

MYOELECTRIC COMPARISON OF TABLE TENNIS FOREHAND STROKE USING DIFFERENT BALL SIZES

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The aim of this study was to examine the differences between forehand top spin strokes with 38 mm and 40 mm balls in table tennis. The participant was filmed as he executed the strokes. To ensure the same condition for all the performances (the same approaching ball trajectory), a table tennis machine was used. Electrodes were placed on the right side of the player's body due to his right-handedness. Absolute muscle involvement was estimated on the basis of averaged EMG signals (mV) measured in all muscles (m. biceps brachii, m. deltoideus, m. pectoralis major). Analysis of variance (ANOVA) was used for calculating differences between overall mean values of averaged EMG signals among all muscles. The peak EMG amplitude of the m. deltoideus anterior reached a value of 2.5 mV, for the 38 mm ball stroke. The comparable contraction values in strokes with balls of both sizes were obtained with the m. deltoideus medialis: the peak values ranged between 2.3 and 2.8 mV with a 38 mm ball and between 2.2 and 3.0 mV with a 40 mm ball. For the m. biceps brachii the peak EMG amplitude ranged from 1 to 2.2 mV and from 1.3 to 2.4 mV for the 38 mm and 40 mm ball strokes, respectively. A similar result was obtained for the m. pectoralis major contractions. Rather uneven intensities of contractions were obtained for the 38 mm ball strokes, ranging from 1.5 mV to 2.6 mV. More balanced values were obtained for the 40 mm ball strokes ranging from 1.6 to 2.2 mV. These findings showed us that in three observed muscles (m. deltoideus anterior, m. biceps brachii, m. pectoralis major) differences in the intensity of EMG signals are significant, so we can conclude that the player uses more muscle activities in a stroke with the larger ball, and also we conclude that the contraction of m. pectoralis major is more powerful when the player hits the larger ball.

Keywords: Table tennis, forehand stroke, EMG, muscle activity.

INTRODUCTION

The ultimate concern in high-performance sport is the final performance, whether it is while training or at the competition. The final output that is observed is dependent on a complexity of factors. Each of them may contribute a variable amount to the performance. In modern table tennis we have changed some rules and some materials due to slowing down the game. But, nevertheless, the majority of top-level players prefer to concentrate on attacking or counter-attacking. Most international competitors favour the forehand spin stroke to produce high velocity and high rotation. However, the stroke angle has been changed since the circumference of the ball has been enlarged. The shoulder girdle muscles are today exposed to different loads than before because shoulder abduction should be performed more quickly and vertically now.

Physical conditioning and strength training, as well as modern physical fitness diagnostic procedures are becoming ever more important in the contemporary sports training process, including table tennis. In the

course of table tennis history, systematic programmed training has become more important after attack strokes have been introduced. Numerous injuries to the shoulder girdle muscles compel us to investigate the strains to which individual muscles are prone in the execution of certain table tennis strokes (Priest & Nagel, 1976; Dervišević & Hadžić, 2002). Some specific tests allow the measurement of specific fundamental factors that are assumed to be important in the performance.

The first functional classification of individual muscles according to certain table tennis techniques was presented by Ogimura (1973). A multiple world champion with a markedly attacking style assigned a great influence primarily to the m. biceps brachii, m. deltoideus, m. pectoralis major and stomach muscles. M. biceps brachii is especially important in his opinion because it is responsible for flexion of the arm in performance of quick forehand spin strokes. Performance of basic returns is based, according to him, on the good functioning of m. triceps brachii and the back muscles. Ogimura's classification is, probably, based on his personal observations and self-observations and considerations, since

no data are available on the systematic influence that particular muscles or muscle groups have on performance of strokes.

Hiruta et al. (1992) found that the level of muscle strength and muscle power for elite table tennis players was similar to that of the average person. One of the reasons why the back strength and the vertical jump were performed so badly seems to be connected to the lack of muscle strength training.

Yet Takeuchi et al. (2002) pointed out that due to the larger diameter and mass of the 40 mm ball, physiological effects may be present and technical adjustments may be required. About 63% of the respondents reported more physical fatigue after the games using the 40 mm ball (compared with 38 mm ball). Therefore, a high level of physical fitness, especially speed endurance, should be enhanced in order to overcome the physical challenges resulting from the larger mass of ball and the longer rallies.

At the beginning of the year 2000, the International Table Tennis Federation announced the replacement of the 38 mm ball with the 40 mm ball. It became evident that, due to the decreased ball speed and rotation, players would have to devote more time to physical preparation if they wanted to perform as well as before. The performance differences between the players in better physical condition and those less prepared became apparent at the World Championship in Osaka in 2001. At the first world championship played with the larger ball, the number of strokes per rally increased, meaning that matches lasted longer and became more demanding. Taking into account the rigours of a two week competition, it turned out that physical preparation, and the additional strengthening of the shoulder area in particular, would become a crucial factor for sport success.

As with most of the acyclic movements, a three-part movement pattern can be observed in table tennis strokes: the preparation phase, followed by the main phase, during which a motoric problem is being solved (i. e. the ball hitting the racket), and the closing phase.

The function of the preparation phase is to optimally prepare for an efficient and economical performance in the main phase. In table tennis, the preparation phase is represented by an arm swing. The principal characteristic of this phase is that its performance is done in the opposite direction to the main phase. The swing of the arm with the racket gives the musculature an optimal means of functioning and a favourable angle of the joints involved in this movement (shoulder, elbow and wrist). The main phase represents the activation of all muscle groups involved in the so-called kinetic chain. The closing phase solely represents an inertness of the main phase which must be immediately interrupted in order to prepare for a new stroke.

From the viewpoint of which individual muscles are involved in a stroke performance, the appropriate physical condition of a table tennis player is questionable. A larger ball requires that the player possess better physical condition, which is determined by the different biomechanical characteristics of a forehand spin stroke. A review of the literature indicates that investigations attempting to examine body action in table tennis have been few and limited in scope.

The aim of our research was to find out if there are differences between forehand top spin strokes with a 38 mm as opposed to a 40 mm ball regarding the shoulder and upper body muscles. The gathered data should facilitate planning of the training process of table tennis players.

METHODS

Design

To design an optimal physical preparation for table tennis players, it is essential first to establish exactly which muscles of the shoulder area work harder due to the large ball (40 mm). We measured the magnitude of the difference in myoelectric signals between the forehand strokes performed with the 38 mm and the 40 mm balls. The greater turn (in the 40 mm ball strike) should ensure the greater angular velocity of the shoulders, which should also assist in generating higher linear velocities of the arm, forearm and hand segments. We analysed the muscles that are primarily involved in the forehand attack: *m. deltoideus*, *m. biceps brachii* and *m. pectoralis major*.

Participants

The intensity, as well as the duration of the contraction of the above-mentioned muscles was measured on a professional male table tennis player, a member of the national team. The data were collected and analysed both visually and quantitatively.

Materials

The EMG signal measurement technique is a standardized one and corresponds to the classical procedure of detection, amplification and registration of bioelectrical activity changes in the skeletal musculature (Mereletti, 1999). It uses a differential mode of detection, with two electrodes, positioned at the midpoint of the measured muscle at a standardized distance of 3 cm (centre to centre) along the muscular fibres. The differential detection successfully suppresses noise (Medved, 2001). The "Elite 2002" (BTS Bioengineering, Milan, Italy) biomechanical system was used for data collection and analysis.

Procedure

The measurements were conducted during 100 forehand top spin strokes performed with balls of two sizes: 38 mm and 40 mm. The participant was filmed as he executed the strokes. To ensure the same conditions for all the performances (the same approaching ball trajectory), a table tennis machine was used. Electrodes were placed on the right side of the player's body due to his right-handedness. The intensity and duration of contractions of the following muscles were measured (Fig. 1):

1. Channel - *m. deltoideus anterior*
2. Channel - *m. deltoideus medialis*
3. Channel - *m. biceps brachii*
4. Channel - *m. pectoralis major*

In this study we have also used a method of kinematic analysis which enables the precise registration and evaluation of the most significant parameters of forehand top spin strikes.

Fig. 1

Electrodes placement



Methods for measured signal processing

Averaged EMG signals were translated into a numerical ASCII format and stored into the computer. SPSS statistical package was used for the statistical signal process.

Absolute muscle involvement was estimated on the basis of averaged EMG signals (mV) measured in all muscles (Medved, 2001). The mean value of averaged EMG signals was calculated for each analyzed muscle, and for both balls. Descriptive statistical parameters (min, max, mean, and SD) were calculated for these data. Analysis of variance (ANOVA) was used for calculating differences between overall mean values of averaged EMG signals among all muscles.

RESULTS

At first it looks as if there are no differences in the intensity of contraction of the observed muscles when striking the 38 mm ball. A more thorough analysis of the signal amplitudes of the observed, loaded muscles, though, reveals certain differences in the features of contraction in favour of the larger ball strokes, as expected.

Fig. 2a

EMG signal of *m. deltoideus anterior* with a 38 mm ball

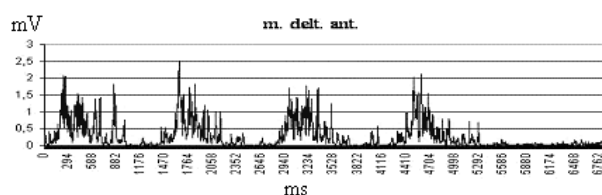


Fig. 2b

EMG signal of *m. deltoideus anterior* with a 40 mm ball

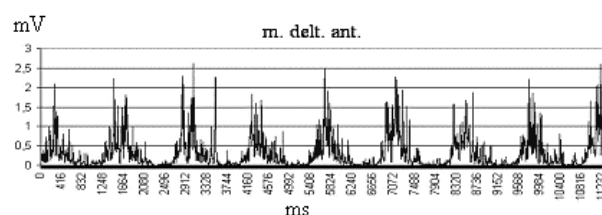


Fig. 3a

EMG signal of *m. pectoralis major* with a 38 mm ball

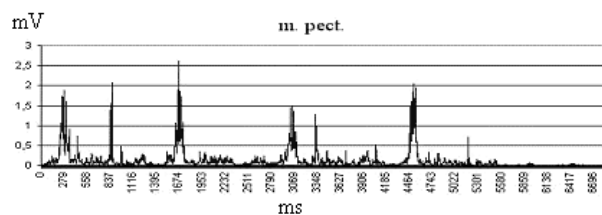
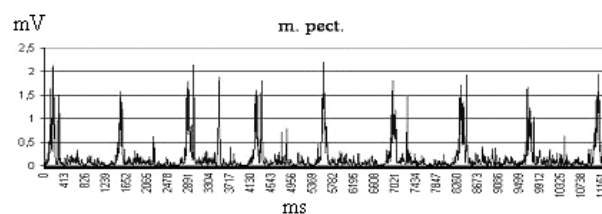


Fig. 3b

EMG signal of *m. pectoralis major* with a 40 mm ball



The peak EMG amplitude of the *m. deltoideus anterior* (Fig. 2a) reached a value of 2.5 mV, for the 38 mm ball stroke, but only for one out of the four registered strokes, whereas for the rest of the three registered

strokes the value approximated 2 mV. With the 40 mm ball (Fig. 2b), nine strokes were registered, and in seven of them the peak EMG amplitude was higher than 2 mV, and in two it exceeded a value of 2.6 mV.

The comparable contraction values in strokes with balls of both sizes were obtained with the *m. deltoideus medialis*: the peak values ranged between 2.3 and 2.8 mV with the 38 mm ball and between 2.2 and 3.0 mV with the 40 mm ball. Due to the results, obviously, *m. deltoideus* is highly involved in stroke execution due to the fact that its primary function is upper arm abduction. In a forehand stroke, the upper arm moves from adduction to a front raise diagonally inwards.

Greater differences in contraction intensities are obvious from the data obtained for the other two observed muscles. For the *m. biceps brachii* the peak EMG amplitude ranged from 1 to 2.2 mV and from 1.3 to 2.4 mV for the 38 mm and 40 mm ball strokes, respectively. The difference is by no means irrelevant when compared to the minute size differences between the old and the new ball.

A similar result was obtained for the *m. pectoralis major* contractions. Rather uneven intensities of contractions (Fig. 3a) were obtained for the 38 mm ball strokes, ranging from 1.5 mV to 2.6 mV. More balanced

values were obtained for the 40 mm ball strokes ranging from 1.6 to 2.2 mV (Fig. 3b).

Another substantial difference existed in the all detected muscles contractions (Fig. 2b, 3b). The 38 mm ball stroke contraction has only one peak (the maximal contraction), whereas in the 40 mm ball stroke two peaks occurred. This peculiarity could be explained by additional voluntary contraction (the so-called squeezing). It further means that muscle contraction in the 40 mm ball stroke lasts somewhat longer than in the 38 mm ball stroke.

There were significant differences in ANOVA, in results between *m. deltoideus anterior*, *m. biceps brachii* and *m. pectoralis major*. In the *m. deltoideus medialis* there were no statistically significant differences between strokes with a 38 and 40 mm ball.

Results of the kinematic analysis of the forehand top spin stroke point out to us that there are differences between the strokes with a 38 as opposed to a 40 mm ball. The peak velocities and speeds of the bat ranged from 8.488 m/s with the smaller ball to 9.485 m/s with the larger ball. Peak velocities of the shoulder, of two different strokes, were found to differ significantly in the vertical direction. The speed of the shoulder ranged from 4.650 m/s in the stroke with smaller ball to 5.619 m/s with the larger ball.

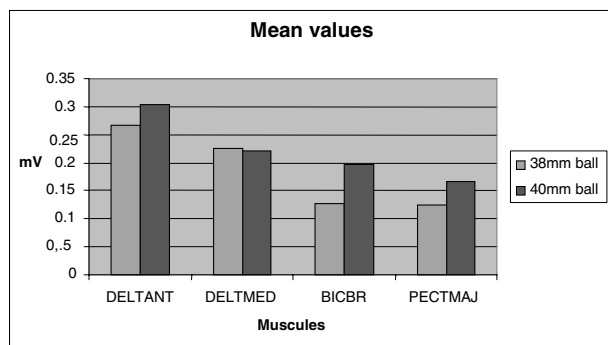
TABLE 1
Basic parameters of EMG signals in mV (descriptive statistics)

	Maximum		Minimum		Mean		SD	
	38 mm	40 mm	38 mm	40 mm	38 mm	40 mm	38 mm	40 mm
DELTANT	2.50492	2.61745	0.00179	0.00234	0.26669	0.30419	0.37062	0.38737
DELTMED	2.75649	2.97182	0.00507	0.00187	0.22477	0.22006	0.33699	0.35829
BICBR	2.11823	2.34271	0.00011	0.00312	0.12668	0.19720	0.22696	0.33222
PECTMAJ	2.60692	2.19047	0.00027	0.00316	0.12478	0.16702	0.25376	0.28705

TABLE 2
Results of ANOVA

		Sum of squares	df	Mean square	F	Sig.
DELTANT	Between Groups	6.029	1	6.029	41.509	.000
	Within Groups	2644.814	18210	.145		
	Total	2650.842	18211			
DELTMED	Between Groups	9.527E-02	1	9.527E-02	.776	.378
	Within Groups	2235.398	18210	.123		
	Total	2235.493	18211			
BICBR	Between Groups	21.320	1	21.320	242.141	.000
	Within Groups	1603.358	18210	8.805E-02		
	Total	1624.678	18211			
PECTMAJ	Between Groups	7.649	1	7.649	101.223	.000
	Within Groups	1376.131	18210	7.557E-02		
	Total	1383.781	18211			

Fig. 4
Mean values of EMG signals



DISCUSSION

The deltoid muscle is 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 (Grana, Lombardo, Sharkey, & Stone, 1989).

Although 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 programme, an analysis of movements involved in a particular stroke, in terms of type, speed, direction, etc., should be done in order to be sure which groups of muscles are involved in these movements (Kondrič, Furjan-Mandić, & Medved, 2003).

It is also very important to mention biomechanical considerations concerning the aerodynamic force of drag, which is a very important factor in relation to the different diameter of the balls. In the case when the machine catapults the balls at the same initial velocity, the ball with a larger diameter has a smaller velocity (due to the bigger drag) at the moment of hitting, and so the subject has more opportunity to hit this ball with a higher velocity of the bat. The second thought is about the subconscious reaction of the player to a larger ball. Experience has shown that the velocity of this one is lower and the player hits it with a higher sharpness to compensate for the higher drag.

Special exercises should be designed to approximate as closely as possible the pattern and rate of movements of an actual table tennis stroke execution. This will activate and train stroke-related groups of muscles, thus enhancing their specific neuro-muscular functions

needed for a particular performance. Dynamic electromyographic studies of the four rotator cuff muscles and the deltoid muscle during arm elevation have shown that all were active throughout the full range of movement (Glousman et al., 1988; Gowan et al., 1987). Inmann et al. (1944) interpreted this as an obligatory multi directional force couple to counteract the effect of the deltoid muscle's longitudinal alignment.

Nevertheless, we must not forget that movement acceleration of a joint involved in a particular stroke will depend on the state of certain muscles, which can influence the joint's degree of flexibility. From this point of view, it is obvious that both the ligamentous structures and muscular ability to contract and relax are important. Therefore, it is essential that table tennis players have good flexibility to assist movement and to control a particular stroke performance. It is also well established that muscle damage can be prevented by training, whether it involves concentric (Bosman et al., 1993) or eccentric exercise (Clarkson & Tremblay, 1988; Balnave & Thompson, 1993).

In our research we did not take into account the rubber gluing although it could have affected the measured parameters. Namely, several layers of glue can change the characteristic of rubber due to which velocity of the ball can be enhanced.

CONCLUSIONS

It is important to document the muscle activity of forward flexion, abduction, external rotation, and internal rotation. Classically, abduction and external rotation strength is diminished or absent with rotator cuff disease. The obtained measurements and graphical displays from the experiment indicate that in general, there is a significant difference in operation of the studied muscles between forehand attack strike using a 38 mm as opposed to a 40 mm ball. Although in three observed muscles (*m. deltoideus anterior*, *m. biceps brachii*, *m. pectoralis major*) differences in the intensity of EMG signals are significant, we can conclude that the player uses more muscle activities in a stroke with the larger ball. The presumption is that the differences would be even greater if the player hadn't undertaken training for more than a year with the larger ball, i.e. if we had done this experiment at the beginning of the use of the 40 mm ball.

We conclude that the contraction of *m. pectoralis major* is more powerful when the player hits the larger ball. From this point of view more attention should be paid to the development of this muscle in the physical preparation of the table tennis player. Qualified table tennis players should, therefore, develop those muscles and muscle groups that are needed for their specific style

of play after they have established a broad foundation of physical fitness. The speed of the game and particularly of the shot utilized in this study suggests that the focus in training should be on speed and power development with no real need for massive strength.

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MYOELEKTRICKÉ SROVNÁNÍ FOREHANDOVÉHO ÚDERU VE STOLNÍM TENISE PŘI POUŽITÍ MÍČKŮ RŮZNÝCH VELIKOSTÍ (Souhrn anglického textu)

Cílem této studie bylo prozkoumat rozdíly mezi forehandovými horními točivými údery s 38mm a 40mm míčky ve stolním tenise. Účastník byl při provádění úderů filmován. Za účelem zajištění totožných podmínek při veškerých výkonech (stejně trajektorie přibližujícího se míčku) byl použit nahrávací stroj pro stolní tenis. Vzhledem k hráčově pravorukosti byly elektrody umístěny na pravé straně hráčova těla. Absolutní svalové zapojení bylo odhadováno na základě zprůměrovaných EMG signálů (mV) měřených ve všech svalech (m. biceps brachii, m. deltoideus, m. pectoralis major). Pro výpočet rozdílů mezi celkovými středními hodnotami zprůměrovaných EMG signálů mezi všemi svaly byla použita analýza rozptylu (ANOVA). Vrcholová amplituda EMG m. deltoideus anterior dosahovala u úderu s 38mm míčkem hodnoty 2,5 mV. U m. deltoideus medialis byly dosaženy s míčky obou velikostí srovnatelné hodnoty kontrakce: vrcholové hodnoty se pohybovaly v rozmezí 2,3 a 2,8 mV u 38mm míčku a v rozmezí 2,2 a 3,0 mV u 40mm míčku. U m. biceps brachii se vrcholová amplituda EMG pohybovala mezi 1 až 2,2 mV u úderů s 38mm míčky a od 1,3 do 2,4 mV u úderů s 40mm míčky. Podobného výsledku bylo dosaženo u kontrakcí m. pectoralis major. U úderů s 38mm míčkem byla dosahována poměrně nerovnoměrná intenzita kontrakcí, a to v rozmezí od 1,5 mV do 2,6 mV. Vyváženějších hodnot bylo dosaženo u úderů s 40mm míčky, kdy se tyto pohybovaly mezi 1,6 až 2,2 mV. Tato zjištění nám ukázala, že u třech sledovaných svalů (m. deltoideus anterior, m. biceps brachii, m. pectoralis major) existují významné rozdíly v intenzitě EMG signálů, a můžeme tedy učinit závěr, že hráč při úderu s větším míčkem používá více svalové aktivity a že kontrakce m. pectoralis major je při úderu do většího míčku silnější.

Klíčová slova: stolní tenis, forehandový úder, EMG, svalová aktivita.

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