ORIGINAL RESEARCH ARTICLE

Isokinetic evaluation of neck strength

D E Du Toit (DPhil)[1]
F J Buys (DSc)[1]
D J L Venter (BSc (Hons))[2]
P E Olivier (MA)[3]

[1]Department of Human Movement Science, University of Port Elizabeth
[2]Department of Mathematical Statistics, University of Port Elizabeth
[3]Department of Human Movement Science, University of Zululand, KwaZulu-Natal

Abstract

Objective. To evaluate the variability and reliability of repeated measurements of isokinetic cervical flexion, extension and lateral flexion strength, in order to establish a method of evaluating neck strength isokinetically.

Subjects. Eighty-one schoolboys with ages ranging between 16 and 20 years and a mean age of 17.4 years participated in the isokinetic evaluation of neck strength.

Method. The isokinetic cervical strength testing was completed on three separate days (T0, T1 and T2) using an isokinetic dynamometer in conjunction with a specially designed halo and stabilising chair. On T0, prior to the isokinetic assessment, an anthropometrical evaluation of the participating subjects was also performed. Although the results of T0 were compared with those of T1, the primary aim of session T0 was to familiarise the subject with the equipment and testing procedures.

Results. The results obtained from the test-retest (T1 and T2) procedure for flexion, extension and lateral flexion were highly correlated; the intraclass correlation coefficient (ICC) for T1 and T2 was 0.89 for peak flexion torque, 0.94 for peak extension torque, 0.91 for peak lateral flexion to the dominant side and 0.92 for peak lateral flexion to the non-dominant side. Cervical range of motion (CROM) results for controlled full range of joint motion movements between T1 and T2 were highly correlated: ICC = 0.97 for flexion/extension (CFRFE) and ICC = 0.95 for lateral flexion (CFRLF). CROM measurements taken during maximal voluntary muscular contraction for flexion/extension (MVCRFE) and lateral flexion (MVCRLF), between T1 and T2 showed no correlation (ICC = 0.42 and ICC = 0.27). Results between the familiarisation session (T0) and the initial test (T1) for flexion, extension and lateral flexion were moderately correlated. The following results were obtained: ICC = 0.65 for peak flexion torque, ICC = 0.77 for peak extension torque, ICC = 0.66 for peak lateral flexion to the dominant side and ICC = 0.72 for peak lateral flexion to the non-dominant side. CFRFE (ICC = 0.80) and CFRLF (ICC = 0.79) were highly correlated but no correlation was found for maximal voluntary contraction range of motion (MVCRLF, ICC = 0.34 and MVCRFE, ICC = 0.27).

Conclusion. Results obtained from this study indicate that a familiarisation session of the subject prior to the testing of cervical strength is warranted. The results also indicate that repeated measures of isokinetic cervical flexion, extension, and lateral flexion strength are highly reliable.

CORRESPONDENCE:

D E du Toit
Department of Human Movement Science
University of Port Elizabeth
PO Box 1600
Port Elizabeth
6000
Tel: 041-504 2518
Fax: 041-504 2770
E-mail: hmadet@upe.ac.za

Introduction

Measures to prevent cervical spinal injuries sustained during rugby union, wrestling, judo, boxing, and American football are widely advocated, and the strengthening of the neck musculature is one of the practical, but neglected preventative measures proposed by many researchers.[8, 10, 25, 34, 55, 59, 68] Although the measurement of force production around all the major joints is well established,[42] there is no isokinetic quantification of the force capabilities of the cervical musculature through the full range of motion.[10, 11 28, 42]

The incidence of cervical spine injuries in rugby has been well documented and is a problem encountered by all rugby-playing countries, viz. South Africa,[40,48] Australia,[45,69] New Zealand,[1,7] Argentina,[5,50] England,[51] and America.[64,65] In South Africa over a two-decade period ranging from 1978 to 1996, 141 cervical spine injury patients were admitted to Conradie Hospital. This translates to 7.05 injuries per annum. A 10-year breakdown shows clearly that an increase in the number of injuries was experienced over the reviewed two-decade period in South African rugby.[42,43] In 1987 Scher[47] examined the period ranging from 1978 to 1987; in this period 54 cases were reported (5.4 injuries per annum). In 1998 Scher[48] examined the period ranging from 1987 to 1996, and in this period 87 injuries were observed (8.7 injuries per annum). Cervical spine injuries occurring in contact sports, such as rugby, are brought about by direct force application to the cervical spine structures. Head impact velocities as slow as 3.1 m.s-1 have been shown to be sufficient to produce a cervical spinal injury.[32] This is the equivalent of falling from a height of only half a metre. Furthermore, approximately 16 kg, which is a small percentage of the total body weight, following the head and neck in an impact with a velocity of 3.1 $m.s^{-1}$ is sufficient to produce a cervical spine injury.[39] Thus in an impact situation the momentum of the upper body alone exerts adequate force to produce a cervical spine injury.

There is thus a clear inability of the cervical spine to stop the moving torso even at very slow velocities.[66] Thus the likelihood of incurring a cervical spine injury in any head impact seems great. However this is not the case. Occurrence of a cervical spine injury depends on various factors including: (*i*) the constraints present which prevent the cervical spine from escaping the moving torso; and (*ii*) the orientation of the impact surface.[2,66]

In most impact situations the head and neck are able to bend out of the path of the moving torso. However if the head is trapped against the impact surface, the possibility of the head and neck escaping the momentum of the moving torso decreases, thus increasing the possibility of cervical spinal injury.[66] Much less force is then required to dislocate the cervical spine when the head is constrained to an immovable surface.[2] This is similar to the common injury mechanics that arise when the scrum collapses. The heads of those in the front row are pinned to the ground and they are unable to extricate themselves. As their teammates continue pushing, hyperflexion of the cervical spine occurs and possible injury.

The orientation of the impact surface or orientation of the head toward the impact surface also plays an important role in the production of a cervical spinal injury. During impacts where the head was already moving out of the path of the moving torso after impact, and in which the cervical spinal force acts immediately to push the head in the same escape direction, the risk of injury was much lower.[39]

Through the course of any contact event the cervical spine is subjected to various forces, with the potential to cause serious injury. Fortunately, the spine is protected by the energy-absorbing capacity of the paravertebral musculature and the intervertebral discs, which effectively dissipate these forces through controlled spinal motion.[56] Neck strengthening can therefore improve the energy-absorption capabilities of the neck musculature and thus also the protection of the cervical spine.

It is obviously not only athletes competing in 'high-risk' sports who are at risk of suffering a cervical spine injury. Many other activities present similar if not greater risk to the participant. The estimated total cost of level 1 neck injuries (Abbreviated Injury Scale) to American society could be as much as $3.9 billion.[68] The majority of these neck injuries can be categorised as whiplash and whiplash- associated disorders.[31] Whiplash injuries, as commonly observed in rear-end impact automobile accidents, are the result of indirect force application to the cervical spine. The injury mechanism has been ascribed to rapid rearward head translation relative to the forward-moving torso,[6,62] or alternatively the hyperextension and flexion of the head due to sudden acceleration and deceleration.[4] Powerful and strengthened neck musculature can protect the cervical spine from whiplash injuries by reducing the load placed on it. Contracted and/or increased tonus of the neck musculature would enable the head to approximate the mass of the body more closely and therefore reduce the angular acceleration experienced by the cervical spine,[8] thus providing increased protection to the cervical spine during an automobile accident.

The use of manual strength tests is commonplace in all clinical evaluations.[17,20,23,24] In 1966 Krout and Anderson[26] employed manual muscle-testing techniques to establish that patients suffering from chronic neck pain had accompanying cervical muscle weakness. This form of muscle function testing is, however, flawed by subjectivity and bias, lack of uniformity and lack of quantification.[18,19,33,36,38,53] Numerous other forms of assessing the force capabilities of the neck musculature have been implemented. They range from the use of a modified sphygmomanometer dynamometer,[61] and electromyogram (EMG)-based instrumentation,[13,49] to manual dynamometers.[3,21,29,52,70,71] All of these assessment methods however have a limiting factor in common. They rely on isometric muscle contraction to obtain their results.

The structuring and implementation of an efficient and accurate method of isokinetically evaluating the neck musculature will not only have positive financial implications, but will also provide health care professionals with improved assessment and rehabilitative methods in the clinical situation.

If neck strength is to be a preventative measure against injury, then the problem that needs to be addressed is how to evaluate neck strength objectively in order to establish normative data for the different sporting codes. A very high mechanical reliability of isokinetic dynamometers has been reported in the literature.[41,42,54] It is the introduction of the human element that needs to be controlled. Adherence to established protocols will enhance intertester and intratester reliability.[42] Protocols for the isokinetic evaluation of each of the major joints of the upper extremity, lower extremity and the trunk have been well established.[42] However the literature does not include isokinetic evaluation of the cervical spine.[10,11,28,42] The principles of isokinetic testing do however remain the same, and should receive careful attention in the development of standardised test protocols. The literature clearly indicates that patient education, familiarisation and a warm-up on the isokinetic device are essential for reliable and valid assessment.[27,42] Proper joint alignment, body positioning, and stabilisation of subjects are crucial in order to eliminate lower extremity involvement in the evaluation of the upper extremity and vice versa.[42]

Study population and methods

To examine the force capabilities of the neck musculature a halo and stabilising chair were developed. The specially designed halo and stabilising chair used in conjunction with an isokinetic dynamometer enabled the measurement of torque production of the neck musculature through the full range of motion during flexion, extension and lateral flexion.

The intraclass correlation coefficient (ICC) was used to establish the correlation between the results obtained from the education and familiarisation session (T0), the initial test (T1), and the subsequent retest (T2) of the neck musculature strength and range of joint motion. The ICC, a univariate statistic, is the preferred technique to determine reliability of repeated measures.[46] The ICCs were calculated by means of the following equation (MS = ANOVA mean sum of squares):

$$ICC = \frac{|MS_{Error} - MS_{Test}|}{|MS_{Error} + MS_{Test}|}$$

Eighty-one subjects were used in order to calculate the test-retest reliability of the isokinetic evaluation of the peak torque through the cervical spine movement patterns of flexion, extension, and lateral flexion. The subjects were chosen from a population of under-19 first XV rugby players who were evaluated in lateral flexion as well as in forward flexion and extension.

The subjects were exposed to an education and familiarisation session (T0) 5 days before the initial (T1) evaluation.[27,43] Once the subjects performed the initial test (T1), another 5-day rest period was observed before the re-test (T2) was conducted. Several studies report a rest period of 2-7 days between the initial and subsequent retest.[14,37,63] During the 5-day rest period subjects were instructed not to do any neck strengthening exercises. Participation in scheduled rugby union practice sessions was not prohibited.

Isokinetic neck strength measurements

The apparatus designed to evaluate the neck strength consisted of three major components: (*i*) the halo; (*ii*) the isokinetic dynamometer; and (*iii*) the stabilising chair.

Isokinetic dynamometer

The standard isokinetic dynamometer head, with specifically designed halo attached, was mounted onto the back of the stabilising chair. The dynamometer was connected to an online computer that visually displayed and recorded the results of the evaluation.

In 1991 Leggert *et al.*[29] proposed certain prerequisites that needed to be fulfilled to ensure the accurate evaluation of cervical spine extension strength. Firstly, the subject's torso had to be fully stabilised so that the contribution of the upper extremities could be minimised and the cervical extensor muscles could be isolated. Secondly, measurements should be made through the full range of joint motion. Thirdly, correction for the influence of gravitational force (head weight) should be made during assessment. Finally, a standardised protocol defining the test position and procedure should be used. The isokinetic cervical spine testing equipment designed and utilised for the purposes of this study satisfied all of the abovementioned recommendations for the accurate assessment of cervical extension strength.

Stabilising chair

The stabilising chair was fully adjustable and was designed to test the neck musculature isokinetically through the movement patterns of flexion, extension, and lateral flexion left and right (Fig. 1). For the purposes of this investigation the chair had to adhere to the following four conditions:(*i*) it had to accommodate any body size; (*ii*) it had to stabilise the subject's body, thus eliminating any unnecessary movement; (*iii*) it had to isolate the musculature of the cervical spine; and (*iv*) it had to be able to accommodate the head of the dynamometer.

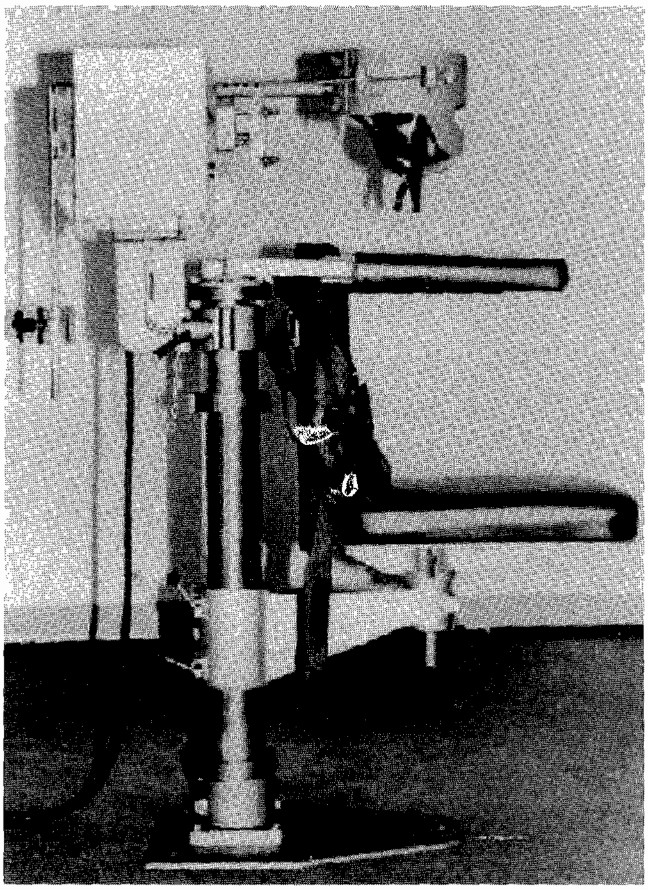

Fig. 1. The isokinetic evaluation apparatus - halo, isokinetic dynamometer and stabilising chair fully assembled.

Halo

The halo consisted of an adjustable 3 mm stainless steel circular frame, which fitted over the subject's head. A boxer's protective headgear served as padding on the inside of the halo. This allowed for comfort during the execution of the required movements and contributed to the stability of the subject's head within the halo. The circumference of the halo was adjustable, so it could fit different head sizes securely. The halo could also be adjusted further or nearer to the dynamometer, thus accommodating various body depths and concurrently retaining cervical spine alignment through the various testing positions. The halo input shaft was attached to the sliding mechanism that joined the halo to the input shaft of the dynamometer input adapter. The shaft runs within the stainless-steel cylinder of the isokinetic dynamometer input adapter (Fig. 2).

The halo and stabilising chair with isokinetic dynamometer allowed for the measurement and recording of a neck musculature strength through the full range of cervical spine flexion, extension, and lateral flexion.

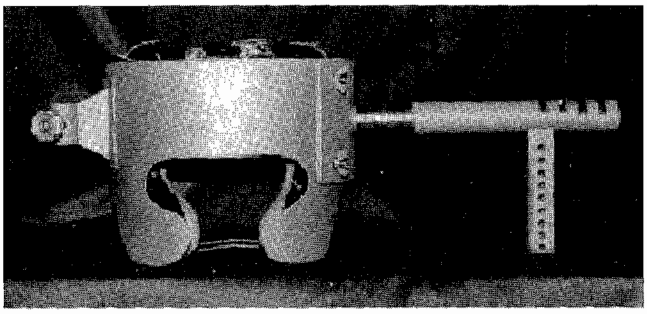

Fig. 2. The halo.

Isokinetic cervical muscular strength testing

Prior to beginning their series of neck strength evaluations, informed consent was obtained and the subjects answered a questionnaire that screened for any prior or current cervical spinal injuries that may have precluded a subject from partaking in the research project.

The evaluation started with the subjects performing a set series of warm-up exercises, which consisted of an active full range of joint motion movements, static stretches, and submaximal isometric contractions. The isokinetic testing of the neck musculature strength took place in the frontal and sagittal planes. Three repetitions of maximal contractions, through the full range of joint motion, were performed as it has been shown to be representative of accurate peak torque values when isokinetically evaluating relevant musculature.[16,44,60] The best recording was selected as representative of peak torque for flexion and extension in the sagittal plane, and lateral flexion to the left and the right in the frontal plane (Fig. 3).

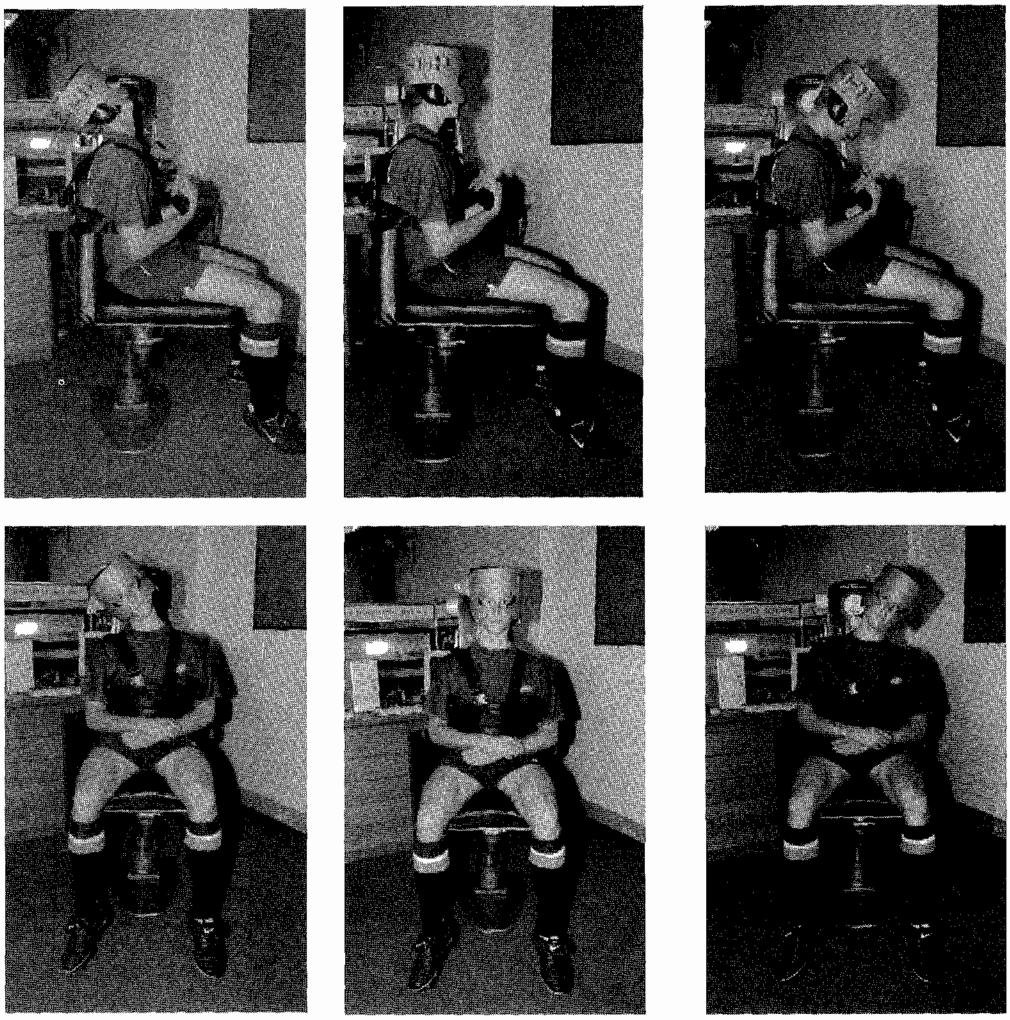

Fig. 3. Top: Movement pattern in the sagittal plane - flexion to extension. Bottom: Movement pattern in the frontal plane - lateral flexion.

The abovementioned set testing protocol was employed and used to perform all the evaluation sessions. On their arrival for the education and familiarisation session (T0) subjects were anthropometrically assessed and instructed via a group demonstration regarding what would be required of them during the isokinetic evaluation. Subjects were then individually assessed. When placed in the stabilising chair the subject's feet were not allowed to touch the ground, thus he could not use his legs to exert force when being evaluated. Once the subject was secured in the stabilising chair by fastening the torso and shoulder restraints, the halo was placed over the head. The circumference of the halo was adjusted to fit the subject's head as securely as possible. Furthermore, padded under-arm supports were firmly placed under the subject's armpits to stabilise the torso further in order to prevent force generation through lateral trunk flexion. Next the dynamometer-input axis was aligned with the spinous process of the subject's seventh cervical vertebrae (vertebral prominence).

The angular velocity of the dynamometer was set at $30^{\circ}.sec^{-1}$ Once the subject was firmly secured in the apparatus and the angular velocity was correctly set, the subject was instructed to perform six submaximal repetitions, which served as a further warm-up. After completing the six submaximal repetitions, the subject's head was placed in the neutral position and the range of motion of the dynamometer was reset to zero. Finally, the subject was instructed to perform three maximal repetitions through the full range of joint motion for flexion and extension. The maximal repetition data were saved for later analysis. As the subject remained seated in the stabilising chair, the under-arm supports were removed and the chair and halo were swivelled through 90° to accommodate the assessment of lateral flexion left and right. The same procedure, as explained, was then followed for the measurement of isokinetic neck strength for lateral flexion left and right.

Results

Three isokinetic neck musculature strength force-time data measurements were recorded for every subject during the movement patterns of forward flexion, extension, and lateral flexion left and right.

From the recorded data three force-time graphs of isokinetic neck strength for every subject were generated and analysed. Peak torque for each movement pattern was determined by obtaining the maximum force production delivered during the movement. The peak torque values for flexion, extension, and lateral flexion left and right, obtained during the education and familiarisation session (T0), the initial test (T1), and the subsequent retest (T2) were all determined in this fashion. The maximum isokinetic efforts by every subject, produced during each of the evaluation sessions, was used to determine the correlation (ICC) between repeated measures of peak torque and repeated measures of cervical range of motion (CROM) in order to establish the reliability of the isokinetic evaluation of neck strength and range of motion.

Anthropometry

The participating subjects were also evaluated anthropometrically prior to the isokinetic assessment. The descriptive statistics are tabulated in Table I.

TABLE I. The mean and standard deviation scores of the anthropometrically measured variables (*N* = 81)

	Mean	SD	CV
Weight (kg)	83.08	9.98	0.12
Height (cm)	179.4	6.72	0.04
Neck circumference (cm)	39.59	1.95	0.05

SD = standard deviation.
CV = coefficient of variation.

Isokinetic evaluation

The peak torque values for flexion, extension, and lateral flexion to the dominant and non-dominant sides were collected during T0, T1, and T2. These results were then utilised to determine the intraclass correlation coefficient (ICC) between T0 vs. T1, and T1 vs. T2 for the measured variables (Table III). The descriptive statistics for the measured variables of peak torque lateral flexion to the dominant side (PLD), peak torque lateral flexion to the non-dominant side (PLN), peak torque extension (PE), and peak torque flexion (PF) are displayed in Table II.

The measurement of CROM was taken twice for each of the movement patterns assessed (flexion/extension and lateral flexion) during each testing session (T0, T1 and T2). The first CROM measurement was recorded during the performance of the three maximal cervical musculature contractions used to determine peak torque. These CROM measurements were labelled maximal voluntary contraction range of motion flexion/extension (MVCRFE) and maximal voluntary contraction range of motion lateral flexion (MVCRLF) respectively. The second CROM measurement was recorded as the subject performed controlled full range of joint motion movements. These CROM measurements were labelled CFRFE for flexion/extension and CFRLF for lateral flexion respectively. The descriptive statistics of these measurements are displayed in Table II. The recorded values of MVCRFE, MVCRLF, CFRFE, and CFRLF were also used to calculate the ICC values between T0 vs. T1 and T1 vs. T2, and are displayed in Table III.

TABLE III. ICC scores of the isokinetic variables measured during T0 vs. T1 and T1 vs. T2 (*N* = 81)

	T0 vs. T1	T1 vs. T2
	ICC	ICC
PLD	0.66	0.91
PLN	0.72	0.92
PE	0.77	0.95
PF	0.65	0.89
CFRLF	0.79	0.96
CFRFE	0.80	0.97
MVCRLF	0.34	0.27
MVCRFE	0.27	0.42

TABLE II. The mean and standard deviation scores of the isokinetically measured variables (*N* = 81)

	T0			T1			T2		
	Mean	SD	CV	Mean	SD	CV	Mean	S.D.	C.V
PLD*	55.88	9.86	0.18	56.59	10.27	0.18	56.26	9.64	0.17
PLN*	53.84	10.19	0.19	54.49	10.59	0.19	54.81	9.82	0.18
PE*	55.84	11.43	0.20	56.49	11.96	0.21	56.79	11.23	0.20
PF*	28.56	8.82	0.31	29.20	8.91	0.31	29.53	8.56	0.29
CFRLF†	114.28	9.97	0.09	114.81	9.94	0.09	114.59	9.60	0.08
CFRFE†	122.85	15.02	0.12	123.65	15.70	0.13	123.37	15.06	0.12
MVCRLF†	103.02	11.09	0.11	105.58	11.67	0.11	106.95	11.43	0.11
MVCRFE†	114.28	15.09	0.13	116.07	16.24	0.14	114.56	13.94	0.12

*Measured in Newton metres (Nm).
†Measured in degrees.

Lateral flexion dominant side

The mean peak torque values obtained from the sample group for isokinetic cervical spine lateral flexion to the dominant side (PLD) during T0, T1, and T2 were 55.88 Nm, 56.59 Nm, and 56.26 Nm respectively. An intraclass correlation of ICC = 0.91 for the mean peak torque values between T1 and T2 was obtained. The intraclass correlation value of ICC = 0.66 calculated between T0 and T1 for PLD is considerably lower than the ICC value seen between T1 and T2. The result (ICC = 0.91) obtained between T1 and T2 for PLD in this study compares very favourably with the reliability results obtained in other studies. The results obtained from other studies scrutinising the reliability of isokinetic assessment found results ranging from ICC = 0.84 and 0.85[43] to ICC = 0.95.[35]

Lateral flexion non-dominant side

The mean peak torque values obtained for the isokinetic cervical spine lateral flexion to the non-dominant side (PLN) assessment during T0, T1, and T2 were 53.84 Nm, 54.49 Nm, and 54.81 Nm respectively. An intraclass correlation of ICC = 0.72 was calculated between T0 and T1. This value is slightly lower than the calculated intraclass correlation between T1 and T2 (ICC = 0.92). The reliability results obtained for PLN correspond well with other reliability results stemming from studies assessing isokinetic evaluation reliability (r = 0.91[22] and ICC = 0.91[16]).

Extension

The mean peak torque values obtained for isokinetic cervical spine extension (PE) during T0, T1, and T2 were 55.84 Nm, 56.49 Nm, and 56.79 Nm respectively. The intraclass correlation shows moderate reliability for the measure of PE during T0 vs. T1 (ICC = 0.77). A notably higher reliability for the measure is seen between T1 and T2 with a calculated intraclass correlation of ICC = 0.95. The obtained reliability results compare well with the range of reliability found in the literature. Isokinetic assessment reliability for major joints ranges from ICC = 0.87[9] to r = 0.95.[58]

Flexion

The mean peak torque values obtained for isokinetic cervical spine flexion (PF) during T0, T1, and T2 were 28.56 Nm, 29.2 Nm, and 29.53 Nm respectively. For the measure of PF the intraclass correlation between T1 and T2 (ICC = 0.89) was found to be much higher than the intraclass correlation between T0 and T1 (ICC = 0.65). These results relate well to those found for isokinetic assessment reliability of other joints (ICC = 0.89[12] and ICC = 0.85.[15])

Cervical range of motion lateral flexion and flexion/ extension

The measurement of CROM presented great variability between the values measured during maximal voluntary cervical musculature contraction (MVCR) and controlled full range (CFR) of joint motion movements.

The mean MVCRLF results obtained during T0, T1, and T2 were 103.02°, 105.53°, and 106.95° respectively. Poor intraclass correlation was calculated for both T0 vs. T1 (ICC = 0.34) and T1 vs. T2 (ICC = 0.27) for the gathered MVCRLF values. Similarly mediocre intraclass correlation scores (T0 vs. T1, ICC = 0.27 and T1 vs. T2, ICC = 0.42) were calculated for the MVCRFE values (T0 $\bar{x}$ = 114.21°, T1 $\bar{x}$ = 116.07°, and T2 $\bar{x}$ = 114.56°). Wolfenberger *et al.*[67] established the mean CROM for flexion/extension, with the use of radiography, to be 108° in a sample (*N* = 39) of 20 - 29-year-old males. Measurements of CROM for flexion/ extension with different instruments, in the same sample group, revealed different results. Dual inclinometry delivered a value of 101°, and with a bubble goniometer 100° of CROM for flexion/extension was obtained.[67]

The mean values observed for CFRLF during T0, T1, and T2 were 114.28°, 114.81°, and 114.59° respectively. Mean values for CFRFE obtained from T0, T1, and T2 were 122.85°, 123.65°, and 123.37° respectively. The intraclass correlation scores calculated for CFRLF and CFRFE for T0 vs. T1 and T1 vs. T2 were much higher than ICC values for MVCRLF and MVCRFE. Intraclass correlation for CFRLF throughout T0 vs. T1 was calculated as ICC = 0.79 and during T1 vs. T2 as ICC = 0.96. Similarly high intraclass correlation scores were calculated for CFRFE (T0 vs. T1, ICC = 0.80 and T1 vs. T2, ICC = 0.97).

Radiographic evaluation is regarded as the 'gold standard' for the evaluation of CROM.[30, 57, 67] This is however not always possible due to the expensive nature of the required equipment. Active CROM for lateral flexion left/right, measured with a goniometer, for a sample (*N* = 20) of males aged 11 - 19 years was calculated to be 91.1°.[72]

Conclusion

Results obtained from this study demonstrated a reliability greater than ICC = 0.89 for the isokinetic evaluation of peak torque and controlled full range of motion of the cervical spine during flexion, extension and lateral flexion. Results obtained from this study therefore support the valid and reliable isokinetic evaluation of the neck musculature strength and range of motion through use of the designed apparatus.

The great disparity between measurements of MVCRLF/FE and CFRLF/FE was unexpected. This can however be attributed to the eagerness of the subjects to produce as much force as possible. As the subject approaches the upper and lower limits of his CROM the capability of the neck musculature to produce maximal force decreases rapidly. This causes the subject to reverse the direction of the movement before the full range of motion of the specific movement is completed.

The results obtained from this study also reveal that an education and familiarisation session on the apparatus is essential to the accurate assessment of the neck musculature strength. This is clearly seen from the ICC results obtained between T0 vs. T1 and T1 vs. T2 for the measured variables. Differences, which were observed, can possibly be attributed to external factors, varying motivation, and/or local muscular fatigue of the subjects.

The development of a method to evaluate the force capabilities of the neck musculature opens numerous possibilities for future studies in the evaluation and rehabilitation of injuries related to the neck musculature. The generation of normative data for various age groups of the sedentary as well as different sporting code populations would provide valuable data when assessing, treating and rehabilitating cervical spine injuries incurred due to sporting activity, automobile accidents, or any other misfortune.

It has been stated that strengthening of the neck musculature needs to receive greater priority in exercise programmes,[8,25,34,55,59,68] especially of athletes participating in high-risk sports, although the optimum mode for strengthening of the neck musculature has not yet been determined. The isokinetic evaluation of neck strength will enable an objective evaluation of neck strength following strength training intervention.

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