

Concurrent validity of fixed-frame vs handheld dynamometer assessment of isometric neck strength

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Abstract

Background

Assessing isometric neck strength is popular and necessary in rugby. Various protocols are used to assess neck strength. This study aimed to determine the concurrent validity of two isometric neck strength testing protocols, i.e. fixed-frame dynamometry (FFD) and handheld dynamometry (HHD), among university-level female rugby players.

Method

Isometric neck strength of 22 female university rugby players (aged 18–26 years) were assessed using a fixed-frame dynamometry and a handheld dynamometer. Three self-perceived maximum effort neck extension, front and lateral flexion were performed according to the device manufacturers' standard procedures. Force (N) for each movement was recorded. Pearson's/Spearman's correlations were performed using SPSS (significance level $p < 0.05$).

Results

For maximum force, moderate correlations ($r = 0.4–0.69$) were observed for front flexion, extension ($r = 0.41$), right ($r = 0.56$), and left ($r = 0.43$) lateral flexion showed moderate correlations. For average forces, front flexion ($r = 0.61$) and right lateral flexion ($r = 0.54$), left lateral flexion ($r = 0.40$) showed moderate correlations, and weak for extension ($r = 0.33$). When looking at rugby playing positions, forwards ($n = 10$) showed moderate correlations for maximum left ($r = 0.65$) and right ($r = 0.63$) lateral flexion, while front flexion and extension showed weak correlations. For backs ($n = 12$), strong correlations were found for maximum ($r = 0.73$) and average front flexion ($r = 0.76$), moderate for extension, and weak-to-moderate for lateral flexion.

Conclusion

The lack of strong consistent agreement between the different testing protocols and equipment suggests that they should not be used interchangeably. It is recommended to consistently use a single system for repeat assessment and longitudinal monitoring. Future research should explore which protocol best correlates with head kinematics to inform relevant test selection.

Background

Neck strength, especially isometric neck extension strength, has been reported to play a crucial role in mitigating the risk of concussion in contact sports such as rugby (1). Studies suggest that increased neck strength, particularly in extension, correlates with fewer concussions among male rugby players,

and that improving neck extension strength by 10% can lead to a 13% decrease in the concussion rate (1). This indicates that improving neck strength is an adjustable intrinsic risk factor for concussions and should be a crucial part of strength and conditioning programmes, particularly for rugby players. Testing isometric neck strength is also therefore particularly important in these team settings. Isometric neck strength is the maximum force the neck muscles can generate while contracting without movement, typically measured during static resistance against an immovable object (2, 3). The assessment thereof can be conducted using various protocols and devices, including handheld dynamometry (HHD) and fixed-frame dynamometry (FFD).

The importance of accurately assessing physical fitness constructs, such as strength, cannot be overstated. Reliability and validity are two key features that influence the accuracy and appropriateness of an assessment protocol. Reliability refers to the consistency of measurements across various situations, ensuring that a measure yields consistent results under stable conditions (4). Validity, in contrast, refers to the extent to which an instrument accurately measures what it is intended to measure, thereby confirming the relevance and accuracy of the assessment (5). Concurrent validity, a specific form of validity, evaluates the degree to which a test correlates with established measures of the same construct when administered simultaneously, this represents the test's effectiveness in mirroring known standards (6).

Handheld dynamometry involves the use of a handheld device to measure muscle strength and is often preferred for its portability and cost-effectiveness (7). However, tester variability can influence outcomes, in particular in environments where weaker and stronger testers administer tests (8). Despite these concerns, research demonstrates high reliability for neck strength measurements using HHD, achieving strong intra-class correlation coefficients (ICCs) across all neck movements, i.e. flexion, extension, side flexion, and rotation (7). Among semi-professional rugby players, investigations into the concurrent validity of tester-operated HHD compared to mounted HHD outcomes also found large-to-very large correlations and good reliability (9). Similarly, an investigation among schoolboy rugby players revealed that a portable HHD neck strength assessment exhibited good-to-excellent reliability across test-retest, intra-rater, and inter-rater evaluations, with ICCs comparable to those of the gold-standard fixed-frame dynamometry (10). Handheld dynamometry is therefore regarded as a reliable and accessible tool for assessing neck strength in research and practical sports settings (9–11).

Fixed-frame dynamometry typically involves using more sophisticated and stationary setups, often found in laboratory environments (12, 13). Fixed-frame setups provide stabilised and controlled conditions that claim to reduce variability in measurements, potentially offering higher precision. Recent studies have demonstrated that the VALD Force-Frame, a modern, new, portable FFD, compared to traditional devices, provides good-to-excellent intra- and inter-rater reliability for measuring peak isometric neck flexion, extension, and lateral flexion strength (2). Neck rotation strength can, however, not be measured using this device. Interestingly, there is not much research on the VALD Force-Frame in rugby or other team sports. This shows that using the VALD Force-Frame to measure neck strength is new. In professional rugby players, the VALD Force-Frame can reliably show differences in neck strength between different

positions and levels of competition which makes it useful for understanding player profiles. (14). These findings indicate that while FFD might not be as user-friendly as HHD, it offers robust, reproducible neck strength measurements, making it a preferred tool for longitudinal monitoring and research where precision and standardisation are critical (2, 15). However, the validity of the VALD Force-Frame vs. HHD neck strength assessment protocols has not been researched.

Establishing the concurrent validity of the VALD Force-Frame relative to the HHD will help determine whether these tools can be used interchangeably for isometric neck strength assessment in athletic populations, specifically female rugby players, as most current research has placed a significant focus on male rugby players. From a practical perspective, this can guide clinicians and sports scientists in selecting the most feasible, reliable, and context-appropriate tool for longitudinal monitoring, return-to-play decision-making, and injury prevention strategies. Furthermore, the study addresses a gap in the literature by providing comparative data between two widely used measurement systems, thereby enhancing methodological rigor and standardisation in future research on neck strength profiling.

Methods

Study design

This was an observational, cross-sectional study.

Participants

A convenience sample was selected based on the geographical proximity of female rugby players to the testing facilities and accessibility to the team. Twenty-two female rugby union players, 18 years or older, registered as part of a university team for the 2024/25 season, participated in the study. Players had to be on the active roster at the start of the season, i.e., have no current injuries or concussions that could be aggravated by participating in this study.

Ethical considerations

Prior to testing, ethical clearance was obtained from the Human Research Ethics Committee (292/2024) of the tertiary institution where the research was conducted. Additionally, participants provided written informed consent and a pre-participation questionnaire. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Procedures

Anthropometrics

Participants' height, weight, and neck girth were recorded before testing. Height (cm) and weight (kg) were recorded using a stadiometer and scale, respectively. Neck girth was recorded in cm using a flexible tape measure. The head and neck anthropometric measurements were measured at the same landmarks as in a previous study (13).

Isometric Neck Strength Testing

Isometric neck strength was measured using two methods: a Fixed-Frame dynamometer the VALD Force-Frame (VALD Performance, Brisbane, Australia) and a Handheld dynamometer the MicroFet 3 (Hoggan Scientific, LLC, UT, USA).

a- Fixed-Frame dynamometer (FFD) testing

The manufacturer's standard neck testing protocol was used to assess all neck strength in all movements (12). Each participant performed a warm-up attempt on the VALD Force-Frame to familiarize themselves with the equipment and testing procedure. The participants were requested to perform three maximum efforts per direction (front flexion, extension, left lateral flexion, and right lateral flexion), with 15 seconds of rest between each effort and 30 seconds of rest between directions. Outcome measures included maximum force in Newtons (N) for each attempt in each direction, and the average force across all three trials.

b- Handheld Dynamometer (HHD) testing

The HHD testing procedure used during this study is described in previous studies (7, 13). The participant was seated on a stool with no back or armrests to prevent bracing. Neck strength was tested in four directions: front flexion, extension, left lateral flexion, and right lateral flexion. The participants held the device in their hands and were then instructed to push into the device with a maximum perceived effort for three seconds. Each participant performed three repetitions per movement with a 15-second rest between attempts and a 30-second rest between directions (13). Outcome measures include maximum force in Newtons (N) from each attempt in each direction, with the average of the three trials being calculated afterwards.

To ensure test reliability, one tester was responsible for administering all HHD tests and another for FFD tests. Both testers were well-versed in both isometric neck strength testing protocols. The participants were tested first on the HHD then on the FFD.

Data analysis

SPSS statistical software (version 30.0.0.0, IBM Corporation, Armonk, NY, USA) was used for statistical analyses. The normality of the data was determined using a Shapiro-Wilk test for normality with a threshold of 0.05. Depending on the normality of the data, descriptive statistics included means and standard deviations (for parametric data) and medians and interquartile ranges (IQR) (for non-parametric data). Analyses were conducted for the whole team (n = 22) and separately for forwards (n = 10) and

backs (n = 12). For each group, maximum force and average force across three trials were analysed for flexion, extension, left lateral flexion, and right lateral flexion. Comparison statistics, Pearson’s correlation coefficient (r) (for normally distributed data) / Spearman's coefficient (for non-normally distributed data), were calculated and used to determine the correlation between the maximal force and average maximum force measured using the two protocols. An independent T-test was used to compare demographic data (age, height, weight and neck girth). Correlation strength was interpreted as negligible (0.00–0.10), weak (0.10–0.39), moderate (0.40–0.69), strong (0.70–0.89) and very strong (0.90–1.00) (16). 95% confidence intervals (CI) were reported for all correlation coefficients to indicate the precision of the estimates. Statistical significance was set at a p-value < 0.05.

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Results

Descriptive statistics for anthropometrics and age are summarised in Table 3.1. There was no significant age difference between backs and forwards. In contrast, forwards were significantly (p<0.05) taller, heavier and had greater neck girths than the backs.

Table 3.1 Age, height, weight and neck girth of each testing group

	All Players (Mean ± SD)	Forwards (Mean ± SD)	Backs (Mean ± SD)	P-Value
	n=22	n=10	n=12	-
Age (years)	21.23 ± 2.20	21.90 ± 2.10	20.67 ± 2.21	0.194
Height (cm)	164.90 ± 6.78	168.20 ± 7.14	162.14 ± 5.29	0.033
Weight (kg)	68.55 ± 15.46	80.74 ± 14.02	58.39 ± 6.93	< 0.001
Neck Girth (cm)	34.12 ± 3.19	37.35 ± 3.08	34.02 ± 2.48	0.011
<i>cm – centimetres; kg – kilograms; SD – standard deviation</i>				

The descriptive statistics and correlations between maximum and average forces as measured with the FFD and HHD are summarised in Table 3.2.

Table 3.2 Maximum and Average Force Correlations Between the Fixed-Frame dynamometer (FFD) and Handheld Dynamometer (HHD)

Maximum Force					Average force			
All Players								
	FFD	HHD	Spearman ¹ / Pearson		FFD	HHD	Spearman ¹ / Pearson	
	Mean (SD)/ <i>Median</i> [IQR]	Mean (SD)/ <i>Median</i> [IQR]	r [95% CI]	P- value	Mean (SD)/ <i>Median</i> [IQR]	Mean (SD)/ <i>Median</i> [IQR]	r [95% CI]	P- value
Front Flexion	174.86 (31.86)	170.56 (40.47)	0.61 [0.25, 0.82]	<0.01	166.67 (30.27)	160.93 (40.47)	0.61 [0.25, 0.82]	<0.01
Left Lateral Flexion	144 [31.38]	140.86 (35.59)	0.43 [-0.01, 0.73] ¹	0.05	138.57 [30.27]	129.26 (32.73)	0.40 [-0.40, 0.71] ¹	0.07
Right Lateral Flexion	148.13 [37.19]	144.14 (35.29)	0.56 [0.17, 0.80] ¹	0.01	127.04 [41.25]	135.51 (35.43)	0.54 [0.14, 0.79]	<0.01
Extension	208.30 (38.35)	221.24 (45.03)	0.41 [-0.01, 0.71]	0.06	193.92 (32.34)	206.27 (39.03)	0.33 [-0.10, 0.66]	0.13
Forwards								
	FFD	HHD	Spearman ¹ / Pearson		FFD	HHD	Spearman ¹ / Pearson	
	Mean (SD)/ <i>Median</i> [IQR]	Mean (SD)/ <i>Median</i> [IQR]	r [95% CI]	P- value	Mean (SD)/ <i>Median</i> [IQR]	Mean (SD)/ <i>Median</i> [IQR]	r [95% CI]	P- value
Front Flexion	188.35 (33.0)	196.53 (31.20)	0.27 [-0.44, 0.77]	0.46	166.96 [54.07]	187.85 (29.67)	0.15 [-0.54, 0.72] ¹	0.68
Left Lateral Flexion	153.50 [62.19]	155.27 (27.74)	0.65 [0.01, 0.91] ¹	0.04	154.21 (35.22)	144.01 (22.74)	0.49 [-0.2, 0.86]	0.15
Right Lateral Flexion	181.38 (47.58)	155.25 [56.13]	0.63 [-0.03, 0.91] ¹	0.05	163.22 (52.49)	148.90 [49.48]	0.58 [-0.11, 0.89] ¹	0.08
Extension	216.85 (39.73)	242.25 (47.55)	0.15 [-0.53, 0.71]	0.68	200.40 (36.05)	225.92 (39.75)	0.04 [-0.61, 0.65]	0.92
Backs								
	FFD	HHD	Spearman ¹ / Pearson		FFD	HHD	Spearman ¹ / Pearson	

	Pearson				Pearson			
	Mean (SD)/	Mean (SD)/	r [95% CI]	P- value	Mean (SD)/	Mean (SD)/	r [95% CI]	P- value
	<i>Median [IQR]</i>	<i>Median [IQR]</i>			<i>Median [IQR]</i>	<i>Median [IQR]</i>		
Front Flexion	163.63 (27.22)	148.93 (34.73)	0.73 [0.27, 0.92]	0.01	156.34 (27.17)	138.51 (34.64)	0.76 [0.34, 0.93]	<0.01
Left Lateral Flexion	136.58 (18.62)	128.85 (37.98)	0.09 [-0.51, 0.63]	0.79	125.55 (18.11)	116.96 (35.49)	0.01 [-0.57, 0.58]	0.99
Right Lateral Flexion	134.75 (18.84)	130.08 (34.70)	0.39 [-0.23, 0.79]	0.21	121.48 (17.04)	121.25 (36.08)	0.36 [-0.28, 0.77]	0.26
Extension	201.17 (37.34)	203.73 (35.84)	0.62 [0.08, 0.88]	0.03	188.51 (29.38)	189.89 (31.18)	0.60 [0.04, 0.87]	0.04
<i>FFD – Fixed Frame Dynamometer; HHD – Handheld Dynamometer; SD -Standard Deviation; IQR – Interquartile Range; CI – Confidence Interval</i>								

Force differences

Descriptive trends suggest that the Fixed-Frame dynamometer generally recorded higher flexion and lateral flexion forces, while the handheld dynamometer tended to measure greater extension forces. This pattern held across overall data and subgroup comparisons between forwards and backs.

Correlations

The relationship between the FFD and HHD varied by direction and player group, with correlation strengths ranging from weak to strong. Strong correlations were observed in backs for front flexion ($r = 0.73$ – 0.76), while forwards showed weak correlations for front flexion ($r = 0.15$ – 0.27) and extension ($r = 0.04$ – 0.15).

Discussion

This study compared the outcomes of the two isometric neck strength testing protocols among female university-level rugby players. Key findings highlight the inconsistent relationships between the FFD and HHD system neck strength testing protocols in female rugby players. The FFD protocol typically measured higher maximum and average force values across the three trials.

With the exception of neck extension, the FFD outputs were typically higher than those of the HHD for the maximum and average force values. This is consistent with previous literature, for all directions where FFDs yielded higher maximum and average force values than HHD (2, 17). One study has however

reported that HHD was also lower than FFD during neck extension (9, 17). These different findings may be due to a) the difference in participant positioning during testing, b) the difference in the testing device stability and c) the difference in manufacturers and load cells used to measure force.

Participant Positioning

The FFD protocol requires players to be in a quadrupled position during testing, while HHD testing position requires players to sit upright. In other studies that used a FFD participants were tested in a seated position, trunk strapped into a chair (9, 17). This may influence the force values as muscle activation patterns are different for each of these testing positions (18). For rugby it may be preferred to test in a quadrupled position similar to that of a scrum, ruck or tackle where the body is bent forward not upright. The variation in extension strength might be attributed to its reliance on the deep cervical extensor muscles, which are intricate (19). Weakness of these muscles may lead to less reliable force measurements, especially if tested in different positions (19). The quadrupled position, may require greater activation of the neck stabilisers to maintain head alignment against gravity which acts perpendicular to the neck in this position as opposed to the upright positioning as with the HHD testing where gravity acts, parallel to the neck, along the spine potentially allowing for more support and less active stabilisation required.

The difference in stability of the two devices

The stability of the measurement devices may influence the accuracy and consistency of recorded force values. Fixed-frame dynamometers provide a stable and secure platform that minimises extraneous movement and operator-induced variability, which may result in higher and more consistent force outputs. Studies have demonstrated that these fixed devices yield good-to-excellent intra- and inter-rater reliability for isometric neck strength measurements in both male and female participants, supporting their use in both sports and clinical settings (2, 20). However, handheld or less stable devices are more susceptible to movement, tilting, or shifting during testing, especially under high force, which may potentially lead to an underestimation of true muscle strength and an increased measurement error (2, 18, 20). Therefore, differences in device stability contribute to the lack of a consistent relationship between different neck strength testing protocols.

Difference in manufacturers and load cells used to measure force

The difference in the parts used to measure the force in each device (load cells) might also contribute to the differences in the findings. For *example*, when the force values from the VALD Force-Frame (a FFD) and the VALD dynamo (a HHD) were previously compared, with participants in the same quadrupled position, it was found that the two devices did not provide the same values, and it was concluded that the devices are not interchangeable (15). Therefore, even if all other testing conditions were replicated, the exact same device should be used for the most reliable testing.

Correlations between different movement force measurements

The correlations for most directions in this study for maximum and average force were mostly moderate, with some movements being strongly correlated and others being weakly correlated. Previous research has also found moderate-to-strong correlations between FFD and HHD, with correlation coefficients between 0.68 and 0.82 (17). Certain movements, such as front and right lateral flexion, showed stronger correlations between the FFD and HHD measurements. This pattern is supported by the previously mentioned methodological differences and can also be explained by several physiological factors. Stronger correlations in front flexion and lateral flexion may be due to more consistent and balanced muscle activation patterns in these directions, as these movements often involve coordinated recruitment of superficial and deep neck muscles, leading to more stable force outputs across devices (19, 21). Extension strength is more dependent on the deep cervical extensor muscles, which are anatomically complex and can vary significantly between individuals. Weakness or altered activation in these muscles can result in compensatory patterns and less consistent force measurements, reducing the correlation between devices (19).

Backs vs Forwards

The findings of this study align well with previous literature, which consistently reports that forwards exhibit higher absolute neck strength than backs, particularly in extension, due to their greater body mass and the physical demands of their playing roles (11, 14, 22, 23). In this study, it was observed that forwards had higher maximum and average force values compared to backs, especially in extension. However, when neck strength is normalised to body weight as a ratio, the differences between forwards and backs are often diminished or become non-significant, as seen in prior research (10).

The results of this study showed that the strength of correlations between measurement directions and devices can vary by position. Backs have stronger correlations for both front flexion and extension (both max and average), and forwards have stronger correlations for right and left lateral flexion. Previous studies have suggested that the greater variability in muscle mass and force production among the forwards, due to their different positional demands and roles in scrummaging and contact, can lead to more variance and sometimes weaker correlations between directions, especially in extension (11, 14, 22). Backs, with less exposure to high-load contact and more balanced strength profiles, tend to show more consistent and stronger correlations across directions and devices (11, 22).

These differences may also be explained by the unique biomechanical and anthropometric characteristics of each position group. Forwards typically have larger neck girth and muscle cross-sectional area, contributing to higher force outputs, but also greater variability, while backs have more balanced flexor extensor ratios, and less extreme anthropometrics result in more consistent measurements (11, 22, 23). These findings are in line with previous literature, highlighting that while absolute strength is greater in forwards, the consistency and correlation of measurements may be higher in backs, depending on the direction and method of assessment.

Cost effectiveness of each device

When comparing HHD to FFD, cost-effectiveness is an important practical consideration. HHD are widely recognised as a more affordable and efficient alternative, offering reliable muscle strength assessment at a fraction of the cost of larger, FFD systems (24, 25). While FFD devices may provide enhanced stability and certain measurement advantages, their high price and lack of portability can be prohibitive for many clinics and field settings (24, 25). Conversely, HHD devices, some of which are now offered at much lower prices, have shown high validity and reliability, making them an economical option for regular clinical and field-based assessments of muscular strength (24, 25). Therefore, when choosing a device, practitioners should consider the advantages of measurement accuracy and consistency in comparison to the significant cost savings and ease of use provided by HHD.

Strengths and Limitations

One of this study's strengths is its focus on female rugby players, a demographic for which research is relatively scarce. Additionally, limited research examines the correlations between the two distinct isometric neck strength testing protocols, despite the need to understand the devices available on the market. This study also ensured consistency among the testers using each piece of equipment, thereby enhancing the reliability of the testing across different participants. In contrast to previous literature, this study allowed participants to exert force against their own strength for the assessment of isometric neck strength using HHD. This approach eliminates the influence of the tester's strength on the HHD's outputs. However, this can become a limitation with weaker players who can't adequately resist their neck strength. Previous studies have indicated that HHD can be constrained by the tester's strength, particularly when the participant is stronger than the tester (26).

The study had some limitations that should be considered when interpreting the results. Notably, participants lacked prior experience with neck strength testing and training, which may have influenced their performance and adaptation to the protocols. This inexperience could affect the accuracy and reliability of the strength measurements obtained. Additionally, due to scheduling constraints, all strength testing per participant had to be conducted on the same day. This might have introduced fatigue or other confounding factors, potentially impacting the consistency of the data collected for that individual. This was managed by providing enough rest per participant between testing directions and devices. However, doing it on the same day eliminates the risk of strength changes between the testing for each device. Another limitation pertains to the specific testing protocols employed for each device. For instance, the FFD is evaluated with the participant in a quadruped position, whereas the HHD is assessed with the athlete seated without back support. This discrepancy in positioning may affect the force exerted between the athlete and the device. The small sample size is also however a limitation and limits the statistical power of subgroup analyses. These limitations highlight the need for caution when generalising the findings and suggest areas for improvement in future research designs.

Future research

Future research with larger cohorts and cohorts with athletes with more experience being tested is needed to explore these discrepancies further. Studies could investigate potential influences such as

positioning, muscle activation and recruitment patterns between devices, and device limitations. Future research should include formal agreement analyses (e.g., Bland–Altman methods) to quantify systematic bias and limits of agreement between devices and strengthen conclusions regarding their interchangeability. As detailed sampling frequency specifications were not easily accessible for the HHD device, future research should directly quantify and compare the sampling rates and signal processing characteristics of dynamometry systems to determine whether these factors influence force output and measurement sensitivity. Additionally, research with the participant in a quadruped position, as in this study, and the FFD testing protocol is limited. Therefore, future research testing neck strength in that position would be beneficial for comparing results.

Practical Application

The results of this research have important practical implications for sport scientists, physiotherapists, and strength and conditioning practitioners working with athletes in contact sports. The lack of consistent agreement between the FFD and HHD systems indicates that they may not be interchangeable, particularly when comparing absolute values or tracking changes over time. Therefore, it is advisable to use one system for longitudinal monitoring consistently. Practitioners should ensure the consistent selection of testing equipment when tracking neck strength over time. Given that the FFD system records higher values, it may be more suitable for monitoring high-force outputs and in environments where the equipment remains stationary and stable due to its size. On the other hand, the HHD may be more beneficial when portability is essential; however, practitioners should be mindful of its potential limitations in measuring peak force in certain directions. A thorough understanding of each system's strengths and weaknesses enables a more accurate interpretation of athlete assessments, supporting data-driven decision-making in performance and injury prevention strategies.

Conclusion

These findings highlight the importance of considering the specific measurement system when assessing neck strength in female rugby players. The choice between FFD and HHD systems may significantly impact the results, particularly for front flexion and extension measurements. Clinicians and researchers should be aware of these differences when interpreting results or comparing data across studies that use different measurement systems. When assessing athletes, clinicians should select a single system and use it consistently to compare the results with previous tests accurately.

Abbreviations

HHD
Handheld Dynamometer
FFD
Fixed-Frame Dynamometer
ICC
Intraclass Correlation Coefficient

Declarations

Ethics approval and consent to participate

Prior to testing, ethical clearance was obtained from the Human Research Ethics Committee (292/2024) of the tertiary institution where the research was conducted. Additionally, participants provided written informed consent and completed a pre-participation questionnaire. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Availability of data and materials

The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

BH, NS & CM conceived and designed the study, BH and MJ collected the data and BH analysed the data, interpreted the results, and prepared the manuscript. All authors read and approved the final manuscript.

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