

Kinematic analysis of pickleball forehand return and skill transfer of accuracy from badminton and tennis players

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Abstract:

As an emerging sport that helps develop agility, coordination, and strategic skills in recreational players, pickleball shares similar abilities found in racquet sports. These shared skills contribute to post-career satisfaction among retired athletes, which in turn promotes lifelong participation among older adults. This research aims to collect kinematic data from racquet sport athletes performing pickleball skills, to inform the development of targeted training programs for both athletes and older adult participants. The study involved twelve participants (N= 12) who were badminton (BG) and tennis (TG) players with formal training and competitive experience. Skill accuracy was assessed while motion is being captured, gathering kinematic data using Kinovea 2023.1.2

Key Words: - Skill transfer, Motor Acquisition, Sustainable Recreation

Introduction

Pickleball, an increasingly popular sport, shares similarities with established racquet sports such as badminton and tennis while incorporating unique modifications. The sport encompasses elements of volleys and striking with a racquet, similar to its counterparts while accentuating its distinctive features. Noteworthy among these distinctions are the incorporation of non-volley zones and underhand striking during service, as elucidated by Philippine Pickleball Federation (2024). Despite its resemblance to tennis in certain aspects, pickleball distinguishes itself by engaging in smaller playing court reminiscent of badminton dimensions, coupled with the utilization of a specialized hard plastic perforated ball that yields a limited bounce.

Beyond the physical dynamics inherent in pickleball, the acquisition and refinement of skills in this sport exhibit correlations with established racquet sports. Donie et al. (2023) highlighted the presence of agility, eye-hand coordination, and concentration, traits commonly observed in badminton players, thus facilitating the development of targeted exercises tailored to enhance such skills. Similarly, the skill set required for tennis, encompassing game psychology variables such as anticipation, strategy formulation, situational awareness, problem representation, and game knowledge, as expounded by Sanchez Mencia et al. (2023), finds resonance in the strategic nuances of pickleball gameplay.

The concept of skill transfer across racquet sports emphasized by previous studies' findings. For instance, Brock and Liu (2023) shared that individuals who engage in both pickleball and badminton demonstrate no discernible disparities in skill acquisition, tactical knowledge, or game performance, thus suggesting a high degree of skill transferability between these disciplines. Moreover, the phenomenon of external focus in pickleball learning, identified as a hallmark of performance enhancement, mirrors analogous findings in the realm of other racquet sports performance and learning, as posited by Starzak et al. (2024).

In sum, the convergence of strategic elements and skill acquisition across pickleball and established racquet sports underscores the multifaceted nature of sport performance and learning paradigms, thus delineating a nuanced understanding of the interplay between these disciplines within the sporting landscape.

Pickleball in Older Adults and Retired Athletes

The seamless transition from professional athletic careers in badminton and tennis to post-retirement recreational activities, such as pickleball, highlights the high skill transferability across these sports. This transition holds significant implications for former athletes seeking to cultivate a diversified post-athletic identity, as emphasized in the work of Schmid et al. (2024). By promoting self-complexity through exploratory engagement, individuals experience a gradual decline in athletic identity, culminating in a sense of satisfaction regarding their sporting careers.

Apart from the challenges of athlete to post-athlete lifestyle transition promisingly addressed by pickleball play, this phenomenon is incidentally observed in other participating cohorts. The recreational pursuit of pickleball has served as a multifaceted solution to in addressing the leisure and physical activity needs among older adults' group. Casper, Bocarro, and Drake (2023) elucidate the potential of pickleball participation in facilitating adherence to recommended physical activity guidelines outlined by the Centers for Disease Control and Prevention (CDC) and the U.S. Department of Health and Human Services (USHHS). Notably, regular engagement in pickleball sessions, as demonstrated by Ryu et al. (2017), not only enhances life satisfaction and social integration among retirees but also serves as an effective coping mechanism for the transition into retirement. Furthermore, empirical evidence suggests a positive correlation between pickleball engagement and mental well-being outcomes, as evidenced by Li et al. (2024), who observed a reduction in depressive symptoms among older adults participating in pickleball activities. Collectively, these findings underscore the benefits of pickleball engagement, positioning it as a holistic and enriching recreational pursuit conducive to enhancing overall quality of life and well-being among older adult populations and retiring racquet sport athletes.

Methods

Sample

The researchers employed purposive sampling in the selection of participants who met specific inclusion criteria. Judgment sampling, a non-probability method, was also necessary ensuring participants' qualification to the criteria set, based on the researchers' initial assessment. The study involved twelve (N=12) experienced players aged 19.92 ± 1.46 years, six in badminton (BG) and six in tennis (TG), who successfully met the eligibility requirements. The participants must have formal training, regional competition experience, a minimum of five years playing experience, and no prior exposure to pickleball to ensure the study's focus on badminton and tennis. This approach ensured the selection of participants, contributing to the validity of scores, and valuable insights for the research.

Study Procedure

Prospective participants received a detailed explanation of the research objectives and procedures before being presented with an informed consent form (ICF). After clarifying all relevant details, they voluntarily signed the ICF, background and other demographics were noted, and handgrip measurements were collected.

Pre-Gathering Routine

Badminton Cohort Warm-up - The warm-up protocol employed in this study commenced with pulse-raising exercises, including running forward and backward with coordinated arm movements, designed to elevate heart rate and prepare the body for physical exertion. This was followed by a series of mobility drills, such as heel raises and trunk twists, aimed at enhancing muscular flexibility and range of motion. Balance-focused exercises, including straight leg swings and lunges, were incorporated to improve postural stability. To further prime participants for rapid movements, quickness drills like fast feet were utilized alongside agility training, such as shadowing movements across the court. The warm-up concluded with knock-up drills, where participants practiced specific strokes and movements to refine technical skills and ensure preparedness for the main training session.

Tennis Cohort Warm-up - The static stretching routine involved holding each position for 10 counts, including neck, forearm, deltoid, triceps, plantar flexor, calf, and ankle stretches, as well as shaking the hands. Dynamic stretches were performed sideline to sideline, starting with half and full arm circles, followed by arm swings up and down, and sideways. The routine also included standing trunk flexion, extension, hyperextension, knee-to-chest stretches, quadriceps stretches, and a standing single-leg twist. Forward and side lunges, high knees, and butt kicks complete the dynamic warm-up sequence.

Data Gathering

1. **Skill Test** - The pickleball performance assessment derived from Louisiana Tech University was conducted on a standard court with designated target zones marked on the opposite side using cone markers. The player uses a polymer core, fiberglass-face paddle (Figure 1) and regulation ball. The test includes variation of baseline, forehand return and backhand return strikes, aiming their returns into the designated four-quadrant target zones. It also used a consistency drill where the player continuously hits the ball to the specified zones twice while responding to the researcher's calls. The scoring was based on the number of successful hits and the accuracy of placement. The test concluded after trials for all target zones and striking variation are completed.
2. **Movement Sampling** - Joint markers were installed in participants' striking arm including acromion process, lateral and medial humeral epicondyles, and radial and ulnar styloid process. Camera weight was set at the level of participants third to fourth lumbar vertebrae, with distance 3 to 5 meters away from execution.

Instrumentation



Figure 1. Polymer Core, Fiberglass-face Paddle

1. SLK Omega Max Pickleball Paddle: Selkirk-made polymer core and fiberglass face paddle, weighing 225 g (Figure 1)
2. Camry EH101 Dynamometer: fitting in the design of the study, the digital handheld device provides a practical and inexpensive tool in measuring general strength, and has shown to provide essential reliability (Huang et al., 2022).
3. 30 fps Android phone camera: 1020P resolution camera from a Redmi 12, Android phone version 14 UP1A.231005.007
4. Movement Analysis Software: the researchers utilized an open-source software, Kinovea 2023.1.2, in the measurement of joint angles as digital goniometer and displacement. It allows review and annotate motion for biomechanical analysis used by recent investigations on sports (Angiolillo, 2024; Uda et al., 2024; Merati et al., 2024)

Ethical Considerations

Proceeding with the one-hour movement performance posed minimal risks to participants, with safety ensured by a warm-up regimen. Participation to the research protocol was voluntary with refreshments provided afterward. The study was approved by Ateneo de Manila University's Ethics Office under Protocol ID: AdMUREC_23_143.

Results

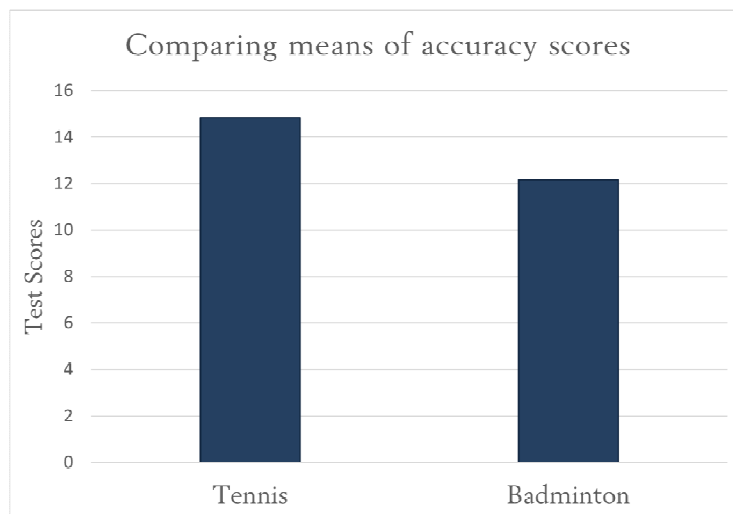


Figure 2. Total accuracy scores of Tennis (TG) and Badminton (BG) Groups

After performing the 3-variation accuracy test, the two groups exhibited diverse accuracy scores. As presented in Figure 2, TG scored with a mean $\pm$ SD of 14.83 ± 3.06 out of a possible 24 points while BG resulted in a relatively lower mean score of 12.17 ± 2.32 . Comparing the trials of all variations in the test, the Mann-Whitney U test results showed no significant difference with U-value of 117.5. However, total score difference of the two groups resulted in a large effect with Cohen's d of 0.983.

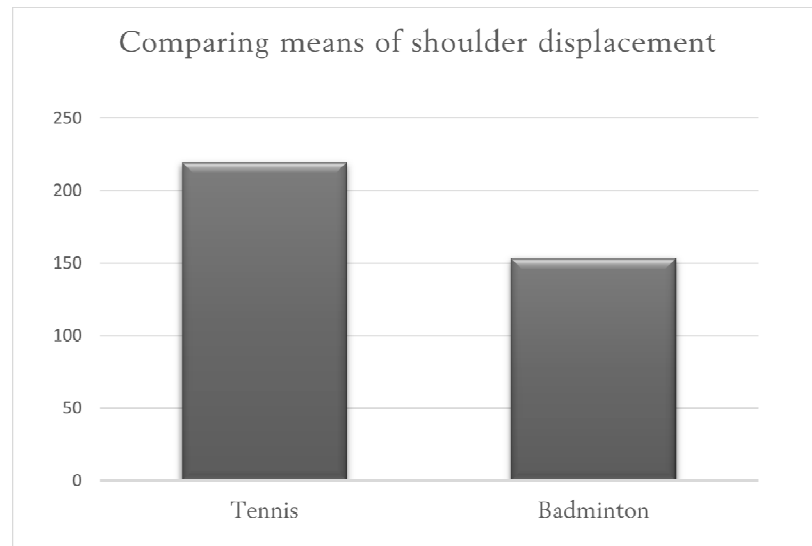


Figure 3. Shoulder displacement of TG and BG during the forehand return technique

Analyzing the shoulder joint during the forehand return variation of the accuracy test, joint tracking revealed a difference in mean $\pm$ SD measurement between the two groups. TG covered a displacement of 219.5 ± 55.29 px, comparing it to a relatively lower from BG with 153.17 ± 52.01 px. With limited number of participants, z-score from the Mann-Whitney U test resulted in 1.68, not significant at $p = 0.09$. However, the effect size supported the large effect of the bar graph representation (Figure 3) with Cohen's d of 1.24. The difference of 66.33 px in mean signified shoulder displacement as factor discriminating TG and BG performance.

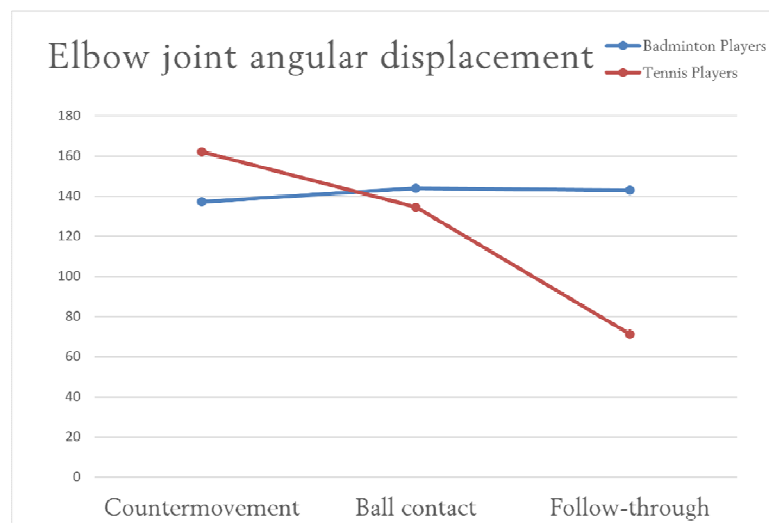


Figure 4. Angular displacement of the elbow joint of both groups

In the movement analysis implemented by the researchers, angular dynamics in the elbow joints of the two groups showed discriminating characteristics. Using the digital goniometer, Figure 4 shows the mean elbow joint angles of BG were 137.15 degrees for countermovement (CM), 143.97 degrees at ball contact (BC) and 142.9 degrees end of follow-through (FT). This produced an angular displacement of 6.82 degrees from CM to BC, and a smaller displacement of 1.07 towards the follow-through. On the other hand, TG displayed greater elbow angle displacement across the three striking phases. Elbow angle measured 162.15 degrees during the CM of TG, 134.53 at BC and 71.18 degrees at the end of FT.

The resulting displacement of 27.62 from CM to BC, and 63.35 from BC to FT. Analyzing elbow angular displacement and shoulder displacement as explanatory variables of accuracy scores, results of the multiple linear regression indicated a weak collective, non-significant effect between elbow angular displacement, shoulder displacement, and accuracy scores, with $F = 1.37$ and $R^2 = 0.12$ ($p = .269$).



Figure 5. Chronophotographs of the elbow joint striking angles of badminton (a) and tennis (b) players across phases ending at the follow-through phase

With BG showing lesser angular displacement across phases, Cohen's *d* uncovered large effect size in CM, and very large in FT, between joint angles of two groups with 1.5 and 3.47 respectively. As seen in Figure 5, the chronophotograph of samples from BG (a) and TG (b) showed a medium effect size in joint angles during the BC phase (Cohen's *d* = 0.6). Visibly, the elbow angle is significantly higher at the CM phase and significantly lower at the FT phase of the sample from TG.

Discussion

Racquet Skills

Agility among badminton players influences performance not limited to racquet sports, ranging from intermediate to advance levels, evident as a tendency to achieve a specific physical task (Donie et al., 2023). Reliance on lunges and pivot are observed, allowing the maximized and quicker change of direction, resulting in an ipsilateral base of support relative to the striking arm. In contrast, the dominant showing of situational awareness (Sanchez Mencia et al., 2023) in other sport, particularly among tennis practitioners uncovered when exposed to a non-tennis racquet task. Advance control transferring to pickleball performance expressed especially with goal-oriented tasks given to practitioners, especially situational awareness in cognitively adapting to an alien skill.

Higher pickleball accuracy scores with predisposed tennis-play tendencies are established with situational awareness and torso angular movements. Presence of torso rotations, not limited to several racquet sports, were seen to be improved with practice (Smith, 1996). Situational awareness guide practitioners towards attention on external focus (Starzak et al., 2024) rather than control conditions, evident in tennis players' dependence on external cues and effective decision-making. In pickleball, this does not only influence accuracy but reflects effective teaching promoting lifelong participation (Merati et al., 2024). The complexity of tennis and badminton leading to career satisfaction is predictable along with the decline of competitiveness with pickleball participation (Schmid et al., 2024). Fulfilment stem from self-complexity, being fundamentally supported by motivation theories such as Harter's, reducing athletic identity but leaning towards sustainability and lifelong participation.

The contrasted arm-leg positions of both groups in this study highlighted further the role of torso movement. Badminton group front leg was ipsilateral to the striking arm, which showed disparity from tennis group with front leg contralateral to the striking arm. Contralateral positioning of the leg allowed greater countermovement range and permitted greater displacement of shoulders and other distal joints of the upper extremities.

Participation Sustainability

The mobility and performance variation across racquet sports inevitably surfaces when cross-sport exposure occurs, where reliance on movement pattern predisposition is high. Upper body mobility, particularly of tennis players in this case, is indispensable in participation results, leading to participant self-efficacy and perceived competence. In other performance components such as speed, speed-inclined racquet sports affect the participants in the same way. Self-efficacy sustains participation as satisfaction drives lifelong involvement.

With the decreased demand on intensity and speed, options for older adults in achieving the sustainable global physical activity recommendations rise through pickleball (Casper, Bocarro, & Drake, 2023). A need to note mobility demands for an integrated participation support systems arise in training and instruction in older

adult preparation. Along with infrastructure support, training advancements promote health sustainability goals better. Structures such as competency support, facility and club access, further nurture pickleball as an enriching leisure for the aging population (Ryu et al., 2017), helping them cope with retirement, and attain an enduring physical activity lifestyle. Such steps are essential in addressing recurrent problems in cardiovascular and other non-communicable diseases, and even mental health and quality of life (Li et al., 2024) involving age groups beyond the elderly. This is consistent with recent pieces of evidence of positive social and psychological effects of pickleball to the elderly, aside from its known health and fitness benefits (Stroesser, Mulcaster & Andrews, 2024), and recent reports of sports preference due to health benefit motivation with this growing sport (West et al., 2024). As established by self-determination theory, this observed motivation is a critical support in achieving the challenging goal of sustainable physically active behavior.

Conclusions and Recommendations

This explorative study on pickleball examined movement patterns from racquet sports players, particularly tennis and badminton, and how these pre-disposed patterns contribute in performing pickleball skills. Findings from accuracy skills testing and kinematic analysis revealed large effect on the type of racquet sport played, specifically on accuracy scores and shoulder displacement in pickleball striking. The difference in torso mobility has also impacted the base of support of participants as seen in their distinct footwork, revealing tennis players with contralateral base of support while ipsilateral for badminton players. The relationship of these kinematic patterns and accuracy performance results shows an important consideration in designing pickleball training programs, benefiting not only the retiring racquet sport athletes but the older adult population as well and helping them achieve a sustainable and lifelong physical activity involvement. While providing pioneering data for pickleball sport development, authors recommend further research on participation effect with regard to functionality improvement, physical activity promotion, and on risk factors involving cardiovascular and metabolic diseases through physiological marker testing. Researchers also recommend the use of more prominent motion capture systems such as Vicon, Qualisys, and three-dimensional systems comparable to Motion Analysis Corporation (MAC).

Conflicts of interest - There are no conflicts of interest to declare.

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