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ORIGINAL ARTICLE

The Regression Modelling of Kinanthropometric and Kinematic Variables in Relation to Ball Velocity of Nigerian Female Tennis Players

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ABSTRACT

Background. Kinanthropometric and Kinematic variable are important in the understanding of performance in various sports. These variables have not been explored among Tennis players in Nigeria. **Objectives.** An exploration to establish a regression model for kinanthropometric and kinematic variables in relation to ball velocity of Nigerian Female Tennis Players. **Methods.** Data were collected through direct standard anthropometric protocol and kinematic videographic technique with four Vicon MX 13 cameras. Subjects for the study were drawn from Nigerian female tennis players who participated in the 14th West African University Games and 19th National Sports Festival. Forty-six (46) of the athletes gave their consent to participate in the study, which took place between October to December, 2018. Data were analyzed using SPSS version 23 to obtain mean, standard deviation, range, Pearson correlation Moment Coefficients and Regression linear analysis which was used to test the hypotheses at 0.05 significant levels. **Results.** Results from this study revealed that there was 60% prediction of interactions of the kinanthropometric and kinematic variables to ball velocity. The results further revealed statistically significant difference in the predicted variables (kinanthropometric and kinematic) to ball velocity at $p<0.05$. The study recommends that during selection processes, coaches should strictly ensure that only athletes with suitable anthropometric features specific for each sport are recruited. Also, the relevant outcome of the analysis should be employed in developing tennis sports as it will contribute to improving performance and increasing accuracy. **Conclusion.** Using standard anthropometric protocols and videographic techniques to establish typical performance profile for Nigerian players would ensure a more reasonable assessment of match performances and assist to set practical training and match targets for coaches and athletes.

KEYWORDS: ***Kinathropometry, Kinematic, Tennis, Kinematic Software***

INTRODUCTION

Tennis as an organized sporting activity forms part of human and social development which contributes to socio-economic growth and also provides entertainment for both participants and spectators (1). In today's tennis competition, serving is the most critical part because it contributes hugely in the winning and losing of a match. In fact, spectators and sports marketers

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pay more attention to the serving skills adopted by tennis players. Therefore, Coaches and Athletes concentrate on how to effectively bring the best of servings in a tennis competition. Certain anthropometric characteristics such as height, weight, are needed to perform optimally in a tennis match. This is because they determine physique which affects the ability of individuals in a tennis sport especially in the serve velocity. Physical and kinematic positions of an athlete may influence the technicality and tactical aspect of the tennis ball velocity especially in the tennis serve which is referred to as the most complex stroke for winning a match (2, 3). For the server to achieve a successful tennis serve, there must be movement of the whole body (4).

According to Girard et al. (5)the knee contributes significantly to serving effectiveness and enhances performance level. This is supported by studies which have indicated that kinetic is involved in the transfer of linear and angular momentum from the legs to the trunk and then to the arm and the racket (6, 7). Furthermore, Hassan (8) pointed out that for reaction time and high ability to return the ball by an opponent to reduce, the tennis ball must be smashed with greater amount of ball velocity; this was in agreement with the position of Bahamonde (7). Significant association between body height and serve speed was reported by Vaverka and Cernoseke (9) and Signorile et al. (10)also reported that anthropometric data will further improve the predictive ability of serve velocity.

Many researchers have conducted studies on how anatomical composition and kinematic variables relate to improve the performance in the tennis (8, 11-14). The outcome of these studies have placed a great need on the importance of understanding sport-specific anatomical and kinematic variables which athletes should have for them to be guided and directed to a certain type of physical activity.

In recent times, economic values that are desirable from sports have grown tremendously; professional sportsmen and women in other countries as well as sports clubs and organizations now earn huge incomes from sponsorship and franchise fees. This direction of the relationship has attracted their governments to give reasonable support to their sports activities. Just like other countries, the Nigerian Government has equally made special interventions in sports by increasing funding, providing modern sporting facilities and granting of incentives in other to encourage athletes. Yet, these grants have no significantly improved performance of Nigerian tennis players in international competitions.

Most recent studies have noted separately the importance of anthropometry and kinematic characteristics in predicting tennis performance (9, 10). However, no study has been able to quantify the combining interaction of kinanthropometry and kinematic characteristics in tennis ball velocity of Nigerian athletes. Since tennis sport requires that the physical structure or composition of an individual should be appropriate and adequate, It has become very pertinent to consider the interactions between kinanthropometric and kinematic characteristics of athletes. Therefore, the study examines the regression analysis of kinanthropometric and kinematic used in ball velocity of Nigeria female tennis players in other to proffer possible tennis serve model that could help in optimal performance both at local and international levels

MATERIALS AND METHODS

Study Design. The researchers adopted multiple research designs which included descriptive survey, correlation research design and cross sectional design.

Participants. This study used forty-six professional Nigerian female tennis players (age =20.78±3.13 years; weight 61.23±8.91kg; height 1.66±0.10m) who participated in the 14th West African University Games and 19th National Sports Festivals held between the period of October-December 2018. Prior to the participation, the participants underwent a medical examination to ensure that inclusion and exclusion criteria were met and were fully informed of the experimental procedures. Informed consent was obtained from each athlete that participated and it was in line with Helzinki's declaration of 2013. There was strict adherence to laws involving human research and was approved by the Ethics Board of the University of Port Harcourt. Approval letter of permission was sourced from Nigerian Tennis Federation and Local Organizing Committees of the different competitions.

Experimental Protocol. Participants were made to have as much time as needed for familiarization by trial testing in the court with their own ball. During the competition, rules guiding the competition were read to the participants and these rules were in line with the laws of International Tennis Federation. There were no instructions on how to position the body when serving the ball. To derive a representation and accurate performance of the recorded tennis velocity, the body angles position of the first five cross counts and down the line shots that landed in the target area and were counted to the advantage of the serve**,** were chosen for analysis.

Data Collection. Standard anthropometric protocol with the aid of stadiometer (model RGZ-160) and anthropometric tape were used to measure the weight, height, BMI, arm span, arm girth, chest girth, hip girth and thigh girth. Percentage body fat was calculated using Michelle (15) formula:

For women: (1.20 x BMI) + (0.23 x age) – 5.4

For kinematics, a total of 10 reflective markers were placed on bony landmarks for digitization (Figure 3.1): head of the 5th metacarpal, styloid process of the radius, distal end of the humerus and proximal end of the ulna, medial femoral condyles, greater trochanter, anterior superior iliac spine, tibial tuberosity, lateral malleoli and head of the 5th metatarsal. Participants wore tight shorts and shirts in order to limit movement of the markers from their anatomical landmarks during the upward movement. Data were captured with four Vicon MX13 cameras (Vicon Peak, Oxford, UK) sampling at 400Hz.

The cameras were strategically positioned around each side of the count at about 4 meters away from the serving point to ensure optimal marker identification. The centre of the baseline was used as the origin of the global coordinate system of XYZ axes where Y axis was pointing forward, the X-axis was positioned to the right and Z axis was the vertical direction. In order to calculate the joint centre positions, captured images were screenshot and transferred to the kinematic software where the angles were traced. Lower and Upper body models were defined as described by Wagner et al. (16) and for easy identification, number was assigned to each athlete.

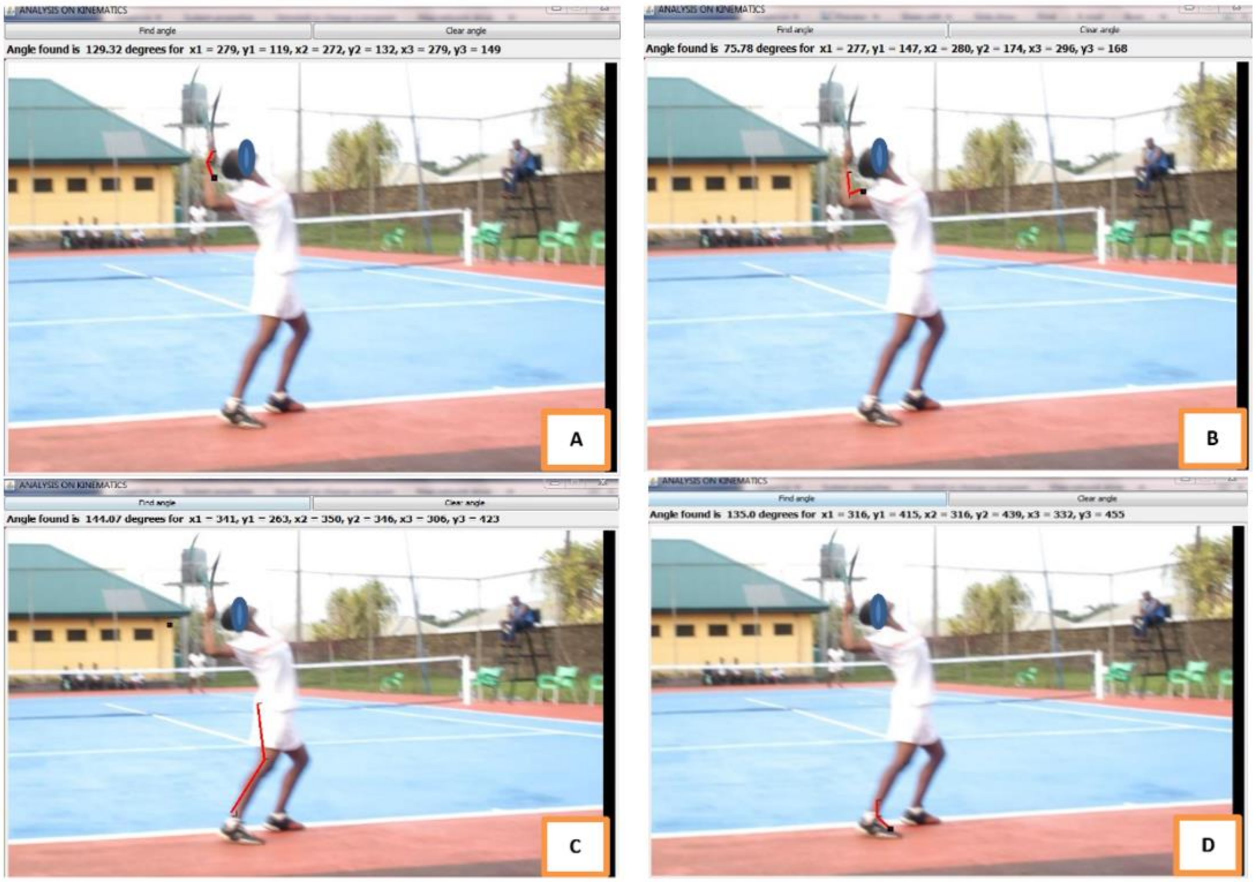

Figure 1. Performance of Female Tennis Players Showing their Kinematics Variables; Phase Definition and Variables of Interest. A: Wrist Angle, B: Elbow Angle, C: Knee Angl, D: Ankle Angle

Kinematic data collected was during the forward swing of the stroke which was determined when the ball goes off from the racket from the point of serve of the server and traveled to the opposite service court of the returner in a horizontal direction movement. The study considered anterioposterior plane which divided the body vertically into left and right halves with each half containing the same mass (17).

Ball velocity that is a performance variable was calculated by dividing the speed of the ball and the time it takes the ball to travel.

$$V = \frac{\text{distance (m)}}{\text{Time traveled by the ball to the opponent court (sec)}} \quad (1)$$

Where V= Velocity of the ball (m/s)

D = distance of the ball (m)

T = Time traveled by the ball to the opponent court (t)

Kinematic variables considered in this study were wrist angle, elbow angle, knee angle and ankle angle of female tennis players.

Definition of Angles Measured in the Study

Wrist Angle. The wrist angle is the angle that is at the center of the wrist joint. It was measured from the head of the 5^{th} metacarpal and the styloid process of the radius.

Elbow Angle. The angulation was formed as a result of the configuration of the articular surfaces of the humerus and ulna which produced a normal valgus angulation of the forearm in relation to the humerus (18). It was measured from the humerus to the proximal end of the ulna.

Knee Angle. The knee joint angle is defined as the dot product of the vector pointing from the hip joint center to the knee joint center and the vector pointing from the knee joint center to the ankle joint center (18). It was measured from the anterior superior iliac spine to the greater trochanter and medial femoral condyles down to the tibial tuberosity.

Ankle Angle. It is the angle formed at the center of the ankle joint. It was measured from lateral malleolus and the head of the 5^{th} metacarpal bone.

Model Specification. This model was specified in line with the research question and hypothesis raised in this study and was transposed into regression equation for the purpose of providing empirical answers to the research question and testing for the tenability of the hypothesis

PFTP = ∑f(Age, Body Weight, Height, BIM, Arm Span, Body Fat, Arm Girth, Chest Girth, Hip Girth, Thigh Girth, Wrist Angle, Elbow Angle, Knee Angle, Ankle Angle) (2)

Estimation of Regression Equations for Female Tennis Players

$$PFTP = \gamma_0 + \gamma_1 AG + \gamma_2 BW + \gamma_3 HG + \gamma_4 BM + \gamma_5 AS + \gamma_6 BF + \gamma_7 AG + \gamma_8 CG + \gamma_9 HG + \gamma_{10} TG + \gamma_{11} WA + \gamma_{12} EA + \gamma_{13} KA + \gamma_{14} AA + \mu \quad (3)$$

Parameters in the Regression Model

γ_0 = Intercepts or Slopes of the Regression Models

$\gamma_1, \gamma_2, \gamma_3, \gamma_4, \gamma_5, \gamma_6, \gamma_7, \gamma_8, \gamma_9, \gamma_{10}, \gamma_{11}, \gamma_{12}, \gamma_{13}, \gamma_{14}$= Coefficients of Age, Body Weight, Height, Body Mass Index, Arm Span, Body fat, Arm Circumference, Chest Circumference, Waist Circumference, Thigh Circumference, Wrist angle, Elbow angle, Knee angle, Ankle angle of Female Tennis participants

μ- represents stochastic or random variable. This represents other factors that could account for sports performance that are not captured in the entire model estimated.

Data Presentation. Descriptive statistics of Mean±SD of five strokes for each player were calculated for all variables. Pearson Product Moment Correlation Coefficient was used to examine the strength and direction of the linear relationship between the variables and multiple linear regressions was adopted to predict the extent kinanthropometric and kinematic variables affect the ball velocity of the sampled athletes. SPSS version 23.0 was used for the analysis.

Table 1. Descriptive Results of Kinanthropometric, Kinematics and Performance Variables of Nigeria Female Tennis Players

Observable Variables	Female		
	Mean ± SD	Minimum	Maximum
Age (years)	21.69±3.69	18.00	30.00
Weight (kg)	64.30±8.35	46.00	92.00
Height (m)	1.73±0.08	1.50	1.96
BMI (kg/m^2)	21.59±2.33	15.55	29.05
Arm span (mm)	177.96±11.31	148.00	203.50
% Body Fat	14.64±2.96	6.60	22.62
Arm girth (cm)	10.52±1.11	7.50	13.10
Chest girth (cm)	33.07±2.51	25.60	39.00
Hip girth	30.55±2.63	20.80	39.00
Thigh girth	19.77±2.54	13.40	27.00
Wrist angle (º)	104.61±25.76	40.60	164.53
Elbow angle (º)	107.55±26.30	30.35	164.28
Knee angle (º)	121.83±28.04	47.20	172.34
Ankle angle (º)	98.21±27.03	41.47	174.46
Distance Covered by the Ball (m)	16.53±1.10	13.50	18.00
Time travelled by the Ball (sec)	6.60±1.62	3.50	10.00
Velocity of the Ball (m/s)	2.65±0.65	1.56	4.50

RESULTS

Table 1 contains the mean and standard deviation of various female athletic performance variables. The strength and direction of linear relationship**s** between the independent (kinanthropometric and kinematic**)** variables and dependent variables (ball velocity) and moderate linear relationship between age and ball velocity (P=0.53) are shown in Table 2. While multiple linear regression that shows the extent of relationship between kinanthropometric and kinematic variables and ball velocity is shown in Table 3.

The Mathematical Representation of the above Interpretations holds as follows:

PFTP = 5.481 + 0.072AG + 0.024BW – 0.545HG – 0.125BM - 0.010AS + 0.048BF + 0.158AG – 0.062GH + 0.015WG – 0.056T – 0.003WA – 0.002EA + 0.003KA – 0.008AA+ μ (4)

Where $PFTP_{velocity}$= Ball Velocity of Female Tennis Player

μ= other excluding variables

From the Model Summary

$P_sMTP_{velocity}$ F (14,31) = 3.336, P<0.0005, R^2=0.601. This implies that all variables added were statistically significant to the prediction at p<0.05

Table 2. Pearson Correlation Result of Nigerian Female Tennis Players

	Anthropometrics and Kinematics Variables													
Performance Variables	**Age (years)**	**Weight (kg)**	**Height (m)**	**BMI (kg/m^2)**	**Arm Span (mm)**	**% Body fat**	**Arm girth (cm)**	**Chest girth (cm)**	**Hip girth (cm)**	**Thigh girth (cm)**	**Wrist Angle**	**Elbow Angle**	**Knee Angle**	**Ankle Angle**
Distance covered by the ball														
r	-0.32^*	0.21	-0.12	0.37^*	0.06	0.32^*	-0.05	0.34^*	0.07	0.08	0.04	-0.05	0.04	-0.13
p-value	0.03	0.16	0.41	0.01	0.71	0.03	0.74	0.01	0.65	0.61	0.82	0.73	0.79	0.39
Time of travel														
r	-0.43^{**}	0.16	-0.01	0.18	0.20	0.12	0.05	0.41^{**}	0.06	0.18	0.05	-0.07	-0.02	0.22
p-value	0.00	0.29	0.96	0.24	0.18	0.41	0.73	0.01	0.71	0.24	0.73	0.65	0.90	0.15
Ball Velocity														
r	0.53^{**}	-0.11	-0.05	-0.06	-0.21	0.05	-0.11	-0.31^*	-0.05	-0.14	-0.04	0.06	0.08	-0.25
p-value	0.00	0.47	0.74	0.68	0.16	0.75	0.48	0.03	0.72	0.34	0.77	0.69	0.60	0.10

*** Correlation is significant at the 0.05 level (2-tailed).**
**** Correlation is significant at the 0.01 level (2-tailed)**

Table 3. Model Summary Multiple Regression Result of Nigerians Female Tennis Players

Model Summary[b]

Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**Change Statistics**					**Durbin-Watson**
					R Square Change	**F Change**	**Df1**	**Df2**	**Sig. F Change**	
1	0.775^a	0.601	0.421	0.31961	0.601	3.336	14	31	.003	1.359

a. Predictors: (Constant),age, weight, height, BMI, arm span, percentage body fat, arm girth, waist girth, chest girth, thigh girth, wrist angle, elbow angle, knee angle and ankle angle
b. Dependent Variable: PFM

Coefficients[a]

Model	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**	**95.0% Confidence Interval for B**		**Correlations**			**Collinearity Statistics**	
	B	**Std. Error**	**Beta**			**Lower Bound**	**Upper Bound**	**Zero-order**	**Partial**	**Part**	**Tolerance**	**VIF**
(Constant)	5.481	4.893		1.120	0.271	-4.499	15.461					
Age (Years)	0.072	0.017	0.534	4.234	0.000	0.037	0.106	0.529	0.605	0.48	0.811	1.234
Weight (Kg)	0.024	0.042	0.510	0.575	0.569	-0.061	0.109	-0.109	0.103	0.065	0.016	61.067
Height (m)	-0.545	2.816	-0.124	-0.194	0.848	-6.288	5.198	-0.049	-0.035	-0.022	0.031	32.017
BMI (Kg/m2)	-0.125	0.123	-0.804	-1.017	0.317	-0.376	0.126	-0.062	-0.18	-0.115	0.021	48.631
Arm Span (mm)	-0.010	0.006	-0.271	-1.606	0.118	-0.023	0.003	-0.212	-0.277	-0.182	0.452	2.211
Percentage Body Fat (%)	0.048	0.023	0.612	2.089	0.045	0.001	0.095	0.048	0.351	0.237	0.150	6.660
Arm Girth (cm)	0.158	0.080	0.499	1.968	0.058	-0.006	0.322	-0.107	0.333	0.223	0.200	5.000
Chest Girth (cm)	-0.062	0.034	-0.369	-1.834	0.076	-0.130	0.007	-0.313	-0.313	-0.208	0.317	3.153
Hip Girth (cm)	0.015	0.024	0.125	0.651	0.520	-0.033	0.063	-0.053	0.116	0.074	0.351	2.848
Thigh Girth (cm)	-0.056	0.025	-0.378	-2.223	0.034	-0.108	-0.005	-0.143	-0.371	-0.252	0.445	2.249
Wrist Angle (^{0})	-0.003	0.002	-0.216	-1.525	0.138	-0.007	0.001	-0.044	-0.264	-0.173	0.642	1.557
Elbow Angle (^{0})	-0.002	0.002	-0.109	-0.850	0.402	-0.006	0.003	0.061	-0.151	-0.096	0.779	1.284
Knee Angle (^{0})	0.003	0.002	0.215	1.476	0.150	-0.001	0.008	0.079	0.256	0.167	0.607	1.647
Ankle angle (^{0})	-0.008	0.003	-0.413	-2.879	0.007	-0.013	-0.002	-0.247	-0.459	-0.327	0.624	1.602

a. Dependent Variable: PFM.
Source: Authors compilation from SPSS Results Outputs, 2019.

DISCUSSION

The possibility of winning a point on the several serves apparently justifies the attention of players to stroke during competition atmosphere. Understanding the advancement in tennis, would assist in the applications beyond professional players and aid the development of proficient servers. Therefore, to achieve the objective of the study it, examined the kinanthropometric and kinematic variables with the level of performance in Nigerian female tennis players. The result of standard coefficients shows statistically significant at grand beta value as -0.189 in multiple regression result, hence contribute in predicting the velocity of the ball serve. The result also revealed that approximately more than two-third of the examined kinanthropometric and kinematic variables such as height, BMI, arm span, chest girth, thigh girth, wrist angle, elbow angle and ankle ankle show significant difference in serve ball velocity with R square of 0.601. This means that variables that contributed significantly to the prediction of the relationship amount for 60% of the variation or changes in serve ball velocity, while the remaining 40% in tennis players are attributed to the other factors that may affect players but they were not captured in this study. These other factors could be traced hot environmental conditions, effects of physical fatigues, unpredicted match length with repeated movements and perceived psychological stress could jointly affect their performance. This was similar to the findings (19-21).

Again, this study tried to identify the multiple correlations between kinanthropometric, kinematic with the velocity of the tennis ball representing performance. This shows strong positive correlation of 0.775. The results of multiple regression not only suggested that kinanthropometric and kinematic variables used in this study could be employed in the evaluation of match behaviours which affects players performance. It would also indicate the influence how different anatomical components can combine to enhance optimal performance in tennis serve.

Going forward, the study observed that despite high percentage contribution from the variables, fast-weak serving strategies were observed in the female tennis players. This was possibly due to the fact that energy was not conserved shortly after first and second serves; this was supported (19). We noted from our findings that the height, BMI, arm span, chest girth, wrist angle and elbow angle combined together contributed significantly to the performance of serve ball velocity which is explained that height provides a good elevator for players, it is not perhaps, surprising due to advantage of height and the experience that age would provide in the tennis competition. This is in agreement with the study of Al-Haliq (22) who stated that increase in height increases the centre of gravity of the body from the earth, thereby providing the player suitable base for directing the strikes in sharp angles which help to increase the accuracy in the strike and allowing the player to perform well.

It was also supported by the study of Amin (23) who reported that the more the height of a player, the more weight position increases and thus increasing the steps both in running to place of the ball and returning to the place of start. Our finding with the significant contribution of the arm span was in agreement with the findings (23). Supporting these findings, Wong et al. (2014) (4) and Ulbright et al. (24) reported that body mass index correlates significantly with the speed ball in the skills and accuracy of serving. The result of the current study revealed moderate relationship between the age of the Tennis players and ball velocity which was in agreement with the study Al-Haliq (22) who reported that age contributed positively to the serving skill accuracy. This is expected because an increase in age increases the experience of the player which contributes to a possible increase in the accuracy of strikes.

The report of Mahjoub (25) supports our findings by pointing out that strength of the grip supports the wrist joint when performing the strikes thereby increasing performance accuracy. Our mean value for elbow angle recorded 107.55 ± 26.30^{o} which was supported by the value of Fleisig et al. (26)who recorded 104.00 ± 12.0^{o} and the wrist angle showed 104.61 ± 25.76^{o} which is significantly lower than the study of Fleisig et al. (26)that recorded 66.00 ± 19.0^{o}. This could be due to training pattern the athletes received and also the intensity of the competition in which these studies share in common. Ultimately, serve outcome appears most closely related to the projection angle of the ball in all players (27).

The results of the current study confirm that kinanthropometric and kinematic variables had an influence on the performance of female tennis players. Previous research showed that the difference of court surfaces, court dimensions, ball types, temperature and humidity might cause players distinct adaptation to the courts, thus resulting in their different performances (28, 29). This may have accounted for the high percentage of the influence of external factors that exist in our study. Taken together, the findings from our study also reinforce that performance in tennis is multifactorial; it depends on their anatomical composition, kinematic body position, mental and tactical factors. This is the first study to establish the efficacy of videographic approach and kinematic software in examining the relationship between kinanthropometric, kinematic variables and sports performance in Nigerian female tennis players during the 14th West African University Games and 19th Nigeria National Sports Festival in the year 2018. Further, given the performance percentage in the combination of some kinanthropometric and kinematic variables, one will ponder on the errors that occur during tennis serves, thus adequate management of these errors would be of a greater concern for the coach and athletes. Practically then, coaches should adhere to selection criteria by focusing more on the anthropometric characteristics that are suited to tennis sport.

CONCLUSION

The study provide noble insight into the performance of Nigerian female tennis players that participated in the 14th West African University Games and 19th National Sports Festivals that held within the period of October-December, 2018. We noted from our findings that height, BMI, arm span, chest girth, wrist angle and elbow angle as combined kinanthropometric variables contributed significantly in the variable of serving performance. Also the use of standard anthropometric protocol and videographic techniques to establish typical performance profile for Nigerian Female Tennis players would facilitate a more reasonable assessment of match performance and assist to set practical training and match targets for Coaches and Athletes.

Future studies with a high number of professional players are needed to support our findings and to be able to create a perfect model for serve in tennis players. We also recommend follow-up studies which would likely improve the general performance of Nigerian tennis players in global competitions.

APPLICABLE REMARKS

- Relevance of Videographic approach and kinematic software in tracing kinematic angles which were used for the combination of anthropometric variables in improving Nigerian female tennis performance.
- Determination of extent of relationship between kinematic and anthropometric variables of female tennis players using multiple linear regression analysis.

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CONFLICT OF INTEREST

No conflict of interest was reported by the authors.

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