THE INFLUENCE OF GRIP POSITIONING ON MUSCLE ACTIVATION PATTERNS IN TENNIS FOREHAND: A PRELIMINARY INVESTIGATION

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This study compared muscle activation patterns during the forehand stroke among thirteen nonprofessional tennis players across three grip positions [Eastern(4), Semi Western(6), Western(3)]. Surface electromyography was used to assess fourteen trunk and dominant upper arm muscles, while hitting forehand crosscourt shots using their preferred grip. Individuals using Semi Western grip demonstrated higher activation of proximal musculature responsible for horizontal flexion/internal rotation at the shoulder (Pectoralis), whereas those using Eastern grip had higher activation in distal musculature (FCU, ECR), acting primarily to control flexion/extension. These differences suggest the Eastern grip requires less axial rotation of the arm but more contribution of wrist flexor/extensors than Semi Western/Western grips, which may relate to grip-specific repetitive strain injuries.

KEYWORDS: tennis, forehand grip, surface electromyography, injury

INTRODUCTION: The forehand is the most commonly used shot in tennis (Reid, Morgan, & Whiteside, 2016). Topspin shots, that involve forward rotation of the ball after impact, are desired by players of all levels as they provide a larger margin for vertical error (i.e. the ball travels higher above the net) while improving the likelihood of ball bounce in the opponent's court (Brody, Cross & Lindsey, 2002). Among tennis players a variety of grip positions are used during forehand topspin shots, including Eastern, Semi Western and Western (Busuttil et al., 2021; Tagliafico at al., 2009). All of these grips are effective in producing both horizontal velocity and forward rotation (topspin), however, previous research has shown that Western grip leads to higher contributions of forearm and hand velocities to racket head velocity in professional athletes compared to Eastern grip (Elliott, Takahashi, & Noffal, 1997).

Many nonprofessional tennis players attempt to adjust their grip position while looking for these more effective topspin shots. However, nonprofessional players, who may lack timing and technical skills, may be more likely to experience injuries while using grips where the wrist plays a key role in developing angular momentum to increase racket speed. In fact, Tagliafico at al. (2009) reported that nonprofessional players who used Western grip experienced more wrist injuries (30%) compared to those using either the Semi Western (10%) or Eastern grips (13%). One plausible injury mechanism could be the reliance on the smaller muscles of the wrist to create racket head velocity in the Western grip, as opposed to the larger muscle groups characteristic of the Eastern style.

To date, research investigating the impact of grip position on muscle activation patterns in tennis forehand has been conducted on professional athletes and often has not compared these three grip styles. Given the high rate of injury among nonprofessional players using the Western grip compared to other grip styles, it is important to understand the muscle activation patterns that underlie these different styles among nonprofessional players to determine plausible injury mechanisms and potential grip recommendations for this cohort. Thus, the purpose of this study was to compare muscle activation patterns of the trunk and dominant arm during the forehand stroke among nonprofessional tennis players using three different grip styles (Eastern, Semi Western, Western).

METHODS: Thirteen nonprofessional tennis players (Mean±SD: 29.5±8.2yrs; 1.69±0.07m, 65.6±11.3kg; 9F, 4M; 15.2±7.3yrs playing tennis; 4.6±4.1hr/wk; Median: Tier 3, Range: 1-3 per McKay et al., 2022), without current injuries or pain that would compromise ability to play, were recruited for this study. Participants were divided among three groups: those that habitually use an Eastern grip (E, N=4); a Semi Western grip (SW, N=6); or a Western grip (W, N=3). Grip style was assessed by a screening questionnaire and verified using video recorded during

the testing session. Participants completed an intake questionnaire about their tennis history, experience and injuries; and were asked to perform approximately 25 crosscourt forehand topspin strokes using their preferred grip and their own racket following a brief warm-up (the first 10 successful shots within the target zone were analyzed). Tennis balls were projected (Playmate Ball Machine, Metaltek Raleigh, USA) at an approximate speed of 57 mph. Participants hit towards a target zone, delineated by flat yellow markers on the diagonal side of the opposite court ($16m^2$). Participants did not change their grip at any point, verified by video. Participants also performed maximal voluntary isometric contractions (MVCs) against external resistance (fixed surface) to maintain isometric contractions.
Muscle activation profiles of 14 muscles on the dominant arm and trunk were recorded using surface electrodes (Trigno, Delsys Inc.): Pectoralis Major (PM), Latissimus Dorsi (LD), Deltoid Anterior (DA), Deltoid Posterior (DP), Deltoid Medialis (DM), Biceps Brachii (BI), Triceps Brachii (TI), Brachioradialis (BR), Teres Major (TM), Trapezius (TZ), Flexor Carpi Radialis (FCR), Flexor Carpi Ulnaris (FCU), Extensor Carpi Radialis (ECR), and Pronator Teres (PT); placements per Basmajian & Blumenstein (1980). Joint kinematic patterns of the upper limb and trunk were assessed using wireless inertial sensors (Opal; APDM Inc., Portland, OR) affixed to hand, forearm, upper arm, sternum and lumbar segments using double-sided tape and elastic straps in the standard positions dictated by the manufacturer; trunk transverse rotation reversals were used to delineate the onset and completion of the forehand stroke. Joint kinematics will not be presented. Muscle burst onsets/offsets were determined using an integrated profile algorithm (Allison, 2003) and magnitudes were normalized to average activity during MVC trials. Mixed model, repeated measures ANOVAs were used to analyze temporal and spatial variables (repeated factor: muscle; between factor: grip style), and one-way ANOVAs were used to examine the effect of grip style at each muscle independently (due to low N). Effect sizes (Partial Eta Squared) will be assessed.

RESULTS: Muscle activation onsets were classified into three groups, activated sequentially. The first group contained only PM, which was activated earlier than the second group, including BI, PT, FCR, BR, FCU, TZ, DA, ECR, TI, LD, TM. The final group, with the latest onsets, included DM and DP (Figure 1).

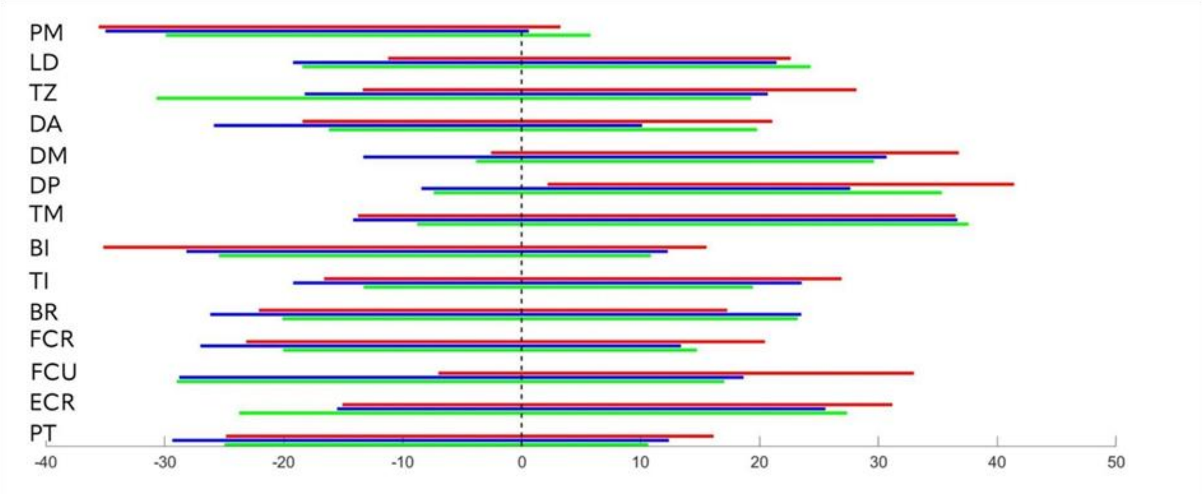

Figure 1: Average EMG burst timing (%) as a percentage of total forehand swing time, aligned by ball contact point. Western (Red bars), Semi Western (Blue bars), Eastern (Green bars).

Significant differences in muscle timing between grips were determined for onsets of the TZ (Partial Eta[2]: η_p^2=0.57) and FCU (η_p^2=0.38) muscles. In the E group, TZ was activated earlier than for the SW (P=0.017) and W (P=0.007) groups. FCU was activated earlier for the SW and E groups, compared to W group (P=0.046 and 0.059, respectively).
Comparing average burst magnitudes, there were few statistically significant findings, likely owing to small group numbers, however, non-significant trends are reported (Figure 2). Participants using SW grip tended to use a higher % of maximal activation at the TZ (η_p^2=0.35)

and PM (η_p^2=0.17) compared to the E (TZ: P=0.075; PM: P=0.21) and W groups (TZ: P=0.18; PM:P=0.34). SW grip participants also had lower activation of PT (η_p^2=0.24) compared to W (P=0.14) and E (P=0.22). Participants using E grip tended to use a greater magnitude of DA (η_p^2=0.23), TI (η_p^2=0.29) and ECR (η_p^2=0.40) activation compared to SW (DA: P=0.15; TI: P=0.088; ECR: P=0.15) and W grips (DA: P=0.18; TI: P=0.14; ECR: P=0.029). Additionally, the E group had a slightly higher activation of FCU (η_p^2=0.17) than the W group (P=0.19).

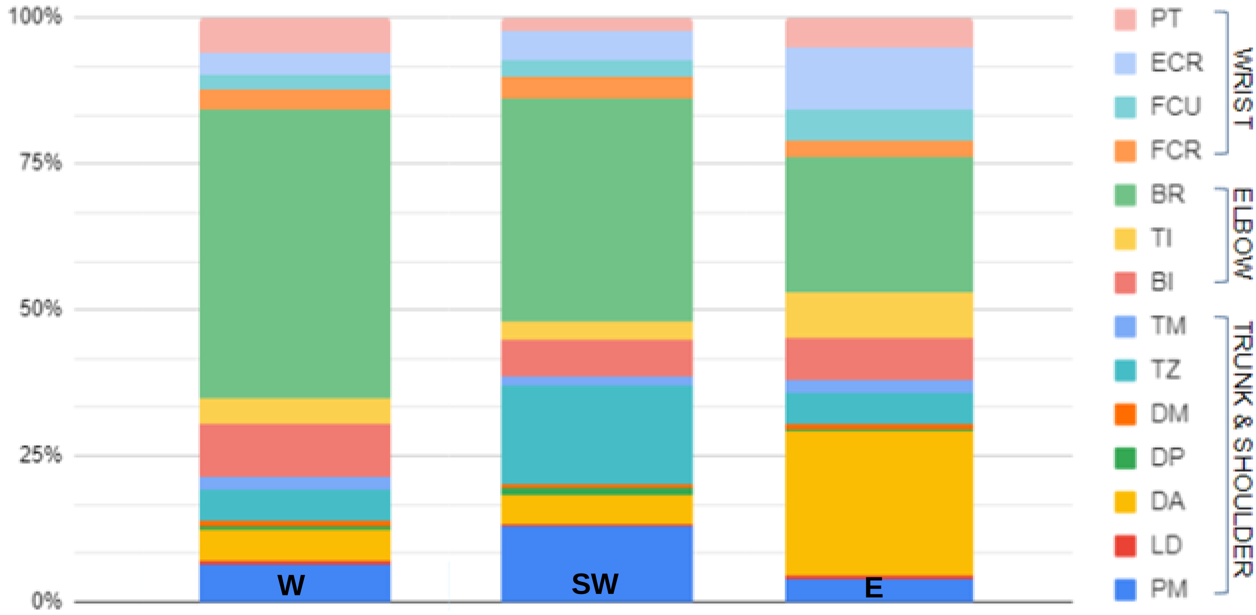

Figure 2: Relative contributions (%) of average burst activation as a percentage of total muscle activity for all muscles, for Western, Semi Western and Eastern grips (left to right).

DISCUSSION: The timing of muscle activations was similar across all grips and followed proximal-to-distal sequence for agonist muscles, while antagonist muscles were activated closer to the contact point. However, some grip-specific trends in muscle magnitude were evident. Individuals using SW grip demonstrated higher activation of proximal musculature (PM and TZ) responsible for horizontal flexion and internal rotation at the shoulder, whereas those using E grip had higher activation in more distal musculature (DA, TI, ECR) likely to generate joint flexion/extension motions. These differences suggest E grip requires less internal rotation of the shoulder during the forehand stroke than the SW and W grips.

On average, the forearm muscles represented ~20% of the total muscle activity during the forehand stroke as they are used to grip the handle to control racket position and thus the direction and spin of the shot. As anticipated, grip-specific forearm muscle activation was evident. The W group demonstrated increased contribution of PT compared to SW and E, suggesting that participants using the W grip may rely more on wrist pronation to create forehand topspin. This is consistent with the findings of Elliot et al. (1997), who reported a non-significant increased contribution of pronation in the W group compared to the E group, although the study assessed joint motion and not EMG as in the current study. In contrast, the SW and E grips favor ECR and FCR contributions to the forehand stroke, suggesting that radial deviation rather than pronation is used to create topspin.

Experience level may have also contributed to the grip-specific differences identified. For instance, in Figure 2, the E group tended to have a greater relative contribution of forearm muscles to the motion. This increase could relate to the lower expertise level among the group's participants as they use the forearm muscles to grip the racket handle more tightly to control racket position. In the current study, the E group consisted of the most recreational players (Median: Tier 2); compared to the other groups, which had more current/former collegiate players (Median: Tier 3 for both W and SW). Less advanced players tend to hit the ball off-center more often, which causes the racket to rotate; to avoid a loss of control these participants might have increased forearm muscle activation (King et al., 2012). Additionally, precision demands, such as the experimentally-imposed target zone, or increased mental pressure, have been shown to lead to increased muscle activation (Visser et al., 2004). Even though all participants had the same task and target, a lower expertise group might have perceived the task to be more difficult, possibly leading to increased muscle activation, particularly at the forearm.

CONCLUSION: The results of the current study suggest that both temporal and spatial muscle activation parameters are influenced by grip style during forehand topspin shots in nonprofessional tennis players. Players using Eastern grip favoured muscles responsible for shoulder flexion, elbow extension and radial deviation, suggesting that more of the forehand stroke motion occurs largely using sagittal/frontal joint motions. Players using Semi Western grip had increased activity among muscles responsible for internal rotation of the shoulder and pronation, suggesting that the motion uses more axial rotation. Differences in the peak and relative contributions of muscle activation required to generate racket velocity and topspin might put players at increased risk for specific injuries, depending on the grip used. For example, increased internal rotation in the SW grip might lead to shoulder overuse injuries, while the W grip with its high reliance on pronation around the contact point might make players more susceptible to elbow injuries. Analysis of joint angles concurrent with EMG may provide further information with which to infer grip-specific mechanisms of injury. Given these findings it may be prudent to caution less experienced players against using the SW or W grips until they have attained sufficient skill to control the racket appropriately. Further investigation should evaluate the relationship between grip-specific muscle activation, skill level and injury incidence to support the validity of these grip recommendations for inexperienced players.

REFERENCES

Allison, G.T. (2003). Trunk muscle onset detection technique for EMG signals with ECG artefact. *Journal of Electromyography & Kinesiology*, 13(3), 209-16, https://doi.org/10.1016/s1050-6411(03)00019-1

Basmajian, J.V., & Blumenstein, R. (1980). *Electrode placement in EMG biofeedback.* Williams & Wilkins.

Brody, H., Cross, R., & Lindsey, C. (2002). *The physics and technology of tennis* (pp. 381–389). Vista, CA: Racquet Tech Publishing.

Busuttil, N.A., Roberts, A. H., Dunn, M. & Middleton, K. J. (2021). Perspectives and practices of accredited tennis coaches when developing stroke technique. In, *39th Conference of the International Society of Biomechanics in Sports* (pp.17-20). Canberra, Australia.

Elliott, B. C., Takahashi, K., & Noffal, G. J. (1997). The influence of grip position on upper limb contributions to racket head velocity in a tennis forehand. *Journal of Applied Biomechanics*, 13,182–196, https://doi.org/10.1123/jab.13.2.182

King, Mark & Kentel, Behzat & Mitchell, Sean. (2012). The effects of ball impact location and grip tightness on the arm, racquet and ball for one-handed tennis backhand groundstrokes. *Journal of biomechanics*, 45, 1048-52, https://doi.org/10.1016/j.jbiomech.2011.12.028

McKay, A.H, Stellingworth, T., Smith, E.S., et al. (2022). Defining training and performance caliber: a participant classification network. *International Journal of Sports Physiology and Performance*, 17, 317-31. https://doi.org/10.1123/ijspp.2021-0451

Reid, M., Morgan, S., & Whiteside, D. (2016). Matchplay characteristics of Grand Slam Tennis; implications for training and conditioning. *Journal of Sports Sciences*, 24, 1–8, https://doi.org/10.1080/02640414.2016.1139161

Tagliafico, A. S., Ameri, P., Michaud, J., Derchi, L. E., Sormani, M. P., & Martinoli, C. (2009). Wrist injuries in nonprofessional tennis players: Relationships with different grips. *American Journal of Sports Medicine*, *37*(4), 760–767, https://doi.org/10.1177/0363546508328112

Visser B, De Looze M, De Graaff M, Van Dieën J. (2004). Effects of precision demands and mental pressure on muscle activation and hand forces in computer mouse tasks. *Ergonomics*, 47(2), 202-17. https://doi.org/10.1080/00140130310001617967

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