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Statistically Analyzing Stress in the Muscles of Bowling ARM of the Medium-Fast Bowlers with the Help of Electromyography

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Abstract - *This study is done for recording and analyzing the electrical activity in Palmaris Longus (PL) and Biceps Brachii (BB) muscles of the bowling arm of the fast bowlers while bowling 'Bouncer' and 'Yorker' Delivery. Seventeen (17) College students volunteered and contributed by participating and also helping in carrying out the experiments. The chosen method of sampling is (n=17, age (years) = 25.18±2.43, height (cm) = 174.05±4.14, weight (kg) = 68.94±6.18). The EMG data was recorded using the Trigno EMG wireless system (model: SP-W02A-1849, DELSYS, USA).These recordings were synchronized, with the timings of the bowler delivering the respective ball, using camera of XIOMI- Redmi4 phone. The results, obtained after doing the statistical analysis, depicts a considerable dissimilarity between the Root Mean Square values of BB & PL muscles while bowling Bouncer with p-value (=0.010), but no significant difference were found between electrical activity of these muscles while delivering Yorker. The inferential statistics suggest that the BB-muscle is under more stress than the PL-muscle while bowling Bouncer.*

Key Words: Biomedical Signal Processing, Electromyography, Root Mean Square (RMS) values, Biceps Brachii & Palmaris Longus, Fast bowling, Yorker & Bouncer, Statistical Analysis.

1. INTRODUCTION

Cricket being one of the oldest games of the world and is among the most attracting sports played in several countries. By seeing evolution from the longer formats to shorter formats, like T-20, cricket has seen a steep increase in the number of spectators watching the game both in the stadium as well as via satellite. Due to this increasing viewership more amount of matches are played every season both domestically and internationally making players getting involved in more muscular activity than ever and thus creating more muscular stress.

There are three major aspects involved in the game of cricket namely batting, bowling and fielding. The biomechanical research is mainly done in batting and bowling aspects of this sport [1]. One of the conclusions of the study conducted by Hazari *et al.* 2016 shows that there is higher risk of injuries in wrist due to Yorker deliveries while risk of shoulder injuries is more while delivering bouncer [2]. This previous work, of Hazari *et al.* [2], is carried forward in the purposed experimental study but in different setting & environmental attributes and the data is examined with different statistical approach.

1.1 Bowling: Significant aspect of Cricket

Bowling, in Cricket, is generally defined as to deliver a 156g cricket ball towards the batsman or his wicket [2]. In the purposed study due to the consideration of the simulated cricket pitch instead of using a general leather ball, used in cricket, a tennis ball of about the same weight was used. To effectively deliver a ball proper body momentum is required and in order to obtain a linear momentum bowlers tend to start bowling with a smooth and rhythmical run-up. While delivering the ball this momentum is carried from feet to the upper body over the front leg of the delivery stride of the bowler [3]. Due to the sequential proximal-to-distal muscle contraction sequential proximal-to-distal joint rotations are generated in the hand, these joint rotations thus produce the hand acceleration [4]. Different bowling zones on the cricket pitch have been classified by the International Council of Cricket (ICC). According to this classification, the area anywhere in the centre of the pitch is termed as Short length (here bouncer is bowled), area 2m away from batting stumps is called Yorker length, further there are full length area and good length area. Yorker and bouncer deliveries are considered to be the most prominent ones amongst the rest of the deliveries bowled by fast bowlers in cricket. As per the ICC, if the bowler drops the ball anywhere in the short length area and targets the level of chest of the batsman than it is called Bouncer, while when the bowler targets the ball in the Yorker length area near the toes of the batman than it is called Yorker delivery.

1.2 Fast Bowling: Concerned Biomechanics

Although cricket is a non-contact sport, playing this game can cause several injuries. Physical demands involved in high-level cricket have been frequently said to be the cause of overuse injuries in cricketers, especially fast bowlers. The study done by Bartlett in 2007 [1] shows that non-contact wrist and shoulder injuries can be caused due to fast bowling. Based on the close analyses of the biomechanics involved in the functioning of the joints, muscles and ligaments and the amount of stress they are placed during fast bowling understanding the mechanism of these non-contact injuries gets simple.

In Cricket, unlike baseball, bowling is not about throwing the ball. As per the ICC regulations on legality of bowling action, to call a ball as fair or legal delivery than while delivering there should be a full swing or rotation of the bowling arm from the instance it reaches the shoulder length to the instance when the ball is released from the hand, with elbow not exceeding or bending more than 15° between these two instances [5]. Mainly, when the eccentrically contracting exterior rotators gets week, due to muscular strain, and can't steady the concentric contraction against the interior rotators, there is imbalance in the muscles and the fast bowlers get vulnerable to shoulder injuries [6]. Due to the fast arm rotations involved while delivering a fast ball in cricket puts great pressure on the shoulder joints and muscles which can further cause shoulder injuries. On similar grounds, by understanding the biomechanics involved in the wrist and forearm areas of the bowling arm the injuries in these regions of the arm can easily be interpreted. Cricket bowlers tend to jerk their wrist, at the time of delivering the ball, so as to produce more bowling speed [7]. An equivalent amount of strain is felt in the forearm and wrist muscles due to this jerk. In the purposed study it is assumed that Yorker and Bouncer deliveries, due to their frequent use, are correlated with more occurrences of strains in forearm and biceps muscles, respectively. This proposed study can be important in showing the muscular stress in the bowling arm through the electrical activity in different muscles while bowling Yorker and Bouncer deliveries.

1.3 Electromyography in Fast Bowling

Due to lot of muscular activity involved in the fast bowling it is required to properly understand its effect on the muscles. The contraction of the muscles and the electrical activity pattern associated with it is most commonly studied using the Electromyography (EMG) [8]. According to another study, it is depicted that as the muscular load is increased there is a linear increase in effective value of the EMG signal [9]. One of the fundamental ways to analyze the muscular activity through electrical activity and to record that activity is surface EMG [2], additionally surface EMG is a convenient non-invasive and scientifically established method used to study about the timing and the amount of the electrical activity of the muscle right through the muscular movement. As per our exploration little amount of research work has been done to analyze the EMG response of the muscular motion of the bowling arm thus opening lot of space for the further research to analyze the muscular activity using the surface EMG.

1.4 Aims and Objectives

This study is done with the aim of observing and analyzing the EMG activity in bowling arms of the amateur medium fast bowlers with certain set of objectives as follows:-

i. To trace the EMG signal from the Biceps Brachii (BB) muscle while delivering 'Yorker' and 'Bouncer' balls and examine the RMS value of the EMG for the duration of delivering the ball.

ii. To trace the EMG signal from the Palmaris Longus (PL) muscle while delivering 'Yorker' and 'Bouncer' balls and examine the RMS value of the EMG for the duration of delivering the ball.

iii. To statistically analyze the RMS values considering both the muscles, i.e. Biceps Brachii and Palmaris Longus, for each delivery (Yorker & Bouncer) being bowled one by one and on the basis of this analysis depicting the difference in the electrical activity in the muscles, if any.

2. METHODOLOGY

2.1 Participants

A total of 17 male participants including 1 left handed and 16 right handed medium-fast bowlers were recruited for the purposed study work. The basis of choosing the aforesaid sample size was the previous studies separately conducted by Hazari *et al.* 2016 [2] and Ahmed *et al.* 2014 [8]. All the participants were given a briefing about the bowling experiments to be conducted through their help and all of them were informed about the statistical analysis to be done after acquiring the EMG signals from the two muscles of their bowling arm and for both the permissions every participant gave their consent. In Fig. 1 an image of a participant is shown while bowling one of the deliveries. Criteria for selecting the participants was based on their cricketing history and chosen bowlers were the ones who have regularly played and bowled in their school, college, or university and have good amount of idea about the game of cricket. The statistical data of the bowlers who took part in experimental study is as follows (mean $\pm$ SD) : n=17, age (years) = 25.18±2.43, height (cm) = 174.05±4.14 and weight (kg) = 68.94±6.18.

Fig. 1: Image of a participant while bowling.

2.2 Experimental Set-Up

The experimental design for conducting the purposed study was done in the Research Laboratory in Electrical Engineering Department, M.I.T.S, Gwalior. In order to smoothly carry out the experiments with all the participants the issue regarding the safety of the equipments and the unfavorable outdoor conditions was considered and thus an indoor arrangement was done for conducting the study. Hence due to this concern of safety and outside environment a 22 yard cricket pitch was simulated just outside the laboratory while the concerned equipments were kept inside the laboratory. The batting end on the simulated pitch is shown in Fig. 2, while Fig.3 shows the bowler's end.

Fig. 2: A participant standing at the batting end.

Fig. 3: A participant ready to ball from the bowling end.

2.3 Familiarization with the Experiment

According to the availability and concerned will of the volunteers, the bowling trials were executed on different days and trials got over within 3 and half weeks. Before starting the individual experiments with different participants, each of them on their respective turn were given an overview session regarding the simulated pitch and the set-up used for recording the data. After this overview each bowler was asked to ball few deliveries, according to their satisfaction, just to get familiarize with the bowling areas on the pitch. Based on a study concluding that a run-up of 14 yards was enough to deliver a fast ball at a speed of 37 m/s [10], a run-up of 14 yards was provided at the bowling end.

2.4 Overview of the Experiment

The proportions of batting and bowling crease and length (2012 cm) of the simulated Cricket pitch are in accordance with the guidelines of the ICC and have been measured and marked on the pitch with the help of a meter tape. The width of the corridor used to simulate the pitch, was almost the same as that of the standard width of 305 cm. The Yorker area is represented on the pitch by marking a line with blue-coloured adhesive tape and the letter 'Y', with red tape, was written within the line to specifically point out the Yorker length. Similarly using the red tape a horizontal line was marked, to show the Short pitch (Bouncer) length, just about the centre of the pitch and letter 'B' was represented using the blue tape to clearly make it visible to the bowlers where the short length is. Both these areas are shown in Fig. 4 and Fig. 5 respectively.

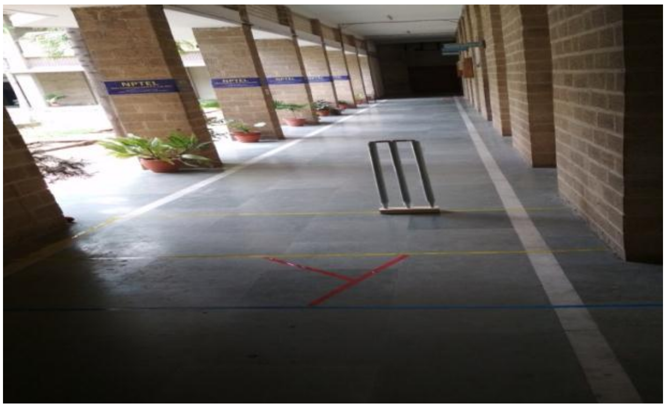

Fig. 4: Letter 'Y' pointing the Yorker length on pitch.

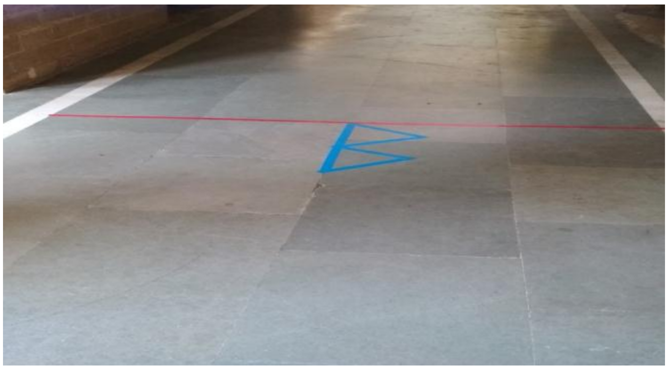

Fig. 5: Letter 'B' pointing the Bouncer length on pitch.

2.5 Sensor Positioning

On the basis of the readings of Hazari *et al.* 2016 [2] wireless-sensors were positioned around the centre of the muscle on the skin surface. These sensors were placed by applying double-sided adhesive tapes. The sensors are capable of communicating with the Trigno EMG wireless system (model: SP-W02A-1849), kept along with desktop in laboratory. The communication range of this system is about 20 m, i.e., each sensor can send the signal to the system within this range. The area of the pitch is so selected that it falls within the reach of transmitting range of the system. In the desktop, the software Trigno EMGworks® Acquisition and Trigno EMGworks® Analysis were used for presenting, monitoring and analyzing the EMG recordings. The wireless system communicates with the mentioned software using a USB cable. For the purpose of synchronization a camera of a phone was employed for the visual recording of the bowling experiments, so that the delivery timing of the ball can be matched with that of the EMG being seen on the desktop inside the laboratory. The work done by Hermens *et al.* 1999 [11] lays down the guiding principle for placing and orienting the sensors.

Fig. 6 shows one of the sensors employed for the said study; the backside of the sensor, which is placed on the skin surface, having electrodes is being shown in Fig. 7. The EMG hardware, placed inside the laboratory is shown in Fig. 8. The system is having a capacity of holding and working with 16 sensors at a time, but for our study only 2 sensors were used. The EMGworks® Acquisition software generates 16 EMG and 48 acceleration channels. As our study is employing only two sensors, thus only 2 such EMG channels were selected. First channel is for data obtained from the Biceps Brachii muscle, while second channel is used for signal obtained from the Palmaris Longus muscle. Fig. 9 shows one of the participants with sensors placed on both the muscles of interest.

Fig. 6: Wireless sensor used for acquiring EMG.

Fig. 7: Electrodes on the backside of the sensor.

Fig. 8: Trigno EMG wireless system (SP-W02A-1849).

Fig. 9. Sensors on muscles using Double-Sided Adhesive tapes.

2.6 Data Acquisition and Analysis

After each sensor was assigned a channel in the Trigno EMGworks® Acquisition software gain value of 300 was given to each channel in the hardware section of the software. Then, to increase the accuracy of deliveries, each participant was given few trials as per their satisfaction. A 50 seconds window was selected in both the channels of afore mentioned software for the purpose of recording the EMG signals obtained through the respective wireless sensors. But for the purpose of the study only that duration of the signal is significant which is recorded at the time of delivering the ball. The interval from the instance of bowler first landing on his front leg to the instance of him releasing the ball out of his bowling hand is considered as the duration of bowling the delivery [2]. Camera of Xiomi-Redmi4 mobile phone was used for recording the videos of all the participants. The camera was initially placed near the system kit and the video recording began simultaneously with the EMG recording for the purpose of synchronization of timing between the raw signal being recorded in the used software and that of the recorded visuals of the bowler. After synchronizing the camera was brought out, within hardly any time, to visually record the bowling experiment and bowler was called out for delivering the required ball. Until satisfactorily observed that the ball was delivered in the required area, under the given time limit, the process was repeated again and again.

Once acquisition of the EMG data for each respective participant was properly done, these raw signals for the purpose of analysis were saved. In the Trigno EMGworks® Analysis software Root Mean Square (RMS) values were obtained for the interval of delivering the ball. The RMS values were obtained by using the analytic set-up of the software only. For this purpose of calculating the RMS values two vertical cursor lines, available in the window showing the raw data in the software, were used to mark the EMG signal over the interval of bowling the delivery. EMG signals, along with the cursor lines marked in yellow and pink colours, for both the concerned muscles of one participant bowling the Yorker delivery are shown in Fig. 10 & Fig. 11 and that for Bouncer are shown in Fig. 12 & Fig. 13. The marking of the raw data in each channel using these cursor lines was made by matching its timing with the duration of delivering the ball as seen through the video recordings. Then the RMS value for the selected region using the cursor lines was easily calculated for both the muscles of every participant delivering the respective delivery. In Fig. 10 to Fig. 13, x-axis represents time in seconds while y-axis indicates the EMG magnitude in volts.

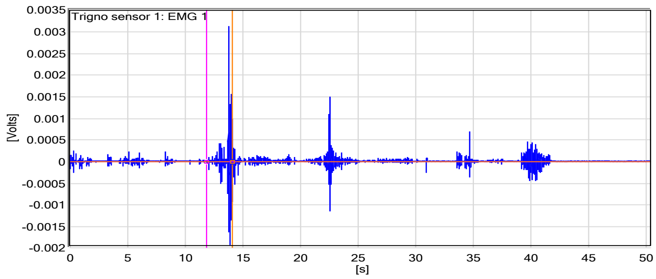

Fig. 10: EMG signal acquired for BB-muscle of a Participant bowling Yorker ball.

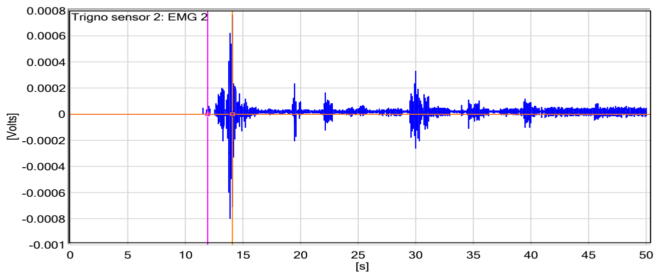

Fig. 11: EMG signal acquired for PL-muscle of a Participant bowling Yorker ball.

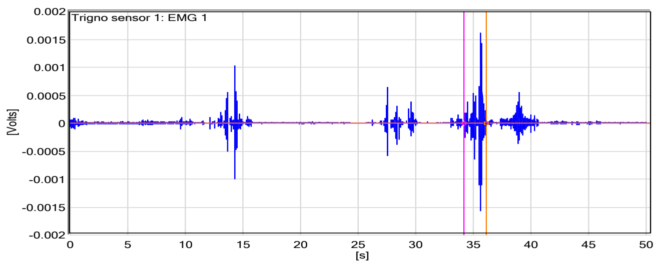

Fig. 12: EMG signal acquired for BB-muscle of a Participant while bowling Bouncer ball.

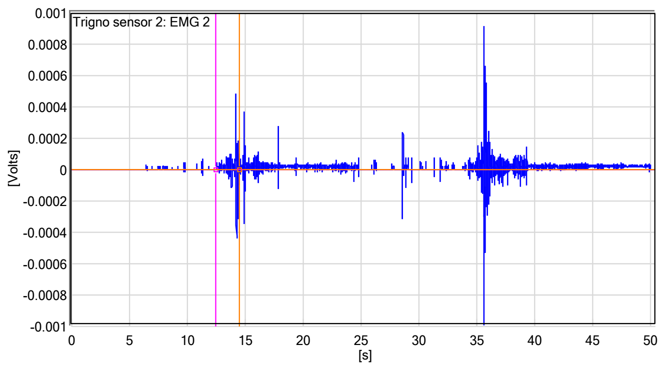

Fig. 13: EMG signal acquired for PL-muscle of a Participant while bowling Bouncer ball.

2.7 Statistical Analysis

The purpose of the Statistical Analysis is to determining the significant difference between data of two muscles for each delivery, i.e., to analyze the difference, if any, in the electrical activity between two muscles once delivering the Yorker ball and once delivering the Bouncer ball.

To find if the data for two muscles differ significantly or not for each type of delivery first of all test of normality is to be conducted so that it can be known what test should be used for further analysis. To confirm the normality of the data Shapiro-Wilk test, along with Histograms and q-q plots, was performed and then afterwards Friedman's test for Yorker and Independent t-test along with one-way ANOVA for Bouncer delivery was done to statistically analyze if there is any significant difference among data of concerned muscles.

Here, for the Normality test Null-Hypothesis is that the respective sets of data are normally distributed, while the Null-Hypothesis for descriptive tests is that there is not a significant difference between the data of group considered. If the test statistics comes to be less than the significant value then this null- hypothesis can be rejected. **SPSS Statistics** software is used for conducting all the tests.

The SPSS software doesn't necessarily require writing a program or algorithm in order to get the required output. All that we have to do is to enter the obtained data values, specify the data variables and give the appropriate command, i.e. the software has inbuilt algorithm to obtain the results for the specified tests. Although, the "Log File" for the particular output corresponding to the data variables and values as entered by us is obtained in the output window itself. These "Log Files" record the events that occur in the software while obtaining the results of the required tests. Such software records of all the statistical tests done in this study are given here.

Log File for Normality Test

```
GET
FILE='C:\Users\user\Desktop\Desktop\SPSS Stats.sav'.
DATASET NAME DataSet8 WINDOW=FRONT.
EXAMINE VARIABLES=YorkerBB YorkerPL BouncerBB
BouncerPL
/PLOT BOXPLOT HISTOGRAM NPPLOT
/COMPARE GROUPS
/STATISTICS DESCRIPTIVES
/CINTERVAL 95
/MISSING LISTWISE
/NOTOTAL.
```

Log File for Independent t-Test

```
GET
FILE='C:\Users\user\Desktop\Desktop\Paramwtric Test
(bouncer).sav'.
DATASET NAME DataSet2 WINDOW=FRONT.
T-TEST GROUPS=Group(0 1)
/MISSING=ANALYSIS
/VARIABLES=BouncerRMS
/ES DISPLAY(TRUE)
/CRITERIA=CI(.95)
```

Log File for One-Way ANOVA Test

```
GET
FILE='C:\Users\user\Desktop\Desktop\Paramwtric Test
(bouncer).sav'.
DATASET NAME DataSet4 WINDOW=FRONT.
ONEWAY BouncerRMS BY Group
/MISSING ANALYSIS
/CRITERIA=CILEVEL(0.95).
```

Log File for Friedman's Test

```
GET
FILE='C:\Users\user\Desktop\Desktop\SPSS Stats.sav'.
DATASET NAME DataSet5 WINDOW=FRONT.
NPAR TESTS
/FRIEDMAN=YorkerBB YorkerPL
/STATISTICS DESCRIPTIVES
/MISSING LISTWISE.
```

The significant difference in the electrical activity, if any, between the two muscles is obtained through the statistical analysis of the RMS values for both muscles as given in Table 1. The statistical value was taken at $\mathbf{p \leq 0.05}$ for the given case of analysis. For the purpose of Inferential statistics (Mean and Standard Deviation) of the data calculated for either of the muscles SPSS software was used.

Further, in order to relate the results of the statistical analysis with the stress produced in the muscles one of the previous studies done by Fukuda in 2010 is used, in this study it was shown that there is a linear relation between the RMS values of the electromyographic signal of a muscle and the stress produced in that muscle [9], i.e.,

$$S \propto RMS_{EMG} \quad (1)$$

Where,

S is Stress in the muscle, and

RMS_{EMG} the RMS value for the EMG signal from muscle.

Table-1: RMS values of the EMG Data in the time interval of bowling the respective deliveries by each bowler.

Bowlers	Root Mean Square values (in volts) calculated from Electromyogram obtained for both the muscles while bowling each delivery			
	Bowling Yorker		Bowling Bouncer	
	BB-muscle	PL-muscle	BB-muscle	PL-muscle
Bowler 1	.07054	.06912	.05187	.03483
Bowler 2	.03946	.03443	.03504	.04118
Bowler 3	.02215	.02949	.02790	.02466
Bowler 4	.05569	.02636	.05153	.04962
Bowler 5	.05382	.05901	.04196	.01909
Bowler 6	.02135	.04524	.04980	.04477
Bowler 7	.15196	.05614	.06584	.05445
Bowler 8	.02358	.01188	.05880	.05914
Bowler 9	.03316	.01902	.06089	.02486
Bowler 10	.01232	.05298	.10177	.04514
Bowler 11	.02408	.03181	.06550	.03987
Bowler 12	.04277	.02704	.04816	.02803
Bowler 13	.02659	.10632	.04882	.03172
Bowler 14	.03073	.03070	.02325	.05922
Bowler 15	.02278	.05244	.06536	.03504
Bowler 16	.06605	.02348	.04322	.04056
Bowler 17	.03724	.05105	.09098	.03383

3. RESULTS

This section shows some key findings determining the statistical variation, between the RMS values acquired for both muscles, considering interval of bowling the each delivery one by one. Table 2 shows the results of the Shapiro-Wilk test. This normality test clearly shows that the data is normally distributed for all data groups obtained from the respective muscle while bowling the said deliveries except for the case of BB-muscle while bowling Yorker; hence the Friedman's test (non-parametric) is to be done to check for the Statistical difference in the muscles while bowling Yorker, while independent t-test along with One-way ANOVA is done to statistically analyze the difference in electrical activity while bowling bouncer.

Table-2: Findings of the Shapiro-Wilk Test done on RMS values for both the deliveries

Bowling Different Deliveries	While Bowling Yorker		While Bowling Bouncer	
Muscle	BB-muscle	PL-muscle	BB-muscle	PL-muscle
p-value	0.0	0.065	0.289	0.758

Table 3 gives the findings of different tests in the statistical analysis to know if data is significantly varied or not and also shows other inferential statistical data obtained for both the cases. The p-values, so obtained, are instrumental in determining the significant dissimilarity between electrical actions in concerned muscles for interval of delivering each ball.

Table 3. Results of different tests in the Statistical Analysis.

Delivery	Muscles	Mean ± Std. Deviation (RMS values of EMG in volts)	Tests	p-value for different tests
Yorker	BB-Muscle	0.0431929 ± 0.03258690	Friedman's Test	0.808
	PL-Muscle	0.0427378 ± 0.02286841		
Bouncer	BB-Muscle	0.0547472 ± 0.02007543	Independent t-test	0.010
	PL-Muscle	0.0391775 ± 0.01193621	One–way ANOVA	0.010

4. DISCUSSIONS

To analyze the EMG signals Root Mean Square (RMS) values are often used. Generally RMS value of electric voltage is defined as the effective value of that varying voltage. To relate the amount of electrical activity produced in muscle with the stress in the respective muscle we have referred to one of the previous studies, as given in equation (1). Thus by using the equation (1) the inferential statistics, i.e. the mean of the RMS values calculated for both the muscles for respective delivery, can be directly related to the stress produced in the muscle. In this section discussion is done on the results obtained for the concerned statistical analysis and on the basis of which certain outcomes are provided.

4.1 While Bowling Yorker

Considering the comparative statistical analysis between both the muscles while bowling Yorker delivery the **Friedman's test** clearly suggest **no** significant distinction among data acquired from both muscles for time interval of delivering the particular ball with **p-value** being equal to **0.808**. Although from the inferential statistics it can be easily seen that RMS values are higher for the EMG data obtained for PL-muscle compared to that for the BB-muscle.

4.2 While Bowling Bouncer

As for this delivery the data set obtained from all the participants came out to be normally distributed, parametric tests were done to check for the statistical difference. The **p-value** obtained from the **independent t-**

test while bowling Bouncer delivery is **0.010**, while that for One-way **ANOVA** test also the **p-value** is **0.010**. This comparative analysis clearly indicates there is significant variation among data acquired from both muscles for interval of completing the particular delivery.

4.3 General Outcomes

Following Deductions are straightforwardly made through the above discussion.

First Outcome: Considering the effect of Yorker delivery on each muscle, as discussed that there's not a very considerable variation among data acquired from either of muscle for completing Yorker ball, thus we can't infer that which muscle is under more strain for this particular delivery by using inferential statistics. To say that both muscles will be equally strained or to call either of the muscles being under more muscular load while bowling Yorker delivery will be incorrect as suggested by Friedman's test.

Second Outcome: As suggested by both independent t-test and one-way ANOVA there is a significant difference between the data set obtained for the two muscles while bowling bouncer, so we can infer the statistics. For the concerned set of population, by using the inferential statistics and the equation (1) it can be easily said that mean of the RMS values obtained for BB-muscle is more when compared to that of the PL-muscle while bowling Bouncer and thus it can be predicted that more stress is in BB-muscle for delivering this ball.

5. CONCLUSIONS

It can be now said through the statistical study that particularly for Bouncer deliveries the electrical activity produced varies significantly in both the muscles making Biceps Brachii under more muscular stress compared to Palmaris Longus. During Yorker balls the two muscles considered for the study don't show significant difference in their electrical activity, so comparative effect of muscular strain in either of the muscles can't be concluded while bowling Yorker deliveries for the considered statistical population.

6. LIMITATIONS

As the concerned instrument was not available, the speed with which ball was delivered couldn't be measured. So employing a speed gun will make the study more productive. The muscular acceleration in the muscle was acquired but couldn't be utilized due to finiteness of the purposed work. The analysis of this acceleration can also help in understanding the mechanics involved in the process of bowling. Analysis of kinematics and kinetics of the muscular activity could have further enhanced the understanding of the fast bowling motion.

7. ACKNOWLEDGEMENT

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