Reliability of Electromyographic Assessment of Biceps Brachii and Triceps Brachii in Cricketers

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ABSTRACT

Objective: The purpose of this study is to determine the intraexaminer and interexaminer reliability of electromyographic assessment of biceps brachii (BB) and triceps brachii (TB) muscles in cricketers.

Methods: Sixteen healthy male cricketers (ages 14-35 years) recruited from Jamia Millia Islamia, New Delhi, India were tested on 2 occasions that were held 1 week apart. On the first occasion, only examiner 1 performed the testing; on the second occasion, examiner 1, examiner 2, and examiner 3 all performed testing. While testing for surface electromyography (sEMG) activity of BB and TB muscles, participants were asked to produce maximal voluntary isometric contraction (MVIC), which was to be held for 5 seconds against the resistance provided by an examiner. Participants performed 3 MVICs per muscle per examiner, with a rest interval of 3 minutes between consecutive contractions. Intraclass correlation coefficient, standard error of measurement, and minimum detectable change were calculated to determine the reliability of repeated sEMG measurements.

Results: Nonsignificant differences were observed for the 2 trials completed by examiner 1 (paired *t* test) and testing done by all 3 examiners (repeated measures analysis of variance) at $P < .05$ for both BB and TB. Intraclass correlation coefficient values ranged from .84 to .86 for BB and .89 to .98 for TB. Standard error of measurement (minimum detectable change) was .052 (.144) mV and .041 (.114) mV for BB intraexaminer and interexaminer reliability testing, respectively, and .018 (.051) mV and .043 (.119) mV for TB intraexaminer and interexaminer reliability testing. Ninety-five percent of the mean differences between almost all of the repeated measurements were found to lie within the agreement intervals estimated by Bland-Altman plots.

Conclusion: This preliminary study suggests that sEMG is a reliable tool with excellent intraexaminer and interexaminer reliability for assessing the activity of BB and TB muscles in male cricketers. These findings suggest that sEMG can be used to assess MVIC activity of these muscles in clinical settings, as well as in research area. (J Chiropr Med 2018;17:151-159)

Key Indexing Terms: *Reproducibility of Results; Upper Extremity; Electromyography*

INTRODUCTION

Surface electromyography (sEMG) being noninvasive in nature finds its use in a wide range of research and clinical applications for quantification of muscle activation during isometric and dynamic conditions.¹⁻⁶ It records the action potentials generated by active motor units at the skin surface.⁵ It has been proven to be a reliable method for the assessment of

activity of upper limb muscles,^{7,8} lower limb muscles,^{1,9,10} paraspinal muscles,¹⁰⁻¹² and abdominal muscles.¹⁰

Moderate to very high reliability between the testing sessions (intraclass correlation coefficient [ICC] = 0.7-0.97) has been reported for quadriceps muscle when tested isometrically¹ and during dynamic activities such as vertical jumping.⁹ Excellent test-retest reliability for repeated sEMG testing of abdominal and lower extremity muscles during bridging and quadruped exercises were also found (ICC = 0.86-0.93).¹⁰ Moderate to very high reliability (ICC = 0.6-0.98) for interday and intraday sEMG testing of lumbar paravertebral muscles has been reported while performing different exercises that are beneficial in back rehabilitation programs.¹¹ These results were further supported by the findings of Ahern et al,¹² who showed repeated lumbar paraspinal sEMG testings to be reliable with Pearson's correlation coefficients, ranging from 0.66 to 0.97 for within-session reliability and 0.26 to

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0.92 for between-session reliability during static and dynamic movements. Intraday and interday reliability of scapular and arm muscles' sEMG amplitude values, including biceps brachii (BB) and triceps brachii (TB), were found to be excellent ($ICC > 0.75$) and good to excellent ($ICC = 0.41-0.98$), respectively, while performing closed kinematic chain exercises, such as wall press, bench press, and push-ups on stable and unstable surfaces in healthy adult men.⁷

The majority of research pertaining to the reliability of sEMG data of upper limb muscles has been completed on a healthy, nonathletic population. Furthermore, sEMG is a frequently used assessment tool for investigating upper limb muscle activity in various sports science research.^{1,13-19} Electromyography (EMG) activity of elbow flexors and extensors has been assessed in different studies on baseball players,¹⁹ triathletes,¹⁷ swimmers,¹⁷ bodybuilders,¹⁸ and cricketers,¹³⁻¹⁵ with recent studies being predominantly conducted on cricket players in whom muscle activity during bowling has been investigated. Bowling is an overhead throwing action that requires functioning of many muscles of upper limb, of which BB and TB play a crucial role.¹³⁻¹⁵ Biceps brachii muscle causes elbow flexion during the cocking phase and contracts eccentrically to control elbow extension and also prevents glenohumeral joint distraction and anterior subluxation during the deceleration phase of throwing.¹⁶ Triceps brachii muscle initially contracts eccentrically during the cocking phase to control elbow flexion and later causes elbow extension both during this phase and later during the acceleration phase.¹⁶

In addition to determining the dynamic activity of BB and TB muscles, previous studies have also assessed the maximal voluntary isometric contraction (MVIC) activity of these muscles for normalizing the EMG values.^{7,14} Maximal voluntary isometric contraction is one of the most common measures used for normalization, which is required for comparison of EMG data across different points, among different participants and between different muscles^{2,20,21} to improve muscle activation levels and reliability of EMG data.^{21,22} Kaplanis et al⁵ showed nonsignificant differences in the results of repeated intraday sEMG testing of BB muscle at 10%, 30%, 50%, 70%, and 100% of MVIC, thus indicating that reliable results were recorded for MVIC testing of BB muscle after a period of time had elapsed, whereas Rota et al²³ found poor between-day reliability with ICC values of 0.36 and 0.41 for BB and TB muscles' MVIC activities in male tennis players. The conflicting findings warrant further investigation and lead us to speculate that sEMG reliability varies across different populations.

Despite frequent research being conducted on investigating BB and TB muscle activities, an investigation into the reliability of BB and TB sEMG assessment has not been reported previously in cricket players. Cricket, being a professional multimillion dollar sport, is the second most

popular sport played worldwide after soccer.^{24,25} As of now, more than 100 countries have been recognized by the International Cricket Council.²⁴ Because of its varied match formats (ie, test and 1-day) and the advent of a new game format (ie, Twenty20), the sport is gaining more and more popularity each day.^{26,27} It thus becomes imperative to establish the reliability of electromyographic assessment of BB and TB muscles in cricketers to ascertain the viability of sEMG methodology in clinical and research settings. The objective of this study was to evaluate the intraexaminer and interexaminer reliability of sEMG assessment of BB and TB muscles in cricketers.

METHODS

Participants and Examiners

Sixteen healthy, interuniversity male cricket players (3 batsmen, 2 medium pace bowlers, and 11 all-rounders), aged 14 to 35 years, from Jamia Millia Islamia, New Delhi, India, volunteered for the study. Out of 16 players, 14 participated in the intraexaminer reliability testing (age: 21.1 ± 6.1 years, height: 173 ± 3.8 cm, weight: 65.5 ± 8.1 kg), and 15 participated in the interexaminer reliability testing (age: 22.5 ± 6.3 years, height: 173.6 ± 3.9 cm, weight: 65.2 ± 7.5 kg). All of the players were in the in-season phase of their macrocycle. The players used to play at in-fielding and out-fielding positions (they were not restricted to a single fielding position) and primarily used the overhead throwing technique during fielding activities. Only participants having at least 4 years of previous cricket experience were chosen. It was made sure that the participants were free of any upper limb injury, acute pain in the upper limb, and fatigue. The participants were informed about the research procedure and were asked to sign the consent form. This study was given ethical clearance from the Jamia Millia Islamia Ethical Committee to carry out this research study. There were 3 examiners who were physiotherapists (1 man, 2 women) by profession, having 3 to 5 years of clinical experience, using sEMG as a routine assessment method for examining muscle activity on patients with neuromusculoskeletal disorders.

Skin Preparation and Electrode Placement

If required, the participant's skin surface was shaved to remove all hair before placing the electrodes on the skin.^{17,18,23,28,29} Also, the skin was gently abraded and prepared using an alcohol swab to lower down the skin impedance (typically less than 10 kilohm) so that the action potentials generated by the muscle fibers can be picked up easily by the electrodes at the skin surface.^{17,18,23,28,29}

It was ascertained that the same examiner applied the electrodes every time during the testing. Disposable bipolar surface electrodes (Ag or AgCl) that had a diameter of 1 cm were placed in line with the muscle fibers in accordance

with the SENIAM (sEMG for the noninvasive assessment of muscles) recommendations.^{7,17,18,23}

Preference to Ag or AgCl electrodes is given over others, thus making electrode-skin impedance a resistance (not a capacitance). Hence, the potential recorded by the electrodes at the skin surface is less affected by movements between skin surface and electrodes.²⁸ Bipolar electrodes are preferred over monopolar ones because monopolar EMGs are not able to reduce crosstalk or interference, which creeps in because of activity of distant muscles, deeper motor units of the muscle under consideration, or some nearby power line. Further, bipolar EMG is a result of difference between 2 monopolar EMGs, and it is thus able to attenuate the contribution of interference.²⁸

For BB, 2 electrodes of the channel 1 were placed on the anterior two-thirds of the arm between acromion process and cubital fossa. For TB, 2 electrodes of channel 2 were placed midway between acromion process and olecranon process, posteriorly. The clavicle served as the site for the fifth electrode that is the reference electrode. An interelectrode distance of 2 cm was kept between the 2 electrodes of a particular channel.²⁹

Instrumentation and Testing

All the participants were tested during the same time of the day. They were asked to have their breakfast at least 3 hours before coming to the laboratory and were advised not to consume caffeinated drinks on the day of testing.⁸ Prior to testing, participants were instructed to perform 10 minutes of standardized upper body warmup (consisting of upper body stretches for 3 minutes, active movements of upper limbs for 2 minutes, 2 sets of 10 repetitions of wall push-ups, 2 sets of 10 repetitions of floor push-ups, and 10 repetitions of clap push-ups). Biceps brachii and TB muscles of the dominant arm²⁹ were tested for MVIC using EMG (ADInstruments, Sydney, Australia) while the participant was seated upright on a chair.

During BB testing, the arm was placed alongside the body with the elbow flexed at an angle of 90° so that the forearm was placed in neutral position. The participant was asked to perform elbow flexion against the resistance offered by the examiner at distal one-third of the forearm.¹⁸

For the TB muscle, both shoulder and elbow joints were flexed at an angle of 90°, with the forearm being placed in a neutral position. The examiner stabilized the distal humerus with 1 hand and applied resistance against elbow extension with the other hand. Participants were instructed to develop maximal force against the resistance offered by the examiner.¹⁷

For the intrarater reliability data, examiner 1 (female) took readings on 2 occasions, separated by a gap of 7 days. It was on the second occasion that examiner 2 (male) and examiner 3 (female) also noted down their readings for the interrater reliability testing. The same order of testing was followed by the examiners every time they tested a participant.

Each examiner tested each of the muscles thrice on every occasion, such that participants were given a rest period of 3 minutes between 2 successive isometric contractions of a muscle. Participants held each of the isometric muscle contractions on a count of 5 seconds. For the data analysis purpose, mean of the 3 values recorded by every examiner during each occasion was considered.^{8,18}

The raw EMG signals were passed through a band-pass filter between 25 and 400 Hz. The sampling rate was kept to be 1000 Hz to obtain root mean square values. During muscle contractions, the physiological activity within the motor units is best reflected by root mean square values, and it is thus the commonest used parameter in research studies.³⁰

Statistical Analysis

PASS 11 software (NCSS, Kaysville, Utah) was used to determine the sample size for the present study. For intraexaminer testing, keeping a power of 0.87, a sample size of 14 participants, with 2 observations per participant, was found necessary to detect an intraclass correlation of 0.90 under the alternative hypothesis when the intraclass correlation under the null hypothesis is 0.6 by using an F-test with a significance level of 0.05. For interexaminer testing, keeping a power of 0.95, a sample size of 15, with 3 observations per participant, was found necessary to detect an intraclass correlation of 0.90 under the alternative hypothesis when the intraclass correlation under the null hypothesis is 0.6 by using an F-test with a significance level of 0.03.

Data were analyzed using SPSS (Version 21) (IBM Corp, Armonk, New York) for Windows. Upon applying Kolmogorov-Smirnov test, data were found to be near normally distributed. Differences between first and second trials for examiner 1 were compared using paired *t* tests. Changes in the means between the examiners were assessed by repeated-measures analysis of variance.

To establish reliability, ICC was used to indicate the extent of combined systematic and random error. Based on the method of Shrout and Fleiss,³¹ an ICC_{2,3} (intraclass correlation coefficient model 2,3) was calculated for both intraexaminer and interexaminer reliability. Intraclass correlation coefficient values in the range of 0.80 to 1.0 were considered to be excellent; ICC values in the range of 0.60 to 0.79 were considered to be good, and values below 0.60 indicated poor repeatability. Ninety-five percent confidence limits were calculated for the ICCs.^{8,23}

To allow the error to be expressed in original units of measurement, the standard error of measurement (SEM) and minimum detectable change (MDC) were calculated using the ICC (SEM = standard deviation [SD] × $\sqrt{1-\text{ICC}}$, MDC = $1.96 \times \sqrt{2} \times \text{SEM}$).³² Standard error of measurement accounts for random variation found with repeated testing in a participant and is a measure of absolute reliability of a measure.^{7,33} Minimum detectable change is the minimum

change in a measure over a given period of time, which can be considered to be statistically significant.³³

Correlation values only tell us about the relationship between 2 repeated measurements with each other and do not inform about the difference between the 2 measurements. Bland-Altman plot estimates an agreement interval where 95% of the differences between the 2 measurements fall within that interval.³⁴

Bland-Altman plots were constructed using MedCalc for Windows, version 18.6 (MedCalc Software, Ostend, Belgium) for visual representations of the errors against true values by plotting the difference between 2 trials against the mean of 2 trials in case of intraexaminer reliability and by plotting the difference between 2 examiners against the mean of 2 examiners in case of interexaminer reliability.³⁴ All statistical analyses were conducted at the 95% level of significance ($P < .05$).

RESULTS

Intraexaminer Reliability

The mean and SD values for each trial are presented in Table 1. Significant differences were not observed between trial 1 and trial 2 for BB and TB MVIC values. Examiner 1 demonstrated excellent intraexaminer repeatability, with high ICC values for both muscles. Also, SEM values were small, indicating minimal random or systematic bias (Table 1).

Interexaminer Reliability

Because data were missing for examiner 1 (first trial), the results from the second trial were used for analyses of interexaminer reliability.³⁵ While calculating SEM and MDC, SD values of examiner 1 (second trial) were considered as baseline.

The mean and SD values for each examiner are presented in Table 2. Significant differences were not found among examiners for both BB and TB MVIC values. High ICC values and small SEM values obtained for both BB and TB muscles indicate excellent interexaminer repeatability and minimal bias, respectively (Table 2). Most data points on the Bland-Altman plot for BB and TB were within 2 SD (Figs 1-3).

DISCUSSION

The main purpose of the present study was to examine interexaminer and intraexaminer reliability of BB and TB muscles using sEMG in cricketers. Major findings suggested that there is excellent intraexaminer repeatability with high ICC values for both of the muscles. Interexaminer reliability also is excellent for both of the muscles, with high ICC values. These findings clearly suggest that electromyographic strength assessment of BB and TB muscles constitutes high interexaminer and intraexaminer reliability and thus can be used in clinical settings and for research purposes, with good consistency.

Reliability of a test informs about the degree of error within its measurements. The intraexaminer reliability assesses the stability of repeated measurements performed by the same examiner on different occasions. Another method to measure consistency of a test is interexaminer reliability test, which means measuring the reproducibility of a test across different examiners.³⁶

The present study shows that sEMG testing of both BB and TB muscles constitutes high intraexaminer reliability with ICC_{2,3} values of 0.84 and 0.98, respectively, which suggest EMG as an assessment tool with excellent intraexaminer reliability. Standard error of measurement for BB and TB was 0.052 mV and 0.018 mV, respectively. Standard error of

Table 1. Intraexaminer Reliability

	T1 (mV) (Mean ± SD)	T2 (mV) (Mean ± SD)	t	P	ICC _{2,3}	P	95% CI	SEM (mV)	MDC (mV)
Biceps brachii	0.3 ± 0.13	0.34 ± 0.11	-1.42	.180	0.84	<.001	0.49-0.95	0.052	0.144
Triceps brachii	0.24 ± 0.13	0.25 ± 0.14	-0.32	.757	0.98	<.001	0.93-0.99	0.018	0.051

CI, confidence interval; ICC, intraclass correlation coefficient; MDC, minimal detectable change; SD, standard deviation; SEM, standard error of measurement; T1, trial 1; T2, trial 2.

Table 2. Interexaminer Reliability

	E1 (mV) (Mean ± SD)	E2 (mV) (Mean ± SD)	E3 (mV) (Mean ± SD)	F	P	ICC _{2,3}	P	95% CI	SEM (mV)	MDC (mV)
Biceps brachii	0.33 ± 0.11	0.36 ± 0.09	0.33 ± 0.11	1.139	.329	0.86	<.001	0.67-0.95	0.041	0.114
Triceps brachii	0.26 ± 0.13	0.27 ± 0.12	0.22 ± 0.08	3.149	.060	0.89	<.001	0.74-0.96	0.043	0.119

CI, confidence interval; E1, examiner 1, E2, examiner 2, E3, examiner 3; ICC, intraclass correlation coefficient; MDC, minimal detectable change; SD, standard deviation; SEM, standard error of measurement.

Fig 1. Bland-Altman plot for BB (A) and for TB (B), representing intraexaminer reliability. Central line represents mean difference between 2 trials. Other 2 lines represent difference between 2 trials $\pm$ 2 SD. BB, biceps brachii; SD, standard deviation; TB, triceps brachii.

measurement indicates reliability among individual participants rather than groups of participants. As the SEM value increases, reliability of the test is said to decrease.³⁷ Higher SEM value for BB suggests that greater individual participant variability is observed for BB intraexaminer strength testing compared with TB. Results of the present research demonstrate excellent interexaminer reliability for both BB and TB muscles with ICC_{2,3} values of 0.86 and 0.89, respectively. Standard error of measurement values were almost similar for both muscles (BB: 0.041 mV, TB: 0.043 mV), as seen with interexaminer testing.

Because ICC value is incorporated during calculation of SEM, MDC conveys information regarding the reliability and responsiveness of the outcome variable. Minimum detectable change values tend to become lesser with greater reliability.³³ Minimum detectable change values ranged between 21.3% of MVIC to 48% of MVIC, with the highest value found for

intraexaminer testing of BB (48%) and lowest value for intraexaminer testing of TB (21.3%), which indicates that a change of 48% of MVIC is needed to be confident that a statistically significant change in strength of BB has occurred beyond measurement error in 95% of the cases upon being tested by the same examiner on 2 separate days.³⁸ Inter-examiner testing yielded MDC values of 34.5% of MVIC for BB and 45.8% of MVIC for TB.

High ICC values found in the present study may be due to several factors. First of all, healthy participants were tested by the examiners. If participants who have any upper limb pathology or pain are tested, the result would be a lower reliability for similar testing.³⁹ Future research studies are needed to assess the reliability of sEMG testing in patient population of cricketers so that their results can be compared with the present results in a healthy population of cricketers. Secondly, the average of 3 values was used for data analysis,

Fig 2. Bland-Altman plot for BB between E1 and E2 (A), between E1 and E3 (B), and between E2 and E3 (C), representing interexaminer reliability. Central line represents mean difference between 2 examiners. Other 2 lines represent difference between 2 examiners $\pm$ 2 SD. BB, biceps brachii; SD, standard deviation.

Fig 3. Bland-Altman plot for TB between E1 and E2 (A), between E1 and E3 (B), and between E2 and E3 (C), representing interexaminer reliability. Central line represents mean difference between 2 examiners. Other 2 lines represent difference between 2 examiners $\pm$ 2 SD. SD, standard deviation; TB, triceps brachii.

which provides a better representation of performance by the participant, as compared to a single test value.³⁹

Rota et al²³ reported very low MVIC ICC values (for between day reliability) of 0.36 and 0.41 for BB and TB, respectively, in young male tennis players. The authors of the previously mentioned study justified the poor ICC values by the fact that isometric contractions are affected by the motivational levels and degree of familiarization given to the participants. The divergence between the results of study by Rota et al and the present study can be explained by differences in the testing methods and populations being tested.

The present study seems to agree with previous studies that had evaluated isometric and dynamic contractions of upper limb and lower limb muscles. Fauth et al reported excellent ICC values (>0.8) for quadriceps and hamstrings muscles during both isometric and dynamic tasks.¹ Similarly, de Araújo et al recorded excellent ICC values (≥ 0.75) for intraday reliability of EMG amplitude values.⁷

The authors could find only 1 study on sEMG that reported interrater reliability; all other reliability studies have reported intraday, interday, or test-retest intrarater reliability. Di Fabio³ had used 3 examiners who took readings on 2 occasions: an initial test and a follow-up session (1 week later) and reported poor to moderate inter-rater reliability. They had tested lower extremity muscles in healthy and hemiplegic individuals aged 42 to 71 years, which seems to be the reason behind differences between the results of their study and the present study. The conflicting findings make the speculation of reliability being population and age specific stronger.

The present results for intraexaminer reliability compare favorably with previous findings of Byl et al,⁴⁰ who had used dynamometer to test the reliability of the BB muscle. They had reported ICC value of 0.933 to 0.961, which is higher than the value of 0.84 reported in the present study. Although, the value in the present study is less than that of Byl et al, still, the results demonstrate excellent reliability, and a greater value in their study could have resulted because of additional stabilization provided by them in

supine position during BB strength testing, unlike sitting position used in the present study.

The present results for interexaminer reliability do not match with the findings of Byl et al.⁴⁰ They had reported ICC value of 0.518 to 0.658, which is very low when compared to the interexaminer ICC value of 0.86 found in the present study. Their low value could have resulted because of inherent difference in the strength of the raters to maintain stability of the dynamometer against the force applied by the participants. The authors can speculate that sEMG is a more reliable method to measure muscle strength, as compared to dynamometry; however, further studies are needed to confirm the findings.

Sex Differences of Examiners

Differences in physical ability of the examiners have been reported to be a confounding factor in the assessment of MVIC. Although 2 female examiners and 1 male examiner were involved in the present study, nonsignificant differences were found between their mean MVIC results. This was an additional important finding observed in the present study, and though it was not a part of the objective of this study, the authors are still reporting it.

A study examining the ability of male and female examiners to assess knee muscle strength found that vertical push force exerted by female testers (to resist knee extension) was only 60% of knee extension force exerted by normal, healthy women, and 40% of the knee extension force exerted by normal, healthy men indicated the inability of the female testers for detection of mild to moderate weakness in male and female participants. Vertical push force exerted by male testers (to resist knee extension) was 96% and 61% of the knee extension force exerted by normal, healthy women, and men, respectively, indicating inability of the male testers for challenging strong male participants.⁴¹ On the contrary, the authors did not find any such sex differences because lower limb muscles were not tested in the present study; instead, it was only BB and TB

muscles, which are upper limb muscles and are smaller in size and are lesser in strength than lower limb muscles.

Significance of the Study

To the best of the authors' knowledge, this is the first study which investigates interexaminer and intraexaminer reliability of strength assessment of BB and TB muscles by using sEMG in cricketers. Testing conditions were in accordance with standardized procedures. The MVIC values which have been generated can be used as reference to compare the sEMG values between healthy and injured players. In addition, the results for mean MVIC can be used for normalization procedures in future.^{2,42} Also, the authors hope that the present findings will help in the objective documentation of muscle activity in cricketers before and after an injury, thus aiding the rehabilitation process.

Limitations and Future Recommendations

The sample size of the present study was small. A larger number of participants would have further reinforced the findings because a larger sample size is known to provide greater consistency and greater agreement among the findings.³⁶ Also, the authors did not specifically choose either batsmen or bowlers as participants in the present study, thus intraexaminer and interexaminer reliability studies of BB and TB muscles in future should include a larger sample, with separate results for bowlers and batsmen.

Although a large age range (14-35 years) required for participants to be included in this study, irrespective of their training age, for wider generalizability and applicability of the authors' findings in the university level cricket players, the longer history of cricket training in older players may also cause a difference in the EMG activity in each muscle compared with the younger players. Future studies should establish the reliability of sEMG in different age groups having similar history of training exposures.

Moreover, intraexaminer reliability testing was done for only 1 examiner, with testing being performed on 2 separate days; future research can test this for 2 or more raters performing the test twice on the same day for a better insight into the results that could be obtained by a rater.

Furthermore, this study tested the MVIC activity of BB and TB muscles only on the dominant side and only in male cricketers. Future studies should consider testing of other upper limb muscles, bilaterally, during dynamic conditions in both male and female cricketers.

CONCLUSION

This preliminary study concludes that sEMG is a reliable tool, with excellent intraexaminer and interexaminer reliability for assessing the activity of BB and TB muscles in male cricketers. These findings suggest that sEMG can

be used to assess MVIC activity of these muscles in both clinical settings and other research areas.

FUNDING SOURCES AND CONFLICTS OF INTEREST

No funding sources or conflicts of interest were reported for this study.

CONTRIBUTORSHIP INFORMATION

Concept development (provided idea for the research): M.E.H.

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Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): M.E.H., J.A.M.

Data collection/processing (responsible for experiments, patient management, organization, or reporting data): D. S., I.A., S.V.

Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): D.S., J.A.M.

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Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): S.V., K.A.

Practical Applications

- Maximum voluntary isometric values for biceps brachii and triceps brachii muscles have been obtained that can be used for normalization purposes in the future.
- This study showed that surface electromyography had excellent intrarater and inter-rater reliability.
- No sex differences were found during the testing; that is, male and female testers yielded almost similar results.

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