The Influence of Court Surfaces on Lower Limb Muscle Activation of Tennis Run-and-Stroke

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This study aimed to examine the characteristics of lower extremity muscle activity between different tennis court surfaces. Six male right-handed elite tennis players were recruited, and their electromyography activity (EMG) during open stance running forehand were collected. Average activity level of rectus femoris (RF), biceps femoris (BF), gastrocnemius (GAS), tibialis anterior (TA) from the lead leg, which normalized by maximal voluntary isometric contractions (MVC) was recorded under different situation (hard court, grass court, clay court). Our study demonstrates that GAS was significantly different and the activation level was greater on a hard court than on clay (p = .005). Tennis players should enhance their gastrocnemius muscle performance when matching from clay to hard court to avoid a higher level of gastrocnemius activation when adapting to a different court, which could lead to an injury.

KEYWORDS: Grand Slam, training, EMG, performance

INTRODUCTION: The characteristics of various courts can affect athletes' performance. Tennis is unique from other sports in that there are various playing surfaces ranging from grass, clay, carpet, and hard court. A previous study of 20,000 amateur tennis players on four types of tennis courts (hard court, clay, sand-fill artificial grass, and red-sand-fill artificial grass) over a 6-month cross-sectional survey found that players who played on multiple surfaces had a higher injury prevalence, particularly of overuse injuries, than those who primarily played on one court surface (Pluim et al., 2018). Current professional tennis tournaments require players to play on three (hard, clay, grass) courts with different characteristics within a very short period, while the Roland-Garros on clay and the Wimbledon on grass are only a month apart. A longitudinal study over 10 years (2003-2012) at The Wimbledon Championships showed that 61% of the injuries in the tournament occurred after the French Open, which was on the clay and before Wimbledon, which was on the grass. Furthermore, knee, ankle and heel are the most common injured joints (McCurdie et al.,2017). Those evidence indicated that switching between playing surfaces would be a higher risk factor for injury in a short period (Fu et al., 2018; McCurdie et al., 2017). A higher friction surface (hard court) produced higher plantar pressure on the front foot during running and hitting the ball, and that was related to the rate of overused-injury (Damm et al., 2014). Therefore, understanding the differences in the activation of the lower extremity muscles for move-and-stroke on different surfaces can help coaches, players, and protection teams propose training directions and recommendations for various surfaces to prevent a higher incidence of injury for players who overuse and alternate between multiple surfaces.

METHODS: Six well-trained right-handed college tennis players (male, age: 22.5 ± 4.1 yr; height: 179.7 ± 4.7 cm; body mass: 74 ± 7.6 kg) volunteered to participate in this study. All participants gave their consent before the experiment and had no history of lower extremity pain within the last half year. All participants were fully informed of the benefits and risks of the investigation before signing. The research design was approved by the Institutional Review Board of Fu Jen Catholic University in Taiwan. The muscle activation signals of the rectus femoris (RF), biceps femoris (BF), gastrocnemius (GAS), and tibialis anterior (TA) were recorded in the right side lower extremity with the Delsys-16 EMG system (Delsys Inc., Natick, MA, USA) at 2000 Hz.

After a 10 min standardized warm-up consisting of dynamic and striking to ensure they familiarize themselves with the process and the environment, two maximal isometric voluntary contractions (5-s duration) were then performed with 2 min rest between them. Participants were required to run 3 meters to the right, step to stop and make a stroke immediately. Each surface required 5 open-stance forehand strokes. (Figure 1) To eliminate random errors caused by adaptation or learning, counterbalanced design was applied. EMG data were filter band-pass-filtered (20–450 Hz, telemetry device property) and full wave rectified. One-way repeated measures ANOVA was used to test the different court surfaces on the selected biomechanical parameter. When the main effect size was significant, the Bonferroni method was used for the post hoc comparison test.

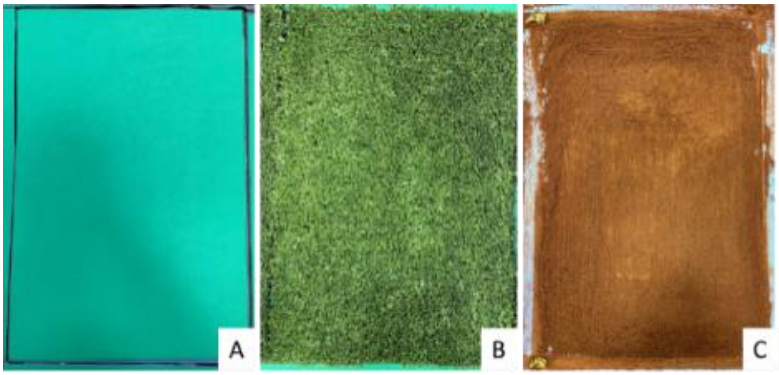

Figure 1: Three different court surfaces, (A) hard court, (B) grass court, (C) clay court.

RESULTS: The comparisons of EMG average activity level of lower limb muscles during run-and-stroke on various court surfaces showed that the GAS was significantly different (p = .001, η2 = 1) and the activation level was greater on the hard court than on clay (p = . 005). No significant differences were found for BF (p = .019, η2 = 0.546), RF (p = .067, η2 = 0.418), and TA (p = .083, η2 = 0.392).

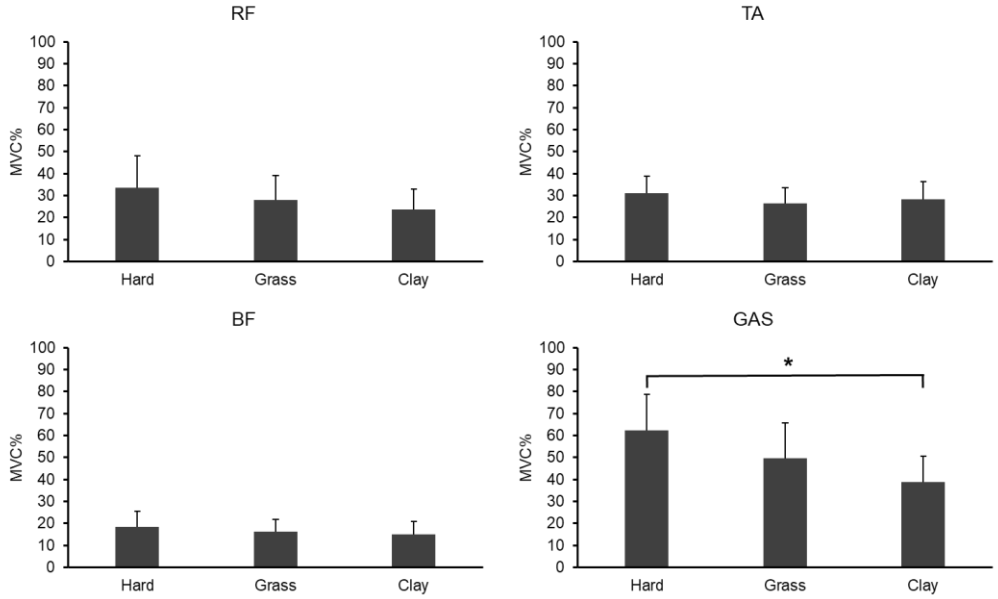

Figure 2: Normalized EMG average activity level of lower limb muscles during run-and-stroke on various court surfaces (% MVC). *: indicates significant difference between different court surfaces (p < .05).

DISCUSSION: The purpose of this study was to investigate the effect of lower limb muscle activation on different court surfaces. To figure out the issue of simultaneous

experimentation in the lab with different court surfaces, a large artificial grass and clay court was created by us to simulate the effects of the actual court. The primary objective of this study was to quantify the effect of different court surfaces on lower limb muscle activation under move-and-stroke conditions, and the data obtained reflected that GAS activation was less on the clay court, possibly due to court specificity. Although the difference in muscle activation was not a significant difference on the clay, there was a longer activation duration due to the sliding feature on the court (Ferrauti et al., 2013). In addition, although there were no significant differences in RF, BF, and TA, the results of this study showed moderate or higher performance in η2 (Bakeman, 2005), suggesting a tendency for greater muscle activation in hard surfaces compared to grass and clay, which may be related to the friction coefficient of the surface. In a previous study comparing tennis-specific running tests on clay and hard court, it was found that it took longer to move on clay courts due to the characteristics of the court, suggesting that different training approaches should be given to tennis players according to the characteristics of the different courts to adapt to the court. The three types of courts in the tennis Grand Slam series have been shown to present different movement characteristics (Starbuck et al., 2016), and the transition between courts may be a risk factor for injury in tennis players (Fu et al., 2018; McCurdie et al., 2017). The GAS is the main plantarflexor of the ankle joint that is an interplay between concentric (pressing) and eccentric (braking) actions. Previous studies have implied greater muscle activation in the GAS when landing during tennis side-step running (Nieminen et al., 2014); studies have classified muscle activation levels as low activity (< 25% MMT), activity moderate (25–40% MMT), activity high (> 40%), and found that muscle activation in the upper-limb during forehand stroke was up to 55% (biceps) (Morris et al., 1989), while we found that muscle activation during running stroke was up to 60%, and that lower limb muscles were not less important than upper limb muscles during the running stroke. Soleus-gastrocnemius injury is a common injury among tennis players (Bisciotti et al., 2022). Our study confirms that the GAS plays an important role in all three courts. The greater muscle activation (around 60%) on the hard-court could indicate the relation between a higher injury rate and the court transition.

During the season, GAS can be strengthened through plyometric training (Hirayama et al., 2017), and it is suggested that tennis players can use plyometric training such as reverse jumping to their regular condition training to enhance the lower limb muscles, which will allow them to adapt to each court more quickly and reduce its impact.

CONCLUSION: Playing on different courts will lead to different lower extremity muscle activation among tennis players, and players trained on the same court for a long period of time might have negative adaptation. The GAS, in particular, has a greater level of activation on hard courts than on red clay courts. The Gastrocnemius is necessary for a good push during running and it plays an important role when the player runs, stops and changes direction, especially on hard courts. Therefore, when players faced with transition from red clay to hard courts, they should strengthen their gastrocnemius in order to avoid injuries related to over-activation of the gastrocnemius.

REFERENCES

Bisciotti, G. N., Corsini, A., Volpi, P., Bisciotti, G. N., Corsini, A., & Volpi, P. (2022). Case Report: Return to Play and Return to Training After Soleus-Gastrocnemius Injury. In Return-to-Play after Lower Limb Muscle Injury in Football: The Italian Consensus Conference Guidelines (pp. 147-154). Springer International Publishing.

Bakeman, R. (2005). Recommended effect size statistics for repeated measures designs. Behavior Research Methods, 37(3), 379–384. https://doi.org/10.3758/bf03192707

Damm, L., Starbuck, C., Stocker, N., Clarke, J., Carré, M., & Dixon, S. (2014). Shoe-surface friction in tennis: influence on plantar pressure and implications for injury. Footwear Science, 6(3), 155-164.

Ferrauti, A., Fernandez-Fernandez, J., Klapsing, G. M., Ulbricht, A., & Rosenkranz, D. (2013). Diagnostic of footwork characteristics and running speed demands in tennis on different ground surfaces. Sports Orthopaedics and Traumatology, 29(3), 172–179.
Fu, M. C., Ellenbecker, T. S., Renstrom, P. A., Windler, G. S., & Dines, D. M. (2018). Epidemiology of injuries in tennis players. Current Reviews in Musculoskeletal Medicine, 11(1), 1–5. https://doi.org/10.1007/s12178-018-9452-9.
Hirayama, K., Iwanuma, S., Ikeda, N., Yoshikawa, A., Ema, R., & Kawakami, Y. (2017). Plyometric training favors optimizing muscle–tendon behavior during depth jumping. Frontiers in Physiology, 8, 16. https://doi.org/10.3389/fphys.2017.00016
McCurdie, I., Smith, S., Bell, P., & Batt, M. (2017). Tennis injury data from The Championships, Wimbledon, from 2003 to 2012. British Journal of Sports Medicine, 51(7), 607–611. https://doi.org/10.1136/bjsports-2015-095552
Morris, M., Jobe, F. W., Perry, J., Pink, M., & Healy, B. S. (1989). Electromyographic analysis of elbow function in tennis players. The American Journal of Sports Medicine, 17(2), 241–247. https://doi.org/10.1177/036354658901700215
Nieminen, M. J., Piirainen, J. M., Salmi, J. A., & Linnamo, V. (2014). Effects of neuromuscular function and split step on reaction speed in simulated tennis response. European Journal of Sport Science, 14(4), 318–326. https://doi.org/10.1080/17461391.2013.785598
Pluim, B. M., Clarsen, B., & Verhagen, E. (2018). Injury rates in recreational tennis players do not differ between different playing surfaces. British Journal of Sports Medicine, 52(9), 611–615. https://doi.org/10.1136/bjsports-2016-097050
Starbuck, C., Damm, L., Clarke, J., Carré, M., Capel-Davis, J., Miller, S., Stiles, V., & Dixon, S. (2016). The influence of tennis court surfaces on player perceptions and biomechanical response. Journal of Sports Sciences, 34(17), 1627–1636.

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