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Influence of fatigue on the muscular activity and performance of the upper limb.

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ABSTRACT

The aim of this study was to examine the effect of fatigue on accuracy, ball speed and muscle activity in the serve and forehand. The fatigue protocol resulted in a decrease of ball speed in serves and of accuracy in forehands, associated with the decreased activation of certain muscles. The players experiencing fatigue seemed to use an adaptation strategy based on the type of stroke, without modifying their inter-muscular coordination. These results make us consider the possibility to work on resistance to fatigue for specific strokes and muscle groups.

Key words: Fatigue, Ball speed, Accuracy, Adaptation strategy.
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INTRODUCTION

With the physical dimension of modern tennis, fatigue becomes an issue that is inextricably linked to the performance of competition. While there is a consensus on the importance of fatigue in tennis and its influence on the outcome of the game, it remains necessary to understand why it occurs in order to limit its effects. Several scientific studies have confirmed the observations of coaches on the degradation of strokes, movements and poor tactical choices occurring in situations of fatigue (Davey et al., 2002). A summary of the results published in this area was conducted by Hornery et al. (2007). It was shown that after a tennis session leading to exhaustion, fatigue led to a 69% decline in precision in groundstrokes and a 30% drop in ball speed in serves (Davey et al., 2002). Similarly, an intense workout of 2 hours resulted in a decrease in speed and precision in groundstrokes and second serves, as well as an increase in the error rate of the latter (Vergauwen et al., 1998). Finally, the electromyography activity (EMG) and the maximal isometric force of the quadriceps decreased significantly during simulated matches (Girard et al., 2006, 2008). According to Girard et al. (2008), the deterioration of the neuromuscular function during a prolonged tennis match could be explained by a failure at both central (motor command) and peripheral (excitation / contraction) levels.

However, in spite of significant fatigue being experienced, some players maintain speed and accuracy on their serve (Hornery et al., 2007). Thus, it seems that during serve, compensatory neuromuscular strategies may occur in situations of fatigue (Girard et al., 2009) to maintain the level of performance. It therefore seems interesting to study the muscular adaptations of the upper limb associated with fatigue in tennis.

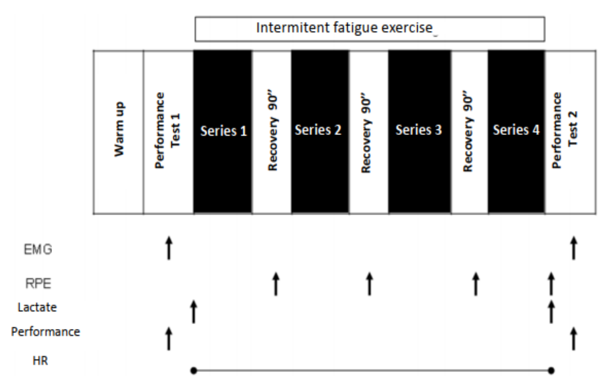

Figure 1: Structure of the experimental protocol and the various parameters measured. (EMG: surface electromyography; RPE: perceived exertion; Performance: measures of accuracy and ball speed; FC: heart rate)

METHOD

Following a standard 20 min warm-up, 8 adult tennis players (ranked 15 to 4/6) were submitted to a test measuring their stroke performance before and after an intermittent exercise leading to fatigue (Figure 1).

The performance test focused on the speed - measured by a radar - and accuracy of the serves and cross-court forehands.

The subjects had to hit a powerful and accurate serve, seeking the ace on the "T". The forehands were fed using a ball machine (3 seconds per stroke). Shot accuracy was evaluated by means of targets, the smallest yielding the most points (Figure 2), a ball bouncing outside the target areas yielding no points. The error rate was calculated as the number of strokes in the target / the total number of strokes. The electrical activity of eight muscles of the dominant upper limb was recorded by the surface EMG during stroke production. The starts, ends, durations and levels of the activation of each muscle were calculated.

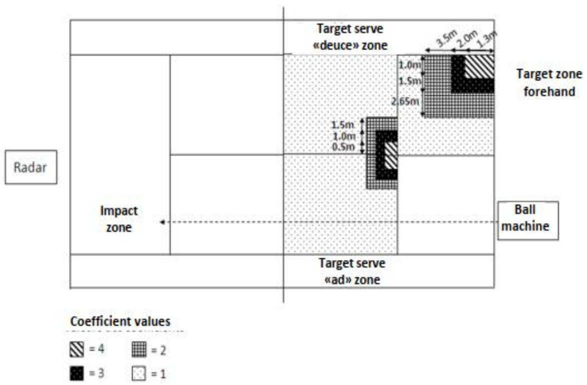

Figure 2. Diagram of the performance test and coefficient values associated with target areas (squares for serves)

The fatigue-inducing exercise consisted of four sequences of 12 repetitions of 1 serve + 8 cross-court forehands (2 seconds per stroke). Recovery periods of 20 seconds (semi-active) between repetitions and 90 seconds (seated) between sequences were allowed (Figure 1). The players had to hit at maximum intensity and reposition at centre court between each forehand. The heart rate (HR), blood lactate concentration ([La] s) and perceived exertion (RPE) were measured during testing.

Repeated ANOVA measures and a Student's t-test were used to assess the differences between the various indicators before and after fatigue.

RESULTS

	SPEED (M.S-1)		ACCURACY		CONSISTENCY (%)	
	Pre	Post	Pre	Post	Pre	Post
Serve	38.9 (10)	37.8 (10) *	1.3 (0.4)	1.1 (0.4)	43.4 (15.4)	48.6 (15.2)
Forehand	26.9 (10)	26.9 (10)	1.3 (0.3)	1.0 (0.2) *	41.7 (15.4)	49.9 (15.2)

Values: mean (standard deviation). * Significant difference between pre and post-test (p <0.05)
Table 1. Performance criteria for serve and forehand in pre and post- fatigue states.

The average heart rate remained constant between the sequences (174.7 ± 10.6 bpm) while the [La] s increased significantly from 2.8 mmol.l-1 to 5.7 mmol.l-1 ($p = 0.04$). RPE values increased between sequences ($p < 0.02$) except between sequences 3 and 4. The players saw their effort as "hard" (RPE = 14.5) during the first sequences, then "very hard" (RPE = 17.5) during the last sequence of the exercise.

Significant decreases were observed in serve speed (3.2%) and forehand accuracy (21.1%) after the fatigue-inducing exercise (Table 1). The error rate also tended to increase, especially in the forehand (27.6%) ($p = 0.056$)

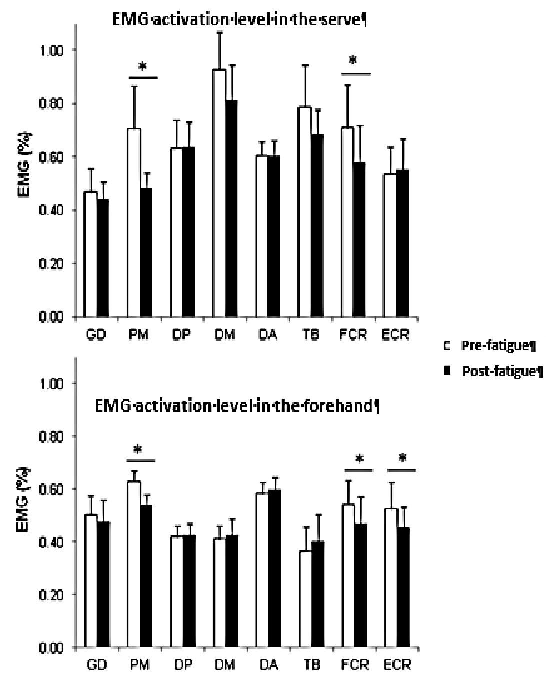

Figure 3. Standardized EMG activation level of upper limb muscles in the serve and forehand in pre and post-fatigue states. (LD: latissimus dorsi; PM: pectoralis major, PD: posterior deltoid; MD: middle deltoid; AD: anterior deltoid, T: triceps, FCR: flexor carpi radialis, ECR: extensor carpi radialis)

LEMG activation levels of the pectoralis major (PM) and flexor carpi radialis (FCR) decreased significantly during the serve and forehand, while they decreased for the extensor carpi radialis (ECR) during the forehand ($p < 0.04$). No difference was reported in the starts, ends and durations of muscle activity, irrespective of the muscle observed.

DISCUSSION

This study brought to light the negative effect of fatigue on serve speed and forehand accuracy, as well as a significant decrease in the amplitude of the PM, FCR and ECR EMG . However, the temporal pattern of the inter-muscular coordination did not seem to change. Given the average heart rate, blood lactate and evaluation of perceived exertion (RPE), the fatigue protocol imposed a workload greater than that of a match, approaching that of an intense rally (Kovacs 2006).The specific fatigue experienced by the player triggered different coping strategies depending on the stroke. Indeed, players decreased their serve speed, probably in order to maintain a high accuracy and a low error rate. However, in forehands, they preferred to preserve speed at the expense of precision and consistency. Despite differences in protocol across studies, our results confirm those of previous work (Hornery et al., 2007). This strategy, whether conscious or unconscious, refers to Fitts' speed-precision conflict, which might explain the inverse evolutions of ball speed and stroke accuracy.

Serve is considered one of the most important elements of the game of tennis (Elliott, 2001) and has a significant impact on the results of a modern tennis match (Gillet et al., 2009). Thus, in training as in competition, the accuracy and consistency of the serve are perceived by players as essential. Regarding the forehand, it has been described as a key stroke of modern tennis (Brabenec, 2000) and is often used as an offensive weapon in order to hit winners. Working on the forehand during training involves exercises with target areas much larger than those used for the serve and that are based more on power than on the search for accuracy. Therefore, these stroke-specific training requirements might influence the strategies adopted in relation to the speed-precision conflict during fatigue situations.

Fatigue could likely cause a remodeling of the inter-muscular coordination in order to maintain task performance. However, no change in the temporal pattern of activation was observed in our study. Still, the loss of speed in the serve could be partly explained by the decreased activity of two muscles involved in generating speed, the PM and FCR, which appear to be determining in the acceleration phase (Morris et al. 1989, Ryu et al., 1988). They are involved, respectively, in the rotation of the shoulder and flexing of the wrist, which contribute 40% and 30% to the total speed of the serve (Elliott, 2006). During a state of fatigue, players seem to decrease the activation of these muscles, causing a decrease in speed. The purpose of this adaptation may be to limit the risk of injury by reducing the amplitude and forces of the movement (Kovacs, 2006). The deterioration of forehand precision could be linked to the decrease of the FCR and ECR EMG activation levels since a decreased activity of these muscles can lead to poor racket control. This decline in muscular activity could cause an alteration of racket holding, wrist stabilization (Morris et al., 1989) as well as impact shock and vibration dampening (Chow et al., 2007). Changes in the EMG activity of the FCR and ECR muscles observed in the forehand, associated with the forearm pains experienced by some players confirm that the high gripping forces generated at impact during groundstrokes lead to significant constraints on the forearm of the player (Davey et al., 2002) and can generate highly localized fatigue.

CONCLUSION

This study highlights the utility of working on serve speed and forehand accuracy while in a state of fatigue. It also seems useful to develop the muscular endurance of the PM and the muscles of the forearm, which appear most susceptible to fatigue. Thus, based on these results, coaches and players will be able to develop a specific training program designed to delay the onset of fatigue and develop effective strategies for maintaining performance, while reducing the risk of injury.

REFERENCES

Brabenec, J. (2000) Why the forehand is a key stroke. ITF Coaching and Sport Science Review 21, 11-13.

Chow, J.W., Knudson, D.V., Tillman, M.D. & Andrew, D.P. (2007) Pre- and post-impact muscle activation in the tennis volley: effects of ball speed, ball size and side of the body. Br J Sports Med 41(11), 754-9. https://doi.org/10.1136/bjsm.2007.037184

Davey, P.R., Thorpe, R.D. & Williams, C. (2002) Fatigue decreases skilled tennis performance. J Sports Sci 20(4), 311-8. https://doi.org/10.1080/026404102753576080

Elliott, B. (2006) Biomechanics and tennis. Br J Sports Med 40(5), 392-6. https://doi.org/10.1136/bjsm.2005.023150

Elliott, B. (2001) The serve. ITF Coaching and Sport Science Review, 24, 3 - 4.

Gillet, E., Leroy, D., Thouvarecq, R. & Stein, J.F. (2009) A notational analysis of elite tennis serve and serve-return strategies on slow surface. J Strength Cond Res 23(2), 532-9. https://doi.org/10.1519/JSC.0b013e31818efe29

Girard O., Guerin P., Teulier C., Millet G.P., Micallef J.P. (2009) Effets de la fatigue sur les coordinations segmentaires au service en tennis : étude préliminaire. pp. 353-360 in Cronier L., Bayle E. (eds.) Le tennis dans la société de demain. AFRAPS.

Girard, O., Lattier, G., Maffiuletti, N.A., Micallef, J.P. & Millet, G.P. (2008) Neuromuscular fatigue during a prolonged intermittent exercise: Application to tennis. J Electromyogr Kinesiol 18(6), 1038-46. https://doi.org/10.1016/j.jelekin.2007.05.005

Girard, O., Lattier, G., Micallef, J.P. & Millet, G.P. (2006) Changes in exercise characteristics, maximal voluntary contraction, and explosive strength during prolonged tennis playing. Br J Sports Med 40(6), 521-6. https://doi.org/10.1136/bjsm.2005.023754

Hornery, D.J., Farrow, D., Mujika, I. & Young, W. (2007) Fatigue in tennis: mechanisms of fatigue and effect on performance. Sports Med 37(3), 199-212. https://doi.org/10.2165/00007256-200737030-00002

Kovacs, M.S. (2006) Applied physiology of tennis performance. Br J Sports Med 40(5), 381-5; discussion 386. https://doi.org/10.1136/bjsm.2005.023309

Morris, M., Jobe, F.W., Perry, J., Pink, M. & Healy, B.S. (1989) Electromyographic analysis of elbow function in tennis players. Am J Sports Med 17(2), 241-7. https://doi.org/10.1177/036354658901700215

Ryu, R.K., McCormick, J., Jobe, F.W., Moynes, D.R. & Antonelli, D.J. (1988) An electromyographic analysis of shoulder function in tennis players. Am J Sports Med 16(5), 481-5. https://doi.org/10.1177/036354658801600509

Vergauwen, L., Spaepen, A.J., Lefevre, J. & Hespel, P. (1998) Evaluation of stroke performance in tennis. Med Sci Sports Exerc 30(8), 1281-8. https://doi.org/10.1097/00005768-199808000-00016 https://doi.org/10.1097/00005768-199808000-00017

Wu, C.L., Shih, M.C., Yang, C.C., Huang, M.H. & Chang, C.K. (2010) Sodium bicarbonate supplementation prevents skilled tennis performance decline after a simulated match. J Int Soc Sports Nutr 7, 33. https://doi.org/10.1186/1550-2783-7-33