ELECTROMYOGRAPHIC COMPARISON OF SQUASH FOREHAND SHOT AFTER MIDCOURT AND FRONTCOURT TRADITIONAL MOVEMENT PATTERNS

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Abstract
Electromyography of sixteen muscles of the lower limb, trunk, and upper limb muscles were compared between forehand shot after traditional midcourt movement pattern and traditional frontcourt movement pattern of a three female squash players (age: 14.5±0.5 years old; height 1.48±0.15 m; mass: 44.67±1.53 Kg), ranked in the Squash National Egyptian team. Surface electromyographic (sEMG) electrodes were placed according to SENIAM guidelines on the skin, superficial to right-sided postural proximal of the trapezius, posterior deltoid, anterior deltoid, triceps brachii, biceps brachii, pectoralis major, serratus anterior, rectus abdominis, external abdominal, glutaeus medius, gluteus maximus, biceps femoris, rectus Femoris, tibialis anterior, gastrocnemius, and soleus muscle. EMG data were 16 bit A/D converted at 1000 Hz and stored on computer. EMG signals were amplified (gain of 400), band pass filtered (10 to 500Hz), full wave rectified using root mean square average, and normalized to the isometric muximum voluntary contraction (MVC). Mean and standard deviation of the muscle activity and work-loading were calculated from the start of the two tasks to the end of forehand shot recovery phase. The results showed that the difference between the Forehand shot after traditional midcourt movement pattern and Forehand shot after traditional frontcourt movement pattern in pectoralis major muscle and rectus abdominis muscle, and no differences existed in the other selected muscles. The study determined the muscle activity (% MVC) for the sixteen selected muscles during the two patterns of forehand shots, and the percentage of work-loading (% Total activity area) for each muscle.

Key words: Muscle activity, forehand, court movement patterns, squash.

INTRODUCTION

One of the major racket sports is squash, this game is characterized by a hand-held racket, and it is also characterized by an area of play that has a specified size. Squash performance is largely characterized by the movement of players and shot selection. The main objective is to move an opponent away from a central area of the court, commonly referred to as the 'T area' (Vuckovic et al., 2014). In order to assess the movement and shot characteristics of squash players it is necessary to have a data collection system that can reliably and accurately record these variables (Atkinson & Nevill, 1998; Vuckovic et al., 2014). Identifying strengths and weaknesses within a performance places emphasis on the key elements necessary to delineate successful outcomes. Viewing racket sports as complex dynamical systems suggests that squash switches between periods of stability (invariance) and instability (variance) (Roddy, Lamb, & Worsfold, 2014).

The assessment of players' capabilities in physiological factors is a challenge because of the unique and varied movement patterns during matches. However, test specificity is important to ensure validity and sensitivity of procedures and to improve the sensitivity with which coaches and scientists can build accurate profiles of player strengths and weaknesses and for the evaluation of interventions (Muller, Benko, Raschner, & Schwameder, 2000; Wilkinson et al., 2012).

The muscular demands of random movement are likely to be much greater and different from movement that is predictable. The ability of muscle to accommodate to unanticipated changes in direction and speed is a crucial performance characteristic in squash but is likely to go undetected by a test in which movement sequences are predictable (Wilkinson, Leedale-Brown, & Winter, 2009). In the forehand Lunges, various segmental rotations of the upper limb contribute to ball speed, often varying with the direction of the shot and speed of the oncoming ball (Reid, Elliott, & Crespo, 2013). Making rapid and frequent changes in direction will involve repeated cycles of acceleration and deceleration with associated strenuous patterns of eccentric and concentric contractions among the lower limb muscle groups (Micklewright & Papapdopoulou, 2008). And also, forehand lunges require more trunk rotation and therefore demand a greater core neuromuscular control to maintain dynamic postural stability (Lin, Hua, Huang, Lee, & Liao, 2015).

Electromyography (EMG) has been used to detect patterns of muscle activation but there have been very few applications in racket sports. Recently, Sakurai and Ohtsuki (2000) reported EMG data on the muscles that control wrist actions (the extensor carpi radialis and flexor carpi radialis) in the 50 ms before impact (Sakurai & Ohtsuki, 2000).

In our literature no research has been completed that assists sports scientists in understanding the muscle activity of the squash forehand. The sequencing of muscle activity of the lower limb, trunk, and upper limb have been described. No published studies, however, have quantified the muscle activity of the lower limb, trunk, and upper limb muscles that contribution in forehand shot performance. Accordingly, the present study compares the changes occurring in squash forehand shot muscle activity after midcourt and frontcourt traditional movement patterns.

METHODS

Participants

Three female squash players (age: 14.5±0.5 years old; height 1.48±0.15 m; mass: 44.67±1.53 Kg), ranked in the National Egyptian team, participated in this study. The parental consent of all players was obtained. This study was approved by the institutional ethics committee of studies and researches. The Participants was asked to execute two tasks (Yarrow & Harrison, 2010). The first task (task 1) was to shadow a squash forehand shot after traditional midcourt movement pattern, starting from the T with a split step and moving to the right with a sidestepping motion, executing forehand shadow shot and return back to the T (Figure. 1). The second task (task 2) was to shadow a forehand shot after traditional frontcourt movement pattern, starting from the T area with a split step and moving forward in J shape toward the right forecourt, executing a forehand shadow shot and retreats to the T area (Figure. 2), (Yarrow & Harrison, 2010).

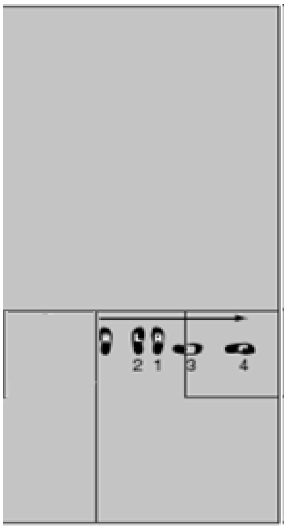

Figure 1. Traditional midcourt movement pattern

Figure 2. Traditional frontcourt movement pattern

Surface electromyography

Self-adhesive, silver-silver chloride surface electromyographic (sEMG) electrodes (SKINTACT, FS-521), Innsbruck, Austria) were placed according to SENIAM guidelines on the skin, superficial to right-sided postural proximal of the following sixteen muscles: Trapezius muscle (T), Posterior Deltoid muscle (D-p), Anterior Deltoid muscle (D-a), Triceps brachii muscle (TB), Biceps brachii muscle (BB), Pectoralis major muscle (PM), serratus anterior muscle (S-a), Rectus abdominis muscle (RA), External abdominal muscle (EA), Glutaeus medius muscle (G-med), Gluteus maximus muscle (G-max), Biceps femoris muscle (BF), Rectus Femoris muscle (RF), Tibialis anterior muscle (T-a), Gastrocnemius muscle (Gas), and Soleus muscle (Sol) (Hermens, Freriks, Disselhorst-Klug, & Rau). The skin overlying the largest visible section of the muscle was prepared by having the subject shave any overlying hair and clean the area vigorously with isopropyl alcohol, to reduce electromyography (EMG) signal impedance. A wireless EMG system (MEGAWIN version 3.1-b12 software, Finland) with a sampling rate of 1000 HZ per channel was used to measure muscle activity of the sixteen muscles in three conditions. EMG data were band –pass filtered at 10-500 HZ and full wave rectified using Average root mean square (Electronics, 2008). The first measurement for each of the sixteen muscles was to have the subjects to perform three trials of isometric maximum voluntary contraction (MVC). Each MVC was performed for 5 s, with 30–60 s rest in between. The highest value of MVC in the three trials for each muscle was used. The second and third measurements were to measure the EMG activity during two different tasks (task 1 and task 2). A fifteen minute warm-up which included general and shoulder-specific mobility exercises, as well as stretch exercises and familiarization trials, were required before players' trials. A total of three trials were recorded for each participant, with one minute rest between trials, the best trial for each participant was selected for analysis. A quantitative analysis of EMG activity was reported by normalizing EMG out. The technique involved the transformation of the EMG signals during the two tasks to a percentage of the signal recorded for maximum voluntary contraction (%MVC) of each muscle being investigated. This normalizing technique was used to compare the changes occurring in forehand shot muscle activity with changes in activity conditions (after traditional midcourt movement pattern vs. after traditional frontcourt movement pattern). In order to get the temporal, and muscles work loading, plunger events were used to mark the starting time, and the end of forehand shot recovery phase for both tasks. The ME6000 system equipped with user friendly MegaWin PC-software (Mega Electronics Ltd.) was used for data transfer, analysis, and storage (Electronics, 2008).

Statistical analysis

For the statistical analysis of the data, the IBM SPSS Statistics 21 was used. Descriptive statistics, Kolmogorov-Smirnov and Shapiro-Wilk tests were used to check for data normality; results show that the activity and work-loading of the selected muscles have a normal distribution. After that, the T-test for independent samples was used to compare the changes occurring in squash forehand shot muscle activity after traditional midcourt movement pattern vs. traditional frontcourt movement pattern.

RESULTS

Table 1. Descriptive Values and T-test of RMS Muscle Activity (%MVC) during Forehand Shot after Traditional Midcourt Movement Pattern and Traditional Frontcourt Movement Pattern.

Skills / Muscles (%MVC)	Forehand shot after traditional midcourt movement pattern		Forehand shot after traditional frontcourt movement pattern		T	Sig.
	M	SD	M	SD		
Trapezius	3.43	0.11	3.79	0.33	-1.79	0.15
Posterior Deltoid	9.83	1.75	10.56	1.35	-0.57	0.60
Anterior Deltoid	5.91	0.71	5.66	0.81	0.40	0.71
Triceps brachii	4.62	0.49	3.98	0.79	1.19	0.30
Biceps brachii	9.72	1.07	9.99	1.04	-0.31	0.77
Pectoralis major	5.94	0.57	7.21	0.16	-3.74	0.02
serratus anterior	5.52	0.75	4.54	0.85	1.50	0.21
Rectus abdominis	4.44	0.50	6.43	0.92	-3.29	0.03
External abdominal	10.74	0.61	12.27	1.23	-1.94	0.12
Glutaeus medius	24.41	3.92	26.26	3.31	-0.62	0.57
Gluteus maximus	11.67	1.30	12.60	0.48	-1.17	0.31
Biceps femoris	21.94	1.39	21.85	1.33	0.08	0.94
Rectus femoris	8.26	0.70	9.08	0.44	-1.71	0.16
Tibialis anterior	12.55	1.34	13.28	2.05	-0.51	0.63
Gastrocnemius	11.66	1.28	12.03	1.31	-0.35	0.74
Soleus	20.03	0.93	20.03	2.08	0.00	1.00

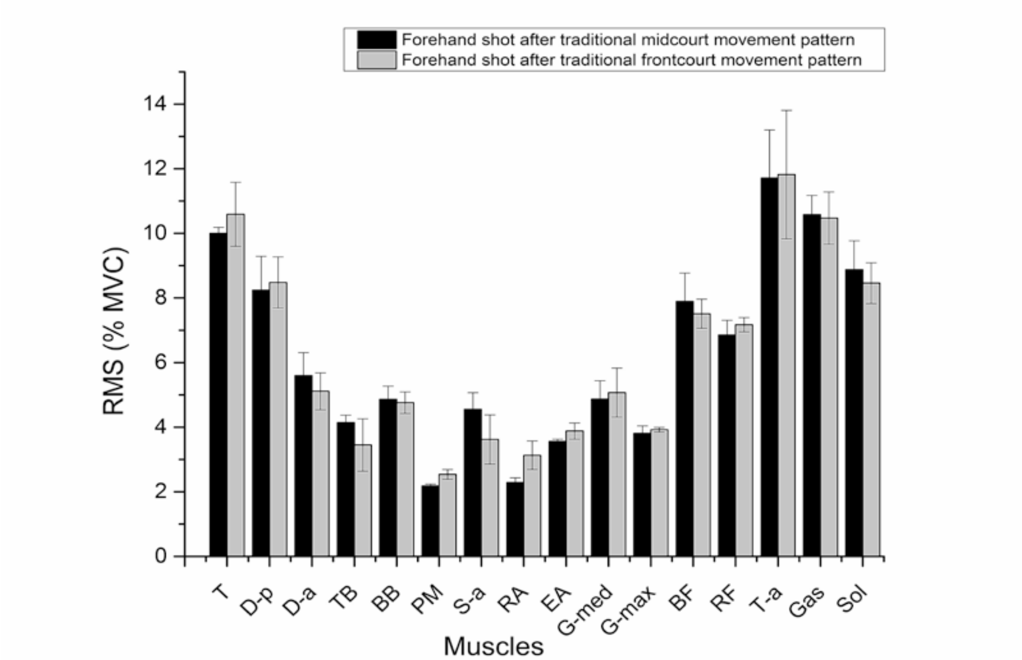

Figure 3. RMS muscle activity (%MVC) during forehand shot after traditional midcourt movement pattern and traditional frontcourt movement pattern. T=Trapezius muscle, D-p=Posterior Deltoid muscle, D-a=Anterior Deltoid muscle, TB=Triceps brachii muscle, BB =Biceps brachii muscle, PM =Pectoralis major muscle, S-a=serratus anterior muscle, RA =Rectus abdominis muscle, EA =External abdominal muscle, G-med =Glutaeus medius muscle, G-max =Gluteus maximus muscle, BF=Biceps femoris muscle, RF=Rectus femoris muscle, T-a =Tibialis anterior muscle , Gas=Gastrocnemius muscle , Sol=Soleus muscle .

Table 2. Descriptive Values and T-test of Muscles Work-loading (% Total area) during Forehand Shot after Traditional Midcourt Movement Pattern vs. Traditional Frontcourt Movement Pattern.

Skills / Muscles (% total area)	forehand shot after traditional midcourt movement pattern		Forehand shot after traditional frontcourt movement pattern		T	Sig.
	M	SD	M	SD		
Trapezius	10.00	0.19	10.59	0.99	-1.02	0.36
Posterior Deltoid	8.24	1.05	8.48	0.79	-0.31	0.77
Anterior Deltoid	5.60	0.71	5.11	0.57	0.92	0.41
Triceps brachii	4.14	0.23	3.45	0.81	1.41	0.23
Biceps brachii	4.86	0.41	4.76	0.33	0.34	0.75
Pectoralis major	2.18	0.06	2.54	0.15	-3.95	0.02
serratus anterior	4.55	0.52	3.62	0.76	1.75	0.15
Rectus abdominis	2.29	0.14	3.13	0.44	-3.15	0.03
External abdominal	3.56	0.07	3.88	0.25	-2.13	0.10
Glutaeus medius	4.87	0.57	5.07	0.76	-0.38	0.73
Gluteus maximus	3.81	0.23	3.92	0.07	-0.83	0.45
Biceps femoris	7.89	0.88	7.51	0.45	0.67	0.54
Rectus Femoris	6.85	0.46	7.17	0.22	-1.12	0.32
Tibialis anterior	11.71	1.49	11.82	1.99	-0.08	0.94
Gastrocnemius	10.58	0.59	10.47	0.81	0.20	0.85
Soleus	8.88	0.89	8.46	0.63	0.67	0.54

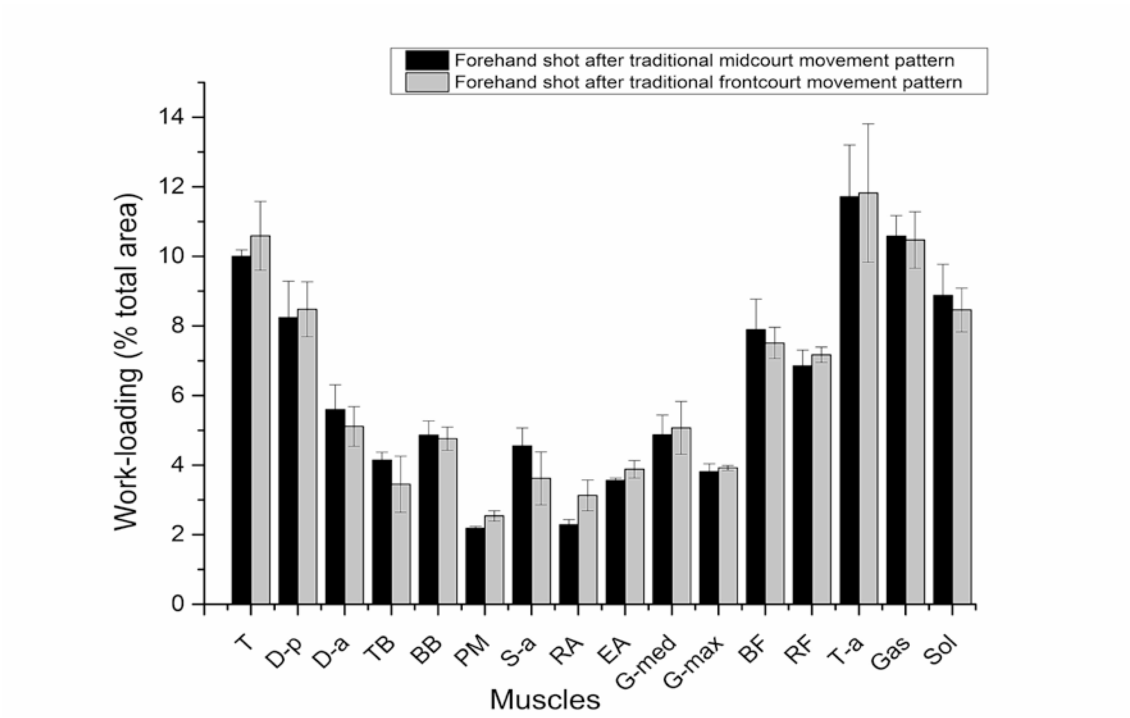

Figure 4. Muscles work-loading (% Total area) during forehand shot after traditional midcourt movement pattern and traditional frontcourt movement pattern. T=Trapezius muscle, D-p =Posterior Deltoid muscle, D-a=Anterior Deltoid muscle, TB=Triceps brachii muscle, BB =Biceps brachii muscle, PM =Pectoralis major muscle, S-a=serratus anterior muscle, RA =Rectus abdominis muscle, EA=External abdominal muscle, G-med=Glutaeus medius muscle, G-max=Gluteus maximus muscle, BF=Biceps femoris muscle, RF=Rectus femoris muscle, T-a=Tibialis anterior muscle , Gas=Gastrocnemius muscle , Sol=Soleus muscle.

DISCUSSION

Squash is a dynamic sport in which most of its movements use the stretch–shortening cycle, and requires multi-joint coordination. Moreover, during squash shots, forces are transferred from the lower body to the upper body, through a sequence of coordinated muscle actions. Since squash shots have become more forceful, it is necessary to emphasize on the musculature of the body. Muscles such as the Trapezius muscle (T), Posterior Deltoid muscle (D-p), Anterior Deltoid muscle (D-a), Triceps Brachii muscle (TB), Biceps Brachii muscle (BB), Pectoralis Major muscle (PM), Serratus Anterior muscle (S-a), Rectus Abdominis muscle (RA), External Abdominal muscle (EA), Glutaeus Medius muscle (G-med), Gluteus Maximus muscle (G-max), Biceps Femoris muscle (BF), Rectus Femoris muscle (RF), Tibialis Anterior muscle (T-a), Gastrocnemius muscle (Gas), and Soleus muscle (Sol) play important roles in a good performance and protect the joints during each shot. They work in concert to help with the actual swing as well as to provide stability.

So, the present study focused on determining the muscle activity and comparing the changes occurring in squash forehand shot muscle activity after traditional midcourt movement pattern (pattern 1) versus traditional frontcourt movement pattern (pattern 2). To our knowledge, this is the first study to investigate both forehand movement patterns in squash.

The main findings of the study were that the lower limb muscles were the most active during the performance (Table 1; 2, Figure 3; 4), because the gluteus maximus, glutaeus medius, biceps femoris, and rectus femoris muscles absorb the shock during landing, or changing direction. They also contract explosively during push off to run, and provide a solid base when hitting a shot from an open stance. Similarly, the gastrocnemius, tibialis anterior, and soleus muscles in the lower leg must be strong during these shots. Moreover, the importance of hip (pelvic) rotation has been highlighted in forehand, and they are required to success the forehand shots (Elliott, 2006).

In addition, the present study showed that the difference between the forehand shot after traditional midcourt movement pattern, and forehand shot after traditional frontcourt movement pattern in two muscles only: pectoralis major muscle (*P-value<0.02*) and rectus abdominis muscle (*P-value<0.03*) (see Table 1; 2). These two muscles burst more explosively during the (right handed) forward swing of the 2nd pattern due to: the counterclockwise rotating of the trunk and upper back as the right arm is flexed and adducted in the forward swing , and the changing of foot position(see Figure 3; 4). Dynamic, explosive movements increase power and coordination in these involved muscles and consequently, the velocity of the forehand increases without sacrificing technique (Bagchi, Rajpoot, & Ghai, 2015).

There are no differences existed in the other muscles, because they are working in the two forehand shots. The greater shoulder abduction would have involved a greater upward rotation of the scapula (Fayad et al., 2006; Yoshizaki et al., 2009) and required activation of the serratus anterior to stabilize the scapula on the thorax, and the trapezius muscle attaches to the skull and helps hold up and rotate the head, it also works in concert with the levator scapulae to move the scapula (Hirashima, Kadota, Sakurai, Kudo, & Ohtsuki, 2002; Kibler, Chandler, Shapiro, & Conuel, 2007). External oblique is a primary muscle of squash movements, especially the loading phase on both forehand patterns. The upper arm, forearm, and wrist segments move as separate units to increase power. The rotation of the upper arm at the shoulder muscles (posterior deltoid muscle, anterior deltoid muscle, triceps brachii muscle, biceps brachii muscle) also play important role in the two patterns of forehand (Elliott, 2006), and elbow flexes during ball contact and follow through of the forehand and the wrist remains firm, but may slightly flex to increase racket velocity. This flexion of the elbow in contact and follow through increases the muscle activation of biceps brachii (Elliott, Marsh, & Overheu, 1989). So, biceps brachii can contribute to both elbow flexion and forearm supination. Accordingly, the amplitude of biceps brachii is modulated during forearm pronation and supination (Barry, Riley, Pascoe, & Enoka, 2008; Koyama, Kobayashi, Suzuki, & Enoka, 2010; Naito, 2004).

Finally, our results suggest that forehand pattern really does have an effect in RMS muscle activity (%MVC), and muscle work loading (% Total area) of pectoralis major muscle and rectus abdominis muscles. Specifically, when forehand pattern change from pattern1 to pattern 2, during the last step of the 2nd pattern, the players widen their crossover step (last step) to reach the shadow ball in the front court corner, resulting in a higher RA muscle activity to flex the core forward. To compensate for this down movement during the last step lunge, the Pectorals major muscle fires more- in the forehand forward swing of the 2nd pattern- to flex the arm forward and up and across the chest to reach the shadow ball and to give more power to the shot. The ranked muscle work-loading results in both forehand patterns quantify the relative contribution of the muscle synergy to the overall muscle activity pattern (François Hug, Turpin, Guével, & Dorel, 2010; Ting & McKay, 2007; Torres-Oviedo & Ting, 2007). Consequently, these results provide a simplified neural control strategy for the control of these complex movement patterns (F. Hug, 2011; Raasch & Zajac, 1999).

CONCLUSIONS

The present study focused on determining the muscle activity and comparing the changes occurring in squash forehand shot muscle activity after traditional midcourt movement pattern (pattern 1) versus traditional frontcourt movement pattern (pattern 2). The study determined the muscle activity (% MVC) for the sixteen selected muscles during the two patterns of forehand shots, and the percentage of work-loading (% Total activity area) for each muscle. This paper has clearly shown that the muscle activity profile difference between the forehand shot after traditional midcourt movement pattern, and forehand shot after traditional frontcourt movement pattern are in pectoralis major muscle (*P-value<0.02*) and rectus abdominis muscle (*P-value<0.03*), and no differences existed in the other selected muscles. These results may help coaches and players for understanding more about muscle activity during the two patterns of forehand shots, and improving the players' performance. On the basis of the promising findings presented in this paper, work on other skills and movement patterns is continuing and will be presented in future papers.

REFERENCES

1. Atkinson, G., & Nevill, A. M. (1998). Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. *Sports Med, 26*(4), 217-238.
2. Bagchi, A., Rajpoot, Y., & Ghai, G. (2015). A comarative elyctromygraphical analysis of triceps medialis and biceps brachii during forehand drive in tennis. *Scholarly research journal for interdisciplinary studies, 3*(19), 3064-3070.
3. Barry, B., Riley, Z., Pascoe, M., & Enoka, R. (2008). A spinal pathway between synergists can modulate activity in human elbow flexor muscles. *Experimental Brain Research, 190*(3), 347-359.
4. Electronics, M. (2008). MegaWin 3.0 Software User Manual (pp. 1-197). KUOPIO, FINLAND: Mega Electronics Ltd.

5. Elliott, B. (2006). Biomechanics and tennis. *Br J Sports Med, 40*(5), 392-396.
6. Elliott, B., Marsh, T., & Overheu, P. (1989). A biomechanical comparison of the multisegment and single unit topspin forehand drives in tennis. *International Journal of Sport Biomechanics, 5*(3), 350-364.
7. Fayad, F., Hoffmann, G., Hanneton, S., Yazbeck, C., Lefevre-colau, M. M., Poiraudeau, S., . . . Roby-Brami, A. (2006). 3-D scapular kinematics during arm elevation: Effect of motion velocity. *Clin Biomech (Bristol, Avon), 21*(9), 932-941.
8. Hermens, H. J., Freriks, B., Disselhorst-Klug, C., & Rau, G. Development of recommendations for SEMG sensors and sensor placement procedures. *Journal of Electromyography and Kinesiology, 10*(5), 361-374.
9. Hirashima, M., Kadota, H., Sakurai, S., Kudo, K., & Ohtsuki, T. (2002). Sequential muscle activity and its functional role in the upper extremity and trunk during overarm throwing. *J Sports Sci, 20*(4), 301-310.
10. Hug, F. (2011). Can muscle coordination be precisely studied by surface electromyography? *J Electromyogr Kinesiol, 21*(1), 1-12.
11. Hug, F., Turpin, N. A., Guével, A., & Dorel, S. (2010). Is interindividual variability of EMG patterns in trained cyclists related to different muscle synergies? . *J Appl Physiol, 108*(6), 1727–1736.
12. Kibler, W. B., Chandler, T. J., Shapiro, R., & Conuel, M. (2007). Muscle activation in coupled scapulohumeral motions in the high performance tennis serve. *Br J Sports Med, 41*(11), 745-749.
13. Koyama, Y., Kobayashi, H., Suzuki, S., & Enoka, R. M. (2010). Enhancing the weight training experience: a comparison of limb kinematics and EMG activity on three machines. *Eur J Appl Physiol, 109*(5), 789-801.
14. Lin, C. F., Hua, S. H., Huang, M. T., Lee, H. H., & Liao, J. C. (2015). Biomechanical analysis of knee and trunk in badminton players with and without knee pain during backhand diagonal lunges. *J Sports Sci, 33*(14), 1429-1439.
15. Micklewright, D., & Papapdopoulou, E. (2008). A new squash specific incremental field test. *Int J Sports Med, 29*(9), 758-763.
16. Muller, E., Benko, U., Raschner, C., & Schwameder, H. (2000). Specific fitness training and testing in competitive sports. *Med Sci Sports Exerc, 32*(1), 216-220.
17. Naito, A. (2004). Electrophysiological studies of muscles in the human upper limb: The biceps brachii. *Anatomical Science International, 79*(1), 11-20.
18. Raasch, C. C., & Zajac, F. E. (1999). Locomotor Strategy for Pedaling: Muscle Groups and Biomechanical Functions. *Journal of Neurophysiology, 82*(2), 515-525.
19. Reid, M., Elliott, B., & Crespo, M. (2013). Mechanics and Learning Practices Associated with the Tennis Forehand: A Review. *Journal of Sports Science and Medicine, 12*, 225-231.
20. Roddy, R., Lamb, K., & Worsfold, P. (2014). The importance of perturbations in elite squash: An analysis of their ability to successfully predict rally outcome. *International Journal of Performance Analysis in Sport, 14*, 652-679.
21. Sakurai, S., & Ohtsuki, T. (2000). Muscle activity and accuracy of performance of the smash stroke in badminton with reference to skill and practice. *J Sports Sci, 18*(11), 901-914.
22. Ting, L. H., & McKay, J. L. (2007). Neuromechanics of muscle synergies for posture and movement. *Curr Opin Neurobiol, 17*(6), 622-628. doi: 10.1016/j.conb.2008.01.002
23. Torres-Oviedo, G., & Ting, L. H. (2007). Muscle Synergies Characterizing Human Postural Responses. *Journal of Neurophysiology, 98*(4), 2144-2156.
24. Vuckovic, G., James, N., Hughes, M., Murray, S., Milanovic, Z., Pers, J., & Sporis, G. (2014). A new method for assessing squash tactics using 15 court areas for ball locations. *Hum Mov Sci, 34*, 81-90.
25. Wilkinson, M., Cooke, M., Murray, S., Thompson, K. G., St Clair Gibson, A., & Winter, E. M. (2012). Physiological correlates of multiple-sprint ability and performance in international-standard squash players. *J Strength Cond Res, 26*(2), 540-547.
26. Wilkinson, M., Leedale-Brown, D., & Winter, E. M. (2009). Validity of a squash-specific fitness test. *Int J Sports Physiol Perform, 4*(1), 29-40.
27. Yarrow, P., & Harrison, A. (2010). *Squash : steps to success*. United States of America: Human Kinetics.
28. Yoshizaki, K., Hamada, J., Tamai, K., Sahara, R., Fujiwara, T., & Fujimoto, T. (2009). Analysis of the scapulohumeral rhythm and electromyography of the shoulder muscles during elevation and lowering: Comparison of dominant and nondominant shoulders. *Journal of Shoulder and Elbow Surgery, 18*(5), 756-763.

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