

SHORT REPORT OPEN ACCESS

Inter-Rater Reliability of Active Cervical Range of Motion Measured With Digital Goniometer in Asymptomatic University-Level American Football Athletes

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1 | Introduction

Cervical spine function plays a pivotal role in the quality of life and activities of daily living (Nayak et al. 2019). However, neck pain is common, with an incidence rate of 519 cases per 100,000 people globally in 2021 (Wu et al. 2025), and is defined as pain in the neck, with or without pain referral into one or both upper limbs, lasting at least one day (Hoy et al. 2014). In American football players, repeated hits to the head are responsible for a variety of neck injuries and discomfort, although more often than not, self-limited and of transient nature (Chung et al. 2019; Deckey et al. 2020). As such, health care professionals working with football athletes are often required to examine the cervical spine and assess its range of motion.

Assessment of cervical spine range of motion (Cx-ROM) is often considered the initial step in evaluating cervical spine function by clinicians. It represents the most commonly reported objective measure of cervical spine function and is frequently associated with, influenced by, or used to explain other spinal conditions or impairments. It can be assessed through a plethora of protocols, either subjectively or objectively (De Koning et al. 2008). Objective assessment of Cx-ROM is typically performed through a variety of inclinometers or goniometers with the cervical range of motion instrument (CROM) being the most utilised (De Koning et al. 2008). Recently, a digital goniometer (EasyAngle, Meloq, Stockholm, Sweden) has been introduced to the market, with limited, but promising evidence. Specifically, it showed excellent concurrent validity (ICC (2,1) = 0.97) compared to the ultrasound-based movement analysis system, excellent intra-rater reliability (ICC (3,1) > 0.90) and moderate inter-rater reliability (ICC (2,1) = 0.66) for the cervical flexion-rotation test (Luedtke et al. 2020). This readily available, low-cost device could be helpful for clinicians in the evaluation of Cx-ROM. However, validation studies, especially in populations prone to cervical pain, injury or dysfunction, such as in the case of football athletes, are warranted. Hence, the aim of this study was to evaluate test-retest reliability of the EasyAngle digital goniometer for Cx-ROM in a group of university-level varsity football athletes.

2 | Methods

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This study was conducted as part of a larger project that received ethical clearance from the Université du Québec à Trois-Rivières Research Ethics Board (CER-23-301-10-06).

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2.1 | Participants

A convenience sample of university-level varsity American football athletes was drawn from participants in a larger study, with eligibility restricted to current members of a men's varsity team within the Greater Montreal region.

Athletes with an active cervical injury diagnosed by a healthcare professional were excluded from the study. Participants were recruited prior to the beginning of the sporting season. The study was approved by the University of Quebec at Trois-Rivières research ethics board (CER-23-301-10-06), and participants provided written consent.

2.2 | Goniometry

Active Cx-ROM was measured using a Meloq EasyAngle (Stockholm, Stockholm County, Sweden) digital goniometer with participants in a seated position. Before measurements were taken, participants were instructed to sit straight, feet flat on the floor, arms resting on the thighs, and look ahead, placing their neck in a neutral position. All six planes of cervical range of motion were evaluated. For both flexion and extension, the goniometer was positioned on the right side of the head in front of the ear. Participants were instructed to bring their chin as close as possible to their chest for flexion and to bring their head as far back as possible, as to look at the ceiling for extension. For lateral flexion measurements, the goniometer was positioned at the back of the head over the nuchal line. Participants were instructed to bring their ear towards their shoulder, without lifting the shoulder, and to keep their chin tucked. For rotation, the goniometer was placed on the right side of the head above the ear. Participants were instructed to turn their head as far back as possible, while keeping the head straight and the chin tucked (Figure 1). Participants were verbally encouraged to perform maximal range of motion in all movement planes and were asked whether any motion elicited pain. Verbal instructions were standardised across participants and examiners. Active Cx-ROM assessments were conducted by two examiners: a certified athletic therapist and a master's-level athletic therapy student. Before the initial data collection session, they both completed a one-hour training session led by one of the co-principal investigators (IP). IP possesses a professional qualification in chiropractic, complemented by a PhD in biomedical sciences, and currently serves as a faculty member in the

Department of Chiropractic at the Université du Québec à Trois-Rivières.

2.3 | Data Collection Flow

Prior to data collection, participants were instructed to perform five active movements for each plane of motion. Measurements were performed independently by examiners in a randomised order. The examiners were blinded to each other's measurements. The order of measurement was randomly assigned to participants according to these three blocks: (1) Flexion and extension, (2) Left lateral flexion and right lateral flexion, and (3) Left rotation and right rotation. Participants were initially evaluated by one examiner (either one or 2, in a random order) and then evaluated by the other examiner in a similar fashion. Each movement was assessed three times, and the average of the three trials was used for analysis.

2.4 | Statistical Analyses

Descriptive statistics (mean $\pm$ standard deviation) were used to characterise active Cx-ROM recorded by each rater. Intraclass correlations (ICC 2,3) with significance level set at $p < 0.05$, were used to evaluate interrater agreement. Strength of association between raters was established according to Portney and Watkins (2015), where values below 0.50 indicate poor reliability, values between 0.50 and 0.75 indicate moderate reliability, values between 0.75 and 0.90 indicate good reliability and values higher than 0.90 indicate excellent reliability. Since we used a convenience sample for the study, following data collection, a post hoc power analysis was conducted using the observed effect sizes to determine whether the achieved sample size provided sufficient power for the primary outcome. A *post hoc* power analysis was conducted in GPower (exact distribution; correlation, bivariate normal model) using the observed effect size (ICC approximated as $r = 0.665$), $\alpha = 0.05$ (two-tailed), and $n = 23$. The achieved power was 0.956 (critical $|r| = 0.413$) (Faul et al. 2007). SPSS version 28.0.0 was used for all analyses.

3 | Results

A total of 23 football players participated in the study and all of them completed all of the Cx-ROM tests. Their mean age was

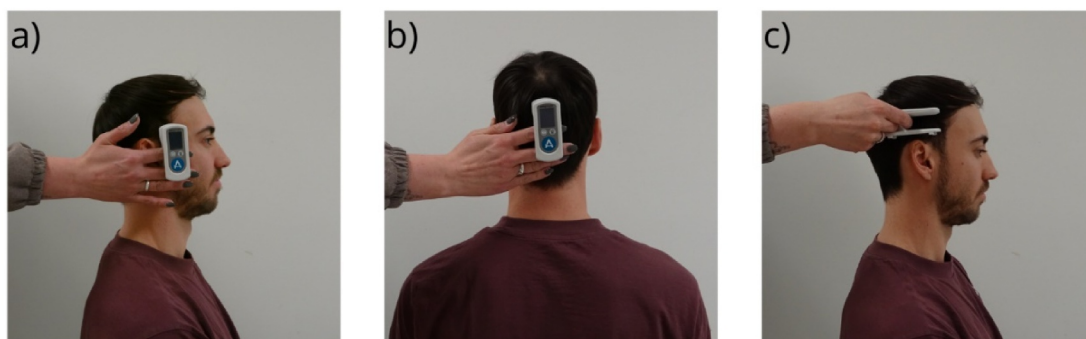


FIGURE 1 | Goniometer positioning for (a) flexion/extension, (b) lateral flexion, and (c) rotation.

TABLE 1 | Test-retest reliability of cervical range of motion with digital goniometer.

Range of motion	Examiner 1 ^a	Examiner 2 ^a	ICC	C.I. (95%)	Interpretation
Flexion	59.37 ± 11.25	56.80 ± 10.05	0.665	(0.217–0.857)	Moderate
Extension	63.83 ± 10.14	61.80 ± 10.95	0.789	(0.506–0.910)	Good
Left lateral flexion	50.59 ± 10.27	49.75 ± 8.67	0.794	(0.522–0.912)	Good
Right lateral flexion	52.65 ± 7.69	48.91 ± 9.58	0.796	(0.465–0.917)	Good
Left rotation	80.55 ± 10.28	80.04 ± 9.64	0.791	(0.510–0.911)	Good
Right rotation	80.36 ± 10.28	81.41 ± 8.47	0.918	(0.809–0.965)	Excellent

^aCorresponding to the pooled means of three trials.

22.83 ± 1.15 years, weight 226.52 ± 66.90 pounds, and height 183.99 ± 7.37 cm. Descriptive statistics with regard to Cx-ROM can be found for both evaluators in Table 1. Values of ICC ranged from 0.665 for cervical spine flexion to 0.918 for right rotation, corresponding to inter-rater reliability spanning from moderate to excellent (Table 1).

4 | Discussion

This study contributes to the limited body of literature on the topic of inter-rater reliability using the EasyAngle digital goniometer to evaluate active Cx-ROM. This is particularly relevant in football athletes, a population recognised as being at heightened risk of cervical spine pain and dysfunction. Findings suggest that a digital goniometer, such as the EasyAngle, is reliable when it comes to the assessment of active cervical range of motion, with moderate (flexion) to excellent (right rotation) inter-rater values, despite the level of clinical training of examiners.

When comparing results from our study to those of Wilson-Smith et al. (2022), who used a different digital goniometer, our ICC values were higher for flexion and rotation, and similar for extension and lateral flexion. In their study as well, flexion exhibited the lowest reliability (Wilson-Smith et al. 2022). When comparing ICC values to those of published work using the same technology on different body joints, values from our study were lower than other studies, such as knee active range of motion (Svensson et al. 2019) and overlapped with values on the hip joint (Duffy et al. 2024; Kim and Kim 2016). This trend towards lower reliability while assessing active Cx-ROM may be explained, in part, by the complexity of the cervical spine movement, which requires combinations of various motions (Bogduk and Mercer 2000). When looking at active Cx-ROM from a planar perspective, flexion exhibited lower reliability than extension. This discrepancy has been minimally reported, and does not seem to be systematic across reliability studies (Rondoni et al. 2017), and could in part be due to natural individual variability of flexion range of motion (Audette et al. 2010). Similarly, right rotation exhibited higher reliability than left rotation. This could be explained by the fact that the goniometer was placed on the right-hand side for evaluations. It would be interesting to see if this discrepancy would remain should the goniometer be moved onto the left side when assessing left rotation.

While interpreting ICC values for this study, it should be put in perspective that mean differences and standard deviations

between raters were minimal. In addition, differences between raters are far below normal changes that can occur in active Cx-ROM in healthy individuals (Stenneberg et al. 2023). On an additional note, active Cx-ROM reported in our study fell within the limits of measurements reported in the literature (Swinkels and Swinkels-Meewisse 2014), suggesting that despite the nature of the football sport and stresses placed on the cervical spine, athletes exhibit within-range active Cx-ROM.

In sum, active Cx-ROM, assessed by healthcare professionals with varying degrees of professional experience, shows adequate inter-rater reliability. Standardised verbal instructions and consistent goniometer placement, as implemented in this study, likely contributed to reduce measurement bias and improving the clinical utility of the device. As such, digital goniometers with limited clinician training may be part of the evaluation of active Cx-ROM; further studies are encouraged on other joints to allow generalisation of our findings and to establish whether increased training could lead to enhanced reliability.

Author Contributions

Mathieu Lanoue: writing – original draft, writing – review and editing, visualization. **Maée Camara:** investigation, data curation, writing – original draft, visualization. **Jean-Christophe Moreau:** writing – original draft, visualization. **Louis De Beaumont:** resources, writing – review and editing. **Isabelle Pagé:** methodology, resources, data curation, writing – review and editing, supervision. **Laurie-Ann Corbin-Berrigan:** methodology, validation, formal analysis, resources, data curation, writing – review and editing, supervision, funding acquisition.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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