Journal of Bodywork & Movement Therapies 47 (2026) 533–541

Contents lists available at ScienceDirect

Journal of Bodywork & Movement Therapies

journal homepage: www.elsevier.com/jbmt

Comparison of visual and electronic assessments of active cervical range of motion in university varsity level American football players: a three-point cohort study

Alexandra Bergeron [a], Catherine Daneau [a,b], Reka Sivasubramaniyam [a], Maée Camara [a], Louis De Beaumont [c,d], Mathieu Lanoue [e], Laurie-Ann Corbin-Berrigan [a,b,d,f,*], Isabelle Pagé [b,f,g,h]

[a] Department of Human Kinetics, University of Québec at Trois-Rivières, Trois-Rivières, Québec, G9H 5H7, Canada
[b] Groupe de Recherche sur Les Affectations Neuromusculosquelettiques (GRAN), University of Québec at Trois-Rivières, Trois-Rivières, Québec, G9H 5H7, Canada
[c] Department of Surgery, University of Montreal, Montréal, Québec, H3T 1J4, Canada
[d] Research Centre CIUSSS-Nord-de-l'île-de-Montréal, Montréal, Québec, H4K 1B3, Canada
[e] Department of Anatomy, University of Québec at Trois-Rivières, Trois-Rivières, Québec, G9H 5H7, Canada
[f] Quebec Pain Research Network, Québec, J1K 2R1, Canada
[g] Department of Chiropractic, University of Québec at Trois-Rivières, Trois-Rivières, Québec, G9H 5H7, Canada
[h] Centre Interdisciplinaire de Recherche en Réadaptation et Intégration Sociale (Cirris), Québec City, Québec, G1M 2S8, Canada

ARTICLE INFO

Keywords:
Neck
Goniometry
Digital goniometer
Visual estimation
Range of motion
Subjective

ABSTRACT

Background: Neck pain is common in contact sports such as football, where rapid and accurate cervical range of motion (ROM) assessment is essential. Electronic goniometers provide reliable measurements but are impractical in field settings, leading clinicians to rely on visual estimation. The accuracy of this method and its improvement with repeated exposure remain unclear.
Objective: To evaluate the agreement (trueness) between subjective visual assessments of active cervical range of motion and measurements obtained using an electronic goniometer, and to determine whether repeated assessments improve agreement over time.
Methods: A three-time-point cohort study was conducted between August and December 2023 in male varsity-level American football players. At each time point, participants completed questionnaires on neck pain and disability and performed active cervical ROM (flexion, extension, side bending, rotation) assessed both subjectively and objectively.
Results: Agreement between subjective and objective evaluations was generally poor to moderate, with flexion and extension showing the lowest concordance. Repeated-measures ANOVA, assessing improvement due to exposition revealed no significant changes for flexion, extension, or rotations ($p > 0.05$). Significant improvements occurred for right side bending ($p = 0.004$) and left side bending ($p < 0.001$), with preseason-to-postseason differences of $-0.44°$ and $-1.64°$, respectively, suggesting a limited learning effect for lateral movements.
Conclusion: Subjective cervical ROM assessment varies by movement plane. Although repeated exposure improves trueness, subjective measures should be interpreted cautiously, and objective tools remain preferable for precise evaluation.

1. Introduction

Cervical pain is highly prevalent in the general population, affecting around 203 million people worldwide, and ranks among the leading causes of disability (Cohen, 2015; Wu et al., 2024). It is estimated that nearly 50% of individuals will experience cervical pain at some point in their lives (Fejer et al., 2006). This condition can arise from a wide range of disorders and underlying factors, including congenital and acquired

* Corresponding author. 3351 blvd. Des Forges, Trois-Rivières, Qc G9A 5H7 Canada.
E-mail address: laurie-ann.corbin-berrigan@uqtr.ca (L.-A. Corbin-Berrigan).

https://doi.org/10.1016/j.jbmt.2026.05.005
Received 3 March 2026; Received in revised form 1 May 2026; Accepted 4 May 2026
Available online 8 May 2026

causes such as trauma and overuse (Cohen, 2015; Gonzalez Rueda et al., 2017; Palmieri et al., 2023; Zwart, 1997).

Sport participation is highly linked with acquired disorders, such as those affecting the cervical spine, although direct mechanisms explaining this phenomenon remain to be studied (Cheever et al., 2022). For instance, many retired contact sport athletes report having sought treatment for neck injuries such as fractures, sprains and neuropraxia during their playing careers (Hind et al., 2020). In contact sports such as American football, impaired active cervical range of motion (ROM) has also been associated with concussion (Smith et al., 2016). Evaluation of cervical spine disorders relies on a multifactorial approach combining self-reported outcomes and objective physical measures (Strimpakos, 2011). Among these, cervical ROM is the most frequently reported objective measure and has even been used to classify clinical presentations (Strimpakos, 2011). It is also considered a useful proxy for pain and kinesiophobia and may reflect other cervical spine impairments (Bahat et al., 2014). Consequently, accurate assessment of cervical ROM is essential in both clinical and research contexts.

In this context, cervical range of motion can be assessed using either subjective or objective methods. Subjective assessment refers to visual estimation by a clinician without instrumentation, whereas objective measurement involves the use of external devices to quantify movement and may include tape measurements, inclinometers, goniometers, compasses, inertial measurement units, and computerized devices (Palmieri et al., 2023; Sukari et al., 2021; Yoon et al., 2019). These approaches may differ in terms of trueness and accuracy, where trueness refers to the closeness of agreement between the average of multiple test results and the true value, while accuracy refers to the closeness of agreement between a measured value and the true value (Squara et al., 2021). Despite decades of evidence demonstrating low inter-observer reliability of visual estimation (de Koning et al., 2008; Youdas et al., 1991), clinicians continue to rely on this method for ongoing patient assessment and monitoring. Consequently, objective measurement devices have long been promoted to reduce clinician over- or underestimation of range of motion (Gajdosik and Bohannon, 1987). However, some of these devices can be expensive and difficult to operate or transport when working with sports teams, making them more practical for controlled laboratory or clinical settings than for field use. In contrast, validated objective tools such as inclinometers and goniometers provide affordable, portable, and reliable alternatives for on-field health professionals, and have been demonstrated to be valid and reliable in both asymptomatic adults and individuals with chronic neck pain (Audette et al., 2010; Law and Chiu, 2013; Williams et al., 2010; Wolan-Nieroda et al., 2020). Although electronic goniometers are often considered the gold standard for assessing cervical ROM in sports medicine (Gajdosik and Bohannon, 1987), their use requires training, and they still involve certain costs. This raises uncertainty regarding whether visual assessment by an experienced therapist provides measurements comparable to those obtained with validated objective instruments, particularly in specific athletic populations, and whether these tools offer a meaningful advantage over clinical expertise in both research and clinical settings.

Given the presence of cervical pain in athletic populations, accurate assessment of cervical ROM is crucial. Notably, approximately 15% of all cervical injuries occur in sports, with male athletes in contact sports such as football being particularly at risk (Deckey et al., 2020). These athletes frequently present with neck pain and may continue to compete despite their condition, prompting rapid and adequate clinical evaluation (Torg, 2009). Importantly, university-level American football players represent a specific population with anatomical and biomechanical characteristics that differ from the general population (Esopenko et al., 2020). In particular, increased cervical muscle mass and soft tissue thickness may influence both cervical ROM and the accuracy of clinical assessments, potentially introducing systematic or proportional bias in measurement (Reynolds et al., 2009). As such, findings derived from general populations may not be directly generalizable to this group. For this reason, it is relevant to compare the agreement of a therapist's visual assessment with that of an objective, validated device that can be easily implemented in both research and clinical settings, to support clinicians in the selection of the most reliable and valid method for measuring cervical ROM. The aim of this study was to evaluate the agreement, defined as trueness, between subjective visual active cervical ROM assessments performed by a certified athletic therapist and measurements obtained using an electronic goniometer in a heterogeneous sample of university-level male football players (reflecting the trueness of the subjective method). In addition, we sought to determine whether repeated assessments improve the therapist's agreement with the reference measurement over time. We hypothesized that the subjective assessments would initially show limited agreement compared to the electronic device, and that agreement between the subjective and objective measures would improve with rater's repeated exposure.

2. Methods

2.1. Study design and setting

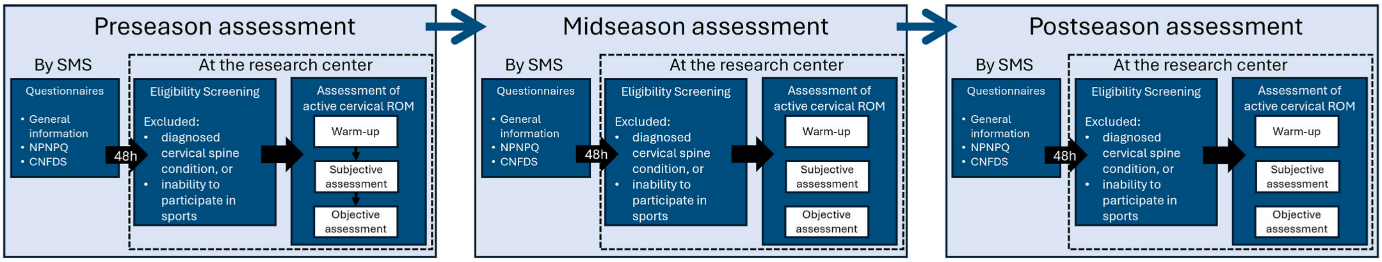
This study employed a three-time-point cohort design conducted between August and December 2023 in male varsity-level American football players from the Greater Montreal area (Québec, Canada). Data were collected at three distinct time points: (1) Preseason, approximately three weeks prior to the start of the regular season (between August 1st and 3rd); (2) Midseason, following the fourth game of the regular season (between September 27th and 29th); and (3) End of season, after the completion of playoffs (between November 28th and 30th). All assessments were performed at the Institut Universitaire de Gériatrie de Montréal research center (Montréal, Québec, Canada). Fig. 1 illustrates the flow of the study procedure.

2.2. Participants

This study was embedded within a larger project that obtained ethics approval from University of Québec at Trois-Rivières' research ethics board (CER-23-301-10-06). Participants were recruited from the pool of athletes enrolled in the larger study and were required to be active members of a male university varsity-level American football team in the Greater Montreal area (Québec, Canada) during the data collection period. Inclusion criteria for the present study were the same as those used in the larger project. Individuals were excluded if they reported an ongoing cervical spine condition diagnosed by a healthcare professional at any point during the study (including new onset), or if they were unable to participate in sport activities at the time of data collection (e.g., injury preventing play). Participants were allowed to take part in one, two, or all three data collection time points, depending on their availability.

2.3. Variables

Prior the three data collection sessions, participants received an automated SMS with a link to an online questionnaire hosted on REDcap (Harris et al., 2009, 2019). The questionnaire collected general information, including participant name, age, height, and weight. It also included 2 patient-reported outcome measures (PROMs) to evaluate neck pain (Northwick Park neck pain questionnaire) (Leak et al., 1994) and level of neck functional disability (Copenhagen neck functional disability scale) (Forestier et al., 2007). The procedures were identical at all three time-points. First, participants were asked whether they currently had a cervical spine condition diagnosed by a healthcare professional or were unable to participate in sport activities. If so, they were excluded from that data collection but reminded that they could take part in subsequent sessions if eligible. Participants then performed an active cervical ROM warm-up consisting of five repetitions of each



SMS, Short Message Service; NPNPQ, Northwick Park neck pain questionnaire; CNFDS, Copenhagen neck functional disability scale; ROM, range of motion

Fig. 1. Flow of the study procedure.

cervical movement, in the following order: cervical flexion, cervical extension, right and left cervical side bending, and right and left cervical rotation. Standardized instructions were provided to all participants, and corrections to movement were given during the warm-up trials if needed. Instructions are presented in Table 1. Following the warm-up, cervical ROM was first assessed subjectively and then measured objectively using an electronic goniometer. Detailed descriptions of these procedures are provided below.

2.4. Patient reported outcomes

At each timepoint, PROMs were used to assess neck pain and function. The Northwick Park neck pain questionnaire, consisting of 9 items (1 optional item based on driving), was used to measure neck pain and its effect on activities of daily life (Jordan et al., 1998). For the purpose of this study, the optional item about driving was removed so that total scores would be based on the same scale for all participants. As per questionnaire instructions, answer to each item was scored from 0 to 4 (questionnaire range: 0-32), where lower scores representing lower pain as opposed to higher scores representing higher levels of pain and disability. The Copenhagen Neck Functional Disability scale, consisting of 15 items, was used to assess disability related to neck pain (Forestier et al., 2007). As per questionnaire instructions, answer to each item was given a score from 0 to 2 (questionnaire range: 0-30), where lower scores indicating low functional disability with regards to neck complaints as opposed to higher scores indicating higher levels of disability.

Table 1
Standardized instruction provided to the participants and frequent errors observed during the cervical ROM warm-up.

Movement	Verbal instructions	Frequent errors
Cervical flexion	"Please flex your head forward, bringing your chin to your chest as far as possible."	- Flexion of only the upper cervical region - Flexion of the upper thoracic spine in addition to the cervical spine
Cervical extension	"Please extend your head backward the furthest possible, as if trying to look at the ceiling."	- Extension of only the upper cervical region
Cervical side-bending	"Please tilt your head sideways the furthest possible, bringing your ear toward your shoulder. Do not lift your shoulder during the movement."	- Raising the ipsilateral shoulder - Combining side-bending with head rotation
Cervical rotation	"Please rotate your head the furthest possible to each side, keeping your head aligned and your shoulders relaxed."	- Rotation of the shoulders, with or without cervical spine involvement - Combining cervical rotation with contralateral side-bending or with extension of the head

2.5. Data measurement

The same certified athletic therapist (RS) conducted all data collection and interactions with participants throughout the study. Prior to the first data collection session, a 1-h training was provided to RS by the principal investigator (IP). IP holds a professional degree in chiropractic and a PhD in biomedical sciences and is a professor in the Chiropractic Department at the University of Québec at Trois-Rivières (Trois-Rivières, Québec, Canada). Rater training was considered completed when the rated demonstrated adequate integration of visual estimation skills across multiple practice subjects. For all data collection sessions, participants were asked to sit upright with their back against the chair, feet flat on the floor, and hands resting on their thighs. Each participant actively performed three blocks of movements for both subjective and objective assessments: (1) flexion followed by extension, (2) left side bending followed by right side bending, and (3) left rotation followed by right rotation. The order of the blocks was manually randomized for each participant but remained the same for both subjective and objective assessments. Each movement was performed three consecutive times, without pause between trials, following the same instructions provided during the warm-up. The evaluator could request a trial to be repeated if the movement was deemed incorrectly performed.

For the subjective assessment, the evaluator estimated the active cervical ROM from the neutral position, with the neutral position defined as the participant sitting upright with the head straight, looking forward. Cervical flexion and extension were observed from the right side of the participant, focusing on the left ear angulation. For cervical side-bending, the evaluator stood behind the participant, observing the ear on the side of movement. For cervical rotation, the evaluator stood on a platform behind the participant, focusing on the nose from above the head. Estimates were recorded in whole degrees, without decimals. The same platform and chair was used for all participants at each time point.

Objective measures of the active cervical ROM from the neutral position were collected using the Meloq Digital Easy Angle goniometer (Stockholm, Sweden) (Fig. 2). This measurement device has shown moderate to excellent reliability in a prior study with similar participants (Lanoue et al., 2026). For cervical flexion and extension, the goniometer was positioned on the right side of the head, in front of the right ear. For side-bending, it was placed behind the participant's head, just above the superior nuchal line. For cervical rotation, the goniometer was positioned on the right side of the head, just above the ear. The range of motion was recorded in whole degrees, without decimals.

2.6. Bias

The objective assessment was performed after the subjective assessment to prevent potential bias that could occur if the evaluator remembered the values from the electronic goniometer.

2.7. Sample size

The sample size was determined by the number of participants

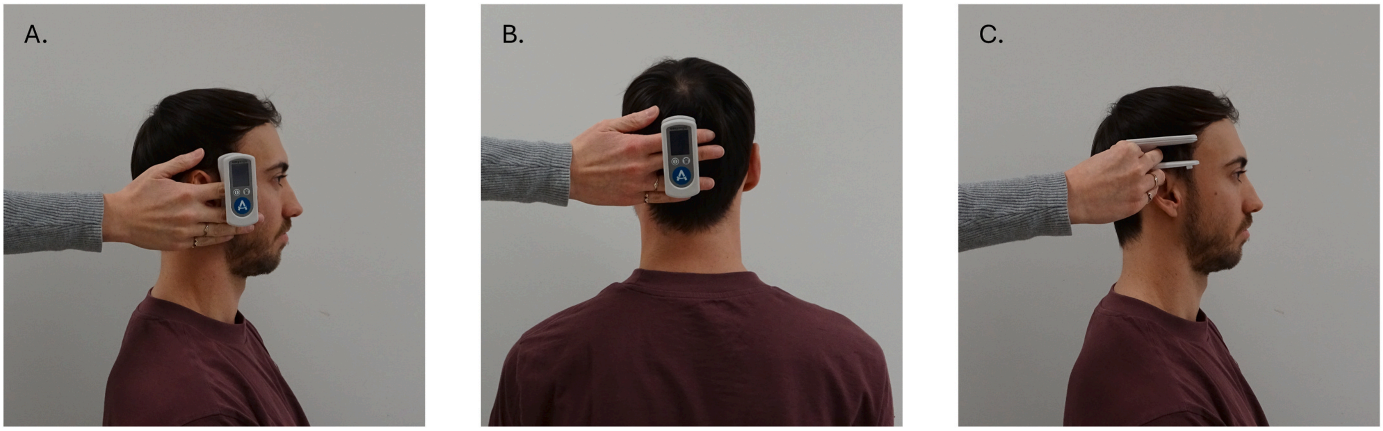


Fig. 2. Objective measure of the active range of motion using the Meloq Digital Easy Angle goniometer: cervical flexion and extension (A.), side-bending (B.) and rotation (C.).

enrolled in the larger project. Since data collection for this study occurred concurrently with the larger project, all participants were invited to take part, resulting in a convenience sample. Based on the recommendations of Bujang and Baharum (2017), a minimum of 17 participants per data collection was expected, assuming a low agreement between the two sets of evaluations (intraclass correlation coefficient [ICC] or Lin's concordance correlation coefficient [CCC] ≤ 0.04) with three ratings performed ($\alpha = 0.05$, power = 80%) (Bujang and Baharum, 2017).

2.8. Statistical analysis

2.8.1. Participants characteristics

Participant characteristics and PROMs scores were analyzed descriptively, using means and standard deviations for normally distributed data and medians with ranges for non-normally distributed data. Among participants who completed all three time points, a repeated-measures analysis of variance (ANOVA) was used to compare PROMs scores across the three time points. Statistical significance was set at $p < 0.05$. SPSS version 29.0.2.0 was used for this analysis.

2.8.2. Subjective assessment trueness

For both the subjective and objective assessments, the ROM obtained across the three trials was averaged for each direction, and this mean value was used for the trueness analysis. In accordance with metrological standards, trueness was evaluated as the closeness of agreement between the mean of the subjective measurements and the mean reference value obtained with the electronic goniometer (Squara et al., 2021). Specifically, subjective and objective assessments were conducted in separate blocks (three repeated subjective assessments followed by three repeated objective measurements), preventing direct one-to-one matching between individual subjective and objective values. Consequently, trueness, reflecting the agreement between measurement sets and the reference standard, was the appropriate measurement property for the present analysis. Subjective and objective measurements were first summarized using means and standard deviations, as these variables followed a parametric distribution. The mean difference between objective and subjective assessments was then calculated along with its standard deviation at each time point and for each movement direction. Trueness was further evaluated using CCC and Bland–Altman analysis. The CCC was chosen over the ICC because it assesses both the consistency and trueness between subjective and objective measures and is more sensitive to systematic differences. CCC was measured by using Microsoft Excel and is measured using the following formula: $p_c = 2p\sigma_x \sigma_y/(\mu_x - \mu_y)^2 + \sigma_x^2 \sigma_y^2$, where $p\sigma$ and μ respectively represent the standard deviation and mean of a measurement set (Lawrence and Lin, 1989). Bland–Altman analysis was used to assess potential bias between the two measures. A systematic bias was considered present when the slope of the bias was non-statistically significant ($p > 0.05$). In other words, a significant slope indicates that the error varies depending on the amplitude of the ROM evaluated. The strength of correlation was interpreted according to Altman's (1991) recommendations for CCC interpretation, where values < 0.20 are considered poor, 0.20-0.40 are considered fair, 0.40-0.60 are considered moderate, 0.60-0.80 are considered *good* and those >0.80 are considered *very good* (Doğan, 2018).

2.8.3. Learning effect

Only participants with complete measurements at all three time-points were included in this analysis. Improvements in subjective assessments were evaluated using a repeated-measures ANOVA to examine whether the mean difference between objective and subjective measures varied across the three time-points for each movement. This analysis was selected based on the normal distribution of the data, which was evaluated using visualization of distributions and Shapiro-Wilk tests. Sphericity was assessed using Mauchly's test and was assumed to be met. When a significant main effect was found, Bonferroni-adjusted post hoc comparisons were conducted to identify which time-points differed significantly. Statistical significance was set at $p < 0.05$. All analyses were performed using SPSS version 28.0.

3. Results

3.1. Participants

Fig. 3 presents the flow chart of this study. In total, 30 participants were enrolled in the larger project and invited to participate in the current study. For the preseason, midseason, and postseason assessments, 24, 29, and 27 participants, respectively, attended the data collection sessions, with none excluded based on eligibility criteria. Twenty-two participants completed all three time-point assessments and were included in the analysis of learning effects. Among these participants, PROMs scores did not differ significantly across the three time-points ($p > 0.05$). Participants' characteristics are presented in Table 2.

3.1.1. Subjective assessment trueness

Table 3 summarizes the variables related to the analysis of the trueness of subjective measures compared with objective measurements. The mean difference between objective and subjective assessments, where a positive value indicates an underestimation of the objective cervical ROM when evaluated subjectively, ranged from $-0.85 \pm 10.70°$ for cervical extension (postseason) to $10.86 \pm 10.40°$ for cervical flexion

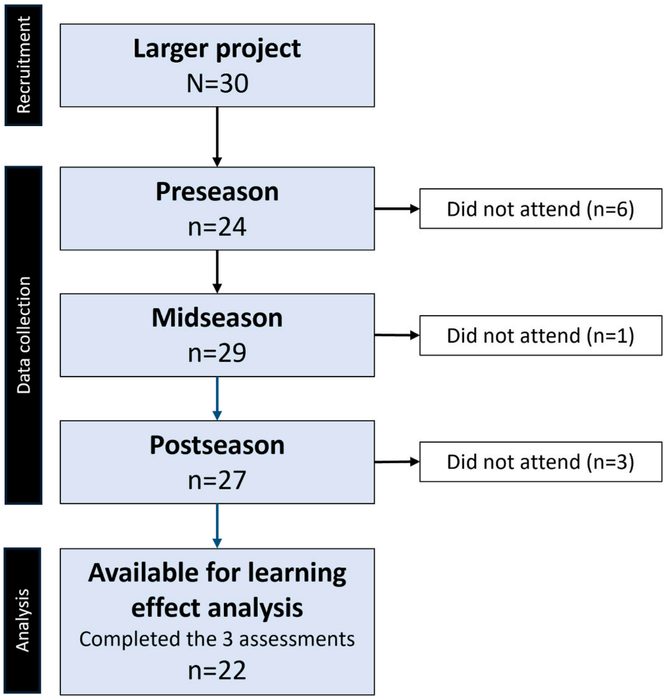


Fig. 3. Flow of participants through the study.

(midseason). Cervical rotation and side-bending assessments generally demonstrated smaller discrepancies between subjective and objective measures. The most accurate subjective estimation was observed for right side bending at the postseason assessment (mean difference = −0.44 ± 7.67°). Concordance, evaluated using the CCC, indicated associations ranging from poor to good, with values between 0.165 [95% CI: −0.204, 0.493] for right rotation (preseason) and 0.768 [0.560, 0.885] for left side bending (postseason). Systematic bias (i.e., non-significant bias slopes) was present for all ranges of motion across the three assessment points, except for cervical flexion at midseason (bias slope = −0.426 [−0.818, 0.035]), right rotation at midseason (0.355 [0.104, 0.605]), and left rotation at midseason (0.554 [0.116, 0.993]). These findings suggest that errors in subjective assessment were independent of the magnitude of the ROM evaluated. Bias estimated using Bland–Altman analysis ranged from −11.185° for cervical extension at postseason to 10.759° for cervical flexion at midseason, with the smallest bias observed for right side bending at postseason (−0.185°).

3.1.2. *Learning effect*

A repeated-measures ANOVA was conducted to assess changes in the subjective measure relative to the objective measure across the three time points among the 22 participants who completed all assessments. Analyses yielded no significant differences between preseason, midseason, and postseason measures for flexion ($\chi^2_{(2,\ 42)} = 0.534$, $p = 0.590$, $\eta^2_p = 0.025$), extension ($\chi^2_{(2,\ 42)} = 1.034$, $p = 0.364$, $\eta^2_p = 0.047$), right rotation ($\chi^2_{(2,\ 42)} = 1.350$, $p = 0.270$, $\eta^2_p = 0.060$) and left rotation ($\chi^2_{(2,\ 42)} = 0.527$, $p = 0.594$, $\eta^2_p = 0.024$). ANOVA analysis revealed a significant effect for right side bending ($\chi^2_{(2,\ 42)} = 6.414$, $p = 0.004$, $\eta^2_p = 0.234$) and left side bending ($\chi^2_{(2,\ 42)} = 21.622$, $p < 0.001$, $\eta^2_p = 0.507$), representing a substantial learning effect. A Bonferroni post-hoc test was used to determine where significant changes (improvement or decline) between time-points were found. A significant improvement of the trueness of the subjective measures in right side bending was observed between preseason (mean difference between objective and subjective, $\bar{x}$ = 4.68 ± 6.81°) and postseason ($\bar{x}$ = −0.44 ± 7.67°) (p = 0.023), as well as between midseason ($\bar{x}$ = 4.80 ± 7.48°) and postseason ($\bar{x}$ = −0.44 ± 7.67°) (p = 0.026). In regards to left side bending, a significant improvement was observed between preseason ($\bar{x}$ = 8.80 ± 5.50°) and midseason ($\bar{x}$ = 2.77 ± 5.48°) (p < 0.001), between preseason ($\bar{x}$ = 8.80 ± 5.50°) and postseason ($\bar{x}$ = −1.64 ± 6.44°) (p < 0.001), and between midseason ($\bar{x}$ = 2.77 ± 5.48°) and postseason ($\bar{x}$ = −1.64 ± 6.44°) (p = 0.035). Mean differences between the objective and subjective measures at each time point for each movement are presented in Fig. 4.

4. Discussion

This study primarily aimed to evaluate the agreement between subjective and objective cervical ROM assessments across three time points, and to explore whether repeated exposure influenced the rater's trueness and precision, in a sample of university varsity-level American football players. Overall, our findings revealed notable discrepancies between subjective and objective assessments, with the magnitude and direction of errors varying according to the movement plane. In this discussion, we first address the trueness of subjective assessments, followed by the potential effects of repeated exposure (learning effects), and conclude with implications for clinical practice and study limitations.

Table 2
Participant characteristics and complete-case participants across time-points.

Characteristics (median, min-max)	Complete data (n = 22)	Preseason (n = 24)	Midseason (n = 29)	Postseason (n = 27)	Repeated measures ANOVA
Age (years)	22, 20-25	22, 20-25	22, 20-25	22, 20-25	
Height (m)	1.84, 1.70-1.93	1.84, 1.70-1.93	1.85, 1.70-1.99	1.85, 1.70-1.99	
Weight (kg)	94.32, 77.27-135.00	94.32, 74.09-135.00	97.72, 77.27-196.82	99.09, 77.27-196.82	
BMI (kg/m^2)	28.56, 24.18-38.20	28.23, 24.18-38.20	28.68, 22.84-52.84	28.81, 22.84-52.84	
PROMs (mean ± SD)		**Preseason (n = 22)**	**Midseason (n = 27)**	**Postseason (n = 27)**	
Northwick Park neck pain questionnaire (/32)	Pre (n = 21): 0.71 ± 0.90 Mid (n = 21): 0.33 ± 0.66 Post (n = 22): 1.32 ± 2.51	0.73 ± 0.88	0.37 ± 0.63	1.07 ± 2.32	n = 21 $\chi^2_{(2,40)} = 3.22$ $p = 0.20$
Copenhagen neck functional disability scale (/30)	Pre (n = 21): 1.62 ± 2.87 Mid (n = 21): 0.86 ± 1.35 Post (n = 22): 3.18 ± 5.99	1.55 ± 2.82	0.89 ± 1.60	3.44 ± 6.39	n = 21 $\chi^2_{(2,40)} = 2.57$ $p = 0.28$

BMI, Body Mass Index; PROMs, patient-reported outcome measures.

Table 3
Trueness of preseason, midseason and postseason active cervical ROM values.

Direction	Time-point	Subjective (mean ± SD)	Objective (mean ± SD)	Mean diff O–S (mean ± SD)	CCC [95%CI]	Strength of association	Blant-Altman Bias	Bias' slope [95% CI]
Flexion	**Pre**	55.2 ± 10.0°	64.6 ± 11.3°	9.43 ± 11.05°	0.329 [0.040, 0.568]	*Fair*	9.389	0.174 [-0.0357, 0.704]
	Mid	56.3 ± 11.7°	67.0 ± 8.3°	10.86 ± 10.40°	0.347 [0.130, 0.532]	*Fair*	10.759	−0.426 [-0.818, 0.035] *
	Post	55.9 ± 8.9°	62.8 ± 9.9°	7.38 ± 11.67°	0.182 [-0.123,0.455]	*Poor*	6.877	0.181 [-0.465, 0.827]
Extension	**Pre**	81.3 ± 8.3°	70.7 ± 9.5°	−10.20 ± 9.56°	0.265 [0.025, 0.477]	*Fair*	−10.528	0.191 [-0.341, 0.723]
	Mid	76.9 ± 12.2°	71.3 ± 10.4°	−6.91 ± 8.58°	0.616 [0.370, 0.782]	*Good*	−5.609	−0.187 [-0.514, 0.140]
	Post	75.4 ± 11.2°	64.3 ± 8.5°	−10.85 ± 10.70°	0.309 [0.085, 0.504]	*Fair*	−11.185	−0.352 [-0.796, 0.093]
Right Side Bending	**Pre**	51.4 ± 8.8°	55.4 ± 10.1°	4.68 ± 6.81°	0.669 [0.406, 0.830]	*Good*	4.000	0.158 [-0.183, 0.499]
	Mid	52.6 ± 7.7°	57.5 ± 9.5°	4.80 ± 7.48°	0.597 [0.355, 0.764]	*Moderate*	4.839	0.241 [0.081, 0.563]
	Post	55.8 ± 9.5°	55.6 ± 8.9°	−0.44 ± 7.67°	0.688 [0.424, 0.844]	*Good*	−0.185	−0.066 [-0.066, −0.419]
Left Side Bending	**Pre**	50.3 ± 10.0°	58.7 ± 11.5°	8.80 ± 5.50°	0,660 [0.453, 0.799]	*Good*	8.306	0.141 [-0.089, 0.371]
	Mid	50.0 ± 8.1°	53.5 ± 8.8°	2.77 ± 5.48°	0.722 [0.512, 0.850]	*Good*	3.471	0.103 [-0.168, 0.375]
	Post	52.2 ± 8.9°	51.1 ± 10.1°	−1.63 ± 6.44°	0.768 [0.560, 0.885]	*Good*	−1.111	0.141 [-0.148, 0.430]
Right Rotation	**Pre**	81.2 ± 7.6°	84.9 ± 8.3°	2.26 ± 8.65°	0.165 [-0.204, 0.493]	*Poor*	3.750	0.152 [-0.579, 0.883]
	Mid	83.4 ± 6.6°	87.7 ± 9.2°	4.91 ± 5.44°	0.668 [0.467, 0.803]	*Good*	4.276	0.355 [0.104, 0.605] *
	Post	80.1 ± 9.8°	83.9 ± 9.9°	5.33 ± 7.00°	0.531 [0.380, 0.813]	*Moderate*	3.765	0.007 [-0.343, 0.356]
Left Rotation	**Pre**	79.9 ± 7.4°	87.2 ± 6.4°	7.03 ± 5.53°	0.418 [0.177, 0.612]	*Moderate*	7.347	−0.183 [-0.571, 0.206]
	Mid	82.1 ± 5.4°	87.4 ± 8.2°	5.58 ± 5.96°	0.340 [0.088, 0.551]	*Fair*	5.368	0.554 [0.116, 0.993] *
	Post	78.7 ± 9.3°	82.9 ± 9.7°	4.85 ± 9.32°	0.646 [0.229, 0.739]	*Good*	4.272	0.050 [-0.370, 0.470]

SD, standard deviation; Mean diff O–S, mean difference between objective and subjective measures; CCC, Lin's concordance correlation coefficient; 95%CI, 95% confidence interval.
* indicates a significant slope of the bias ($p < 0.05$).

4.1. Subjective assessment trueness

Our findings reveal notable discrepancies between subjective and objective assessments of cervical ROM across all time points. The mean differences ranged from an underestimation of objective cervical ROM during cervical extension at postseason (−10.85 ± 10.70°) to an overestimation during cervical flexion at midseason (10.86 ± 10.40°). Rotation and side bending exhibited smaller discrepancies, with right side bending at postseason (−0.44 ± 7.67°) showing the greatest trueness. Overall, concordance between measures was limited for most movements and time points, with lower agreement for flexion and higher for left side bending. Consistent with these mean differences, systematic biases were largest for extension and flexion and smallest for right side bending. This may partly reflect the evaluator's position on the right-side during assessments, which could have facilitated better visual alignment and estimation for movements toward that side. This consideration may be particularly relevant in a population of American football players, who typically present with greater neck girth, potentially influencing the ease with which movements can be visually assessed depending on evaluator positioning (Esopenko et al., 2020).

Taken together, these results suggest that the trueness of subjective cervical ROM evaluation depends strongly on the movement plane and the evaluator's position, leading to better agreement for side bending and rotation compared to flexion and extension.

Our findings are consistent with Hirsch et al. (2014), who reported greater errors in subjective estimation of cervical ROM for flexion and extension (Hirsch et al., 2014). Similarly, Whitcroft et al. (2010) found poor to fair accuracy for flexion and extension and moderate accuracy for side bending and rotation when comparing subjective and objective measures (Whitcroft et al., 2010). Interestingly, Whitcroft and colleagues also reported high inter-rater reliability for subjective cervical ROM assessment (ICC range: 0.80–0.90), suggesting that discrepancies in accuracy are method-related rather than evaluator-dependent. These observations are further supported by Hwang et al. (2023), who reported similar patterns in subjective evaluation of shoulder range of motion (Hwang et al., 2023).

4.2. Learning effect

Our results indicate that flexion, extension, and rotation appear less sensitive to repeated practice, as reflected by the absence of significant differences across time points for these movements. In contrast, the significant improvements observed in right and left side bending suggest that lateral movements may benefit more from repeated exposure. Post-hoc analyses revealed that gains in side-bending occurred progressively, with the most pronounced improvements between preseason and postseason. This pattern may reflect cumulative effects of increased familiarity with the assessment procedure. Overall, these findings suggest that learning effects are constrained and movement-specific, rather than generalized across all planes of motion. Although learning effects in subjective visual estimation of cervical ROM have been reported previously, they have typically been associated with targeted interventions designed to improve accuracy rather than with a passive approach such as ours.

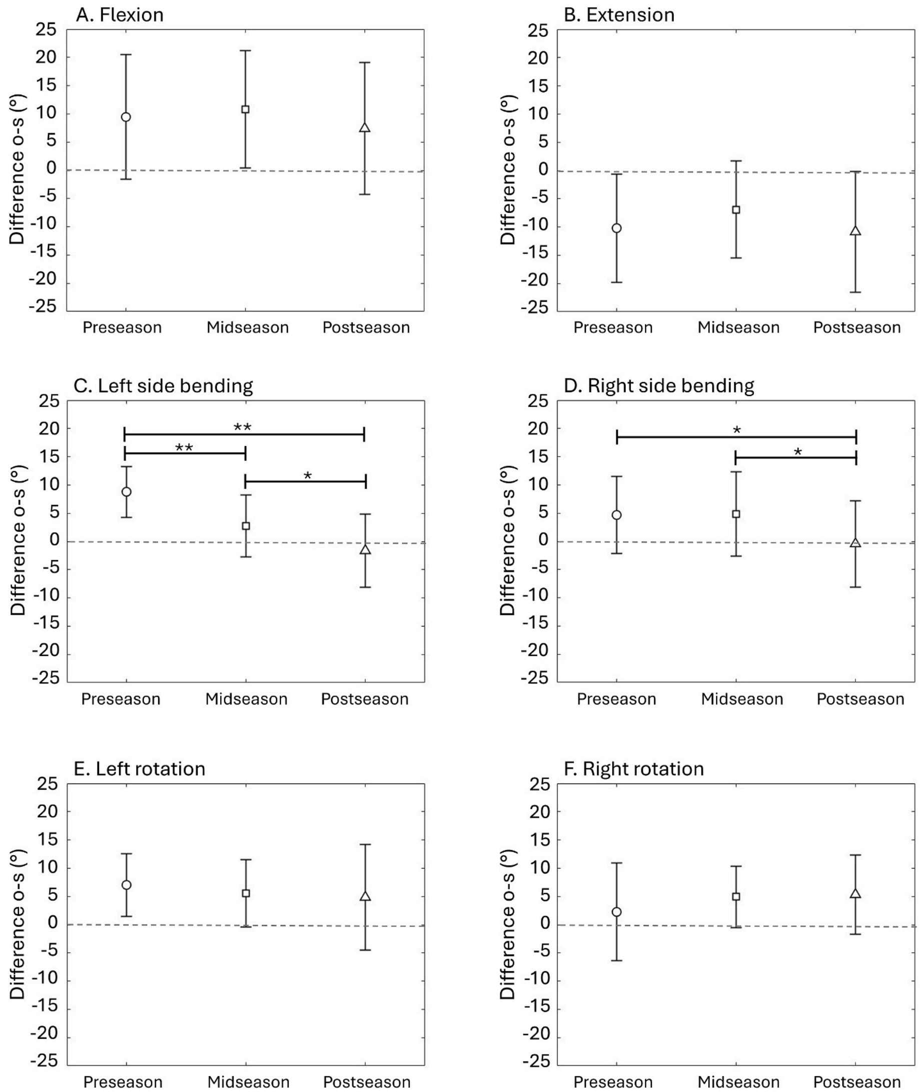


Fig. 4. Mean differences between objective and subjective measures at each time point for cervical flexion (A), extension (B), left side bending (C), right side bending (D), left rotation (E), and right rotation (F). Significant differences are indicated as $*p < 0.05$ and $**p < 0.001$.

Visual observation undeniably plays a pivotal role in clinical evaluation, offering valuable insights for diagnosis and management. However, clinicians—as well as researchers—should remain aware that subjective measures carry an inherent risk of error, particularly in range of motion assessment. The literature on the accuracy and trainability of such evaluations remains limited, given the complexity of human movement. These findings further suggest that training can enhance agreement, as defined as trueness, but only to a certain extent.

4.3. Study limitations

Data were collected by a single certified athletic therapist, which ensured consistency across time points but precluded the analysis of inter-rater reliability for both proposed measures. Although the sample size was adequate for power analysis, a larger cohort could have improved participant retention across time points. Furthermore, the study was conducted within a broader project involving American football players, which increased sample homogeneity but may restrict external validity, as the findings may not generalize to other populations. In addition, the use of a convenience sample may introduce selection bias, as participants may not be representative of the target population. Finally, results from this study apply to the electronic goniometer used for data collection, and results may not be directly transferable to other similar devices.

While these limitations should be considered, this study has several strengths. The inclusion of three time points allowed for the evaluation of potential learning effects associated with repeated exposure to the objective assessment, which is a relevant consideration for clinician training. In addition, the study incorporated both objective and subjective measures of cervical ROM, enabling a comprehensive evaluation of selected assessment approaches available to clinicians working in sports settings or with athletes, although these tools represent only a subset of the measurement options currently available.

5. Conclusion

Subjective visual assessment of cervical ROM shows variable agreement with objective measurements, with the greatest discrepancies observed for flexion and extension and higher trueness for side bending and rotation, in a cohort of Americal varsity-level football players. Repeated exposure to the assessment procedure resulted in modest improvements in lateral bending, suggesting a limited learning effect for certain movement planes. These findings highlight that the trueness or accuracy of subjective cervical ROM evaluation depends on the movement plane, the evaluator's position, and the complexity of the joint, and that subjective measures should be interpreted with caution. Objective tools remain valuable for precise and reliable assessment, particularly in clinical or research settings where small differences in range of motion are clinically relevant. Clinicians working in sports settings who may favor visual (subjective) estimation due to time constraints and convenience should be encouraged to adopt objective measurement tools, given their limited training requirements and enhanced metrological properties.

Data statement

Data will be made available from corresponding author upon reasonable request.

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work, the authors used Microsoft Copilot to assist with language editing (grammar and clarity). After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

Funding

This work was supported by the Quebec Pain Research Network (RQRD).

CRediT authorship contribution statement

Alexandra Bergeron: Data curation, Formal analysis, Visualization, Writing – original draft. **Catherine Daneau:** Formal analysis, Validation, Visualization, Writing – original draft, Writing – review & editing. **Reka Sivasubramaniyam:** Conceptualization, Investigation, Methodology, Writing – review & editing. **Maée Camara:** Data curation, Investigation, Validation, Writing – original draft. **Louis De Beaumont:** Funding acquisition, Validation, Writing – review & editing. **Mathieu Lanoue:** Validation, Visualization, Writing – original draft. **Laurie-Ann Corbin-Berrigan:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Project administration, Resources, Supervision, Validation, Writing – review & editing. **Isabelle Pagé:** Conceptualization, Methodology, Project administration, Resources, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

Authors wish to thank Amélie Apinis-Deshaies and Raphaelle Créniault for their help in participant recruitement.

References

Altman, D.G., 1991. Practical Statistics for Medical Research. Chapman & Hall.
Audette, I., Dumas, J.P., Cote, J.N., De Serres, S.J., 2010. Validity and between-day reliability of the cervical range of motion (CROM) device. J. Orthop. Sports Phys. Ther. 40 (5), 318–323. https://doi.org/10.2519/jospt.2010.3180.
Bahat, H.S., Weiss, P.L.T., Sprecher, E., Krasovsky, A., Laufer, Y., 2014. Do neck kinematics correlate with pain intensity, neck disability or with fear of motion? Man. Ther. 19 (3), 252–258. https://doi.org/10.1016/j.math.2013.10.006.
Bujang, M.A., Baharum, N., 2017. A simplified guide to determination of sample size requirements for estimating the value of intraclass correlation coefficient: a review. Archives of orofacial science 12 (1).
Cheever, K., King, J., Kawata, K., 2022. The association between contact sport exposure and cervical sensorimotor dysfunction: a scoping review of implications for future musculoskeletal injury risk. Chiropr. Man. Ther. 30 (1), 50. https://doi.org/10.1186/s12998-022-00458-w.
Cohen, S.P., 2015. Epidemiology, diagnosis, and treatment of neck pain. Mayo Clin. Proc. 90 (2), 284–299. https://doi.org/10.1016/j.mayocp.2014.09.008.
de Koning, C.H., van den Heuvel, S.P., Staal, J.B., Smits-Engelsman, B.C., Hendriks, E.J., 2008. Clinimetric evaluation of active range of motion measures in patients with non-specific neck pain: a systematic review. Eur. Spine J. 17 (7), 905–921. https://doi.org/10.1007/s00586-008-0656-3.
Deckey, D.G., Makovicka, J.L., Chung, A.S., Hassebrock, J.D., Patel, K.A., Tummala, S.V., Pena, A., Asprey, W., Chhabra, A., 2020. Neck and cervical spine injuries in national college athletic association athletes: a 5-Year epidemiologic study. Spine 45 (1), 55–64. https://doi.org/10.1097/BRS.0000000000003220.
Doğan, N.Ö., 2018. Bland-altman analysis: a paradigm to understand correlation and agreement. Turkish journal of emergency medicine 18 (4), 139–141. https://doi.org/10.1016/j.tjem.2018.09.001.
Esopenko, C., de Souza, N., Conway, F., Todaro, S.M., Brostrand, K., Womack, J., Monaco, R., Buckman, J.F., 2020. Bigger necks are not enough: an examination of neck circumference in incoming college athletes. J. Prim. Prev. 41 (5), 421–429. https://doi.org/10.1007/s10935-020-00600-5.
Fejer, R., Kyvik, K.O., Hartvigsen, J., 2006. The prevalence of neck pain in the world population: a systematic critical review of the literature. Eur. Spine J. 15 (6), 834–848. https://doi.org/10.1007/s00586-004-0864-4.
Forestier, R., Françon, A., Saint Arroman, F., Bertolino, C., 2007. French version of the copenhagen neck functional disability scale. Jt. Bone Spine 74 (2), 155–159. https://doi.org/10.1016/j.jbspin.2006.03.002.
Gajdosik, R.L., Bohannon, R.W., 1987. Clinical measurement of range of motion: review of goniometry emphasizing reliability and validity. Phys. Ther. 67 (12), 1867–1872. https://doi.org/10.1093/ptj/62.2.184.
Gonzalez Rueda, V., Lopez de Celis, C., Barra Lopez, M.E., Carrasco Uribarren, A., Castillo Tomas, S., Hidalgo Garcia, C., 2017. Effectiveness of a specific manual approach to the suboccipital region in patients with chronic mechanical neck pain and rotation deficit in the upper cervical spine: study protocol for a randomized controlled trial. BMC Muscoskelet. Disord. 18 (1), 384. https://doi.org/10.1186/s12891-017-1744-5.
Harris, P.A., Taylor, R., Minor, B.L., Elliott, V., Fernandez, M., O'Neal, L., McLeod, L., Delacqua, G., Delacqua, F., Kirby, J., 2019. The REDCap consortium: building an international community of software platform partners. J. Biomed. Inf. 95, 103208. https://doi.org/10.1016/j.jbi.2019.103208.
Harris, P.A., Taylor, R., Thielke, R., Payne, J., Gonzalez, N., Conde, J.G., 2009. Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. J. Biomed. Inf. 42 (2), 377–381. https://doi.org/10.1016/j.jbi.2008.08.010.
Hind, K., Konerth, N., Entwistle, I., Theadom, A., Lewis, G., King, D., Chazot, P., Hume, P., 2020. Cumulative sport-related injuries and longer term impact in retired male Elite-and amateur-level rugby code athletes and non-contact athletes: a retrospective study. Sports Med. 50 (11), 2051–2061. https://doi.org/10.1007/s40279-020-01310-y.
Hirsch, B.P., Webb, M.L., Bohl, D.D., Fu, M., Buerba, R.A., Gruskay, J.A., Grauer, J.N., 2014. Improving visual estimates of cervical spine range of motion. Am. J. Orthoped. 43 (11), E261–E265.
Hwang, S., Ardebol, J., Ghayyad, K., Pak, T., Bonadiman, J.A., Denard, P.J., Menendez, M.E., Amini, M.H., Shah, A., Hartman, A., 2023. Remote visual estimation of shoulder range of motion has generally high interobserver reliability but limited accuracy. JSES Int. 7 (6), 2528–2533. https://doi.org/10.1016/j.jseint.2023.07.002.
Jordan, A., Manniche, C., Mosdal, C., Hindsberger, C., 1998. The copenhagen neck functional disability scale: a study of reliability and validity. J. Manipulative Physiol. Therapeut. 21 (8), 520–527.
Lanoue, M., Camara, M., Moreau, J.C., De Beaumont, L., Pagé, I., Corbin-Berrigan, L.A., 2026. Inter-rater reliability of active cervical range of motion measured with digital goniometer in asymptomatic university-level American football athletes. Muscoskel. Care 24 (1), e70205. https://doi.org/10.1002/msc.70205.
Law, E.Y., Chiu, T.T., 2013. Measurement of cervical range of motion (CROM) by electronic CROM goniometer: a test of reliability and validity. J. Back Musculoskelet. Rehabil. 26 (2), 141–148. https://doi.org/10.3233/BMR-2012-00358.
Lawrence, I., Lin, K., 1989. A concordance correlation coefficient to evaluate reproducibility. Biometrics 255–268. https://doi.org/10.2307/2532051.
Leak, A.M., Cooper, J., Dyer, S., Williams, K.A., Turner-Stokes, L., Frank, A.O., 1994. The northwick park neck pain questionnaire, devised to measure neck pain and disability. Rheumatology 33 (5), 469–474. https://doi.org/10.1093/rheumatology/33.5.469.
Palmieri, M., Donno, L., Cimolin, V., Galli, M., 2023. Cervical range of motion assessment through inertial technology: a validity and reliability study. Sensors (Basel) 23 (13). https://doi.org/10.3390/s23136013.
Reynolds, J., Marsh, D., Koller, H., Zenenr, J., Bannister, G., 2009. Cervical range of movement in relation to neck dimension. Eur. Spine J. 18 (6), 863–868. https://doi.org/10.1007/s00586-009-0894-z.
Smith, L., Ruediger, T., Alsalaheen, B., Bean, R., 2016. Performance of high school football players on clinical measures of deep cervical flexor endurance and cervical active range of motion: is history of concussion a factor? Int. J. Sports Phys. Ther. 11 (2), 156–163. https://www.ncbi.nlm.nih.gov/pubmed/27104049.
Squara, P., Scheeren, T.W.L., Aya, H.D., Bakker, J., Cecconi, M., Einav, S., Malbrain, M.L.N.G., Monnet, X., Reuter, D.A., Van Der Horst, I.C.C., 2021. Metrology part 1: definition of quality criteria. J. Clin. Monit. Comput. 35 (1), 17–25. https://doi.org/10.1007/s10877-020-00494-y.
Strimpakos, N., 2011. The assessment of the cervical spine. Part 1: range of motion and proprioception. J. Bodyw. Mov. Ther. 15 (1), 114–124. https://doi.org/10.1016/j.jbmt.2009.06.003.

Sukari, A.A.A., Singh, S., Bohari, M.H., Idris, Z., Ghani, A.R.I., Abdullah, J.M., 2021. Examining the range of motion of the cervical spine: utilising different bedside instruments. Malays. J. Med. Sci. 28 (2), 100–105. https://doi.org/10.21315/mjms2021.28.2.9.

Torg, J.S., 2009. Cervical spine injuries and the return to football. Sports Health 1 (5), 376–383.

Whitcroft, K.L., Massouh, L., Amirfeyz, R., Bannister, G., 2010. Comparison of methods of measuring active cervical range of motion. Spine 35 (19), E976–E980.

Williams, M.A., McCarthy, C.J., Chorti, A., Cooke, M.W., Gates, S., 2010. A systematic review of reliability and validity studies of methods for measuring active and passive cervical range of motion. J. Manip. Physiol. Ther. 33 (2), 138–155. https://doi.org/10.1016/j.jmpt.2009.12.009.

Wolan-Nieroda, A., Guzik, A., Mocur, P., Druzbicki, M., Maciejczak, A., 2020. Assessment of interrater and intrarater reliability of cervical range of motion (CROM) goniometer. Biomed Res. Int., 8908035 https://doi.org/10.1155/2020/8908035.

Wu, A.-M., Cross, M., Elliott, J.M., Culbreth, G.T., Haile, L.M., Steinmetz, J.D., Hagins, H., Kopec, J.A., Brooks, P.M., Woolf, A.D., 2024. Global, regional, and national burden of neck pain, 1990–2020, and projections to 2050: a systematic analysis of the global burden of disease study 2021. Lancet Rheumatol. 6 (3), e142–e155. https://doi.org/10.1016/S2665-9913(23)00321-1.

Yoon, T.L., Kim, H.N., Min, J.H., 2019. Validity and reliability of an inertial measurement unit-based 3-Dimensional angular measurement of cervical range of motion. J. Manip. Physiol. Ther. 42 (1), 75–81. https://doi.org/10.1016/j.jmpt.2018.06.001.

Youdas, J.W., Carey, J.R., Garrett, T.R., 1991. Reliability of measurements of cervical spine range of Motion—comparison of three methods. Phys. Ther. 71 (2), 98–104. https://doi.org/10.1093/ptj/71.2.98.

Zwart, J.A., 1997. Neck mobility in different headache disorders. Headache 37 (1), 6–11. https://doi.org/10.1046/j.1526-4610.1997.3701006.x.