VARIABILITY IN KICKING LIMB JOINT COORDINATION – A STRATEGY USED WHEN SERVING THE MULTI-PLANAR KUDA AND SILA SERVES

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The purpose of this study was to investigate differences in kicking limb joint coupling coordination between kuda and sila serve techniques in the sport of sepaktakraw. Nine sepaktakraw servers, highly proficient in both techniques, participated in this study. Angle-angle plots and NoRM indices established variability in hip-knee and knee-ankle joint coordination. Similar angle-angle plots between trials within subjects suggested consistency in technique, but with some degree of joint coordination variability. Although not statistically different, larger hip-knee joint coordination variability and variation in individual knee-ankle joint coupling coordination between trials may be how servers adapt to the differences in ball placements at impact. This adaptation may be a strategy to generate maximal *kuda* kicking limb speeds necessary for optimal impact.

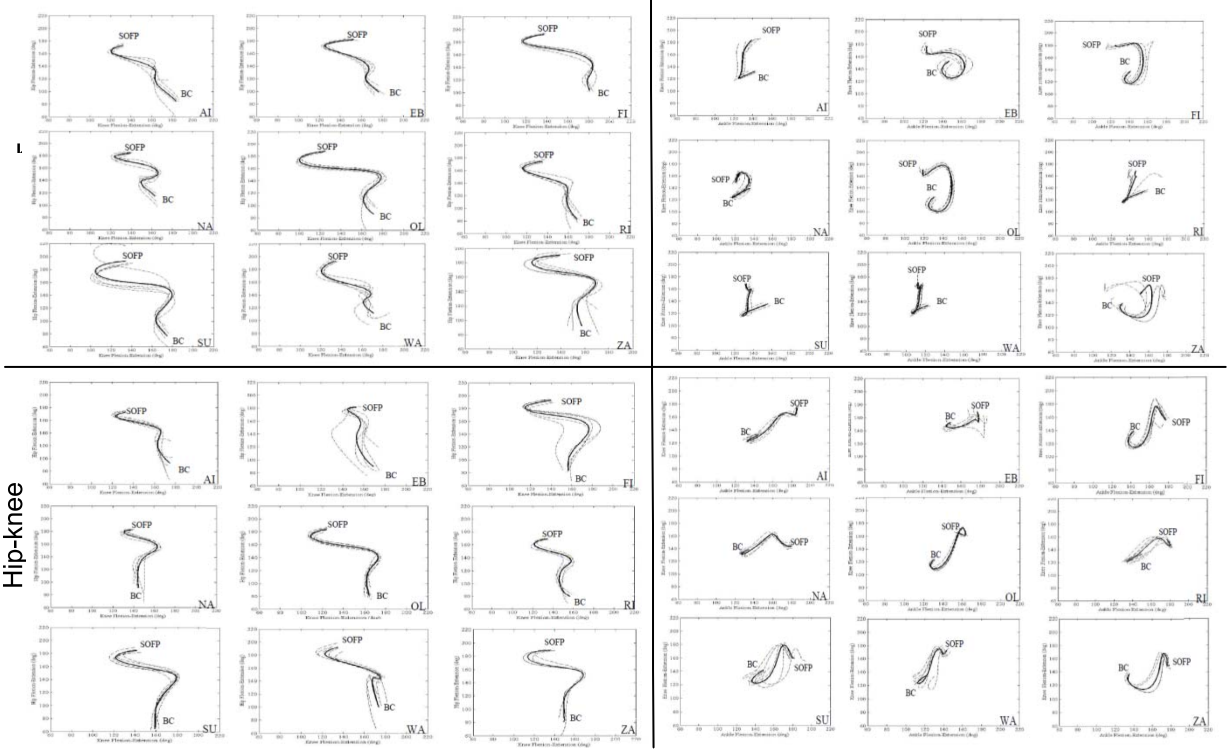
KEY WORDS: sepaktakraw, multi-planar kicking, joint coordination, variability.

INTRODUCTION: Studies have reported that variations in movement patterns are not necessarily errors, but essential elements to normal function; one that offers flexibility in adapting to perturbations (Hamill, van Emmerik, Heiderscheit & Li, 1999; van Emmerik & vanWegen, 2000). When performing complex sport skills, variability in movement patterns is an adaptive mechanism utilised by trained athletes to find the best possible solution necessary to generate positive performance outcomes (Todorov & Jordan, 2002; Davids, Glazier, Araújo & Bartlett, 2003; Chow, Davids, Button & Koh, 2006). Sepaktakraw is a complex sport that begins with a serve. The two main serves in sepaktakraw are the kuda and sila techniques. When serving in sepaktakraw, the ball is tossed to where the server points to in mid-air. As the tossed balls never have the exact same trajectory, the server must adjust their kicking limb coordination toward ball impact. Thus, the objective of this study was to investigate differences in kicking limb joint coordination variability during kuda and sila serving. Variability in kicking limb joint coordination may a strategy used when serving in sepaktakraw.

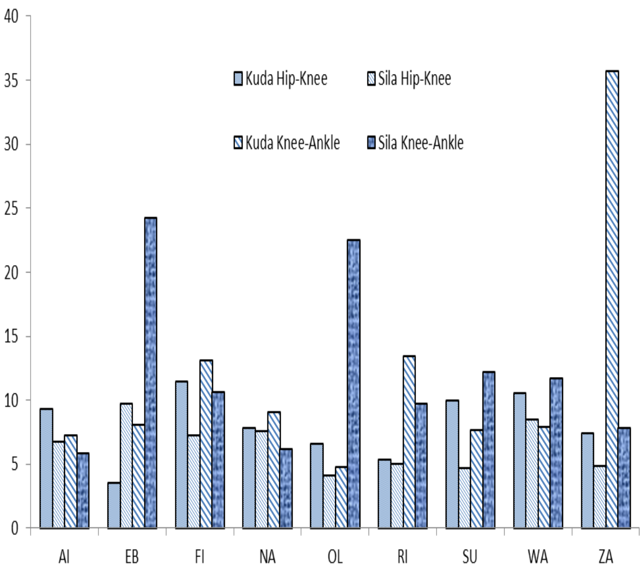
METHODS: 9 players, highly skilled and proficient in kuda and sila serves, performed 20 trials for each respective serve. Only 5 successful kuda and sila serve trials (highest ball velocities, net clearance, and ball lands within playing boundaries across court) were selected from each player for final analysis. The criterions for successful serves mimicked actual competition scenarios. 7 high speeds optical cameras capture all kuda and sila trials. Using the hip, knee and ankle joint kinematics capture in three-dimensional space, hip-knee and knee-ankle angle-angle plots were determined for each trial from start of force-production phase (SOFP) to instant of ball-contact (BC). Participants' kicking limb was divided into hip-knee and knee-ankle joint couplings. Angle-angle profiles created for each coupling and coupling angles were calculated using the orientation of the resultant vector to the right horizontal between two adjacent points on the relative motion plots. The resulting range of values for each coupling (0^{o}-180^{o}) were obtained via conversion of raw data radians to degrees. Normalised root mean squared (NoRMS) indices, a procedure developed by Sidaway, Heise & Schoenfelder-Zohdi (1995), were used to quantify variability in joint coupling coordination.To calculate NoRMS, joint angles were expressed in relative terms to avoid neutral joint positions and the joint angles should be greater than zero and less than 360^{o}. Higher NoRMS indicates greater variability, whereas a lower index indicates lower variability in movement patterns coordination. Differences in NoRMS for each coupling between techniques were statistically analysed using t-test via SPSS Software. Eta-squared (η^2) was used to determine a measure of effect size. An effect size of 0.05 was considered small, 0.10 as intermediate and >0.20 as large (Cohen, 1988). Effect size (ES) was used to further evaluate the relevance of this mean difference.

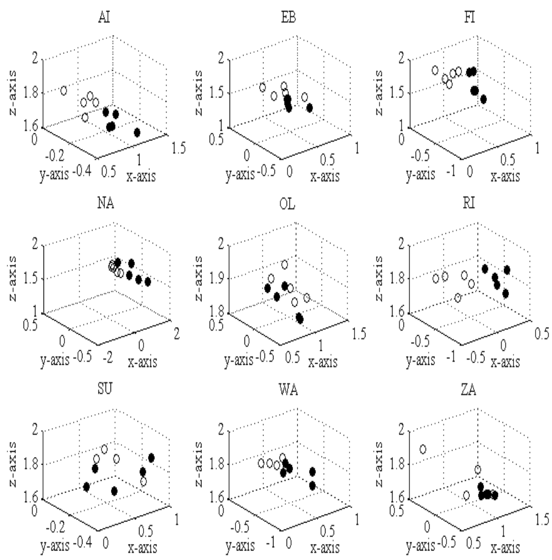
RESULTS: Characteristics of kuda and sila hip-knee angle-angle plots from SOFP to BC were similar for each trial (T1-T5) between and within subjects. Although similar for trials (T1-T5) within subjects, the characteristics of kuda and sila knee-ankle angle-angle plots from SOFP to BC were different between subjects.

B A



Knee-ankle joint coupling





Sila

Statistical analysis revealed no significant differences in hip-knee and knee-ankle NoRMS between technique (hip-knee: p=0.163; knee-ankle: p=0.927). Hip-knww NoRMS were larger for kuda (ES=0.67), but knee-ankle NoRMS were larger for sila (ES=0.10). Kuda ball velocities were significantly higher than sila (P=0.00). Distribution of *kuda* (white) and *sila* (black) ball placements at impact (along x-, y-, and z-axes) between trials (T1-T5) within and between subjects (AI-ZA) are illustrated in Figure 2 above.

DISCUSSION: Differences in hip-knee and knee-ankle angle-angle plots between trials is evidence of kicking limb joint coordination variability when performing the *sepaktakraw kuda* and *sila* serve kicking techniques. Considering that ball velocities were consistent between trials (T1-T5), these differences suggest that each server varies their movement patterns when performing the two serves. While differences in hip, knee and ankle joint angular displacements suggest differences in kicking limb length between serves at impact (Sujae & Koh, 2008), differences in hip-knee and knee-ankle angle-angle plots between trials (Figure 1) probably suggest variability in joint coordination in relation to different ball placements at impact. Despite all subjects being highly trained and proficient athletes, the presence of coordination variability in kicking limb joint couplings may be adaptation to ball placements when performing the two serves. It is, therefore, safe to conclude that when serving in sepaktakraw, servers should vary their technique or movement patterns by adjusting their hip-knee and knee-ankle joint coordination in relation to the placement of the ball at impact for optimal impact. This may be crucial when serving in sepaktakraw as the ball tossed to the server is never at the same spot in mid-air between trials (T1-T5) (Figure 2). Indeed, studies have reported that variability is an adaptive mechanism utilised by trained players to generate consistent positive outcome measures (Todorov & Jordan, 2002; Davids et al., 2003; Chow et al., 2006) as variability, which is innate, is an essential element to normal function, one that offers flexibility in adapting to perturbation (Hamill et al., 1999; vanEmmerik & VanWegen, 2000).

Differences in NoRMS affirmed variability in hip-knee and knee-ankle joint coordination as the kicking limb swings to impact. Considering that the kuda serve is more complex than sila, the kuda kicking limb should exhibit greater hip-knee and knee-ankle joint coordination variability as it swings to impact. However, NoRMS for hip-knee joint coupling were larger for kuda than sila and NoRMS for knee-ankle joint coupling were larger for sila than kuda. Although not significant, larger hip-knee NoRMS when compared to sila possibly suggests greater variability in thigh and shank segment coordination when performing the kuda serve and larger knee-ankle NoRMS when compared kuda possibly suggests greater variability in shank and foot segment coordination when performing the sila serve. Since the same subject performed both serves, it is worth speculating that when serving in sepaktakraw, there is a need to vary specific joint coupling coordination as the kicking limb swings to impact depending on the type of serve performed. This may be a crucial strategy utilized by trained sepaktakraw players to sever specific optimal impact.

Although, there were variability in knee-ankle joint coordination, knee-ankle angle-angle plots for both kuda and sila serves were different between subjects. When compared to hip-knee angle-angle plots, these differences strongly indicate some degree of individualism in kicking limb joint coordination, in particular knee-ankle joint coordination. Given that there may be individual differences between subjects in terms of body morphology and kicking limb lengths, it may be that these differences are affordance candidates that directly specify what the server needs to do without compromising performance outcome measures. While differences in hip, knee and ankle flexion joint angle range of motion between subjects suggest differences in kicking limb length in relation to the placement of the ball at impact were reported Sujae and Koh (2008), individual hip-knee and knee-ankle joint coordination variability between trials within subjects points to how each athlete adapts to the differences in ball placements at impact. Research on affordance in sports performance has shown that affordance candidate refers to the objective properties of the environment in which the performer acts in relation to his or her personal capabilities (Hristovski, Davids, Araujo, & Button, 2006). As such, it may be that the coordination becomes player specific and that the ability of each player to adapt and adjust this to kick the ball regardless of its placement at impact are, therefore, possible affordance candidates, which will then affords what the server has to do to ensure optimal swinging of the kicking limb for an optimal impact. When serving in sepaktakraw, the coordination of hip-knee joints may be serve specific while the coordination of the knee-ankle joints may be player specific and that the ability of servers to adapt and adjust his coordination pattern to kick the ball regardless of its placement at impact. Indeed, studies have reported that affordance candidate in sports performance refers to the objective properties of the environment in which the performer acts in relation to his or her personal capabilities (Hristovski et al., 2006). For this reason, similar angle-angle plots between trials (T1-T5) for each technique suggest consistency in technique, but with some variability in joint coupling coordination as both kuda and sila kicking limbs may have demanded major adjustments in movement patterns of the thigh, shank and foot segments as the kicking limb swings along technique specific kicking trajectories to impact (Sujae & Koh, 2008).

CONCLUSION: Larger variability in kuda hip-knee joint coupling coordination and larger variability in sila knee-ankle joint coupling coordination between trials may suggest specific kicking limb joint adaptations to ball placement at impact. Hence, when serving in sepaktakraw, servers may need to adjust their kicking technique by varying joint coordination according to situational demands or constraints (i.e. ball placements at impact, body morphology and kicking limb lengths) for optimal impact. Coaches, therefore, should accept variability in kicking limb joint coordination in relation to ball placements for optimal impact a strategy utilized by trained servers when serving in sepaktakraw and not view it as errors in technique or movement patterns that could compromise performance outcome measures.

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