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Original Article

Electromyographic evaluation of upper extremity muscles during forehand and backhand table tennis drives

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Abstract
This study aims to identify the Electromyographic comparison of upper extremity muscles during table tennis drive (forehand and backhand topspin drive). The idea behind conducting this research was to figure out the relative contribution of selected muscles of the upper extremities while performing forehand and backhand Table Tennis Drives. Many studies have been published before where EMG analysis was done on Forehand drive. The present study uses a comparative approach to observe meaningful and statistically valid differences in EMG analysis while performing Forehand and Backhand Drives. Observed Root mean square (RMS) values provided by EMG-analyzer were taken into consideration for analysis. For the compilation of the study a total of Fifteen (15) female university table tennis players who were right-hand dominant (age 21.2±2.3 years, height 161.9±7.8 cm and body mass 62.2±6.9 kg) and had a minimum of six years of playing experience selected as sample for this study. The selected upper extremity muscles based on reviews were flexor carpi radialis (FCR), extensor carpi radials (ECR), biceps brachii (BB), pectoralis major (PM), anterior deltoid (AD) and stomach oblique (SO). The EMG signals data was collected through Wireless surface electromyography having eight channels. A fixed window of 100 ms was used to calculate the RMS (root mean square) value of the signals. One-way ANOVA was used as a statistical technique for comparison and a separate post-hoc test was conducted for pairwise comparison. The study concludes that Pectoralis Major and Anterior Deltoid muscles are important factors for forehand and backhand topspin drive.

Keywords: Electromyography, Table Tennis, Forehand Drive, Backhand Drive, Upper Extremity Muscles.

Introduction

Table tennis is recognized as the quickest ball game in the world. Players execute short distances during rallies as table tennis is conducted on a small field. To hit the ball effectively, players should be capable of completing fast powerful movements to change direction immediately and quickly(Le Mansec et al., 2018).

Table tennis is a challenging game that requires a unique balance of speed, deceleration, trajectory change, and balance awareness to generate adequate strokes. To understand the skills required to be successful in competitive tournaments, skilled performers should train for many years. Footwork and stroke are the two aspects of table tennis movements. Footwork contains a variety of activity variations (e.g., one step, short steps, and crossover) some of which are executed at varied frequencies and with a high level of agility. The stroke entails a variety of sport-specific tactics (for example, drive, chop, and block) and is executed at various frequencies with various forms of spin applied to the ball(Li et al., 2020).

A top table tennis player should have tremendous physical ability, technical ability, and tactical awareness. The goal of a table tennis player's basic training is to minimize the stress that exercises place on the body so that any level of physical activity can be accomplished more easily and a large number of sessions can be performed(Kondri et al., 2010).

Table tennis's main attacking techniques are both the forehand and backhand drives. The comparison between forehand and backhand drives is an interesting topic for table tennis players to analyze. Table tennis research has previously focused on the actions of forehand strokes. This includes research such as Kasai & Mori's (1992) assessment of the forehand table tennis drives' movement pattern. According to Yoshida, Sugiyama, and Murakoshi (2004), the time between the ball rebounding on the table and the contact point of forehand drives was approximately 0.2 seconds (Tsai et al., 2010) observed those table tennis players were using the forehand drive to enhance the racket path angle during the upswing phase as well as to increase the racket tilt angle in advance(1Hsin-Hsueh Huang, 2Yi-Chang Hsueh, 2Yu-Yuen Chen, 2Ting-Jui Chang, 2013).

The tennis serves sEMG investigation was utilized to discover patterns of muscle activation in the lower trunk (Chow et al., 2003). The frequency of integrated electromyography of a forehand backspin was observed to be higher than that of a forehand forespin(Tsai et al., 2010). The tibialis anterior muscle was involved initially

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during the push-up with the leg muscles, followed by the waist, shoulder, wrist, and hand, and ultimately the full impacting movement (Gołaś et al., 2017). In previous studies, we found that performance levels are linked with movement features(Fu et al., 2016).

The purpose of this study was to compare the EMG variables among those six muscles for the contribution of muscles in the forehand and backhand drive. A separate analysis was also conducted to identify the muscles whose contribution was highest during forehand and backhand drives.

In the process of the literature review it was noticed that in the game of Table Tennis, there is a scope for researching backhand drive, as in the past most of the studies have been conducted on forehand drive only. To study the actual difference in electrical activity produced inside selected muscles of the upper extremity, a reading of the root mean square was recorded.

The outcome suggests that the approach may effectively anticipate individual muscle forces during forehand and backhand drives, allowing us to gain a better knowledge of the dynamic movement process in humans. In this paper, we first describe the course of action in the process. Next, we compare the individual muscle forces of forehand and backhand drives. Finally, we reach a conclusion that might be useful in a methodical, and scientific training of Table Tennis.

Material & Methods

Subjects

In this study, 15 female university table tennis players who were right-hand dominant were included (age 21.2±2.3 years, height 161.9±7.8 cm, and body mass 62.2±6.9 kg). Limb dominance was selected by asking the subjects about which hand they would prefer to hit the ball. During the data collection, the participants had a minimum of six years of playing experience. Only physically active participants who had no recent record of the upper extremity, spinal, or neurological injury that may affect muscular force during the drive were chosen as participants. Before data collection, the participants were requested to sign written consent forms, and the technique for EMG recording was explained clearly to them. The departmental research committee of the Lakshmibai National Institute of Physical Education authorized the study's conduct by the Helsinki Declaration(Nijhawan et al., 2013).

Figure 1: Surface Electromyography (Bioengineering, 2011).

Procedure

As a part of the warm-up, the subjects performed five minutes of dynamic stretching, surface electrodes were attached to selected muscles of the upper extremity, including the Flexor carpi radialis (FCR), extensor carpi radials (ECR), biceps brachii (BB), pectoralis major (PM), anterior deltoid (AD), and stomach oblique (SO). The skin surface where the electrodes were placed was cleaned with alcohol and shaved when felt necessary. Electrodes were placed over the belly of each muscle parallel to the muscle's line of action with a center-to-center distance of 2.5 cm.

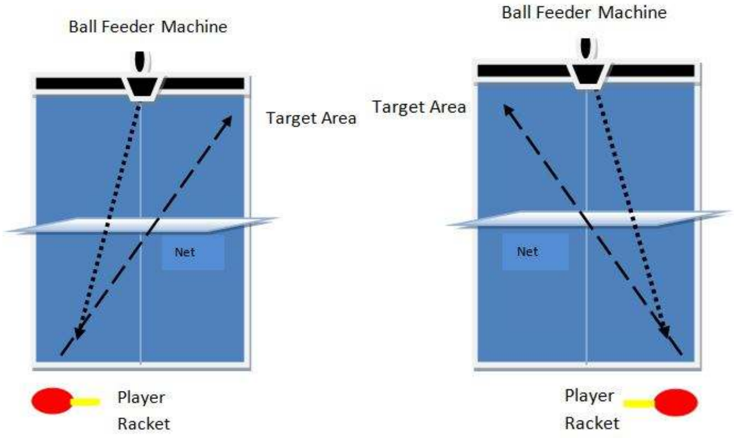

Figure 2 **Figure 3**

Figure 2,3: Set up for separate analysis of forehand and backhand drive skills and EMG recording.

The SENIAM (Surface Electromyography for Non-Invasive Assessment of Muscle) group's recommendations were followed for the procedure of electrode placement in the muscles. Wireless surface electromyography with eight channels (BTS FREEEMG, S.P.A., Italy) was used for the acquisition of EMG signals from the selected upper extremity muscles. In all trials, the participants served with an effort comparable to their serves during competition. In the test, athletes performed following a self-selected action to moderate the ball, which was served by a special table tennis ball machine previously calibrated; the ball machine throw the ball for up to 10 sec for each skill and the test was repeated three times. Tests were conducted in a table tennis hall of the Institute. The floor was made of synthetic rubber which was at par with training and competition courts. The ball machine was placed 1.2 m away from the opponent's court and it was used to project backspin balls directly to the backside of the subjects' court. Sufficient time was given for participants to warm up and familiarize themselves with the measuring instrument. Since players were proficient in the backhand backspin loop technique, only a brief instruction was needed to ensure the motion quality. During testing, participants were asked to perform the skill one by one(forehand and backhand drive) continuously. At least three successful trials were performed for each subject. The smoothness of arm movement was judged by the players themselves and the quality of the skill was supervised by their coaches. Data were collected separately for both skills in three trials(Wang et al., 2018).

Data Analysis

Analysis of the EMG signals was carried out in BTS EMG Analyzer software (version 2.9.40.0). The EMG signals were bandpass-filtered using the Butterworth smoothing technique with a lower cut-off frequency of 20 Hz and a higher cut-off frequency of 400 Hz. A fixed window of 100 µs was used to calculate the RMS (root mean square) value of the signals(Karlsson et al., 2000). The maximum activation was assessed using interpolation of an electrical stimulus to all or part of the nerve supply to a muscle during maximum voluntary effort(Halaki & Gi, 2012).

Statistical Analysis

IBM SPSS (version 20.0.0) software was used for the statistical analysis of the acquired data. The Shapiro-Wilk test detected normal distribution of the data **$p<0.05$**, and parametric tests were thus applied. One-way ANOVA was conducted to compare muscle activation in the upper extremity (including muscle activation in both forehand and backhand drive), and separate one-way ANOVAs for forehand and backhand drive were also performed. A Tuckey HSD post hoc test was conducted for pairwise comparison.

Results:

There was a significant difference in upper extremity muscle involvement during forehand and backhand table tennis drive ($p<.05$) Table 2.

Table 1. Descriptive Statistics of Upper extremity muscles (RMS) activation during Forehand and Backhand Drive Table Tennis Drive

Muscle	N*	RMR values during muscle activation				Mean		SD	
		Max.		Min.					
		Forehand Drive	Backhand Drive	Forehand Drive	Backhand Drive	Forehand Drive	Backhand Drive	Forehand Drive	Backhand Drive
Anterior Deltoid	15	482.87	480.11	155.54	109.79	323.93	281.78	97.81	117.32
Biceps Brachii	15	251.88	239.85	106.81	101.45	179.31	154.17	52.30	46.48
Flexor Carpi Radialis	15	279.21	244.00	158.69	102.68	204.02	161.35	36.34	42.40
Extensor Carpi Radials	15	184.99	241.58	82.42	89.20	125.29	142.03	28.62	44.03
Pectoralis Major	15	519.71	456.77	238.71	87.84	365.62	231.91	101.55	96.28
Stomach Oblique	15	183.20	368.37	49.81	27.33	117.24	118.77	44.08	82.93

Abbreviations N= Number of Participants; **Max=** Maximum Range; **Min=** Minimum Range; **SD=** Standard Deviation

Anterior deltoid and pectoralis muscles are activated largely in forehand drive and backhand drive compared to extensor carpi radialis and stomach oblique which show less activation. When comparing upper extremity muscles activation during forehand and backhand drive larger maximum and minimum activation differences were found in stomach oblique and pectoralis major Table1.

Table 2. ANOVA table for the data on Upper Extremity Muscles Root Mean Square

Stroke	Group	Sum of squares	df	Mean Square	F	Sig. (p-value)	Partial η2	Levene Statistic
Forehand Drive	Between Groups	801678.72	5	160335.74	36.14	**.000**	.683	8.96(.000 sig.)
	Within Groups	372621.99	84	4435.98				
	Total	1174200.71	89					
Backhand Drive	Between Groups	288621.95	5	57724.39	9.67	**.000**	.365	4.81(.001 sig.)
	Within Groups	501304.12	84	5967.91				
	Total	789926.07	89					

About Table 2, it can be inferred that the main effect of the drive (forehand and backhand) is significant as the obtained p-value **.000< 0.05** the accepted level of significance. From the above table, it can be inferred that the action potential generated by 6 selected muscles is not the same for all cases. A similar trend was observed for each drive.

Table 3. Forehand Drive data Post hoc comparison of means using Tukey's HSD test

All Muscles (I)	All Muscles (J)	Mean Difference (I-J)	Std. Error	Sig.
Anterior Deltoid	Biceps Brachii	**144.62****	24.32	**.000**
	Flexor Carpi Radialis	**119.91****	24.32	**.001**
	Extensor Carpi Radialis	**198.64****	24.32	**.000**
	Stomach Oblique	**206.69****	24.32	**.000**
Biceps Brachii	Anterior Deltoid	**-144.62****	24.32	**.000**
	Pectoralis Major	**-186.30****	24.32	**.000**
Flexor Carpi Radialis	Anterior Deltoid	**-119.91****	24.32	**.001**
	Pectoralis Major	**-161.60****	24.32	**.000**
	Stomach Oblique	**86.78****	24.32	**.034**
Extensor Carpi Radialis	Anterior Deltoid	**-198.64****	24.32	**.000**
	Pectoralis Major	**-240.32****	24.32	**.000**
	Biceps Brachii	**186.30****	24.32	**.000**
	Flexor Carpi Radialis	**161.60****	24.32	**.000**
	Extensor Carpi Radialis	**240.32****	24.32	**.000**
	Stomach Oblique	**248.38****	24.32	**.000**
Stomach Oblique	Anterior Deltoid	**-206.69****	24.32	**.000**
	Flexor Carpi Radialis	**-86.78****	24.32	**.034**
	Pectoralis Major	**-248.38****	24.32	**.000**

**The mean difference is significant at the 0.05 level.

Table 3. The following interpretations were made based on Post-hoc analysis for the forehand drive:

The observed electrical activity of the anterior deltoid muscle was significantly different than all other muscles except the pectoralis major. The observed electrical activity of the Biceps brachii muscle was significantly different than all other muscles except the flexor carpi radialis, extensor carpi radialis, & Stomach oblique. The observed electrical activity of the Flexor carpi radialis muscle was significantly different than all other muscles except the Biceps brachii, & extensor carpi radialis. The observed electrical activity of the Extensor carpi radialis muscle was significantly different than all other muscles except flexor carpi radialis, Biceps brachii, & Stomach oblique. The observed electrical activity of the Pectoralis major muscle was significantly different than all other muscles except the anterior deltoid. Observedelectrical activity of the Stomach oblique muscle was significantly different than all other muscles except the extensor carpi radialis, & Biceps brachii.

Table 4. Backhand Drive data Post hoc comparison of means using Tukey's HSD test

(I) All Muscles	(J) All Muscles	Mean Difference (I-J)	Std. Error	Sig.
Anterior Deltoid	Biceps Brachii	**127.60****	28.21	.002
	Flexor Carpi Radialis	**120.42****	28.21	.005
	Extensor Carpi Radialis	**139.74****	28.21	.001
	Pectoralis Major	**49.86**	28.21	.681
	Stomach Oblique	**163.00****	28.21	.000
Flexor Carpi Radialis	Anterior Deltoid	**-120.42****	28.21	.005
	Biceps Brachii	**7.18**	28.21	1.000
	Extensor Carpi Radialis	**19.32**	28.21	.993
	Pectoralis Major	**-70.55**	28.21	.293
	Stomach Oblique	**42.58**	28.21	.808
Pectoralis Major	Anterior Deltoid	**-49.86**	28.21	.681
	Biceps Brachii	**77.73**	28.21	.193
	Flexor Carpi Radialis	**70.55**	28.21	.293
	Extensor Carpi Radialis	**89.87**	28.21	.083
	Stomach Oblique	**113.13****	28.21	.010

**The mean difference is significant at the 0.05 level.

Table 4.-The anterior deltoid shows a significant activation difference in 80% of selected muscles, as compared to Biceps brachii, Flexor Carpi Radialis, Extensor Carpi Radialis, and Pectoralis major muscles showing a significant difference with only 20% of selected muscles during Backhand drive

During the Forehand Table Tennis Drive, Pectoralis Major and Anterior Deltoid mostly show significant differences with all selected muscles, but for the Backhand Drive, only the Anterior Deltoid was verified in Tables 3 & 4.

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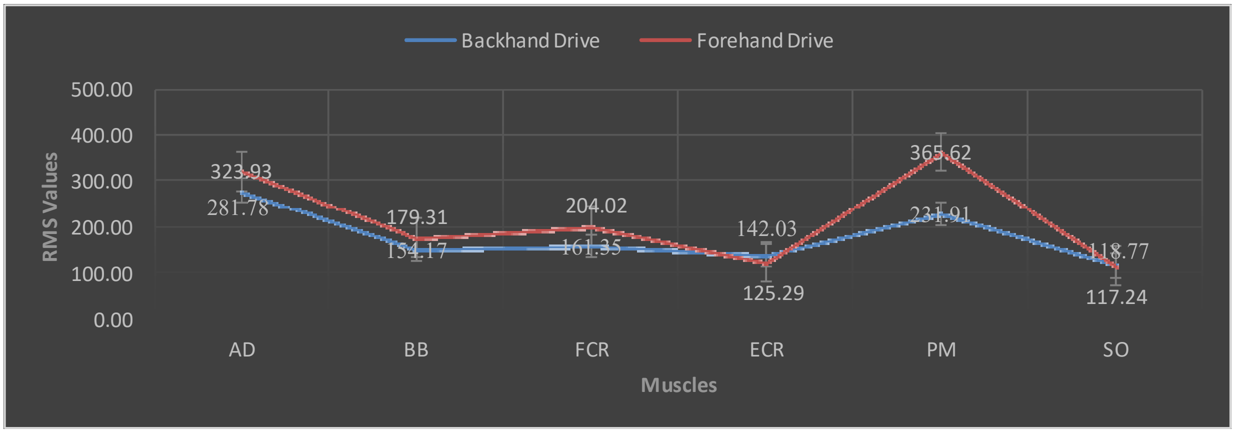

Figure 4. Normalized muscle activation of upper extremity muscles during Backhand drive and Forehand drive.

Table 5. Paired Samples t-Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	**Forehand Flexor Carpi Radialis** **Backhand Flexor Carpi Radialis**	42.67	42.45	10.96	19.16	66.18	3.89	14	**.002**
Pair 2	**Forehand Pectoralis Major** **Backhand Pectoralis Major**	133.72	81.17	20.96	88.77	178.67	6.38	14	**.000**

In table-5 mean differences among all intended pairs of independent variables have been shown. The prime focus of the investigation was to find out the significant difference in the RMS reading of a particular muscle at the time of execution of forehand and backhand drive skills. In column 10 pairs with significant mean differences have been highlighted with bold function.

Discussion:

The findings of the study show a significant contribution of selected muscles for forehand and backhand drive. In response to the research question that whether force generation differs in selected muscles at the time of execution of forehand and back-hand drive skill, the study found that out of six selected muscles, two muscles (Flexor Carpi Radialis & pectoralis major) were noticed to generate significantly different electrical activity for each stroke.

There was a significant difference in muscle activation during the forehand drive and backhand drive. Although all selected muscles contributed in forehand and backhand drive in table tennis, anterior deltoid, and pectoralis muscles show considerably larger contributions. Pectoralis Major and Anterior deltoid show a significant activation difference with 80% of selected muscles, as compared to Biceps brachii and Extensor Carpi Radialis muscles, which show a significant difference with only 40% of selected muscles during Forehand drive. During Backhand drive anterior deltoid shows significant activation differences in 80% of selected muscles, as compared to Biceps brachii, Flexor Carpi Radialis, Extensor Carpi Radialis, and Pectoralis major muscles which shows a significant difference with only 20% of selected muscles. The findings of this study also show similar muscle involvement patterns i.e. Pectoralis Major, Anterior Deltoid, Flexor Carpi Radialis, Biceps Brachii, Extensor Carpi Radials, Stomach Oblique for forehand and backhand drive except for Anterior Deltoid, which was much involved in backhand drive than pectoralis major.

(Kondric & Mandic 2002, Kondric, Furjan-Mandic & Medved, 2003) The study explains the value of strength in table tennis is no longer an issue of debate, we should be careful not to work on the development of massive strength exclusively. Our first concern should be to ensure all-round strengthening of the body and herewith to avoid injuries. When selecting exercises for a strengthening program, an analysis of movements involved in a particular stroke, in terms of type, speed, direction, etc., should be done to make sure which groups of muscles are involved in these movements(Maheshwari et al., 2022).

(Glousman et al., 1988; Gowan et al., 1987) also concerned with designing Special drill creation to replicate the pattern and tempo of movement of a genuine table tennis stroke execution as nearly as feasible. This will activate and train stroke-related muscle units, improving their specialized neuromuscular processes for specific performance. When performing arm elevation, dynamic Electromyographic tests of the four rotator cuff muscles were done and it was observed that all the four rotator cuff muscles, along with the Deltoid were found engaged throughout the range of motion, similar results were observed in the present research study too for the deltoid muscle.

In the process of generalization of the research findings of the present study, this would be wise to note the findings of a research study conducted by (Bosman et al., 1993) and (Clarkson & Tremblay, 1988; Balnave & Thompson, 1993). These studies discuss the importance of remembering that the speed with which a joint move during a stroke is influenced by the status of certain muscles, which might affect the joint's flexibility. Both ligamentous structures and muscles' ability to contract and relax is significant from this perspective. As a result, it is advisable that a table tennis player must have a high level of flexibility to aid movement and control a specific stroke performance. A well-known fact states that muscle damage can be avoided through exercise, whether it is concentric or eccentric.

Ogimura (1973) presented the first functional classification of individual muscles for certain table tennis techniques. His study reveals that multiple world champions with highly offensive style play, are heavily influenced by biceps brachii, deltoideus, pectoralis major, and abdominal muscles. Biceps brachii, he believes, is particularly significant because the muscle is responsible for arm bending during rapid forehand spin strokes. According to him, the proper functioning of the triceps brachii and the back extensor muscles is required for fundamental returns to be achieved. The findings of the present study are in line with the study of Ogimura 1973 where both studies agree that biceps brachii and pectoralis major plays a vital role in performing offensive strokes in Table Tennis.

However, findings based on Grana, Lombardo, Sharkey& Stone (1989) reveal that the deltoid muscle causes the dominant force providing arm elevation. The deltoid muscle's sheer force tends to displace the humerus in a cephalic direction opposed by the weight of the arm and the action of the rotator cuff musculature. The rotator cuff is critical for providing assistance in abduction, opposing the upward sheer force of the deltoid muscle, and providing for joint stability by glenohumeral compression.

Limitations:

In this research, we did not consider the rubber gluing, which could affect the measured parameters. Namely, several layers of glue can change the characteristic of rubber due to which the velocity of the ball can be enhanced. This study is limited to All India Inter-Varsity level university Table Tennis players who were right-hand dominant and had a minimum of six years of playing experience.

Conclusions:

The study concludes that except for flexor carpi radialis and pectoralis major, all other selected muscles contract more or less similarly while performing forehand and backhand drive skills in Table Tennis.

The observed results and graphical displays from this research study showed Pectoralis Major (PM) and Anterior Deltoid (AD) muscles with significant force differences from Flexor Carpi Radialis (FCR), Extensor Carpi Radials (ECR), Biceps Brachii (BB), and Stomach Oblique (SO) muscles.

This study concludes that Pectoralis Major (PM) and Anterior Deltoid (AD) muscles play a significant role in forehand and backhand topspin drive. From this point of view, greater interest is to be paid to the improvement of these muscles in the physical training of table tennis players. Qualified Table Tennis coaches should be focused on muscle training programs for a particular style of play.

Conflicts of Interest - The authors declare no conflict of interest.

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