CEU

A Comparison of Various Cervical Muscle Strength Testing Methods Using a Handheld Dynamometer

David A. Krause, PT, DSc, OCS,*,† Kelsey A. Hansen, SPT,‡ Matthew J. Hastreiter, SPT,‡ Taylor N. Kuhn, SPT,‡ Molly L. Peichel, SPT,‡ and John H. Hollman, PT, PhD†

Background: Cervical muscle strength, proposed as a modifiable risk factor in concussions, can be assessed using various methods. The purpose of this study was to compare the reliability and force outputs of 3 methods that use handheld dynamometry (HHD) for assessing cervical muscle strength.

Hypothesis: All 3 testing methods are reliable, and force outputs are significantly different between methods.

Study Design: Repeated-measures reliability.

Level of Evidence: Level 5.

Methods: The study used a convenience sample of 30 participants. HHD "make tests" for cervical extension, flexion, and right and left side bending were performed using lying push tests, sitting push tests, and sitting pull tests. A sole examiner performed all tests. Two testing sessions were conducted 1 week apart. Analysis included intraclass correlation coefficients (ICCs), repeated-measures analyses of variance ($\alpha = 0.05$) with post hoc Bonferroni tests, and minimal detectable change (MDC) calculations.

Results: All testing methods were reliable; the lying push test had the greatest point estimate values (ICC, 0.89-0.95). Significant differences in force were found between the 3 testing methods. The MDC was most sensitive for the lying push method.

Conclusion: Of the 3 cervical muscle testing methods investigated, the lying position with a push test had the largest ICC according to the point estimate and the most sensitive MDC. Force values between the 3 methods were significantly different, which suggests that consistent testing methods should be used.

Clinical Relevance: Results from this study support the clinical use of an HHD "make test" in a lying position for assessing cervical muscle strength. The test is reliable and more sensitive to change compared with tests in a seated position.

Keywords: muscle strength dynamometer; neck muscles; reproducibility of results

Cervical muscle strength has been proposed as a modifiable risk factor in concussion. Collins et al[3] reported that for every 1-pound increase in neck strength, the odds of sustaining a concussion decrease by 5%. Stronger neck musculature may decrease risk by minimizing the amount of head movement in response to an external force. A sex-based difference in neck strength has been described, with males having greater strength than females,[5,7,14] and greater head-neck acceleration and displacement in response to an external force have been reported for females.[14] Differences in neck strength were proposed as a contributing factor. In addition to concussion, other cervical conditions have been associated with neck strength. Ylinen et al[15] reported significantly less isometric strength in individuals with chronic neck pain compared with healthy controls.

Methods for measuring cervical muscle strength are not standardized. Various instrumentation, positioning, restraints, use of push or pull methods, and break or make tests have been used. Instrumentation for testing cervical muscle strength includes custom-made machines,[1,4,16] isokinetic equipment,[2,5,11]

From †Department of Physical Medicine and Rehabilitation, Mayo Clinic, Rochester, Minnesota, and ‡Mayo Clinic School of Health Sciences, Mayo Clinic College of Medicine and Science, Rochester, Minnesota

*Address correspondence to David A. Krause, PT, DSc, OCS, Department of Physical Medicine and Rehabilitation, Mayo Clinic, 200 First Street SW, Rochester, MN 55905 (email: krause.david@mayo.edu).

The authors report no potential conflicts of interest in the development and publication of this article.

DOI: 10.1177/1941738118812767

tension scales,[3] and handheld dynamometry (HHD).[6,8-10,14] Use of HHD is relatively quick and easy for capturing objective strength values. Its advantages include affordability and portability. Testing with HHD can be performed with the participant seated[3,5,6,8,14] or lying on an examination table.[2,9-11] If the person is seated, the trunk can be stabilized with straps or positioned against an immovable structure such as a table.[6] With HHD, both pulling[6] and pushing[8,9,14] methods have been reported.

Data have not been reported on the reliability and recorded force values for different testing methods using HHD to assess cervical muscle strength. Thus, the purpose of this study was to compare the reliability, force outputs, and minimal detectable change (MDC) of 3 testing methods that use HHD for assessing cervical muscle strength. Our hypotheses were that testing cervical muscles with HHD would be reliable for all testing methods and that force outputs would be significantly different between methods.

METHODS

Participants

Before they began the study procedures, all participants provided signed consent. This study was approved by our institutional review board. According to an a priori power analysis, 22 or more participants would provide more than 80% power to detect a 30-point difference in test-retest reliability. A total of 30 healthy participants (15 women, 15 men) between the ages of 18 and 30 years were recruited. Inclusion criteria required absence of current cervical pain or condition that would compromise performance of a maximal isometric contraction of the cervical musculature; pain-free active flexion, extension, and side bending; and a negative Spurling compression test. Participants were excluded if they had any current neck pain or a history of cervical injury or condition requiring medical care within the past year.

Instrumentation

Tests were conducted using an ergoFET HHD (Hoggan Scientific, LLC). Participants were positioned using an Adapta ADP 300 adjustable-height treatment table (Chattanooga Group) and a standard chair without armrests, which was positioned against the table for stabilization during testing.[6]

Procedures

Testing involved two 30-minute sessions separated by 1 week. Before testing, an examiner recorded the participant's height (in centimeters) and weight (in kilograms). Participants underwent a screening evaluation consisting of active cervical flexion, extension, and lateral bending followed by a Spurling test. After participants warmed up with 10 repetitions each of cervical flexion, extension, and right and left side bending, they performed a single 3-second isometric, submaximal hold for each of those motions.

Neck strength for cervical flexion, extension, right side bending, and left side bending was tested using 3 methods: a lying push test, a seated push test, and a seated pull test (Figure 1). Testing order was randomized for each participant using a computer-based random number generator. Participants used the same warm-up and testing order for both sessions.

The same examiner tested all participants with HHD "make tests," which are isometric hold tests where the participant cannot move the resisting force. In these tests, the resisting force was the dynamometer held by the examiner. HHD is reliable if the examiner's strength is greater than the tested muscle group.[13] The testing procedure consisted of 3 isometric contractions held for 3 seconds for the 4 cervical motions. A 30-second rest was given between each contraction. The first of the 3 contractions for each motion was submaximal (50% of maximal effort) to give the participant an opportunity to become acquainted with the motion. Two maximal contractions were then performed, and the peak force of both maximal contractions was recorded.

Consistent procedures were used for placing the dynamometer. The dynamometer pad or strap was centered on the forehead just superior to the eyebrows for flexion tests. For extension, it was positioned slightly superior to the external occipital protuberance.[8,14] To test right and left side bending, the pad or strap was placed on the lateral aspect of the head just superior to the ear.

Data Processing

Force values were normalized to body weight (BW). The normalized force values from the 2 maximal effort tests were averaged and used for analysis.

Statistical Analysis

Statistical analysis was performed using SPSS statistical software (v 22.0; IBM Corp). Descriptive statistics were calculated on participants' weight and age. Intraclass correlation coefficients (ICCs) were calculated to determine the intrarater reliability for the 3 test methods as ICC(3,*k*). Repeated-measures analyses of variance ($\alpha = 0.05$) were conducted using a post hoc Bonferroni correction to examine multiple comparisons when significant. Statistical significance was established as $P = 0.05$. MDC at the 95% confidence level (MDC_{95}) was calculated as follows:

$$MDC_{95} = z \cdot SD \cdot \sqrt{2(1 - ICC)}$$

where z is the z-score (1.96) at the 95% confidence level, and SD is the standard deviation of the first measurement distributions.[12]

RESULTS

Descriptive

A total of 30 healthy participants (15 women, 15 men) with a mean age of 23.8 years (range, 21-30 years) were involved in the study. The mean weight was 73.2 kg (range, 50.3-107.9 kg).

Reliability

There was no significant difference in reliability between testing conditions. According to the point estimate, ICC reliability coefficients from the lying position (ICC, 0.89-0.95) were equal to or greater than measurements from the seated push test or the seated pull test (Table 1).

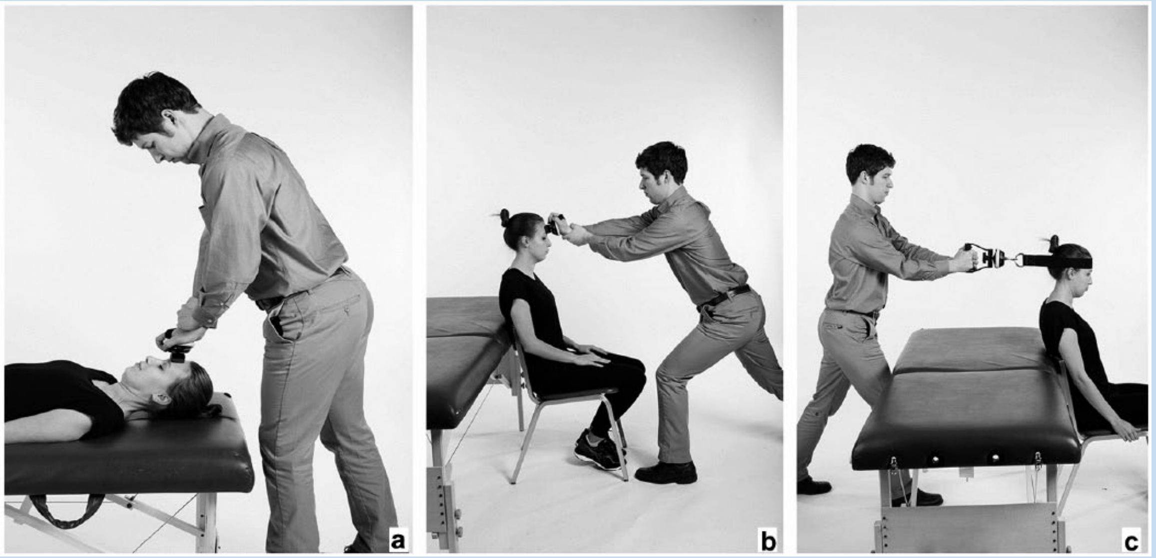

Figure 1. Cervical flexion testing: (a) lying push test, (b) seated push test, and (c) seated pull test.

Table 1. Intraclass correlation coefficient (ICC[3,*k*]), 95% CI, and minimal detectable change for 3 tests

Test	ICC(3,*k*)	95% CI	MDC, %BW
Lying push			
EXT	0.93	0.85-0.97	4.49
FLEX	0.90	0.79-0.95	3.60
RSB	0.89	0.78-0.95	4.85
LSB	0.95	0.88-0.97	3.19
Seated push			
EXT	0.63	0.21-0.82	10.81
FLEX	0.76	0.49-0.88	6.74
RSB	0.90	0.80-0.95	3.27
LSB	0.87	0.72-0.94	4.74
Seated pull			
EXT	0.88	0.75-0.94	7.07
FLEX	0.90	0.80-0.95	4.60
RSB	0.89	0.76-0.95	4.49
LSB	0.85	0.68-0.93	5.10

BW, body weight; EXT, extension; FLEX, flexion; LSB, left side bending; MDC, minimal detectable change; RSB, right side bending.

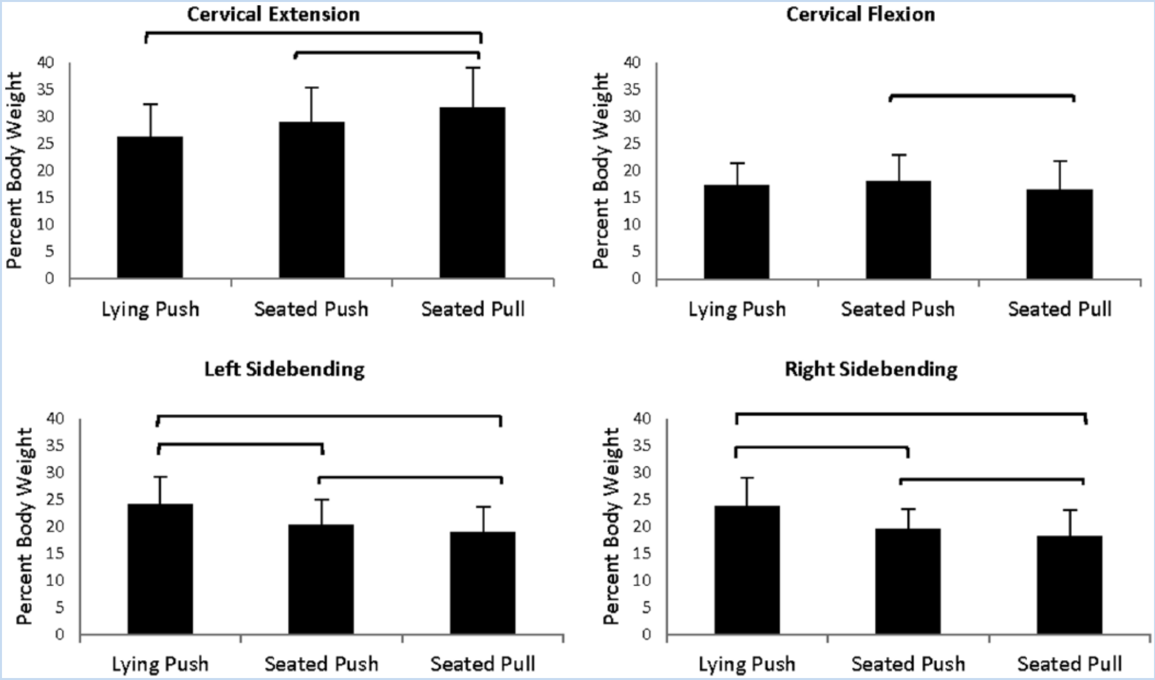

Figure 2. Normalized force values as percentage of body weight. Brackets indicate significant differences in force between positions.

Force

Cervical Extension

The average normalized force for extension was significantly greater in the seated pull test than in the seated push test ($P = 0.04$) and the lying push test ($P < 0.01$) (Figure 2).

Cervical Flexion

The average normalized force for flexion was significantly greater in the seated push test than in the seated pull test ($P < 0.01$) (Figure 2).

Cervical Side Bending

During both right and left side bending, the average normalized force was significantly greater for the lying push test than for the seated push test (right, $P < 0.01$; left, $P < 0.01$) and the seated pull test (right, $P < 0.01$; left, $P < 0.01$), and for the seated push test than for the seated pull test (right, $P = 0.01$; left, $P < 0.01$) (Figure 2).

Measurement Error

The MDC was most sensitive for the lying push test (range, 3.19-4.85 %BW). The MDC ranged from 3.27 to 10.81 %BW for the seated push test and from 4.49 to 7.07 %BW for the seated pull test (Table 1).

DISCUSSION

Our first hypothesis was confirmed as we found cervical muscle testing using an HHD reliable for all testing methods. Our second hypothesis was not entirely confirmed as most but not all force output values were significantly different between testing methods.

Reliability results for the lying push test compare favorably with reported values for similar lying tests. Average ICCs ranged from 0.89 to 0.95. Mihalik et al[9] reported ICCs of 0.82 to 0.97, and Nagai et al[10] reported a range of 0.79 to 0.97. The lying position provides advantages for stabilizing a patient because, unlike a seated position, the lying position does not require straps or a fixed object for stabilizing the trunk. The lying position also gives the examiner a mechanical advantage because the examiner can assume a position using BW to effectively provide resistance against the force of the participant. Although we did not investigate reliability between examiners of different strengths, the mechanical advantage for the examiner with the lying position may minimize the effect of examiner strength when assessing cervical strength.

Direct comparison of these force value results with those of other studies is challenging given the different techniques of both obtaining and reporting these values. Some have reported ratios of cervical flexion to cervical extension for healthy participants. Using a Kin-Com computerized dynamometer to record peak isometric strength, Garces et al[5] reported a ratio of 0.60. Jordan et al,[7] using a neck exercise machine with a strain-gauge dynamometer, reported a ratio of 0.59. For comparison, using mean flexion and extension force values from the lying push test obtained in session 1, we calculated a ratio of 0.66, or a cervical flexion force 66% of the extension force. The comparability of our ratios with others demonstrates convergent validity.

MDC values are helpful for assessing change over time. Of the 3 cervical testing methods we investigated, the lying method had the MDC value most sensitive to change. As an example, with a neck flexion strengthening program, a difference of more than 3.60 %BW between 2 measurements would be larger than measurement error and would imply that a strength change had occurred.

Limitations of this study include the use of a sole examiner for all testing. While examiner strength can influence HHD results, participants were not able to overcome the strength of the examiner for any test conducted. Compared with seated methods, the lying position minimizes the influence of examiner strength related to the positioning advantage of the examiner. Another limitation was likely fatigue due to multiple tests. We attempted to minimize fatigue with rest periods and only 2 maximal contractions. Because participants were young and healthy, results are likely not generalizable to other populations.

CONCLUSION

HHD is a reliable method for assessing cervical muscle strength. Force values can vary considerably, so consistent methods should be used for comparing tests. HHD is more sensitive to change over time in the lying position than in seated positions.

Clinical Recommendations

SORT: Strength of Recommendation Taxonomy Grade
A: consistent, good-quality patient-oriented evidence
B: inconsistent or limited-quality patient-oriented evidence
C: consensus, disease-oriented evidence, usual practice, expert opinion, or case series

Clinical Recommendation	SORT Evidence Rating
Results from this study support the clinical use of an HHD “make test” in a lying position for assessing cervical muscle strength.	B

REFERENCES

1. Almosnino S, Pelland L, Stevenson JM. Retest reliability of force-time variables of neck muscles under isometric conditions. *J Athl Train*. 2010;45:453-458.
2. Cagnie B, Cools A, De Loose V, Cambier D, Danneels L. Differences in isometric neck muscle strength between healthy controls and women with chronic neck pain: the use of a reliable measurement. *Arch Phys Med Rehabil*. 2007;88:1441-1445.
3. Collins CL, Fletcher EN, Fields SK, et al. Neck strength: a protective factor reducing risk for concussion in high school sports. *J Prim Prev*. 2014;35:309-319.
4. Eckner JT, Oh YK, Joshi MS, Richardson JK, Ashton-Miller JA. Effect of neck muscle strength and anticipatory cervical muscle activation on the kinematic response of the head to impulsive loads. *Am J Sports Med*. 2014;42:566-576.
5. Garces GL, Medina D, Milutinovic L, Garavote P, Guerado E. Normative database of isometric cervical strength in a healthy population. *Med Sci Sports Exerc*. 2002;34:464-470.
6. Geary K, Green BS, Delahunt E. Intrarater reliability of neck strength measurement of rugby union players using a handheld dynamometer. *J Manipulative Physiol Ther*. 2013;36:444-449.
7. Jordan A, Mehlsen J, Bulow PM, Ostergaard K, Danneskiold-Samsoe B. Maximal isometric strength of the cervical musculature in 100 healthy volunteers. *Spine (Phila Pa 1976)*. 1999;24:1343-1348.
8. Mansell J, Tierney RT, Sitler MR, Swanik KA, Stearne D. Resistance training and head-neck segment dynamic stabilization in male and female collegiate soccer players. *J Athl Train*. 2005;40:310-319.
9. Mihalik JP, Guskiewicz KM, Marshall SW, Greenwald RM, Blackburn JT, Cantu RC. Does cervical muscle strength in youth ice hockey players affect head impact biomechanics? *Clin J Sport Med*. 2011;21:416-421.
10. Nagai T, Abt JP, Sell TC, et al. Neck proprioception, strength, flexibility, and posture in pilots with and without neck pain history. *Aviat Space Environ Med*. 2014;85:529-535.
11. Schmidt JD, Guskiewicz KM, Blackburn JT, Mihalik JP, Siegmund GP, Marshall SW. The influence of cervical muscle characteristics on head impact biomechanics in football. *Am J Sports Med*. 2014;42:2056-2066.
12. Schmitt JS, Di Fabio RP. Reliable change and minimum important difference (MID) proportions facilitated group responsiveness comparisons using individual threshold criteria. *J Clin Epidemiol*. 2004;57:1008-1018.
13. Stratford PW, Balsor BE. A comparison of make and break tests using a hand-held dynamometer and the Kin-Com. *J Orthop Sports Phys Ther*. 1994;19:28-32.
14. Tierney RT, Sitler MR, Swanik CB, Swanik KA, Higgins M, Torg J. Gender differences in head-neck segment dynamic stabilization during head acceleration. *Med Sci Sports Exerc*. 2005;37:272-279.
15. Ylinen J, Salo P, Nykänen M, Kautiainen H, Häkkinen A. Decreased isometric neck strength in women with chronic neck pain and the repeatability of neck strength measurements. *Arch Phys Med Rehabil*. 2004;85:1303-1308.
16. Ylinen JJ, Rezasoltani A, Julin MV, Virtapohja HA, Mälkiä EA. Reproducibility of isometric strength: measurement of neck muscles. *Clin Biomech (Bristol, Avon)*. 1999;14:217-219.