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Evaluating the Intra-Rater and Inter-Rater Reliability of Fixed Tension Scale Instrumentation for Determining Isometric Neck Strength

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ABSTRACT

International Journal of Exercise Science 14(3): 563-577, 2021. PURPOSE: The purpose of this study was to evaluate the reliability of a fixed tension scale instrumentation, comparing the intra-rater and inter-rater reliability between seating and standing measurement techniques. Instrumentation developed from this study will be utilized to assess isometric neck strength in future studies comparing neck strengthening protocols. METHODS: Isometric neck strength for eight movements (cervical/capital flexion, cervical/capital extension, left/right lateral flexion, left/right cervical rotation) as well as anthropometric measurements were evaluated for thirty-one participants through the use of a novel neck strength assessment protocol. RESULTS: The fixed tension scale instrumentation and methods used in this study demonstrated good to excellent intra-rater reliability (ICC range from 0.78 to 0.97) as well as moderate to excellent inter-rater reliability (ICC range from 0.73 to 0.91) for both measurement techniques. PRACTICAL APPLICATIONS: This study will provide foundational knowledge for the reliable assessment of neck strength. Additionally, the findings will provide a cost-effective, portable, and reliable instrument for measuring isometric neck strength. CONCLUSIONS: Seated and standing measurement techniques demonstrated similar intra and inter-rater reliability. Inter-rater reliability tended to be lower with motions (capital flexion and extension) that required the participants to face directly towards or away from the instrumentation. This could be due to participant positioning or unfamiliarity with those specific movements. The assessment protocol utilized in this study demonstrated comparable inter-rater reliability to another cost-effective method for evaluating isometric neck strength.

KEY WORDS: Cervical spine assessment tool, mild traumatic brain injury, fixed frame dynamometry

INTRODUCTION

Traumatic brain injury (TBI) is defined as "an alteration in brain function, or other evidence of brain pathology, caused by an external force" (11). TBI characteristics include subdural/epidural bleeding, as well as local or diffuse bruising, increased swelling, and decreased blood flow to the brain (5). For non-fatal cases, physical consequences of TBI can range anywhere from temporary transient effects on cognitive function to permanent disability (5). Even in cases of mild traumatic brain injury (mTBI), symptoms include headaches, poor concentration, fatigue, depression, irritability, and disordered sleep (5). Factors that may influence the severity of a TBI include age, sex, body composition, comorbidities, and previous brain injuries, although evidence is limited (5). In 2014, approximately 2.88 million hospital emergency department visits, hospitalizations, or deaths due to TBIs were recorded (1). It is estimated that every year in the United States, there are approximately 300,000 sports-related TBIs (4).

TBIs can result from several mechanisms, including falls, motor vehicle crashes, sports injuries, and assaults. Understanding the causes of TBI is essential for developing mechanism-based prevention methods (16). Recently, there has been increasing interest in examining the association between neck strength and risk of mTBI to develop a strength-based prevention method (8). Such evidence suggests that increased neck strength leads to decreased head acceleration, decreased head displacement, and decreased rapid velocity changes following a collision. These factors, in turn, may decrease the risk or severity of mTBI (17). Even a small decrease in velocity during an accident may lead to a significant decrease in mTBI risk (18). Collins et al. (2014) measured the isometric neck strength of high school athletes during their preseason and monitored in-season mTBI incidence rates finding those who sustained a mTBI also had an 11-22% decrease in overall neck strength (2).

Neck strengthening has been recognized as an inexpensive, widely available, and easily adaptable method for mTBI prevention (2). While neck-strengthening protocols may be effective and easy to implement, finding a reliable, widely available neck strength assessment tool to identify at-risk individuals has proven to be difficult (2, 3). There is also a lack of research indicating an optimal neck strength assessment protocol that is cost-effective and portable, while still maintaining reliability (19). As such, the authors of this manuscript developed a portable and inexpensive isometric neck strength assessment tool. The tool developed differs, from that of other products previously used, by the addition of a stable attachment point.

Currently, the fixed frame dynamometry is a widely recognized *gold-standard* method of reliable isometric neck strength assessment, requiring the use of a large wall/frame-mounted machine with a fixed base (19). The fixed-frame dynamometry apparatus secures the participant to the instrument, through the use of straps or support pads, to provide stabilization (13, 14, 15). Intra-rater and inter-rater intra-class correlation coefficient (ICC) values can be classified as either excellent, good, moderate, or fair, to compare overall reliability (9).

This phase one study evaluated the intra-rater and inter-rater reliability of a portable fixed tension scale instrumentation system using both seated and standing techniques. The purpose was to evaluate an isometric neck strength assessment method that is reliable, portable, and cost-effective for future research designed to compare neck-strengthening protocols. The authors hypothesized that the developed novel neck strengthening assessment tool would prove to be as reliable as the fixed frame dynamometry scale.

METHODS

Currently, there is a deficiency in research that examines all eight neck-movements including cervical and capital extension, cervical and capital flexion, left and right lateral flexion, and left and right cervical rotation. Previous studies have used hand-held tension scales to measure cervical neck strength with poor reliability outcomes (2, 6, 7, 13, 14, 15, 19). For this study, the authors developed a novel neck strength assessment tool, utilizing a digital fixed tension scale, to reduce the chance of evaluator error thereby increasing reliability. The digital fixed tension scale was secured with a thick gauge wire to allow for portability and increased reliability. The researchers examined the relationship between seated versus standing isometric neck strength assessment utilizing the novel instrument. Reliability, for both seated and standing, was determined through inter and intraclass correlation coefficient (ICC) values. Comparisons of the values for both seated and standing were assessed to determine the optimal testing position for future studies. The ICC values were then compared to existing data on neck strength assessment (2, 6, 7, 13, 14, 15, 19). This research was carried out fully in accordance with the ethical standards of the International Journal of Exercise Science (12).

Participants

Volunteer participants were recruited from the university community by electronic recruitment via class group email, classroom visits, and word of mouth. Participants had to be at least eighteen years of age and without a history of any of the following: severe head injury, acute/chronic musculoskeletal neck injury, severe migraines, head/neck surgery, thyroidectomy, heart disease, and/or high blood pressure. After screening for eligibility, there were 31 participants (10 men and 21 women) between the ages of 18 and 25. Each participant was informed of the benefits and risks of the investigation before signing the institutionally approved informed consent document to participate in the study. The study was approved by the University Institutional Review Board (IRB) for Research Involving Human Subjects. A power analysis revealed a minimum of 12 participants based on a minimal acceptable reliability of 0.70, $\alpha = 0.05$, $\beta = 0.20$, and number of raters (k) = 2.

Protocol

Anthropometric measurements were assessed and recorded for each participant (Table 1). Head and neck circumferences were assessed using a measuring tape. Measurements included upper neck circumference assessed at the level of the first cervical vertebrae, lower neck circumference assessed at the level of the seventh cervical vertebrae, and head circumference assessed at the supraorbital margin. Also, height and body mass were assessed using a stadiometer and weight scale, respectively.

Table 1. Age and Anthropometric Measurements for 31 Participants

	Age (yr)		Weight (kg)		Height (cm)	
Gender	Mean	Range	Mean	Range	Mean	Range
Males	22.2 (1.9)	19.0 - 25.0	79.7 (9.7)	65.4 - 97.4	178.6 (6.7)	169.0 - 189.3
Females	20.6 (1.5)	18.0 - 23.0	71.0 (18.3)	52.4 - 127.7	167.0 (7.3)	155.4 - 184.5
	Head Circumference (cm)		Neck Circumference C1 (cm)		Neck Circumference C7 (cm)	
Gender	Mean	Range	Mean	Range	Mean	Range
Males	57.5 (0.9)	56.2 - 59.0	39.1 (1.8)	36.5 - 42.0	40.2 (2.0)	37.0 - 43.0
Females	55.8 (2.0)	53.0 - 60.0	34.0 (2.7)	30.0 - 42.0	34.9 (2.8)	32.0 - 42.0

Isometric neck strength values were measured using the fixed tension scale instrumentation proposed in this study (10). The instrument consisted of the AWS TL-440 tension scale, attached by D-ring carabiner to the Grainger galvanized steel-coated assembly cable, connected by another D-ring carabineer to the MediCordz head harness (Figure 1). The AWS TL-440 tension scale is traditionally used as an industrial or agricultural hanging scale. The capacity of the scale is 440 x 0.5lb and is portable since it is powered by two AAA batteries. The neck strength assessment instrument was fixated using an S-hook to attach the tension scale to the Rogue Squat Rack system, which was the property of the institution's School of Health and Applied Human Sciences (Figure 1) (10). The total price of the instrumentation was approximately $110. The tension scales used in this study were deemed accurate within 0.23 kg by the North Carolina Department of Agriculture and Consumer Services Standards Division.

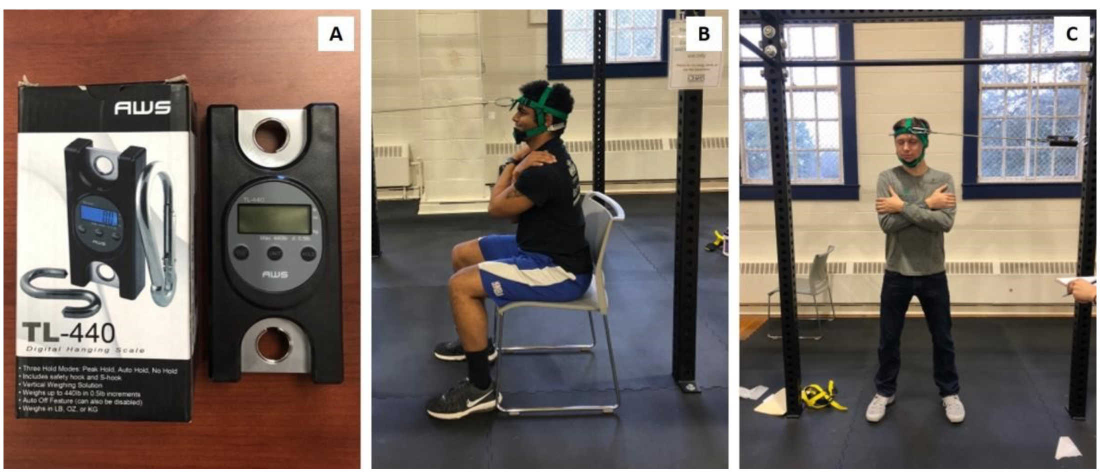

Figure 1. Tension Scale and Testing Positions

Participants chose one of nine predetermined time slots to attend for data collection, each time slot allowed for four people to participate simultaneously. The participant was provided the informed consent form before attending the testing session. Upon arrival at the data collection session, a researcher provided the subject with an oral presentation of the informed consent and ensured any questions the participant had regarding the study were answered. If the participant wished to continue the study, the subject and researcher signed the informed consent form. The participant was also required to sign the medical history screening form to ensure they had none of the exclusionary conditions. The informed consent and medical history screening forms were kept separate from all other data collection forms and remained confidential within the members of the research team. Data collected from this study was reported in an aggregated fashion.

The testing protocol consisted of two stations: the anthropometrics station and the strength station. The anthropometrics station consisted of one evaluator, who measured and recorded the anthropometric measurements of height, body mass, and head/neck circumferences for each participant. Since these measurements were assessed using a standard procedure, the evaluator was interchangeable. Two undergraduate research assistants, each identified specifically as Evaluator A or Evaluator B, who performed all neck strength assessments for the entirety of the study, operated the strength station. The purpose of the strength station was to measure the isometric neck strength of each participant in the following eight movements: cervical flexion and extension, capital flexion and extension, left and right lateral flexion, left and right cervical rotation. The head strap portion of the instrumentation was secured tightly to the head and chin of the participant. Each isometric contraction was held for three seconds (2) and repeated three times per movement, with the evaluator encouraging the participant to elicit a maximum contraction. The evaluator recorded the numerical value displayed by the tension scale after each contraction, as this value represented the maximal force (in kilograms) the participant could produce per contraction.

Isometric neck strength was assessed by each evaluator using both the seated and standing measurement techniques (Figure 1). Participant positioning varied per movement evaluated for both the seated and standing methods, as described in Table 2. In the seated position, the participant was instructed to sit upright in the chair with feet flat on the floor shoulder-width apart, arms crossed against chest, and hands touching shoulders. In the standing position, the participant was instructed to stand upright with arms crossed against chest, and feet shoulder-width apart, either in-line or tandem stance depending on the motion being assessed (Table 2). Participants completed the full isometric neck strength assessment a total of four times.

Table 2. Participant Positioning for Eight Neck Movements

Cervical Extension	Body Position to Anchor:	Front Facing the anchor point/tension scale
	Head Harness	Carabineer attached to the anterior harness hook
	Feet Placement Standing:	Tandem stance
	Feet Placement Seated:	Flat on floor shoulder-width apart
	Contraction Instructions:	Contract neck muscles posteriorly while lifting the chin up
Capital Extension	Body Position to Anchor:	Front Facing the anchor point/tension scale
	Head Harness	Carabineer attached to anterior anchor hook
	Feet Placement Standing:	Tandem stance
	Feet Placement Seated:	Flat on floor shoulder-width apart
	Contraction Instructions:	Contract neck muscle posteriorly with no upward
L Lateral Flexion	Body Position to Anchor:	Right side facing the anchor point/tension scale
	Head Harness	Carabineer attached to the R lateral harness hook
	Feet Placement Standing:	In-Line (Heel to Toe)
	Feet Placement Seated:	Flat on floor shoulder-width apart
	Contraction Instructions:	Tilt head toward the left shoulder
L Cervical Rotation	Body Position to Anchor:	Right side facing the anchor point/tension scale
	Head Harness	Carabineer attached to the anterior harness hook
	Feet Placement Standing:	In-Line (Heel to Toe)
	Feet Placement Seated:	Flat on floor shoulder-width apart
	Contraction Instructions:	Rotate head toward the left shoulder
Cervical Flexion	Body Position to Anchor:	Back facing the anchor point/tension scale
	Head Harness	Carabineer attached to the posterior harness hook
	Feet Placement Standing:	Tandem stance
	Feet Placement Seated:	Flat on floor shoulder-width apart
	Contraction Instructions:	Contract neck muscles downward anteriorly
Capital Flexion	Body Position to Anchor:	Back facing the anchor point/tension scale
	Head Harness	Carabineer attached to the posterior harness hook
	Feet Placement Standing:	Tandem stance
	Feet Placement Seated:	Flat on floor shoulder-width apart
	Contraction Instructions:	Contract neck muscle anteriorly with no downward
R Lateral Flexion	Body Position to Anchor:	Left side facing the anchor point/tension scale
	Head Harness	Carabineer attached to the L lateral harness hook
	Feet Placement Standing:	In-Line (Heel to Toe)
	Feet Placement Seated:	Flat on floor shoulder-width apart
	Contraction Instructions:	Tilt head towards the right shoulder
R Cervical Rotation	Body Position to Anchor:	Left side facing the anchor point/tension scale
	Head Harness	Carabineer attached to the anterior harness hook
	Feet Placement Standing:	In-Line (Heel to Toe)
	Feet Placement Seated:	Flat on floor shoulder-width apart
	Contraction Instructions:	Rotate head towards the right shoulder

*Tandem stance: Heel of one foot at the toe of the other foot
*Each of these motions is to be performed with arms crossed against chest, hands touching shoulders

The qualitative participant data collected in this study supported the quantitative findings that there was no clear distinction in reliability between seated and standing techniques. At the end of the testing protocol, each participant was asked to report if they felt that one technique, standing or seated, allowed for more compensatory action (e.g., using their body to produce more force). The responses were dividing equally between the two methods, reinforcing the idea that while both the seated and standing techniques demonstrated moderate to excellent reliability, neither was superior to the other. More research needs to be conducted to determine whether either measurement technique can be considered the "most reliable" method for this specific neck strength assessment protocol.

Statistical Analysis
Intraclass correlation coefficient (ICC) was used in this study to analyze intra-rater and inter-rater reliability, as it is a common reliability index reflecting both degrees of correlation and agreement between measurements (9). ICC was used to compare strength values between trials for each neck movement to determine the intra-rater reliability for Evaluator A and B using both the seated and standing measurement techniques. The difference in average strength values between Evaluator A and B for all movements were also compared using ICC to determine the inter-rater reliability of each method. For all participants, the first trial for each movement was omitted from analysis as a practice round, allowing individuals to accustom themselves to performing each movement. The values collected from these first trials were excluded from statistical analysis. ICC values reported in this study were classified using the guidelines established by Koo and Li (2016) which states that "ICC values less than 0.5 are indicative of poor reliability, values between 0.5 and 0.75 indicate moderate reliability, values between 0.75 and 0.9 indicate good reliability, and values greater than 0.90 indicate excellent reliability" (9).

RESULTS

All reliability indices (ICC and 95% CI values) for intra-rater reliability with Evaluators A & B are reported in Tables 3-6. The ICC values between the two trials for the seated and standing measurement techniques ranged from 0.78 to 0.97, demonstrating good to excellent intra-rater reliability for both methods. For the seated technique, ICC values ranged from 0.78 - 0.97, with an average of 0.90 for Evaluator A and 0.93 for Evaluator B (Tables 3 & 4). For the standing technique, ICC values ranged from 0.85 - 0.96, with an average of 0.90 for Evaluator A and 0.92 for Evaluator B (Tables 5 & 6). All reliability indices for inter-rater reliability are reported in Tables 7 & 8. The ICC values between Examiner A and B for standing and seated measurement techniques ranged between 0.73 to 0.91, demonstrating moderate to excellent inter-rater reliability for both methods. For the seated technique, ICC values ranged from 0.73 to 0.89, and standing from 0.68 to 0.91, with an average of 0.81 for both methods.

Table 3. Evaluator A Seated Intra-rater ICC Values

Head/Neck Movement	Trial 1 Avg. (SD)	Trial 2 Avg. (SD)	Mean Diff	Intra ICC	95% lower	95% upper
Cervical Extension	6.70 (3.50)	6.81 (3.34)	-0.11	0.96	0.91	0.98
Capital Extension	6.68 (3.22)	6.77 (3.04)	-0.10	0.85	0.71	0.93
L Cervical Lateral Flexion	4.66 (2.51)	4.77 (2.26)	-0.11	0.92	0.84	0.96
L Cervical Rotation	3.25 (1.72)	3.37 (1.84)	-0.12	0.94	0.87	0.97
Cervical Flexion	5.10 (2.17)	5.17 (2.09)	-0.07	0.78	0.59	0.89
Capital Flexion	5.15 (2.02)	5.34 (2.32)	-0.19	0.91	0.82	0.96
R Cervical Lateral Flexion	4.43 (1.97)	4.35 (1.81)	0.08	0.93	0.86	0.97
R Cervical Rotation	3.55 (1.80)	3.50 (1.89)	0.06	0.90	0.81	0.95

Table 4. Evaluator B Seated Intra-rater ICC Values

Head/Neck Movement	Trial 1 Avg. (SD)	Trial 2 Avg. (SD)	Mean Diff	Intra ICC	95% lower	95% upper
Cervical Extension	6.62 (3.88)	6.61 (3.39)	0.01	0.90	0.80	0.95
Capital Extension	6.38 (3.25)	6.65 (3.38)	-0.26	0.94	0.88	0.97
L Cervical Lateral Flexion	4.41 (2.42)	4.37 (2.08)	0.04	0.90	0.80	0.95
L Cervical Rotation	3.15 (1.87)	3.26 (1.92)	-0.12	0.95	0.91	0.98
Cervical Flexion	4.76 (2.29)	5.06 (2.34)	-0.30	0.93	0.86	0.97
Capital Flexion	5.16 (2.51)	5.35 (2.35)	-0.18	0.89	0.77	0.94
R Cervical Lateral Flexion	4.28 (2.10)	4.23 (2.11)	0.05	0.96	0.93	0.95
R Cervical Rotation	3.33 (1.89)	3.43 (1.92)	-0.10	0.97	0.95	0.99

Table 5. Evaluator A Standing Intra-rater ICC Values

Head/Neck Movement	Trial 1 Avg. (SD)	Trial 2 Avg. (SD)	Mean Diff	Intra ICC	95% lower	95% upper
Cervical Extension	4.02 (1.80)	3.99 (1.71)	0.03	0.87	0.75	0.94
Capital Extension	4.32 (1.72)	4.37 (1.85)	-0.05	0.89	0.79	0.95
L Cervical Lateral Flexion	4.82 (2.12)	4.88 (2.20)	-0.06	0.91	0.81	0.95
L Cervical Rotation	3.44 (2.05)	3.58 (2.05)	-0.14	0.96	0.92	0.98
Cervical Flexion	3.83 (1.71)	3.86 (1.56)	-0.03	0.91	0.83	0.96
Capital Flexion	4.08 (1.38)	4.08 (1.85)	0.00	0.85	0.71	0.93
R Cervical Lateral Flexion	4.97 (1.89)	5.01 (2.26)	-0.04	0.88	0.76	0.94
R Cervical Rotation	3.75 (1.94)	3.88 (2.03)	-0.14	0.96	0.92	0.98

Table 6. Evaluator B Standing Intra-rater ICC Values

Head/Neck Movement	Trial 1 Avg. (SD)	Trial 2 Avg. (SD)	Mean Diff	Intra ICC	95% lower	95% upper
Cervical Extension	3.98 (1.56)	3.97 (1.67)	0.01	0.91	0.82	0.96
Capital Extension	4.26 (1.52)	4.37 (1.64)	-.011	0.88	0.77	0.94
L Cervical Lateral Flexion	4.73 (2.08)	4.77 (2.23)	-0.05	0.95	0.90	0.98
L Cervical Rotation	3.28 (1.87)	3.31 (1.82)	-0.03	0.95	0.90	0.98
Cervical Flexion	3.79 (1.39)	3.97 (1.45)	-0.18	0.89	0.78	0.95
Capital Flexion	4.22 (1.72)	4.23 (1.64)	-0.01	0.88	0.77	0.94
R Cervical Lateral Flexion	4.81 (1.96)	4.79 (1.94)	0.02	0.92	0.84	0.96
R Cervical Rotation	3.45 (1.86)	3.57 (1.78)	-0.12	0.94	0.88	0.97

The overlapping 95% confidence intervals between the two methods indicate comparable inter-rater reliability between seated and standing measurement techniques. There is a tendency for decreased inter-rater reliability indices for motions involving the participant facing directly towards or away from the instrumentation. These motions include cervical flexion and extension as well as capital flexion and extension. The results reported from these four motions demonstrated overall lower ICC values as well as a greater range between lower and upper 95% confidence intervals.

The results of this study indicated that neither measurement technique, seated or standing, was superior to the other. For Evaluators A and B, an average of the ICC values for all eight neck movements was calculated to compare the overall reliability between seated and standing techniques. The average intra-rater ICC values for seated and standing, respectively, were 0.90 and 0.90 for Evaluator A and 0.93 and 0.92 for Evaluator B. This congruency in average ICC values between trials indicates that the intra-rater reliability of the standing and seated techniques is comparable. The average inter-rater ICC values were the same for both methods, with a value of 0.81, indicating that inter-rater reliability is equivalent between seated and standing measurement techniques.

While little difference was reported between seated and standing techniques overall, there were observed differences in inter-rater reliability between movements based on participant positioning. For both seated and standing measurement techniques, the highest inter-rater ICC values were reported when the participant was positioned with their side toward the instrument. This included left and right lateral flexion as well left and right cervical rotation. For both methods, the inter-rater ICC values reported for these four motions ranged from 0.81 - 0.91, indicating good to excellent inter-rater reliability (Tables 7 & 8).

Table 7. Inter-rater Seated ICC Values

Head/Neck Movement	Trial 1 Avg. (SD)	Trial 2 Avg. (SD)	Mean Diff	Intra ICC	95% lower	95% upper
Cervical Extension	6.75 (3.38)	6.61 (3.54)	0.14	0.73	0.50	0.86
Capital Extension	6.73 (3.01)	6.51 (3.27)	0.21	0.74	0.52	0.87
L Cervical Lateral Flexion	4.71 (2.34)	4.39 (2.20)	0.33	0.89	0.79	0.95
L Cervical Rotation	3.31 (1.75)	3.21 (1.87)	0.11	0.84	0.69	0.92
Cervical Flexion	5.14 (2.01)	4.91 (2.28)	0.23	0.83	0.67	0.91
Capital Flexion	5.25 (2.12)	5.25 (2.36)	-0.01	0.78	0.58	0.89
R Cervical Lateral Flexion	4.39 (1.86)	4.26 (2.09)	0.13	0.81	0.64	0.90
R Cervical Rotation	3.53 (1.80)	3.38 (1.89)	0.15	0.82	0.66	0.91

Table 8. Inter-rater Standing ICC Values

Head/Neck Movement	Trial 1 Avg. (SD)	Trial 2 Avg. (SD)	Mean Diff	Intra ICC	95% lower	95% upper
Cervical Extension	4.01 (1.70)	3.98 (1.58)	0.03	0.85	0.71	0.93
Capital Extension	4.34 (1.74)	4.31 (1.53)	0.03	0.68	0.42	0.83
L Cervical Lateral Flexion	4.85 (2.11)	4.75 (2.13)	0.10	0.91	0.83	0.96
L Cervical Rotation	3.51 (2.03)	3.29 (1.82)	0.22	0.91	0.82	0.96
Cervical Flexion	3.84 (1.60)	3.88 (1.38)	-0.04	0.68	0.43	0.84
Capital Flexion	4.08 (1.55)	4.23 (1.63)	-0.14	0.75	0.53	0.87
R Cervical Lateral Flexion	4.99 (2.01)	4.80 (1.91)	0.19	0.86	0.72	0.93
R Cervical Rotation	3.82 (1.97)	3.51 (1.80)	0.31	0.80	0.62	0.90

In contrast, motions that involved the participant facing directly towards or away from the instrumentation reported the lowest inter-rater ICC values. These motions included cervical flexion and extension, as well as capital flexion and extension. For both methods, the inter-rater ICC values reported for these four motions ranged from 0.68 - 0.85, demonstrating lower reliability values than the other four movements assessed. Participants reported these motions easier to produce compensatory motion, as the nature of the position allowed the participant to lean away from the instrumentation to increase force production.

DISCUSSION

Overall, the intra-rater and inter-rater reliability indices reported were considered moderate to excellent for both seated and standing conditions. However, there was minimal quantitative data supporting one method, seated or standing, as superior to the other. Furthermore, participants facing directly towards or away from the anchor point while performing capital flexion and extension resulted in lower inter-rater reliability.

Nevertheless, the results indicated the protocol and instrumentation utilized as a reliable method for assessing isometric neck strength. Specifically, the fixed tension scale instrumentation and methods demonstrated an overall good to excellent intra-rater reliability, as well as moderate to excellent inter-rater reliability. These findings are significant, as there is an increasing need for a neck strength assessment protocol that is cost-effective, portable, and reliable (3). The transportable fixed tension scale instrumentation costs approximately $110, indicating that this method of isometric neck strength assessment has the potential for widespread implementation. Although the main purpose of this study was to examine the intra and inter-rater reliability of a new fixed tension scale instrument (10), it does allow for the comparison of ICC values between instruments. Excellent intra-rater reliability was reported when using a fixed-frame dynamometry apparatus to assess isometric neck strength (13, 15), compared to good to excellent intra-rater reliability for the methods described in this study. Thus, similar ICC values as to that of the fixed-frame dynamometry was indicated by the data while providing a viable option for individuals seeking a cost-effective portable device.

Decreased inter-rater reliability for movements such as capital flexion and extension may be associated with positioning. However, participant unfamiliarity with these specific types of movements could also influence reliability. When collecting data, members of the research team noted the majority of the participants struggled to properly perform both capital flexion and extension, as they were unfamiliar with these motions. There is a lack of research regarding a neck strength assessment protocol that accurately measures capital flexion and extension. Due to the absence of data, it is difficult to determine the primary factor causing the overall decrease in inter-rater reliability for capital motions observed in this study. However, increasing the amount of participant instruction on how to perform the movements should be considered for future research using this assessment protocol.

A critical observation made by the research team, while not reflected by the ICC values, was the instrumentation's inability to easily assess cervical rotation. The anchor point and line of pull during execution of cervical rotation isometric contraction resulted in slippage of the head harness. As such, most participants experienced some level of difficulty with cervical rotation. Of the 31 participants, 26 reported left and right cervical rotation were the least favorable, due to the constant slippage and readjustment of the head harness. The use of a swim cap should be considered for future implementation for participants with fine hair to prevent slippage of the head harness during cervical rotation.

Other studies decreased the participant's ability to compensate by using straps or pads to stabilize the participant (6, 7, 13, 14, 15). However, participants reported they felt left and right lateral flexion as well left and right cervical rotation, while seated or standing, allowed for the least amount of compensation. This decrease in compensation might be due to the sideways positioning, as it may limit the participant's ability to use their body to increase force production values. This study did not include a method of participant stabilization to simplify the neck strength assessment protocol, increasing its portability and ease of implementation. Thus, adding a mechanism to further steady the participant should be considered for future implementation to increase the overall interrater reliability of the neck strength assessment protocol.

The intra-rater reliability values reported in this study for both the seated and standing measurement techniques closely resembled the current literature examining isometric neck strength measurement protocols. The authors noted positive ICC values, good to excellent, for the previous studies assessing intra-rater reliability (Table 9). Good to excellent reliability between trials was established for both seated and standing measurement techniques in this study, indicating that the intra-rater reliability of the neck strength assessment protocol is comparable to other available methods. As shown in Table 9, excellent intra-rater and good to excellent inter-rater reliability was reported when using a fixed-frame dynamometry apparatus to assess isometric neck strength (13, 15). Likewise, when examining the intra-rater reliability of a custom fixed-frame apparatus that simulated "contact posture" for rugby players, good to excellent reliability was established (Table 9), but with a greater inconsistency in results (14). While the literature claims that fixed-frame dynamometry is a reliable method for assessing neck strength, it may be impractical for use in most clinical settings, due to its high-expense and non-transportable nature (19).

Table 9. Intra-rater and Inter-rater ICC Values for Literature Review Studies

Title	Author	Intra-rater ICC Values*	Inter-rater ICC Values*
Neck-Strength: A protective Factor Reducing Risk for Concussion in High School Sports *ICC values compared only to handheld dynamometer	Collins et. al (2014)	________	75% above 0.8
Intra-rater Reliability of Neck Strength Measurement of Rugby Players Using a Handheld Dynamometer	Geary et. al (2013)	0.80 – 0.95	________
Reliability of a Novel Technique for the Measurement of Neck Strength	Hall et al. (2017)	0.89	0.90
The Reliability of Measuring Neck Muscle Strength with a Neck Muscle Force Measurement Device	Rezasoltani et. al (2003)	0.94 – 0.95	0.92 – 0.97
Reliability of Repeated Isometric Neck Strength and Endurance Testing in a Stimulated Contact Posture	Salmon et. al (2015)	0.80 – 0.95	________
Intratester and Intertester Reliability of Neck Isometric Dynamometry	Strimpakos et. al (2004)	0.93 – 0.97 (seated) 0.95 – 0.99 (standing)	0.88 – 0.94
Evaluating the Reliability of a Novel Neck-Strength Assessment Protocol for Healthy Adults Using Self-Generated Resistance with a Hand-Held Dynamometer	Versteegh et. al (2015)	0.94 – 0.97	0.87 – 0.95

*ICC (Intra-class correlation coefficient): Inferential statistic that determines the degree of correlation and agreement between measurements
*ICC values reported as either a range or percentage of values above 0.8

The inter-rater reliability values reported were analogous to the findings in a previous research study claiming to assess the reliability of "cost-effective" neck strength measurement instrumentation (2). Collins et. al (2014), assessed reliability for four neck movements (cervical flexion/extension and left/right lateral flexion) and reported inter-rater reliability ICC values as "75% above 0.8" when compared only to a handheld dynamometer (2). When examining the values reported, for the same motions assessed by Collins et al. (2014), the ICC values ranged from 0.68 to 0.91, with 75% of ICC values above 0.8 (Tables 7 & 8) (2). Similarities in reported ICC values indicate that the assessment protocol utilized demonstrates equivalent inter-rater reliability to another cost-effective method for neck strength assessment, as reported by Collins et al. (2014) (2). To note, the Collins et al. (2014) study did not compare their neck strength assessment tool to the *gold-standard* fixed-frame dynamometry and also received donations for portions of their assessment tool (2). As such, the overall cost of the neck strength assessment tool, in the Collins et al. (2014) study, was inherently reduced (2). In contrast, the inter-rater reliability values reported were lower than the values reported by studies utilizing more expensive methods for neck strength assessment. Studies that assessed instrumentation over $750 reported good to excellent inter-rater reliability, with ICC values ranging from 0.87 - 0.97 (Table 9). Hall et al (2017), developed a novel neck strength assessment tool indicated its reliability and portability (7). The ICC values for intra-rater reliability ranged from 0.87 - 0.97 and inter-rater ICC values ranged from 0.90 - 0.97 indicated both intra- and inter- reliability was good to excellent (7). Although, the ICC values for the Hall et al. (2017) apparatus proved to be reliable, the tool itself has a weight of roughly 70lbs and a relatively large footprint as compared to the neck strength assessment tool developed by the authors of this manuscript (7). Furthermore, the Hall et al. (2017) study fails to identify the cost of each of the two pieces included in the device (7). Nevertheless, the Hall et al. device is a reliable option for neck strength assessment (7).

Overall, our study had several limitations. First, all strength measurements were conducted within 90-minutes. The long duration of the testing protocol could have caused the participants to experience some level of fatigue, thus influencing strength outcomes. Second, seated measurements were conducted before standing measurements for all participants. Therefore, the participants had more practice performing each motion by the time they were evaluated using the standing technique, in comparison to the seated technique. The discrepancy in participant education between methods may have affected the overall outcomes. Third, the same-day nature of the data collection protocol may have resulted in poor performance of each isometric contraction conducted by the participants as they were only briefly informed on how to properly execute each movement. Increasing participant education before collecting data could have impacted the results. Lastly, the sample of 31 participants used in this study had a very narrow age range, from 18 to 25 years. Future studies utilizing this neck strength assessment protocol should use more participants with a larger age range to better represent the general population.

The fixed tension scale instrumentation and methods used in this study demonstrated good to excellent intra-rater reliability, as well as moderate to excellent inter-rater reliability, indicating this protocol is a reliable method for assessing isometric neck strength. However, the results from the study suggest that neither measurement technique, seated or standing, was superior to the other. Furthermore, there was a tendency for inter-rater reliability values to be lower with capital neck motions that involved the participant facing directly towards or away from the instrumentation. The assessment protocol utilized in this study demonstrated equivalent inter-rater reliability to other cost-effective method for evaluating isometric neck strength. Thus, the neck strength assessment tool and protocol may be considered a more viable choice by clinicians seeking a portable, light-weight, and cost-effective means for the reliable assessment of isometric neck strength.

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