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นิพนธ์ต้นฉบับ (Original article)
ชีวกลศาสตร์ทางการกีฬา (Sports Biomechanics)

การเปรียบเทียบคิเนเมติกส์ของรยางค์ส่วนบนเชิงสามมิติระหว่างมาร์คเกอร์แบบง่าย และคลัสเตอร์มาร์คเกอร์ในขณะเสิร์ฟเทนนิส

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บทคัดย่อ

ในการศึกษานี้ได้เลือกเปรียบเทียบข้อมูลคิเนเมติกส์ของรยางค์ส่วนบนในขณะเสิร์ฟเทนนิสระหว่างมาร์คเกอร์แบบ ง่าย (ANAT) และคลัสเตอร์มาร์คเกอร์ (CAST) โดยเลือกวิเคราะห์ 3 เหตุการณ์ของมุมข้อศอกและข้อไหล่ เพื่อเปรียบเทียบ ผลการศึกษาพบความแตกต่างอย่างมีนัยสำคัญใน 6 คู่ซึ่งเป็น ช่วงของการเคลื่อนไหวข้อศอก, ความเร็วเชิงมุมของการ หมุนข้อไหล่เข้าภายใน-ออกภายนอก ในขณะที่หน้าไม้กระทบลูกเทนนิส, มุมการงอ-เหยียดของข้อศอกในขณะที่หัวไม้อยู่ จุดต่ำสุด, มุมการงอ-เหยียดของข้อไหล่ในขณะที่หัวไม้อยู่จุดต่ำสุด, , มุมการงอ-เหยียดของข้อไหล่ในขณะที่หน้าไม้ กระทบลูกเทนนิสและ มุมการหุบ-กางของข้อไหล่ในขณะที่หน้าไม้กระทบลูกเทนนิส จากงานวิจัยก่อนหน้านี้ ความเร็ว เชิงมุมของการหมุนข้อไหล่เข้าภายใน-ออกภายนอกเป็นส่วนสำคัญถึง 54% ของความเร็วหัวไม้เทนนิส ความเร็วเชิงมุม ของข้อไหล่, ข้อศอก และข้อมือ มีความสัมพันธ์กับความเร็วของลูกเสิร์ฟ จากผลการทดลองการเปรียบเทียบ 18 ตัวแปรใน การวัดด้วย ANAT กับ CAST โมเดล มี 6 ตัวแปรที่ให้ผลแตกต่างกัน ดังนั้น ข้อมูลนี้ก็จะเป็นประโยชน์สาหรับการตัดสินใจของนักวิจัยที่จะเลือกชุดโมเดลที่เหมาะสมในการทาวิจัยต่อไป

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คำสำคัญ : การเปรียบเทียบ, รยางค์ส่วนบนสามมิติ, คิเนเมติกส์, มาร์คเกอร์แบบง่ายและคลัสเตอร์มาร์คเกอร์, เทนนิสเสิร์ฟคิเนเมติกส์

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COMPARISON OF 3-D UPPER LIMB KINEMATICS BETWEEN SIMPLE AND CLUSTER MARKER SETS DURING TENNIS SERVE

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ABSTRACT

The objective of this study was to compare two biomechanical models; anatomical system technique (ANAT) and a calibrated anatomical system technique (CAST) during tennis serve. We chose 3 events of elbow and shoulder angles to compare. The result showed significant difference in 6 pairs of shoulder and elbow joint which were ROM of elbow flexion-extension, shoulder internal-external velocity during impact frame, elbow flexion-extension angle during racket low point, shoulder flexion-extension angle during racket low point, shoulder flexion-extension angle during impact and shoulder adduction-abduction angle during impact in tennis serves. From the previous research, the shoulder internal-external rotation velocity produced the greatest contribution (54%) to the racket head velocity. The velocity transmitted from shoulder to elbow and wrist affected racket head velocity during the tennis serve. From these results, the comparisons of 18 variables from ANAT and CAST models showed significant differences in 6 variables. Therefore this information will be useful for researcher's decision to choose the appropriate model for further research.

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Keywords: COMPARISON, 3-D UPPER LIMB, KINEMATICS, SIMPLE AND CLUSTER MARKER SETS, TENNIS SERVE KINEMATICS

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INTRODUCTION

The efficient serve will be performed by a correct biomechanical movement with acceleration which will consequently transmit to the tennis ball[1-4]. The segment velocities increase from shoulder, elbow, wrist and end at the racket center. Most biomechanical analysis of athlete movements used kinematic data to explain a quantitative description. Nowadays, there are 2 main models using for three-dimensional kinematic study, an anatomical system technique (ANAT) or simple marker model and a calibrated anatomical system technique (CAST) or cluster marker model. ANAT uses specific anatomical landmarks to define joint centers and axes while CAST is the semi-rigid cluster of four kinematic markers which are placed over the skin surface of the body segment and not associated with bony point. The four markers are located on the quasi-isotropic distribution which minimizes the error from skin movement. Exell et al. (2009)[5-6] compared ANAT and CAST of temporal and angular characteristics of lower limb joints kinematics in sprint running. Results showed that both methods were similar in the continuous knee flexion-extension profile, and discrete timings for all joints during maximal sprint running. They purposed that further work should be investigated for the effects of upper body movement on hip angle. In overhead sport motion, Well et al. (2013) compared ANAT and CAST in 8 cricket bowlers[7]. They found that there were significant difference between model differences in elbow joint flexion-extension (F/E) angles at upper arm horizontal (UAH) and ball release (BR) but no significant difference in extension range. There were little studies comparing the kinematics between ANAT and CAST marker models of the upper limb. Thus, the aim of this study was to measure the kinematics of the upper limb comparing between these 2 models during tennis serve.

METHODS

Participants

Seventeen male tennis players had age range between 18-35 years old (mean age =21 year, mean weight = 69 kg and height = 177 cm) volunteered for this study. Participants must have a minimum of 2 year experiences in tennis competition. All subjects were informed the risks and signed the consent forms that had been approved from the Ethics Committee, Mahidol University Institution Review Board (MU-IRB).

Procedure

Three-dimensional kinematic data was collected with BTS SMART DX 5000 (BTS Bioengineering™, Italy). Flat serve motions were captured at the sampling rate of 200 Hz. Two different biomechanical models (marker sets) were attached to the body at the same time. ANAT consisted of 18 retroreflective markers which attached to the following landmarks; head, sternum, cervical vertebra 7, right and left acromion, sacrum, right and left anterior superior iliac spine, right and left olecranon processes, right and left ulna styloid processes, right and left radius styloid processes, right and left 3rd metacarpal[8]. The CAST consisted of 34 retroreflective markers which similar to the ANAT but included 4 rigid markers on the upper arm and lower arm on both sides.[9-10] During data collection, the 34 retroflective markers were captured but each model was separated computed and analyzed. All participants performed 3 maximal effort flat serves in biomechanic laboratory at Mahidol University. Raw 3-D kinematic data were digitized using SMART tracker software. The data were interpolated and filtered with low pass at cut off frequency of 10 Hz. All kinematic variables were analyzed using Visual 3D program (C-motion Inc., USA).

Statistical Analysis

The statistical package SPSS for Windows (SPSS version 16, Chicago, IL, USA) was used for all statistical procedures. Shapiro Wilk test was employed to ensure the normality of data. Student paired t-test was used to determine the statistical differences of selected upper limb kinematics between two different models. Differences were considered at $p < 0.05$.

RESULTS

Means and SD of the kinematic data of elbow flexion-extension and shoulder internal-external rotation velocity in tennis serves (ball impact frame) were presented in Table 1. In elbow flexion-extension velocity, these two marker sets were not significant difference (α = 0.434) but there were significant difference in shoulder internal-external rotation angle which α = 0.017.

Table 1 Kinematic data of elbow flexion-extension and shoulder internal-external-rotation velocity in tennis serves (at ball impact)

	Mean(±SD)	*p*-values	Sig. (2-tailed)
Elbow flexion-extension velocity (/s)			
ANAT	192.66(±84.04)	-0.803	0.434
CAST	209.01(±69.32)		
Shoulder internal-external rotation velocity(/s)			
ANAT	178.46(±68.09)	-2.668	0.017*
CAST	216.88(±72.64)		

Means and SD of the kinematic data of elbow flexion-extension in tennis serves at trophy position, racket low point and impact events were presented in Table 2. In trophy position and impact event of elbow flexion-extension angle, these two marker sets were not significant difference (α = 0.056 and 0.509 respectively) but significant difference was observed in racket low point event in elbow flexion-extension angle which α = 0.029.

Table 2 Kinematic data of elbow flexion-extension angle in tennis serves

	Mean(±SD)	*p* -values	Sig. (2-tailed)
Elbow flexion-extension angle ()			
Trophy position			
ANAT	105.27(±17.44)	-2.054	0.056
CAST	108.69(±19.28)		
Racket low point			
ANAT	123.60(±17.43)	2.401	0.029*
CAST	118.04(±10.86)		
Impact			
ANAT	33.30(±11.53)	-0.676	0.509
CAST	34.72(±13.12)		

Means and SD of the kinematic data of shoulder internal-external rotation in tennis serves at trophy position, racket low point and impact events were presented in Table 3. In trophy position, racket low point and impact event of shoulder internal-external rotation angle, these two marker sets were not significant different (α = 0.121, 0.210 and 0.101, respectively).

Table 3 Kinematic data of shoulder internal-external rotation angle in tennis serves

		Mean(±SD)	*p* -values	Sig. (2-tailed)
Shoulder internal-external rotation angle (°)				
Trophy position				
	ANAT	47.32(±29.64)	-1.631	0.122
	CAST	55.73(±25.94)		
Racket low point				
	ANAT	39.29(±18.91)	1.303	0.210
	CAST	31.14(±14.74)		
Impact				
	ANAT	33.62(±20.69)	1.742	0.101
	CAST	25.34(±21.53)		

DISCUSSION

There were 4 key events in tennis serve, ball release, trophy position, racket low point and impact. In this study, we chose 3 events to compare trophy position, racket low point and impact because there are lots of movements in these 3 events[11-13]. Two types of biomechanical models are currently used in the study of human movement; ANAT and CAST. Each model has its own advantage and disadvantage. The ANAT requires minimal markers attach to the bony landmarks. The CAST requires extra markers known as cluster markers attach to the segments which provides redundant data and more accurate results because of less skin movement but requires the equipment and takes time for data analysis more than ANAT. According to my knowledge, in tennis serve, both biomechanical models were used in previous studies. However, no previous study compared the kinematic results of these two models in tennis serve. The results from this study showed that there were no significant difference at trophy position, racket low point and impact (43.32 for ANAT and 55.3 for CAST, 39.29 for ANAT and 31.14 for CAST, 33.26 for ANAT and 25.34 for CAST, respectively). Shoulder internal rotation is one of the major variables in tennis serve because it is a major contributor to the tennis serve linear velocity[1-4]. In this investigation, the results showed that the shoulder internal-external rotation velocity was 178.46 deg/s for ANAT an 216.88 deg/s for CAST different from Elliott et al., (1995) which was 2090 deg/s[1-4] and Flesig et al., (2007) which was 2420 deg/s for ANAT in elite tennis player groups[14-15]. For elbow flexion-extension angle at trophy position and impact events, there were no significant difference. The elbow flexion-extension velocity during impact were 192.66 °/s for ANAT and 209.01 deg/s for CAST which were difference from previous report of Elliott et al. (1230 °/s)[1-4] and Flesig et al. (1510 deg/s)[14-15]. The results of the shoulder internal-external rotation velocity and the elbow flexion-extension velocity from this research were less than those 2 previous studies because the subjects in this study were amateurs while the previous research studies investigated in the elite tennis players.

CONCLUSION

In conclusion, investigation of 3D upper limb motion in the tennis serve can be used either ANAT or CAST techniques because it yields similar results in most major variables except shoulder internal/external rotation. Since shoulder internal-external joint angle and velocity in tennis serve are important variables particularly during impact, CAST is recommended if researchers want to study these variables because it provides more accurate results. Nevertheless, this technique requires more number of cameras, complex set up and time consuming. Reason to select biomechanical model depends on researchers' judgement based on research questions.

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