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The reliability of isometric neck strength assessments in trained individuals

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ABSTRACT

Cervical muscle strength has been identified as a modifiable risk factor for concussion and cervical spine injury. At present, there is a dearth of research investigating reliable methods of measuring neck strength which are: suitable for implementation into a sporting environment (for example: a strength and conditioning suite, training facility and match facility), accessible to athletes who play contact sport or are at risk of suffering concussion, and which can be used for regular testing, monitoring and evaluation of groups of athletes. The aim of this investigation was to examine the reliability of a method of measuring isometric neck strength using a portable dynamometer (PD) mounted on a custom-built bracket, appropriate for use in an applied sport and exercise environment. Measurements were conducted in flexion, right-side flexion, extension, and left-side flexion using a PD and custom-built rack. Fourteen participants had their isometric neck strength measured in two sessions, 24 h apart at a university strength and conditioning gym. Participants completed three isometric contractions in each of the four directions with 30 s between each repetition. Participants peak isometric neck strength measurements and time to peak force measurements were used for data analysis. The height of the PD and order of pushing positions remained constant between both sessions. This method demonstrated strong relative and absolute reproducibility for measuring peak isometric force (PF) of the neck musculature in all directions (PF ICC ranged between 0.78 - 0.94 across all directions. PF r ranged between 0.81 - 0.92 across all directions. PF CV% ranged between 8.86 - 10.43 in all directions). However, findings show poor relative reproducibility for the measurement of time to peak isometric force (TPF). Systematic bias was small and the difference between the trials for PF and TPF were not significant ($p > 0.05$ in all directions).

1. Introduction

Sports related concussion (SRC) has received growing attention in both the sports medicine community, as well as the media due to the increase in prevalence in both youth and senior sport (Mannix et al., 2016). For instance, in the 2017/2018 English Premiership Rugby season, concussion was the most reported match injury (17.9 per 1000 hours) for the seventh consecutive season, contributing 20% of all match injuries (England Professional Rugby Injury Surveillance Project Steering Group, 2018). Concussion in sport occurs as a result of sudden impacts and collisions to the head or body, causing the brain to move and subsequently bump against the skull (Weed, 1935). The force of the brain being pushed against the side of the skull can damage blood vessels, nerve fibres, cause bruising and disrupt normal brain function, thus resulting in a mild traumatic brain injury (TBI) called concussion (Cosgrave & Williams, 2019; Pearce et al., 2018; Weed, 1935). The 2019 American Medical Society for Sport Science (AMSSM) (Harmon et al., 2019) concussion position statement highlighted that prevention of cervical spine injuries and concussion is not possible. However, assessment, monitoring and management of such injuries, including preventative measures to decrease the incidence and severity, are valuable when improving the safety of contact sports (Harmon et al., 2019).

Research into TBI in contact sport has led to an interest in measuring, monitoring, and training neck strength (Almosnino et al., 2010; Collins et al., 2014; Eckner et al., 2014; Harmon et al.,

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2019). Current research suggests that low neck strength is a potential modifiable risk factor that may contribute to elevated concussion risk, due to the greater linear and angular head displacements, velocities and accelerations which occur post impact (Eckner et al., 2014). It has been found that stronger muscles are capable of absorbing higher forces due to greater tensile stiffness and the ability to produce torque more rapidly than weaker muscles, which intern attenuates the heads response to impact (Conley et al., 1997; Dempsey et al., 2015; Eckner et al., 2014). This was demonstrated by Viano et al. (2007) who found stiffer necks reduced head displacement, acceleration and velocity and reduced concussion incidences in footballers; and further by Mihalik et al., (2010) who proposed that the ability to anticipate a collision in Rugby allowed for greater activation of cervical muscle structure and mitigated the severity of the impact, by having greater neck stiffness to absorb the external force applied to the head and neck. A growing body of research suggests that measuring, monitoring, and improving neck strength through strength training could have a positive impact on mitigating the severity and occurrence of such injuries (Collins et al., 2014; Conley et al., 1997; Dempsey et al., 2015).

Isokinetic dynamometry is considered to be the gold standard for measuring isometric limb strength (Dvir & Prushansky, 2008), however to date, there is no agreement on what is considered to be the gold standard for measuring isometric neck strength either in field-based or clinical settings, this is due to the range of custom-built equipment which is currently used to assess isometric neck strength. Despite the range of equipment, clinical studies have shown that measuring isometric neck strength in four directions: flexion, right-side flexion, extension, and left-side flexion, to be reliable and valid, however, the equipment used was laboratory based and tailored towards collecting clinical data in both symptomatic and asymptomatic participants (Chiu & Lo, 2002; Dvir & Prushansky, 2008; Jordan et al., 1999). A number of studies have been successful in demonstrating clinical reliability, validity, and relevance (Chiu & Lo, 2002; Dvir & Prushansky, 2008; Jordan et al., 1999; Prushansky et al., 2005), yet there has been little attention directed towards ensuring there are reliable methods available which are suitable for implementation in applied sport environment, such as gyms, sports grounds and changing rooms.

Existing literature shows a range of different equipment and protocols have been used to measure isometric neck strength (Bohannon, 1993; Chiu & Lo, 2002; Collins et al., 2014; Conley et al., 1997; Dempsey et al., 2015; Dvir & Prushansky, 2008; Jordan et al., 1999; Krause et al., 2019; Mihalik et al., 2010; Olivier & du Toit, 2008; Prushansky et al., 2005; Versteegh et al., 2015; Viano et al., 2007). The widely reported methods used to measure isometric neck strength reliably are: Handheld dynamometry (HHD) using a portable dynamometer (PD), fixed frame dynamometry (FFD), manual muscle testing (MMT) and isokinetic measurements. HHD, FFD, MMT and isokinetic measurements are commonly used for assessment and rehabilitation purposes. Within the existing body of research, each method of measuring cervical neck strength has been thoroughly investigated (Bohannon, 1993; Chiu & Lo, 2002; Collins et al., 2014; Conley et al., 1997; Dempsey et al., 2015; Dvir & Prushansky, 2008; Jordan et al., 1999; Krause et al., 2019; Mihalik et al., 2010; Olivier & du Toit, 2008; Prushansky et al., 2005; Versteegh et al., 2015; Viano et al., 2007). However, the current body of research has not investigated the application of aforementioned methods' in an applied sport environment as a potential preventative measure against TBI in contact sport. This is most likely to be because of the inaccessible, time consuming nature of current equipment, meaning it is not feasible to carry out measurements in applied settings.

Therefore, the method devised here, aims to address the barriers and difficulties which arise when implementing the current methods of measuring neck strength into an applied sport and exercise environment. For example, existing methods utilising FFD and isokinetic measurements are largely laboratory based, requiring specialised equipment such as computerised load cells and elaborate fixtures to stabilise the head, neck, and torso (Almosnino et al., 2010; Chiu & Lo, 2002; Dvir & Prushansky, 2008; Jordan et al., 1999; Prushansky et al., 2005). Previously reported methods have also emphasised the importance of being restrained at the shoulder, torso, and hip (Almosnino et al., 2010; Chiu & Lo, 2002; Dvir & Prushansky, 2008; Jordan et al., 1999; Prushansky et al., 2005) however, research has acknowledged that trunk stabilisation limits construct validity and the relevance of strength measures (Olivier & du Toit, 2008) whilst also impacting the ability to process large numbers of athletes due to time available and accessibility to equipment in order to complete the measurements.

Irrespective of the equipment used to measure isometric neck strength, the populations which have been examined to date is mainly limited to symptomatic clinical populations or normative asymptomatic populations (Almosnino et al., 2010; Bohannon, 1993; Chiu & Lo, 2002; Dvir & Prushansky, 2008; Jordan et al., 1999; Krause et al., 2019; Prushansky et al., 2005; Versteegh et al., 2015). The participants used in existing research were not athletic populations, therefore findings cannot be generalised and applied to trained athletes. Furthermore, findings have previously reported that the strength of the person administering the testing procedure using HHD or MMT to be a limitation, as tester strength has a major impact on the reliability of data collected (Bohannon, 1993; Krause et al., 2019). For an HHD or MMT to be used as a monitoring or screening tool, it would require the same strong person to administer and provide resistance for all tests to ensure that the resistance provided would be the same and therefore ensure the test is reliable (Bohannon, 1993). In clinical settings, where participants are weaker this would not pose a problem. However, it would be extremely difficult for one person to provide consistent and adequate force for a whole squad of athletes on a regular basis. Finally, the present study also aims to rectify ethical and safety issues associated with testing protocols which apply external pressure to the cervical spine (Conley et al., 1997) by ensuring that there is no external resistance being applied to the head and neck, and only using self-generated force, therefore decreasing the likelihood of injury.

To summarise, despite research identifying that neck strength could play a role in mitigating concussion (Collins et al., 2014; Dempsey et al., 2015; Eckner et al., 2014), the need for a reliable method of neck strength assessment which could be suitable for application in an applied sport environment has been largely overlooked. It is therefore of great interest for researchers to identify a reliable method to measure neck strength suitable for implementation in a sport environment and in a trained population.

In the future, it is anticipated that data collected via this method will inform a reliable, easily accessible alternative to laboratory-based measurements suitable for asymptomatic athletes. In-turn, due to the wider accessibility, it is thought strength and conditioning practitioners will be able to collect reliable data which could be used to guide practice surrounding neck strength training and monitoring.

Therefore, the aim of this research is to examine the reliability of a standardised method of measuring cervical neck strength in flexion, right-side flexion, extension, and left-side flexion using a PD and custom-built rack; suitable to for implementation in an applied sport environment and to be used by trained athletic populations.

2. Methods

Fourteen participants had their isometric neck strength measured in four directions: flexion, right-side flexion, extension, and left-side flexion, in the sagittal and transverse planes. This was performed in two sessions with 24 h in between each session. Measurements taken from the PD were PF measured in kg, and TPF measured in s. The dynamometer recorded force in N, the dynamometers setting allowed these values to be converted to kg upon recording. Expression of force in kg rather than N was preferred as it provided more context to the measurements. Therefore, from here onwards force will be expressed as kg, and not N. In the week prior to the data collection sessions, participants attended a familiarisation session where the PD was fitted to their height and low intensity practice trials in all four directions took place. The same investigator performed all measurements using the same method.

2.1. Participants

Participants recruited were athletes who trained with the strength and conditioning department. All participants had experience of structured strength training for > 2 years and performed strength training 3 times per week. All participants had undergone basic isometric neck strength training as part of their individualised training programs. The inclusion criteria detailed those participants should not be suffering or undergoing treatment for any head or spinal injury and could not have any known congenital spine abnormality. Prior to taking part in the study, participants attended a briefing and provided written informed consent. All procedures conformed to the declaration of Helsinki and institutional ethical approval was granted prior to any experimental procedures.

2.2. Procedure

Isometric neck strength was measured using a PD (Lafayette Dynamometer, Model 01165, Lafayette, California, USA) and a custom-built steel bracket, which was mounted to a wall in the University Strength and Conditioning Suite (Figure 1).

Figure 1: Isometric neck strength testing equipment

Participant's torso length was measured whilst seated with the head in the Frankfurt Plane. The measurement was taken from the iliac crest to the C7 vertebra using a tape measure. Once torso length had been measured, the PD was fitted to each participant.

Ensuring the head was in the Frankfurt plane, for flexion, the pressure pad was in line with the nose, superior to the eyebrows and in the centre of the forehead. In right and left-side flexion positions, the pressure pad was in line with and above the ear, avoiding the temple. In the extension position, the pressure pad was positioned in the centre of the back of the participants head (Figure 2).

Figure 2: Pushing positions: flexion, right-side flexion, extension, and left-side flexion.

To adjust the height of the PD, four metal bolts were unscrewed, and the PD moved up or down to suit the participant. To secure, the metal bolts were re-screwed and tightened (Figure 1). During the familiarisation session, low intensity practice trials were employed to assess whether the height was appropriate for each participant. Once confirmed, the height of the PD was recorded and set for each participant. This height remained consistent for both testing sessions.

To measure isometric neck strength, participants were seated on a standardised bench with their feet flat on the floor, palms flat to their thighs (Figure 2). Participants' feet were held in position by another participant throughout the test to prevent them from moving. The bench chosen did not have a back or arm rests to prevent bracing the trunk against a chair (Versteegh et al., 2015) (Figure 2).

Prior to the experimental procedure, each participant repeated three sub-maximal isometric contractions in each direction to warm up. For the experimental procedure, participants completed three maximal effort repetitions in each of the four directions with 30 s rest between each repetition. Participants were given 60 s rest whilst they changed pushing position. For every contraction completed, participants pushed until volitional failure and participants were instructed to stop pushing when they felt they could no longer maintain a strong isometric contraction. This allowed for the optimal time for peak isometric force to be determined. Results were displayed immediately on the PD screen and PF and TPF were recorded for all participants. The two data collections sessions were scheduled 24 h apart, participants repeated the protocol which required them to complete three repetitions in each of the four directions in: flexion, right-side flexion, extension, and left-side flexion (Figure 2). The order of pushing positions was randomised using a simple randomisation approach via a Microsoft Excel formula. Previously recorded positions were used to standardise the procedure.

The maximum scores in each direction for PF and associated TPF were used for analysis. All data are presented as mean ± SD. The alpha level was set to 0.05 a priori. Data analyses were performed using the SPSS Programme (IBM SPSS Statistics Software Version 26.0, SPSS Inc, Armonk, New York, USA). Peak values for PF and TPF were used for statistical analysis.

3. Results

The statistical methods chosen are used to demonstrate the reliability of the method used to measure isometric neck strength. Hedge's g was chosen to calculate effect sizes (ES) as the sample size was below 20 participants. ES of 0.20 was small, 0.50 was medium and 0.80 large (Vogt & Johnson, 2015). Systematic error in the repeatability of the trials was evaluated using paired sample t-tests; the magnitude of bias was determined from the mean ratio from ratio of limits agreement (RLOA) analysis. To measure reproducibility of the method between trials, Pearson's correlation coefficient (r) and intra-class correlation coefficient (ICC) was used to evaluate the intra-rater reliability of the method. Furthermore, to confirm absolute reproducibility, percentage coefficient of variation (CV%) limits of agreement (LOA) (Bland & Altman, 1986) and standard error of measurement (SEM) were calculated independently of the ICC.

The descriptive characteristics of participants are presented in Table 1. The mean PF produced in all pushing positions follows: flexion: 16.92 ± 4.73 kg, right-side flexion: 16.95 ± 5.21 kg, extension: 26.73 ± 10.77 kg, left-side flexion: 17.59 ± 4.51 kg. Results show that in flexion, on average it took 4.16 ± 1.62 s to reach PF, right-side flexion: 5.01 ± 1.22 s, extension: 4.50 ± 1.64 s, and left-side flexion: 5.42 ± 1.51 s. All participants reached PF before 7 s.

3.1. Systematic bias between trials

There was no significant difference between PF in the two trials ($p > 0.05$; Table 2), this was also found to be similar for TPF (PF: flexion: $p = 0.89$, right-side flexion: $p = 0.40$, extension: $p = 0.83$, left-side flexion: $p = 0.78$; TPF: flexion: $p = 0.64$, right-side flexion: $p = 0.39$, extension: $p = 0.84$, left-side flexion: $p = 0.97$). Table 2 shows that the mean ratios for both PF and TPF are similar for both measures, however there is greater discrepancy in the mean ratios of PF and TPF in the right-side plane of movement compared to the other planes of movement (Table 2). Individual variation in PF and TPF are presented in Figures 3 and 4.

3.2. Absolute reproducibility in outcome measurements

Random error in outcome measurements is presented in Table 3. Reproducibility analyses indicate that mean change in PF between the two session was low in flexion, left-side flexion, and extension, however there was a greater change between scores between the two sessions in right-side flexion (Table 3). For TPF measurements, the greatest percentage change in scores occurred in flexion and right-side flexion. There were minor changes in extension and left-side flexion (Table 3). TPF had smaller SEM values compared to PF values. CV% values ranged from 8.9% to 10.4% for PF, and were deemed acceptable (Bland & Altman, 1986; Vogt & Johnson, 2015). However, TPF CV% were deemed large. LOA and RLOA were deemed to be acceptable for both PF and TPF, furthermore, no proportional bias was found for PF and TPF in any direction. The ES for all directions in PF were: flexion: $g = 0.04$ right-side flexion: $g = 0.32$, extension: $g = 0.08$ and left-side flexion: $g = 0.10$, they are considered small (Bland & Altman, 1986; Vogt & Johnson, 2015). These results are also mirrored in TPF: flexion: $g = 0.18$, right-side flexion: $g = 0.36$, extension: $g = 0.08$, left-side flexion: $g = 0.02$.

Table 1: Participant descriptive characteristics (Mean ± SD)

Sex	*n*	Age (y)	Seated stature (m)	Stature (m)	Body mass (kg)
Male	9	22 ± 3	0.96 ± 0.48	1.83 ± 0.49	94.1 ± 15.3
Female	5	21 ± 1	0.92 ± 0.47	1.76 ± 0.10	66.0 ± 10.6

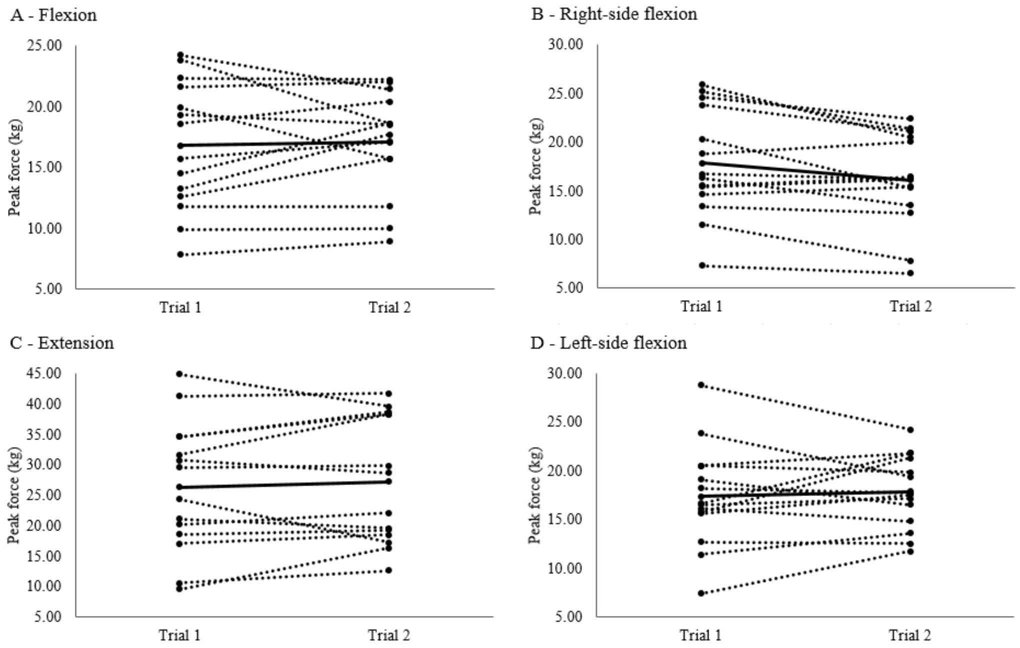

Figure 3: Individual variations in PF (A) flexion, (B) right-side flexion, (C) extension and (D) left-side flexion. Dashed lines represented individual participants and the solid line represents the group mean.

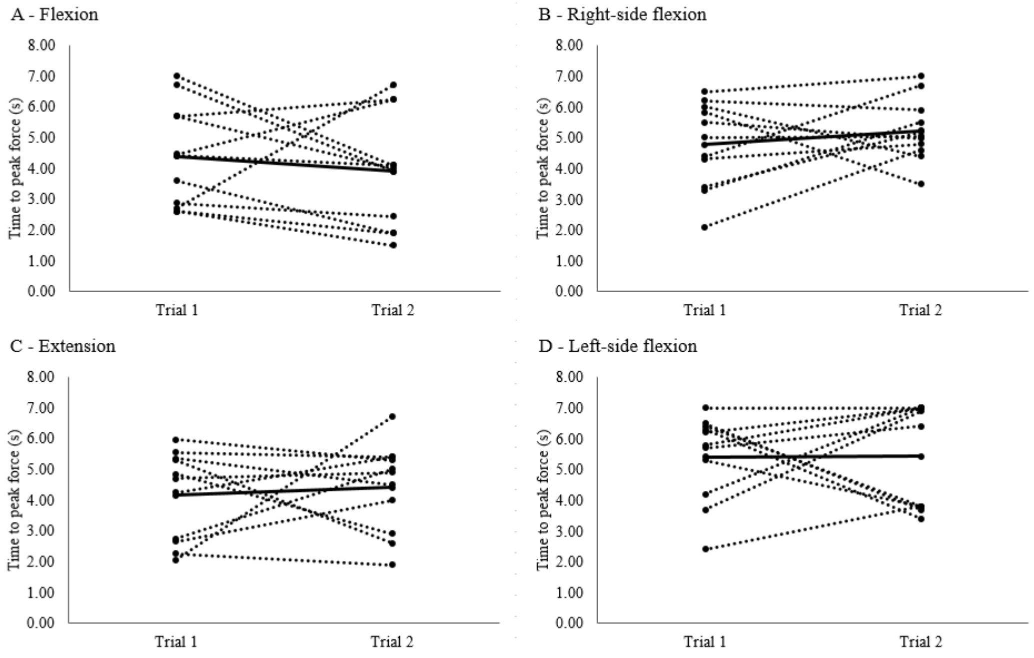

Figure 4: Individual variations in TPF (A) flexion, (B) right-side flexion, (C) extension and (D) left-side flexion. Dashed lines represented individual participants and the solid line represents the group mean.

Table 2: Systematic bias between PF (kg) and TPF (s) measurements in all four pushing positions (*p* value was determined from test re-test data) (LOA = limits of agreement, RLOA = ratio limits of agreement).

Pushing position	Variable	Mean ± SD Trial 1	Mean ± SD Trial 2	T-Test (*p* value)	LOA mean ratio	RLOA mean ratio
Flexion	PF	16.80 ± 5.31	17.04 ± 4.26	0.89	0.99	0.98
	TPF	4.31 ± 1.56	4.01 ± 1.72	0.64	1.08	1.05
Right-side flexion	PF	17.81 ± 5.57	16.10 ± 4.87	0.40	1.11	1.04
	TPF	4.78 ± 1.41	5.24 ± 1.01	0.39	0.91	0.93
Extension	PF	26.29 ± 10.77	27.16 ± 10.39	0.83	0.97	0.99
	TPF	4.56 ± 1.36	4.43 ± 1.94	0.84	1.03	0.94
Left-side flexion	PF	17.35 ± 5.27	17.84 ± 3.78	0.78	0.97	0.98
	TPF	5.41 ± 1.41	5.44 ± 1.67	0.97	0.99	1.00

Table 3: Absolute reproducibility statistics between trials 1 and 2 for determining PF (kg) and TPF (s) in all four pushing positions.

Pushing position	Variable	Δ% Mean	CV (%)	S_x	LOA (mean bias± 2s)	RLOA (mean bias x/ ÷ 2s)	SRD
Flexion	PF	1.45	8.86	0.89	5.83 to -5.35	1.48 to 0.94	2.48
	TPF	-7.05	25.69	0.32	4.04 to -3.44	0.67 to -0.47	0.88
Right-side flexion	PF	-9.59	9.57	0.98	6.14 to -2.72	0.17 to -0.07	2.73
	TPF	9.67	23.90	0.26	3.64 to -2.72	0.38 to -0.28	0.72
Extension	PF	3.30	10.00	1.96	8.69 to -6.95	0.18 to 0.14	5.44
	TPF	-2.87	28.54	0.32	3.83 to -3.57	0.52 to -0.42	0.89
Left-side flexion	PF	2.80	10.43	0.85	6.78 to -5.80	0.22 to -0.14	2.73
	TPF	0.50	25.45	0.32	4.32 to -4.26	0.41 to -0.37	0.89

Δ = Change, CV% = Coefficient of variation percentage, S_x = Standard error of the mean, SRD = Smallest real difference

Table 4: Relative reproducibility for determining PF (kg) and time to TPF (s) in all four pushing positions.

Pushing position	Variable	ICC	ICC CI	*r*
Flexion	PF	0.85	0.60-0.95	0.86*
	TPF	0.35	-0.22-0.75	0.34
Right-side flexion	PF	0.92	0.77-0.97	0.92*
	TPF	0.14	-0.47-0.66	0.14
Extension	PF	0.94	0.80-0.98	0.94*
	TPF	0.39	-0.18-0.77	0.40
Left-side flexion	PF	0.78	0.49-0.94	0.81*
	TPF	0.00	-0.58-0.58	<0.01

ICC = Intraclass correlation coefficient, ICC CI = Intraclass correlation coefficient confidence interval, *r* = Pearson's correlation coefficient. *Significant to 0.05 level.

3.3. Relative reproducibility in outcome measurements

Reproducibility statistics for the method used to test PF and TPF are presented in Table 4. This method has strong relative reproducibility for PF in all directions. However, Table 4 indicates weak relative reproducibility of TPF as ICC and *r* values were found to be below the accepted levels for good to excellent reliability.

4. Discussion

Despite there being clinical studies, which measure neck strength using laboratory equipment (Almosnino et al., 2010; Bohannon, 1993; Chiu & Lo, 2002; Dvir & Prushansky, 2008; Jordan et al., 1999; Krause et al., 2019; Prushansky et al., 2005; Versteegh et al., 2015) a reliable and accessible method to measure isometric neck strength in a sport environment, has yet to be established. The primary aim of this paper was to examine the reliability of a method of measuring isometric neck strength using a PD and custom-built rack, suitable for practical use in an applied environment. The reliability statistics employed in this study allows for greater comparison to clinical methods used to measure isometric neck strength and establishes whether this method can yield reliable results.

Data presented supports the use of a PD fixed onto a wall mounted bracket in an applied sport and exercise environment, as it demonstrates similar levels of reliability to methods used in clinical research and laboratory-based studies of isometric neck strength. For example: ICC scores for flexion, right-side flexion, extension, and left-side flexion for a range of different clinical, laboratory and custom-built equipment, have been reported between 0.80 – 0.99 (Almosnino et al., 2010; Chiu & Lo, 2002; Dvir & Prushansky, 2008; Jordan et al., 1999; Prushansky et al., 2005). ICC scores for the method and equipment used in this research range between 0.78 and 0.94 across all four directions, with CV% values ranging from 8.9% to 10.4% for PF. Left-side flexion demonstrated the lowest reliability of the four directions, a possible explanation of this is the dominance or sidedness of the athletes. Unfortunately, this data was not collected, however further investigation is warranted to understand how this may impact the reliability of the left-side flexion measure. Overall, despite the range in the comparative ICC and CV% scores, which is likely to be attributed to the difference in equipment, experimental conditions and participants, the results indicate isometric neck strength can be measured reliably within a sport environment without visiting a laboratory or using elaborate, specialist equipment; therefore, enabling greater accessibility for athletes who are at risk of sustaining a TBI, or undertaking rehabilitation post injury.

Despite limited analysis of the reproducibility of TPF measurements of the cervical spine musculature in athletes, there were notable differences in levels of reliability found in previous research in clinical settings. It has been reported that CV% for rate of force development (RFD) measured using custom-built laboratory equipment, ranged from 5% - 9% with ICC scores ranging between 0.90 - 0.99 in active adult males (Almosnino et al., 2010). Our results showed CV% ranged from 23% – 29%, with ICC scores ranging between 0.00 - 0.39 in athletes. The findings of this present study do corroborate results from existing research investigating the reliability of methods used to measure RFD in sport environments. For example, RFD has been found to be less reliable than maximal force-based qualities when assessed via force plates in a range of different movements such as: countermovement jumps (CMJ), drop jumps (DJ) and isometric mid-thigh pull (IMTP) (Dos'Santos et al., 2018; Hernández-Davó & Sabido, 2014; Hori et al., 2009).

It is not clear if the incomplete stabilization of the torso was associated with the poor reliability of the TPF measure. The removal of torso stabilization may have led participants to accelerate their head into the pad thus creating differences between readings. However, if this were so, it could have been expected that the PF measurements would also have been unreliable, however PF was found to be a highly reliable measure of isometric neck strength.

An unexpected finding identified that on both data collection sessions, all participants reached their PF within 7 s of beginning the isometric contraction, in all directions. Compared to TPF for other muscles this is significantly longer, however as there is little information available investigating TPF of the neck musculature, there were no prior expectations of what this figure may have been.

Overall, the preliminary findings presented here support the use of this equipment to measure PF in an applied sport and exercise environment as it demonstrates a reliable, less time consuming and complex method of measuring isometric neck strength. This method allows for ongoing monitoring and evaluation of neck strength for athletes during a season, which could see those who are at risk of sustaining TBI to be identified prior to sustaining an injury, rather than only accessing one-off measurements at the point of injury. This could allow for tailored recommendations to be prescribed to athletes in order to minimise the incidence of concussion or assist in the return to play from concussion. Furthermore, the test utilises easily movable equipment, which allows for the equipment to be mounted in an area which athletes use every day, such as a gym or training facilities. This will increase athletes' access to the equipment and in turn also increase the amount of reliable data available for practitioners to analyse and use to inform training prescription. This could lead to an improved understanding of the role neck strength plays in sport and concussion.

To conclude, the aim of this study was to determine whether the measuring of isometric neck strength using a PD mounted on a custom-built bracket exhibited suitable levels of reliability appropriate for use in a sport environment. Findings from this study are important as current methods of measuring isometric neck strength are largely clinical assessments, laboratory based, and require complex equipment which results in them being inaccessible for athletes who could benefit from monitoring and evaluation of their neck strength.

The method detailed here is a reliable method of quantifying PF of the neck musculature in asymptomatic athletes, in a sport environment. However, this method is not reliable when measuring TPF. The results of this research may prove valuable in the assessment and monitoring of isometric neck strength for athletes who take part in sport. Implementation of this equipment and method in future research should aim to identify the effects that sports have on peak isometric neck strength. Furthermore, future research should seek to measure isometric neck strength in contact sports and analyse the impact that tailored recommendations as a result of monitoring peak isometric neck strength, has on the incidences and return to play from concussion in contact sports.

Conflict of Interest

The authors declare no conflict of interests.

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