	0.081	0.596	–0.111	0.464
Retraction	–0.170	0.265	–0.162	0.283

No significant correlation was found after the Sharpened Bonferroni adjustment.

strength between different angles of flexion ($p < 0.001$) and between men and women ($p < 0.001$). Maximal isometric extensor strength levels at 20° extension for men and at 40° extension for women. Moreover, there was a significant difference in muscle strength between different angles of extension ($p < 0.001$) and between men and women ($p < 0.009$). When the muscle strength of men was compared to that of women, there were significant differences (all $p < 0.028$) in isometric neck muscle strength in all six different directions between males and females (Table 4). Isometric neck muscle strength of males was 1.2–1.7 times that of females. There was no significant correlation between physical measurements (height and weight) and isometric neck muscle strength for both men and women (Table 5).

Table 4 Result of mean difference and independent sample *t*-test on the differences in isometric neck muscle strength in different directions between men and women

	Mean difference (N)	*p*-value
Flexion at 0°	29.75	<0.001#
Flexion at 20°	29.83	<0.001#
Flexion at 40°	23.73	<0.001#
Extension at 0°	14.56	0.027#
Extension at 20°	20.22	0.004#
Extension at 40°	17.49	0.022#
Left lateral flexion at 0°	11.02	0.021#
Left lateral flexion at 20°	14.03	0.003#
Right lateral flexion at 0°	14.00	0.003#
Right lateral flexion at 20°	17.84	0.001#
Protraction	31.77	<0.001#
Retraction	13.08	0.013#

#*p*-value, for comparing isometric neck muscle strength between men and women, was still significant after the Sharpened Bonferroni adjustment.

Discussion

The maximal isometric strength values for the extensors and flexors of the cervical spine for both gender vary in different studies.[7,15,16,19] Vernon *et al.*[19] reported lower strength values in the directions of flexion and extension (46 N and 79 N) as they measured 40 young adult males (average age 25) with a modified sphygmomanometer dynamometer. A recent study by Jordan *et al.*[15] measured the cervical flexor strength (59–91.1 N) and extensor strength (78.4–133.3 N) in 100 healthy subjects with a strain-gauge dynamometer. Overall their findings for the cervical flexor strength were similar to those in our series except that their findings for the extensor strength were higher than those in our study (54.–98.1 N). Staudte *et al.*[13] found even higher results (56–252.8 N) when they measured the maximum extensor strength in 249 healthy subjects (143 women and 106 men, aged 14–84) by using a battery-powered manual muscle tester. There are several possible reasons for the observed differences in strength measurements among different

Table 5 Correlations between physical measurements (height and weight) and isometric neck muscle strength in each gender

	Male				Female			
	Weight		Height		Weight		Height	
	r	*p*-value	*r*	*p*-value	*r*	*p*-value	*r*	*p*-value
Flexion at 0°	0.159	0.297	0.007	0.962	0.156	0.299	0.164	0.277
Flexion at 20°	0.095	0.533	–0.057	0.711	0.250	0.094	0.053	0.727
Flexion at 40°	0.040	0.796	0.048	0.755	0.083	0.585	0.210	0.162
Extension	0.049	0.751	–0.016	0.916	0.056	0.710	0.059	0.697
Extension at 20°	0.073	0.635	–0.010	0.947	0.100	0.510	0.134	0.374
Extension at 40°	0.049	0.747	0.086	0.575	0.024	0.876	0.169	0.261
Left lateral flexion at 0°	0.271	0.072	0.077	0.616	0.266	0.074	0.063	0.676
Left lateral flexion at 20°	0.134	0.381	–0.017	0.912	0.238	0.111	0.061	0.686
Right lateral flexion at 0°	0.351	0.018	0.173	0.255	0.371	0.011	0.107	0.481
Right lateral flexion at 20°	0.274	0.068	0.097	0.527	0.406	0.005	0.109	0.469
Protraction	0.040	0.797	–0.057	0.710	0.254	0.089	0.212	0.158
Retraction	0.051	0.738	0.070	0.650	0.027	0.857	0.073	0.628

No significant correlation was found after the Sharpened Bonferroni adjustment.

studies. In some (for example the study by Jordan *et al.*[15]) it may be due to the training effect. It may also be due to subject selection or ethnic differences between Caucasian and Chinese. The other possible reasons may be variations in measurement procedures and the equipment used in different studies, which may have led to involvement of other extrinsic muscles during testing.[13,15] However, we believe that it is important to isolate the cervical spine from other trunk muscles for an accurate measurement of cervical muscle strength. The shoulder restraint system used in our current study may help to isolate cervical from thoracic motion and minimize procedural error.

For isometric strength in the direction of lateral flexions Vernon *et al.*[19] reported a higher strength values (79 N for right lateral flexion and 85 N for left lateral flexion) than our current study (68 N and 64 N) for similar age group (male 20–39). Our further analysis with paired *t*-test demonstrated no significant difference in lateral flexion to either side in women but in men, lateral flexion to the right side is 11% stronger than that to the left. Vernon *et al.*[19] also reported a 6–8% difference of isometric neck muscle strength in lateral flexions in 40 young male adults. We hypothesize that this might be due to the fact that men were more involved in heavy manual work and most people are right-handed, leading to higher demand on the neck muscles over the right side in male subjects. However, we did not measure the distribution of dominance in the sample, this is a limitation of this study. Further study is required to test this hypothesis.

To our knowledge there are no other reports on the isometric strength for protraction and retraction, so no comparisons with results elsewhere can be made. However, we believe that weakness in these muscles should not be neglected, as it may cause muscle imbalance and affect the overall stability of the cervical spine.[20]

The machine could not measure isometric muscle strength in the direction of left and right rotations. This is another limitation of this study.

No significant difference was found in muscle

Clinical messages

- Men have approximately 20–70% greater isometric neck muscle strength than women.
- People can maintain high levels of cervical muscle strength in different directions up to their seventh decade.
- There is no significant correlation between physical measurements and isometric neck muscle strength for men and women.

strength in different age groups. These results show that the subjects in this study were able to maintain a good level of isometric neck muscle strength in all directions until their seventh decade (we had included only a few subjects aged over 80). These findings correlate with data from other researchers[13,15] who investigated the relationship between cervical extensor strength and age in men and women. Moreover, Langrana and Casey[21] reported that muscle strength of the lumbar spine was also maintained until the sixth or seventh decade.

When the isometric muscle strength at different angles was compared, maximum isometric muscle strength for flexion was observed at 20° flexion for men and at 40° flexion for women. Jordan *et al.*[15] suggest that maximum isometric flexor strength develops at 45° of flexion for both men and women. Our results also showed that differences from the neutral position were greater for women (30.4%) and less for men (15%) and these were similar to previous findings.[15] Maximal isometric extensor strength levels at 20° extension for men and at 40° extension for women were consistent with the findings of Jordan *et al.*[15] who showed that all subjects in their study exhibited high strength levels at 15° to 30° of extension compared with the neutral position.

As in other studies[13,22] we found that men in the current study had greater maximal isometric neck strength in all directions than women with isometric strength in men 1.2–1.7 times that in women.

Correlations between physical measurements (height and weight) and isometric muscle strength values for different directions were all insignificant for both men and women. Jordan *et al.*[15] reported similar insignificant findings for flexion and extension in women. But in contrast to our results, they found that there was a significant correlation between height and isometric muscle strength for flexion and extension in men. Further investigations are needed to document the correlations between physical measurement and isometric neck muscle strength in different directions for men and women.

Clinical implications

Although neck pain does not always result from muscle weakness, recent studies have demonstrated that patients with neck pain have decreased neck muscle strength and endurance when compared with subjects without neck pain.[11,23] Other studies also demonstrate that intensive strength training of the neck muscles for patients with neck pain has promising results in terms of pain relief and self-reported disability.[8,11] The present study describes the maximal isometric strength values in six different directions of the cervical spine in men and women from their second to their eighth decade of life. These findings can be used as a baseline reference for comparative evaluation of patients with neck pain. Similar to another study,[15] our results also demonstrate that the neck extensor muscle exhibits approximately twice the maximal strength relative to the body weight of the head-neck complex[15] (7–8% of body weight). Jordan *et al.*[15] further suggested that simple antigravity training would be insufficient for the strengthening of neck muscles[8,11] and clinicians are therefore advised to use adequate resistance in their strengthening programme for neck muscles. More studies are required to find out the adequate resistance for strengthening of neck muscles. Finally, the following observations should also be noted in relation to the rehabilitation of patients with neck pain. In accordance with other muscle groups, men have approximately 20–70% greater isometric neck muscle strength than women. As both men and women can maintain high levels of cervical muscle strength up to their seventh decade, strengthening exercise for the neck muscles could also be considered for our 'elderly' patients.

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