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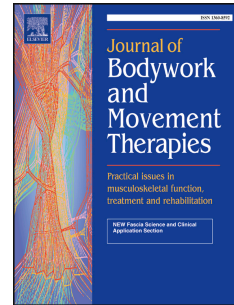
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# Accepted Manuscript

Isometric endurance test of the cervical flexor muscles – reliability and normative reference values

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## Isometric endurance test of the cervical flexor muscles – reliability and normative reference values

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**ABSTRACT**

**Objective.** To obtain reference values for the isometric endurance test (IET) of the cervical flexor muscles, investigate its reproducibility, and compare the results with the maximal isometric strength test (MIST) of the cervical flexor muscles.

**Design.** Cross-sectional non-comparative study with single group repeated measurements.

**Methods:** Altogether 219 healthy females aged 20 to 59 years volunteered to participate in the study. The IET was performed in the supine position and MIST seated. The reproducibility was evaluated by the intraclass correlation coefficient (ICC) and an analysis described by Bland and Altman. The relationship between the two measuring methods was evaluated by Pearson's correlation coefficient.

**Results:** The mean (SD) IET time was 60 (33) seconds with no significant differences between the age groups of each decade. The ICC for intrarater repeatability was 0.80. However, the Bland-Altman analysis suggested moderate variation in repeated measurements. Pearson's correlation coefficient between the IET and MIST was 0.56.

**Conclusion:** Normative reference values for the IET are presented. Although the ICC showed good repeatability, one should consider that the change at follow-up visits has to be considerable to be clinically relevant. The correlation between the endurance time and maximal flexion strength was moderate. Thus IET of the cervical flexor muscles may be used in the clinic like the Biering-Sorenson test has been used to assess fatigue of the trunk extensor muscles.

**Key words:** Non-specific neck pain, endurance strength, maximal strength, isometric contraction, intrarater reliability.

## Introduction

Neck pain is common in the adult population. The results of a large survey conducted in Finland showed that 41% of people aged 30 years or more have experienced neck pain during the previous month and 6% suffer from chronic neck pain (1). Similar results have been obtained in other epidemiologic studies in western industrialized countries (2). Neck pain has shown to be the most common reason to visit a physician in primary health care (3). Moreover, people suffering from chronic neck pain use healthcare services twice as often as the general population and thus comprise a considerable burden to the health care system.

In comparison studies, women have shown to have about 60 % of the maximal isometric neck strength (MINS) achieved by men (4-5). Accordingly, one factor why chronic neck pain is more common among females may be their lower muscle strength, even though the weight of the head that needs to be carried is quite equal between genders. Indeed, several studies have shown that neck pain is related to low MINS among patients, i.e., patients with chronic neck pain have considerably weaker neck muscles compared to their healthy controls (6-10). Moreover, randomized controlled studies have shown improvement in neck muscle strength as a result of regular long-term specific exercising in patients with chronic neck pain (11). This improvement has resulted in reduction of neck pain and disability. However, an accurate and precise measurement of the MINS requires equipment that is seldom available in clinical practices. Thus simple, fast, but still precise enough tests for clinical practice are welcome.

The purpose of this study was to evaluate the isometric endurance strength of the cervical flexor muscles in healthy women to obtain reference values for clinical examination and

rehabilitation of patients suffering from chronic neck pain. The second aim was to evaluate the repeatability of the isometric endurance test (IET) of the cervical flexor muscles. Finally the results were compared to the maximal isometric strength test (MIST) results of the same study population.

## Methods

Volunteers were recruited by the study personnel, who sent information about the study to the personnel of the largest employers in the City of Jyväskylä. The subjects were primarily employees of the City of Jyväskylä, the local hospital, and various industrial facilities, and consisted of both blue-collar and white-collar workers. The youngest age group was primarily made up of students. The subjects completed a questionnaire containing questions on their health status, occupation, and competitive-sports activities. The inclusion criteria were that the subject should be healthy, female, and aged 20 to 59 years. The exclusion criteria were neck and shoulder pain experienced within the previous 6 months, previous or current injuries or other disorders of the neck-shoulder area, arthritis, fibromyalgia, severe depression or mental disorder, or an active competitive sports career. Out of 241 volunteers, 18 were excluded due to neck-shoulder symptoms, three for not giving the information requested and the data of one person was lost. A total of 219 females were enrolled in the study. The purpose of the study and the study protocol was explained to the subjects, after which the subjects gave their written consent. The study was approved by The Ethics Committee of the Central Finland Health Care District.

Anthropometric measurements included body height and mass. The IET was performed in the supine position with craniocervical flexion. Subjects were instructed to tuck in their chins and then to raise their heads approximately 2-3 cm above the plinth and the forehead against a position detector stick. This position has shown to activate both the deep and superficial neck muscles (12). The time when the test position remained stable, until the forehead began to drop from the stick, was measured in seconds (s) with a stopwatch. There was one week between the two measurement sessions. All measurements were made by the same physical therapist who had several years of clinical experience in neck muscle strength tests. The MIST

was performed with the subject in the sitting position with the force gauge mounted in a sturdy stand and the subject fastened to it (13). Two warm-up trials were performed, followed by three maximum-effort trials in each direction. If the result of the third trial was 5% or more above the highest of the 2 previous trials in that direction, additional trials were performed until the improvement remained under 5%. We have previously reported the MIST results of the same study population (14).

### **Statistical analysis**

The results are expressed as means with SDs and with 95% confidence intervals (CIs), and as medians with interquartile (25th-75th percentile) ranges. Statistical comparisons among age groups were done by analysis of variance (ANOVA) with Sidak's adjustments for pairwise correlations. Pearson's correlation coefficients with bootstrapped 95 % confidence intervals were calculated between IET and MIST results. The intraclass correlation coefficient (ICC 2,1) was used to examine intra-rater reliability for the IET. The reliability is regarded as acceptable if  $ICC > 0.75$  (15). The standard error of measurement (SEM) was used as a parameter of absolute reliability and agreement; it was calculated as the square root of residual variance from one-way analysis of variance. The confidence intervals for SEM were obtained using the degrees of freedom associated with estimated residual variance and percentage points from corresponding chi-square distribution (16). An analysis described by Bland and Altman was also done in which differences between two IET measurements were set against the corresponding mean for each patient, to show the variability of the results at the individual level (17). To determine the smallest change in each impairment measure that can confidently be considered to exceed measurement error at a 95% confidence level, the Minimum Detectable Change (MDC) was calculated according to the following formula:  $MDC = 1.96 \cdot \sqrt{2} \cdot SD \cdot \sqrt{(1 - \text{test-retest reliability coefficient})}$  (18).

### **Results**

The anthropometric data, IET and MIST results of the participants in the different age groups are presented in Table 1. Although the oldest age group was the shortest in height, this age group was the heaviest. The weight, and thus the body mass index as well, increased with advancing age, leading to the significant difference between the youngest and oldest group.

PLACE TABLE 1 HERE

There was a great variation in individual IET among all age groups as shown in Figure 1. However, there were no statistically discernible differences in endurance time between the different age groups. No significant correlations were found between age or height and endurance time. Only small positive association was observed between body mass and neck flexor endurance time ( $r = 0.16$ ,  $p=0.05$ ).

PLACE FIGURE 1 HERE

Intra-class correlation for intra-rater reliability was good between repeated measurements in the ICFMET with ICC 0.80 (95 % CI: 0.57 to 0.91). The Bland and Altman analysis indicated moderate differences between the repeated measurements with no clear tendency towards lower or higher values on the second measurement (Figure 2). The limits of agreement were between -27 to 41 with lower limit 95%CI; -40 to -14 and upper limit 28 to 54. The standard error of measurement was 13 s (95 % CI: 10 to 18).

PLACE FIGURE 2 HERE

The comparison of the individual values of the IET with MIST results in Figure 3 shows a considerable variation in both measures as well as in the relationship. However, the regression line shows that there is correlation between endurance time and the maximal strength of the cervical flexor muscles. Pearson's correlation coefficient of 0.56 (95 % CI: 0.44 to 0.64) also showed a moderate association between endurance and maximal strength. It varied from 0.48 to 0.64 in different age groups ( $p = 0.01$ ). There was no significant difference in results when adjusted with height, weight or BMI.

PLACE FIGURE 3 HERE

## Discussion



In the present study, the IET results were shown to vary individually from a few seconds up to two minutes in all age groups. Very low neck muscle strength affects every day life because one has to support the head while rising up from the supine position. Quick acceleratory movements of the body may cause the head to move into the opposite direction, which may predispose neck muscles to a strain injury if the stabilizing muscles are too weak to protect the vulnerable soft tissues.

One would assume that body size is an important factor for endurance strength – a larger body often means bigger muscles. However, we did not find correlation between endurance time and height, and only weak correlation with body weight. This is in accordance with the previous findings that only very low or no correlation at all between the MINS and anthropometric measures have been found in women (19). In the cadaver study, the cross-sectional areas of neck muscles did not scale proportionately with body height and weight (20). The reason may be that the weight of the head does not vary as much as body size and thus the load on the neck muscles is fairly similar.

The IET has been performed in several studies in the supine position with the head lifted approximately 2-3 cm off the plinth. The reported mean endurance time has varied from 14 to 37 s in healthy females in different studies (Table 2). Most studies obtained lower mean endurance time compared to the present study. The possible reason may be that in the present study we used a stick to show subjects the level at which they tried to hold their head as long as possible. In previous studies, subjects had to try to keep the head in place without any specific feedback of the position. The considerable variation in results of the previous studies is probably due to the small amount of subjects in each study. Individually, neck flexor muscle endurance time has shown large variation from a few seconds to over two minutes in different studies. Thus study population selection may have had an effect on the results. The range of endurance time in the current study varied from 6 to 246 s. Thus the best time was over 40 times longer than the shortest. The variation in endurance time is larger compared to that found in maximal isometric strength, ranging from 30 N to four times that in the same study population (14). Several studies have reported only the average endurance time for the whole study population, although they have contained both males and females. Due to significant differences in neck strength and endurance times between sexes, shown in many studies, the average endurance

time counted for men and women together is not a useful reference value in clinical practice and thus were not included in table 2.

PLACE TABLE 2 HERE

Our findings are consistent with the previous reports of the reliability of cervical flexor muscle endurance time tests. The intrarater reliability for the IET performed in the supine position has been evaluated in several studies with the intraclass correlation coefficient (ICC). Grimmer (1994) found an excellent intrarater agreement (0.92) with repeated measurements one month apart (21). Olson et al. (2006) found from moderate to good intrarater agreement (0.71 to 0.79) for three testers performing tests on the session (21). Horneij et al. (2002) found good intra-rater repeatability (0.79) between test days with a five day interval (23). Painkra et al. (2014) found good to excellent intra-rater reliability (0.82–0.93) on the same test session (24). We did not include the neck extensor endurance test in the present study, because it has shown poor agreement in previous studies (25, 26). Since extensor muscles are much stronger, the test time is often quite long and thus the test may measure more psychical than physical effort and cannot be recommended for clinical practice. Although ICC values have shown to be moderate or good, it does not tell much about the usefulness of the IET in clinical practice. Moreover, it is blind to systematic error.

A systematic improvement in endurance time in consecutive tests has been observed in several studies. Grimmer (1994) found a systematic improvement of 1 s on the second measurement (21). Horneij et al. (2002) found a 4 s improvement in average endurance time when there was a 5-day interval between tests (23). Olson et al. (2006) found a significant improvement of 3 s in the mean endurance time, when there were 1 to 2 days between trials (22). The tests have been performed close in time so no significant increase in muscle strength was expected. Thus, it is suspected to be due to the learning effect. However, the reported changes are small compared to what can be expected from the training effect.

The minimal detectable change (MDC) for the IET has been reported by Shahidi et al. (2012) 34 s, Harris et al. (2005) 42 s, and Juul et al. (2014) 45 s for healthy subjects (24-26). The variation of the value may be considered to depend on different study populations and testers, and the higher values are close to our result. Both Harris et al. (2005) and Juul et al. (2014) found that the Bland-Altman analysis showed very broad limits of agreement, indicating limited agreement

between the examiners (24, 27). Similar results were obtained in the present study. One should consider the wide individual variability of repeated measurements while making conclusions about the improvement of the endurance time at follow-up visits.

Endurance time can be used to evaluate muscle function in patients with chronic neck pain.

Harris et al. (2005) compared the IET of healthy subjects and patients with non-specific neck pain (27). The mean (SD) neck pain in the visual analog scale (VAS) was 24 (13). They reported significantly lower neck flexor endurance time in the patient group compared with the controls. Peolsson et al. (2011) tested healthy people and patients with non-specific neck pain with the VAS mean 35 (22), but the duration of pain was not informed (28). The patients had significantly lower neck flexor muscle endurance times compared to controls. They found a significant correlation between the IET time and neck pain. In the study by Juul et al. (2014), the patients' mean neck pain in the VAS was 50 (21), the neck disability index (NDI) 16 (8), and the symptoms had lasted for more than four weeks (24). They found no significant difference between the patient group and the healthy controls. Shahidi et al. (2012) compared the neck flexor muscle endurance time of healthy people and patients with neck pain for longer than three months (26). They found no difference between the groups, but the amount of neck pain was not reported, and the mean NDI was only 14 (7). Low neck pain and disability, as well as the short duration of symptoms, may explain why there has been no difference in endurance strength between patients with neck pain and healthy controls in some studies. Males have shown to have significantly longer neck flexor muscle endurance times compared to females (28,29). Men also have more variation in endurance times. However, several studies have analyzed results without separating the sexes, which should be considered as a confounding factor.

The IET and MIST results showed a moderate association despite being different aspects of muscle performance. People need endurance more often than maximal strength in everyday normal life, and thus the endurance test has its justification from the clinical point of view. Patients with chronic neck pain have shown to have lower MINS compared with patients with chronic neck pain in several studies. Similar results have been obtained while comparing the MINS of healthy people (14) and patients (30) in larger studies while using the same strength test device and protocol. It is not clear whether weak neck muscles are the cause of neck pain or if neck pain results in a weaker musculature, but studies have shown that there is a clear connection between neck pain and weakness. Moreover, intensive neck strength exercises have shown to be effective in the treatment of chronic neck pain compared to the low intensity

exercises (11). Exercise frequency and total exercise dose in the exercise program have also shown to be important factors in the treatment of chronic non-specific neck pain (31).

The Biering-Sorensen test has been used for evaluating the isometric endurance of trunk extensor muscles. Its reproducibility and discriminative validity has shown to be good and the test has been used commonly for evaluating muscle performance in patients with low back pain (32). Similarly the IET may be used for evaluating muscle performance in patients with neck pain before and after rehabilitation programs.

## Conclusions

The reference values of mean flexor muscle endurance times are presented for healthy subjects. However, it is important to consider the great individual variation while interpreting the results in clinical practice. In spite of the acceptable intrarater repeatability of the IET expressed by ICC, there was considerable variation in consecutively repeated measurements, as well as a tendency to improve in the second test occasion. The improvement in endurance time as a result of specific neck exercises may well exceed this variation. Thus, the neck flexor muscle endurance test can easily be performed without equipment and is suitable for the clinical examination of neck pain patients to show a baseline level and to follow-up on the effectiveness of the rehabilitation of neck endurance strength. Moreover, the results demonstrate that the IET does not take much time to perform. This is an important aspect while considering the IET to be included as a part of basic examination in clinical practice for patients suffering from neck pain.

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Table 1.

	All	Age groups				P-value between age groups
		20-29 yrs	30-39 yrs	40-49 yrs	50-59 yrs	
	n=219	n=57	n=50	n=51	n=61	
Height (cm), mean (SD)	166 (6)	167 (6)	166 (6)	165 (6)	164 (4)	0.028*
range	(153-184)	(153-182)	(155-180)	(156-184)	(155-173)	
Body mass (kg), mean (SD)	66 (11)	62 (8)	65 (9)	66 (12)	70 (11)	<0.001†
range	(44-106)	(44-100)	(47-84)	(50-106)	(53-99)	
BMI (kg/cm <sup>2</sup> ), mean (SD)	24.0 (3.7)	22.2 (2.8)	23.5 (3.2)	24.0 (3.9)	26.1 (3.5)	<0.001‡
range	(17.9-36.0)	(17.9-35.9)	(18.2-33.1)	(18.3- <sup>26</sup> 72)	(19.4- 35.9)	
Flexion strength (N), mean(SD)	74 (20)	78 (21)	74 (18)	72 (23)	72 (18)	0.35
range	(31-139)	(37-129)	(33-109)	(33-139)	(31-139)	
Flexion endurance (s), mean (SD)	60 (33)	62 (25)	59 (34)	58 (38)	59 (36)	0.91
range	(6-246)	(13-111)	(10-181)	(6-246)	(6-196)	

Abbreviation: BMI, body mass index; SD, standard deviation.

\* Group aged 20-29 years different than the group aged 50-59 years ( $P=0.030$ ).

† Group aged 20-29 years different than the group aged 50-59 years ( $P=0.001$ ); group aged 30-39 years different than the group aged 50-59 years ( $P=0.038$ ).

‡ Group aged 20-29 years different than the group aged 40-49 years ( $P=0.038$ ) and that aged 50-59 ( $P<0.001$ ); group aged 50-59 years different than that aged 30-39 years ( $P<0.001$ ) and that aged 40-49 years ( $P=.007$ ).

Table 2.

**Mean** neck flexor muscle endurance time (**SD**) in healthy subjects found in previous studies. The subjects lifted and kept the head approximately 2-3 cm/10° above the plinth during the test.

	N	s
Grimmer 1994	38	14 (4)
Horneij et al. 2002	22	77 (29)
Olson et al. 2006	21	20 (9)
Domenech et al. 2011	63	29 (14)
Peolsson et al. 2011	56	37 (11)
Painkra et al. 2014	30	38 (12)

Abbreviations: N, number of subjects; s, seconds

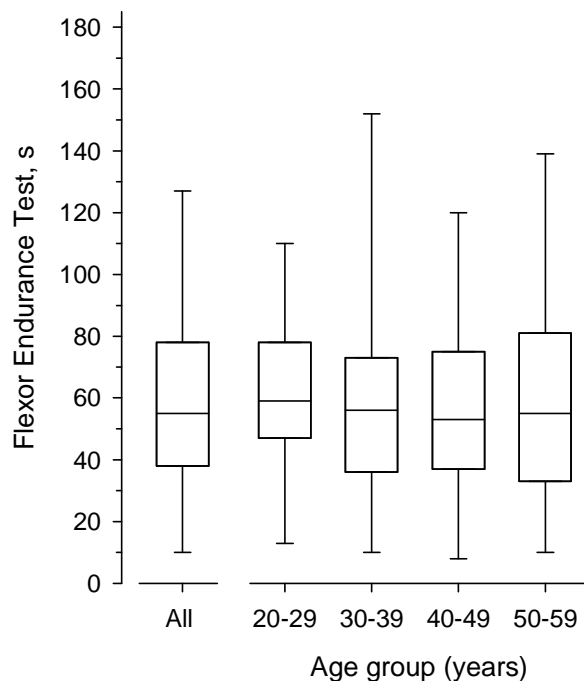


Figure 1. Isometric endurance times in the neck muscle strength test in different age groups. The box shows median (50th percentile) and interquartile (25th and 75th percentile) ranges and the whiskers indicate 2.5th or 97.5th percentiles.



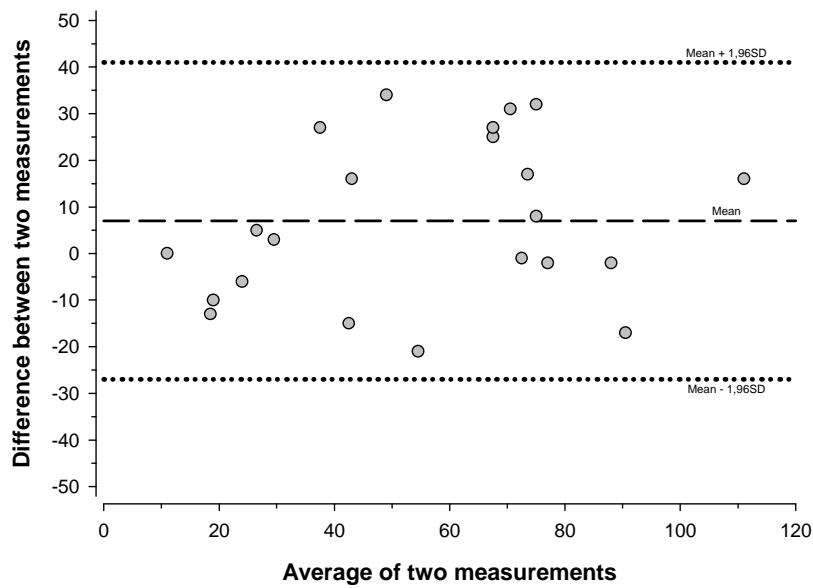


Figure 2. The difference in isometric endurance time (s) between the first and second measurements, plotted against their mean for each patient. The dotted lines show 95% limits of agreement.

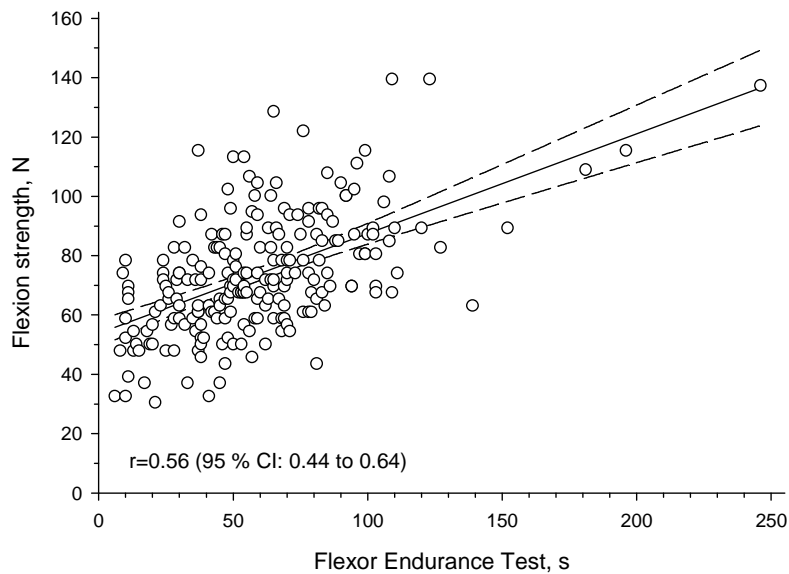


Figure 3. Correlation between isometric endurance time (s) on the x-axis and maximal isometric neck strength (N) on the y-axis. The regression line (solid line) and 95% percent confidence intervals (dotted lines) are presented.