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ISOKINETIC NECK MUSCLE STRENGTH-RATIOS IN SAGITTAL AND FRONTAL PLANES: MEN AND WOMEN ARE DIFFERENT, BUT AGE DIFFERENCES ARE A MYTH

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ABSTRACT

Strengthening of neck muscles has therapeutic value, but should be done with due cognisance of agonist/antagonist strength ratios. Limited information regarding dynamic neck strength ratios is known to guide rehabilitation. The purpose of the current research was to delineate and compare isokinetic strength-ratio data for flexion/extension and lateral flexion to the non-dominant/dominant side of the neck stratified according to gender and age. Healthy males (n=221) and females (n=231) aged 19 to 69 years were assessed and strength ratios and 95% confidence intervals were calculated. Strength ratios were analysed using ANOVA analysis with Scheffè post hoc tests, to determine whether significant differences existed between gender and age categories. Males had a significantly larger (p<0.05) flexion/extension strength ratio than the females (males= 0.63±0.14; females= 0.56±0.16). No significant difference was observed between males (1.03±0.11) and females (1.03±0.12) for lateral flexion strength ratio. No significant differences in strength ratios were observed between age categories within each gender. Isokinetic strength ratios of gender-discriminant age categories presented contribute to the delineation of dynamic neck muscle function. The use of gender-specific isokinetic strength ratios is warranted, but not age specific ratios.

Key words: Neck muscles; Muscle strength; Rehabilitation.

INTRODUCTION

Normal function of the head-neck complex requires effectively integrating the static and dynamic tasks of the neck muscles (Dvir & Prushansky, 2008). Muscle weakness (Portero *et al*., 2001; Ylinen *et al*., 2004; Prushansky *et al*., 2005; Cagnie *et al*., 2007; Pearson *et al*., 2009; Scheuer & Friedrich, 2010), or altered activation (Lindstrøm *et al*., 2011; Lindstroem *et al*., 2012; Schomacher *et al*., 2012; Boudreau & Falla, 2014), leads to a compromise of these static and dynamic tasks and could be associated with pain and/or disability. Strength assessment and rehabilitation of the neck muscles are thus crucial when the neck is injured (Falla, 2004; Dvir & Prushansky, 2008; Jull *et al*., 2008; Elliott *et al*., 2010).

The use of proprioceptive and dynamic-resisted strengthening exercises for the shoulder muscles surrounding the neck, as well as the neck muscle, in the treatment of chronic or frequent neck disorders is supported in literature (Sarig-Bahat, 2003; Vincent *et al.*, 2013). Moreover, the literature shows that neck pain prevention, among the general population, can be achieved effectively through neck strengthening exercises (Linton & Van Tulder, 2001). Although strengthening of the neck muscles has therapeutic value, doing so without due cognisance of the agonist/antagonist strength ratios that exist in the neck, is ill advised. This is because strength ratios, used clinically, indicate the capacity of opposing muscles crossing the joint to co-activate and facilitate dynamic joint stability (Blackburn *et al*., 2000) by reducing angular velocity and range of motion (Lindstrøm *et al*., 2011). Thus, by altering the agonist/antagonist strength ratio from the norm could have consequences for joint stability.

For isometric neck flexion to extension, a strength ratio of about 0.6 among the general population has been reported (Jordan *et al*., 1999; Garcés *et al*., 2002; Lindstrøm *et al*., 2011). Conversely, an isometric ratio of about 1.0 has been reported for the lateral flexors, due to the bilateral symmetry of the neck musculature (Chiu *et al*., 2002; Lindstrøm *et al*., 2011).

Limited information regarding the dynamic functioning of the neck muscles is available because of the large volume of isometric strength assessment methods reported in literature (Portero & Genriés, 2003). Moreover, no standardised method of isometric or isokinetic measurement of neck strength exists. Researchers use a variety of different methods, which lack uniformity and consequently results are incomparable. The use of strength ratios is, however, an attempt to eliminate the influence of the diverse testing methods available.

PURPOSE OF RESEARCH

To address, in particular, the lack of knowledge regarding the neck muscles' dynamic function, some researchers have employed isokinetic dynamometry as an assessment method (Du Toit *et al*., 2003; Du Toit *et al*., 2005; Deslandes *et al*., 2008; Olivier & Du Toit, 2008; Olivier *et al*., 2010). Nonetheless, little is known regarding dynamic agonist/antagonist neck muscle strength ratios across genders and age categories. The purpose of the study reported here was to delineate the isokinetic flexion/extension (F/E) and lateral flexion to the non-dominant/dominant side (LN/LD) strength ratios for various age categories and both genders. Furthermore, statistical analyses were performed to identify significant differences between the generated gender and age categories for the determined strength ratios.

METHODS

Ethical Clearance

Clearance for the study was obtained from the Research Ethics Committee (Human) of the Nelson Mandela Metropolitan University.

Participants

Healthy male (n=221) and female (n=231) participants were sampled through purposive and snowballing techniques. Informed consent was obtained from all participants prior to anthropometrical and isokinetic assessment. To ensure accuracy of the strength ratio reference data generated, outliers (z-score>3) were eliminated from the data set. This resulted in the total number of participants evaluated, determined through the addition of the quantities displayed according to the gender-discriminant age categories, numbered 452.

Anthropometric measurements

The anthropometric variables, height and weight, were measured prior to the isokinetic assessment and, for the sake of completeness, the unique methods used to measure neck girth and length are explained fully.

Neck girth and length

Neck girth and length were measured while the participant sat with the head in the Frankfort plane. Neck girth was measured with a steel tape, which was placed directly superior to the thyroid cartilage and perpendicular to the long axis of the neck. Care was taken not to pull the tape to tight (Norton *et al*., 1996). Neck length was regarded as the distance from the spinous process of the vertebral prominence (C7) to the occipital notch at the base of the skull, as measured with a sliding calliper (Du Toit *et al*., 2003).

Isokinetic neck muscle strength assessment

The equipment used to measure isokinetic strength during flexion, extension and lateral flexion of the neck has been validated and reported on elsewhere (Du Toit *et al*., 2003). A Cybex II isokinetic dynamometer was used to measure concentric torque production during the above-mentioned movements. Testing speed was set at $30^{o}.s^{-1}$, which is similar to speeds used in other studies (Portero *et al*., 2001; Portero & Genriés, 2003). The slow testing speed contributes to the safety of the assessment protocol employed, accommodating the vulnerability of the neck with slow acceleration to peak torque thus avoiding the need for a ramping protocol.

The participants completing a thorough warm-up prior to performing maximal effort repetitions, which enhanced the safety of the assessment protocol employed. The warm-up consisted of active full range of joint motion movements, stretches and submaximal isometric contractions. Additionally, once the participant was correctly positioned in the testing equipment, 6 submaximal, increasing to maximum, warm-up movements were performed against the isokinetic dynamometer. Correct positioning of the participant centred on the alignment of the dynamometer input axis to C7. Other researchers (Portero *et al*., 2001; Portero & Genriés, 2003), have suggested a dynamometer input axis alignment that corresponds to the junction between C7 and T1. C7, however, provided a clearer reference point for alignment and, therefore, it was preferred. The maximum torque produced during 3 maximal effort repetitions was recorded and used for the analysis of the data.

Statistical analyses

Gender-discriminant age categories (Males: M19 to 29, M30 to 39, M40 to 49, M50 to 59, M60 to 69; Females: F19 to 29, F30 to 39, F40 to 49, F50 to 59, F60 to 69), were used to group the calculated data. Possible significant ($p<0.05$) differences between the genders and gender-discriminant age categories were sought by means of ANOVA analysis with Scheffè post hoc tests. The effect size, only of identified significant differences, was determined with the use of eta squared (η^2). Eta squared results were interpreted as follows: $\eta^2= 0.02$

represented a small effect size; η^2= 0.13 a medium effect size; and η^2= 0.26 a large effect size. The calculation of 95% Confidence Intervals (CIs) (M ± [S.E.M. x t-crit$_{95}$]), according to the gender-discriminant age categories, were performed to serve as reference data. Statistica software was used to perform all statistical analyses.

RESULTS

Table 1 displays descriptive data according to the gender-discriminate age categories. Males, as a group, were significantly (η^2= 0.35) heavier and taller than the females. Moreover, they had significantly (η^2= 0.48) larger neck circumferences, as well as significantly (η^2= 0.42) longer neck lengths.

TABLE 1. **ANTHROPOMETRIC DATA ACCORDING TO GENDER AND GENDER-DISCRIMINATE AGE CATEGORIES**

Gender	**Age**	**n**	**Weight (kg)** Mean±SD	**Height (cm)** Mean±SD	**Neck Girth (cm)** Mean±SD	**Neck Length (cm)** Mean±SD
Males	All	221	82.98±17.82	175.10±7.38	39.63±3.84	11.92±1.59
	19-29	67	77.47±16.18	176.48±7.25	37.98±2.94	12.15±1.54
	30-39	66	85.13±21.55	174.54±7.28	39.34±4.05	12.44±1.59
	40-49	30	82.17±12.92	172.53±8.71	39.05±3.39	12.13±1.30
	50-59	30	86.95±15.55	175.27±6.85	42.11±3.41	10.89±1.35
	60-69	28	87.73±16.24	175.71±6.56	42.22±3.70	11.04±1.48
Females	All	231	72.82±15.89	161.90±6.53	34.23±2.92	10.82±1.23
	19-29	62	64.57±14.83	164.81±6.23	32.28±2.24	10.99±1.24
	30-39	61	78.21±18.80	160.75±6.44	34.35±3.04	11.09±1.14
	40-49	35	79.42±12.32	160.75±6.53	35.24±2.74	11.05±1.05
	50-59	42	74.68±13.87	161.65±5.58	35.28±2.78	10.62±1.19
	60-69	31	68.72±8.53	159.79±6.87	35.36±2.34	9.97±1.24

TABLE 2. **NECK STRENGTH-RATIO ACCORDING TO GENDER**

	Flexion/Extension			**Lateral Flexion** *Non-dominant/Dominant*		
Gender	n	Mean±SD	95% CIs	n	Mean±SD	95% CIs
Males	219	0.63±0.14*	0.65 0.61	219	1.03±0.11	1.04 1.01
Females	229	0.59±0.16	0.61 0.57	230	1.03±0.12	1.04 1.01

* $p<0.05$ Males have greater neck strength ratio [small effect size (η^2= 0.017)]

It was found that the F/E ratio was affected by gender; the LN/LD ratio, however, was not (Table 2). The mean F/E ratio of 0.63±0.14 of the males was marginally but significantly (η^2= 0.017) greater than that (0.59±0.16) of the females. The significant difference between the males and females for the measure of F/E ratio is highlighted by the different 95% CIs calculated (Table 2). Males had a 95% CI upper limit for the F/E ratio of 0.65 and a lower limit of 0.61. On the other hand, in the case of the females, the 95% CIs were 0.61 and 0.57. The LN/LD ratio of 1.03±0.11 of the males was similar to the ratio of 1.03±0.12 of the females and no significant difference was observed. Hence, the 95% CIs for males and females were similar.

The agonist/antagonist strength ratios according to the gender-discriminate age categories are displayed in Table 3.

TABLE 3. **NECK STRENGTH-RATIO FOR GENDER-DISCRIMINATE AGE CATEGORIES**

Gender	**Age**	**n**	**Flexion/Extension** Mean±SD	95% CIs	n	**Lateral Flexion** *Non-dominant/Dominant* Mean±SD	95% CIs
Males	19-29	67	0.62±0.13	0.65 0.59	67	1.01±0.11	1.04 0.99
	30-39	65	0.66±0.15*	0.69 0.62	65	1.04±0.10	1.06 1.01
	40-49	29	0.65±0.14	0.71 0.60	30	1.03±0.10	1.07 0.99
	50-59	30	0.57±0.12	0.62 0.53	30	1.02±0.15	1.07 0.96
	60-69	28	0.60±0.15	0.66 0.54	27	1.05±0.10	1.09 1.01
Females	19-29	62	0.65±0.16	0.69 0.61	62	1.03±0.11	1.06 1.00
	30-39	61	0.54±0.14	0.58 0.51	60	1.05±0.12	1.08 1.02
	40-49	35	0.54±0.17	0.60 0.48	35	0.98±0.13	1.02 0.93
	50-59	42	0.61±0.16	0.66 0.56	42	1.05±0.11	1.08 1.01
	60-69	29	0.57±0.11	0.62 0.53	31	1.00±0.11	1.04 0.96

* $p<0.05$ Males have a significantly larger ratio [medium effect size (η^2= 0.36)]
Note: The differences between the number of observations per gender per age group per test is a reflection of the fact that not all participants could complete the specific test.

F/E ratios for all age categories were observed in a narrow band ranging from 0.54 to 0.66 and statistical analyses showed that it was unaffected by age amongst males and females. Inter-gender statistical analyses revealed only 1 significant difference between the male and female age categories, which was shown to be a large effect size (η^2= 0.36). This was between males and females in the age category, 30- to 39-years-old. LN/LD ratios ranged from 0.98 to 1.05 across the gender-discriminate age categories. No significant intra- or inter-gender differences among age categories, with regard to LN/LD ratios, were found.

DISCUSSION

Although isokinetic strength assessment is regarded as the gold standard method for dynamic muscle testing (Dvir, 2004), little research regarding the dynamic functioning of the neck muscles are available (Portero & Genriés, 2003; Olivier *et al*., 2010). The data provided in Tables 2 and 3 give a comprehensive picture of the dynamic agonist/antagonist neck muscle strength ratios across gender and age categories. Isometric ratio data, from literature, show very similar results to the isokinetic ratio data reported in this study.

Among males, isometric F/E ratios ranging from 0.58 to 0.83 have been reported (Jordan *et al*., 1999; Vasavada *et al*., 2001; Garcés *et al*., 2002; Strimpakos *et al*., 2004; Cagnie *et al*., 2007; Lavallee *et al*., 2013). Notably, large scale studies, such as those by Jordan *et al.* (1999) and Garcés *et al*. (2002), have reported isometric F/E ratios of 0.59 and 0.67 respectively, for males over a large age range. With respect to females, Lindstrøm *et al*. (2011) found an isometric F/E ratio of 0.61 among healthy control subjects. Cagnie *et al*. (2007) also found an isometric F/E ratio of 0.63 among healthy women aged 20 to 59 years. Interestingly, a large scale study conducted by Salo *et al*. (2006) reported an isometric F/E ratio of only 0.39 for a sample of 220 females. Based on reported isometric F/E ratio values among females by other researchers, the values range from 0.41 to 0.83 (Jordan *et al.*, 1999; Vasavada *et al*., 2001; Garcés *et al*., 2002; Strimpakos *et al*., 2004; Ylinen *et al*., 2004; Lavallee *et al*., 2013).

In the present study, the dynamic F/E ratio ranged from 0.57 to 0.66 and 0.54 to 0.65, according to the age categories, for males and females respectively (Table 3). The mean isokinetic F/E ratios of 0.63 and 0.59 found in this study, for males and females aged 19 to 69 years respectively, compare well with isometric ratios found in the literature.

Similar isokinetic F/E ratios to those reported here are also highlighted in the literature. Deslandes *et al*. (2008) reported an isokinetic F/E ratio for nine male participants to be 0.61. Among 183 male rugby players, a large isokinetic F/E ratio of 0.70 was reported (Olivier *et al*., 2008). This altered F/E strength ratio was related, however, to the specific requirements of participating in rugby (Olivier *et al*., 2008). Among the general population, the larger extensor strength compared to flexor strength, as indicated by the F/E ratio, reflects the obvious muscle mass differences and the postural role of the extensor musculature (Jordan *et al*., 1999; Cagnie *et al*., 2007; Zheng *et al*., 2013). Moreover, the extensor musculature possesses a mechanical advantage, due to a longer lever arm, compared to the flexor musculature (Peolsson *et al*., 2001).

The significantly larger F/E ratio for males compared to females observed in this study has not been found in other studies (Jordan *et al*., 1999; Peolsson *et al*., 2001; Garcés *et al*., 2002; Cagnie *et al*., 2007). This significant difference shows that females are proportionally weaker in flexion and/or proportionally stronger in extension compared to males. Zheng *et al*. (2013)

noted in their study that individual neck muscle volume proportions were consistent between men and women, except for the longuscapitus, obliquscaptitis inferior and sterno-cleidomastoid muscles. Vasavada *et al*. (2008) also noted gender-differences in neck muscle size. According to the results reported by Zheng *et al*. (2013), it seems plausible that gender-related volumetric differences in the sterno-cleidomastoid muscle (primary bilateral cervical flexor) may be responsible for females being proportionally weaker in flexion compared to males.

The isokinetic LN/LD ratio determined (1.03) for males and females in this study was similar. This ratio corresponded well with previously reported isometric ratios from the literature, which range from 0.92 to 1.04 (Vasavada *et al*., 2001; Chiu *et al*., 2002; Strimpakos *et al*., 2004; Lindstrøm *et al*., 2011). The isokinetic LN/LD ratio results of the present study, therefore, compare well with other isokinetic ratios for the lateral flexors reported in the literature. Portero and Genriès (2003) found an average isokinetic LN/LD ratio of 1.01 for a variety of individuals. Similarly, Olivier and Du Toit (2008) reported an isokinetic LN/LD ratio of 0.99, while Deslandes *et al*. (2008) determined a ratio of 1.00.

It was found that the isokinetic F/E ratios were affected by gender but not by age. The isokinetic LN/LD ratio, however, was unaffected by both gender and age. No significant intra-gender differences among the age categories were observed for either the isokinetic F/E or LN/LD ratios. The consistency of these ratios across age categories suggest that age associated strength decreases equally affect neck flexors, extensors and lateral flexors (Jordan *et al*., 1999; Garcés *et al*., 2002; Lavallee *et al*., 2013).

Pertaining to the isokinetic testing procedure employed, there were the following limitations. The slow testing speed used, combined with the large range of motion, over which testing was conducted, could have affected findings of peak torque if pain was provoked during the assessment. Care was, nevertheless taken during the screening of volunteers to exclude those with current neck pain or recent history thereof.

The results of this study addresses the lack of knowledge pertaining to the dynamic functioning of the neck muscles by delineating and providing, where appropriate, strength ratio reference data through two planes of neck movement. Reference data according to gender can be used successfully in the rehabilitation of individuals with neck muscle weakness, whether using the isometric, concentric or isokinetic modalities.

CONCLUSION

Isokinetic neck strength-ratio data collected and statistically analysed indicated that the use of gender specific strength-ratio reference data is warranted. On the other hand, however, no evidence exists to support the use of intra-gender age specific strength-ratio reference data.

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