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# ANTHROPOMETRIC PROFILE AND MAXIMUM SERVE SPEED IN MALE TENNIS PLAYERS FROM A PERUVIAN SPORTS MEDICAL CENTER

## PERFIL ANTROPOMÉTRICO Y VELOCIDAD MÁXIMA DE SERVICIO EN TENISTAS VARONES DE UN CENTRO DEPORTIVO MEDICO PERUANO

Diana Santisteban [1], Horus Viru-Flores [1], Helman Roque Quezada [2], Jamee Guerra Valencia [3], Robert Vega-Vega [4], Juan Carlos Ezequiel Roque-Quezada [4]

ORIGINAL PAPER

## ABSTRACT

**Objective:** To evaluate the relationship between anthropometric profile and serve speed in male Peruvian tennis players. **Methods:** A quantitative, observational, cross-sectional, and analytical study was conducted with 79 male tennis players from the FiXU sports medical center in Lima, Peru, during 2023 and 2024. Variables such as height, weight, BMI, and limb dimensions were measured. Serve speed was assessed using a calibrated speed gun. **Results:** The average serve speed was 94.38 km/h (±9.98). The average height of the players was 174.61 cm (±4.17) and the average weight was 72.20 kg (±6.97). Height (r=0.796) and weight (r=0.533) showed significant correlations with serve speed. Weekly playing hours (r=0.611) and years of experience (r=0.435) also showed positive associations. Linear regression identified height (B=1.91, p<0.001), weight (B=0.76, p<0.001), and forearm length (B=6.00, p<0.001) as significant predictors of serve speed. **Conclusion:** Height and weight are significant predictors of serve speed in Peruvian tennis players. Limb measurements and years of experience positively influence serve speed, while BMI showed no significant correlation.

**Keywords:** Anthropometry; Body Weights and Measures; Tennis; Sports; Athletic Performance. (Source: MESH-NLM)

## RESUMEN

**Objetivo:** Evaluar la relación entre el perfil antropométrico y la velocidad del servicio en tenistas varones peruanos. **Métodos:** Se realizó un estudio cuantitativo, observacional, transversal y analítico con 79 tenistas varones del centro médico deportivo FixU en Lima, Perú, durante 2023 y 2024. Se midieron variables como altura, peso, índice de masa corporal (IMC), y dimensiones de las extremidades. La velocidad del servicio se evaluó usando una pistola de medición calibrada. **Resultados:** La velocidad promedio del servicio fue de 94.38 km/h (±9.98). La altura promedio de los jugadores fue de 174.61 cm (±4.17) y el peso promedio de 72.20 kg (±6.97). La altura (r=0.796) y el peso (r=0.533) mostraron correlaciones significativas con la velocidad de servicio. Las horas de juego semanal (r=0.611) y los años de experiencia (r=0.435) también presentaron correlaciones positivas. El análisis de regresión lineal identificó a la altura (B=1.91, p<0.001), el peso (B=0.76, p<0.001), y la longitud del antebrazo (B=6.00, p<0.001) como predictores significativos de la velocidad de servicio. **Conclusión:** La altura y el peso son predictores significativos para la velocidad de servicio en tenistas peruanos. Las medidas de las extremidades y los años de experiencia influyen positivamente, mientras que el IMC no mostró correlación significativa.

**Palabras clave:** Antropometría; Pesos y Medidas Corporales; Tenis; Deportes; Desempeño Atlético. (Fuente: DeCS- BIREME)

[1] Universidad Privada San Juan Bautista, Lima, Peru.
[2] Centro Médico Deportivo FiXU, Lima, Peru.
[3] Universidad Privada del Norte, Lima, Peru.
[4] Hospital de Emergencias Jose Casimiro Ulloa, Lima, Peru.

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## INTRODUCTION

In tennis, the serve is the only stroke entirely under the player's control, unlike other strokes that are responses to the opponent. This stroke represents a challenge due to the complexity of its biomechanics and is considered the most complicated stroke in tennis[1,2]. It requires the activation of multiple muscles in different body segments, coordinated to generate and combine vertical and horizontal forces, allowing the player to achieve an optimal serve in terms of ball speed and accuracy [3,4]. For its analysis, a model has been developed that divides the serve into three phases and eight stages [5]. This model helps coaches, physical conditioning specialists, and sports physicians design specific exercises to improve performance and reduce the frequency of injuries in players[5,6].

Given the importance of the serve in modern tennis for winning a game, numerous studies have attempted to identify predictors of serve speed (SS). These studies evaluate physical performance through tests such as the overhead medicine ball throw (MBT) and the countermovement jump (CMJ), as well as anthropometric characteristics such as height, weight, body mass index, and the length of the upper and lower limbs, including the arm, forearm, thigh, and leg [6,7]. Although the overhead medicine ball throw is the most studied upper body strength test for estimating serve speed, it is crucial to note that a possible limitation of this test is the difference in kinetics compared to the serve stroke[6,8,9].

Regarding anthropometric measurements, several studies have identified significant associations between player height and serve speed. One of the hypotheses proposed to explain this result is that greater upper and lower limb lengths could contribute to developing greater kinetic force in the serve, which is directly related to ball speed. Therefore, various studies measure the length of arms, forearms, thighs, and legs [10,11]. In relation to the individual's weight and body mass index, their influence on serve speed has been associated with greater torque force in the muscle activation necessary for the rotation of a body segment [12,13]. There is little evidence in the international context and no publications at the national level. In the absence of studies in sports medicine in the area of tennis, this study aims to evaluate for the first time in the national context, the relationship between the anthropometric profile and serve speed in male tennis players at a sports center in Lima, Peru during the years 2023 and 2024.

## METHODS

### Study Design

Observational, cross-sectional, and analytical studies properly aligned with the STROBE checklist for cross-sectional observational studies[14].

### Population

Male tennis players from the FiXU sports medical center in the years 2023 and 2024.

### Selection Criteria

Inclusion criteria were: playing experience of more than 5 years, participation in local and/or inter-club tournaments, and age greater than or equal to 18 years and less than or equal to 35 years. Exclusion criteria were: any participant who did not wish to fill out the informed consent, complete the anthropometric measurements, participate in Association of Tennis Professionals (ATP) tournaments, or present functional and/or organic medical conditions that affect the generation of upper and lower body strength.

### Sample and Sampling

For the sample size calculation for correlational studies, the epidemiological package Epidat version 3.2 was used. The correlation reported for body height and serve speed of r=0.31 published by Hayes et al. [3], a statistical power of 80%, and confidence intervals of 95% were used, resulting in a sample size of 79 tennis players for the study. A simple random probabilistic sampling without replacement was carried out on the sample frame provided by the sports medical center.

### Variables and Instruments

In this study, the dependent variable was the maximum serve speed, measured in kilometers per hour (km/h). The evaluation was carried out by a sports physician and a physical trainer from the medical center. Each participant performed 10 serves with a 10-second rest interval between each, selecting the maximum value of

the 10 serves performed. Before the evaluation, each participant performed an adequate 15-minute warm-up. The tests were carried out at the same time for all participants on a clay tennis court, ensuring consistent conditions.

A calibrated Bushnell Velocity speed gun, with a range of 16-177 km/h and an accuracy of +/- 2 km/h, was used to measure serve speed. The gun was properly calibrated before each evaluation session, following the manufacturer's recommendations and using a standard speed tuning fork to ensure measurement accuracy. It was positioned 3 meters behind the baseline and at the evaluator's chest height, pointing directly towards the ball's trajectory to obtain accurate readings. Additionally, measurements were performed under standard conditions to minimize variations in results. These methodological aspects ensure the validity and reliability of the data obtained in the study.

**Exposure Variables**

The following anthropometric variables were considered as exposure variables in the study: body height in centimeters, body weight in kilograms, body mass index (BMI), and the length of the arm, forearm, thigh, and leg segments in centimeters. Height was measured after maximum exhalation, with the participant positioned in the Frankfurt plane and with an accuracy of 0.1 cm, using a Seca stadiometer. Weight was recorded with an accuracy of 0.05 kg, evaluating the individual dressed in light clothing using an Omron BF511 electronic scale, which was calibrated before each measurement session according to the manufacturer's recommendations. BMI was calculated using the formula: weight/height in meters^2. The measurement of body segments was performed with a Cescorf segmometer, considering the anatomical reference points proposed by the International Society for the Advancement of Kinanthropometry (ISAK). All measurements were taken by an ISAK Level 1 certified anthropometrist. Sociodemographic variables, such as age, years of experience, and weekly playing hours, were also recorded.

**Statistical Analysis**

Statistical analysis was conducted using SPSS version 25. Descriptive analysis for quantitative variables was performed by calculating central tendency and dispersion measures of mean standard deviation. For inferential statistical tests, correlation tests were used. The Pearson statistical test was applied, evaluating the correlation coefficient, which ranges between -1 and +1, to determine the presence, direction, and strength of the correlation between the variables. Subsequently, a bivariate linear regression model was used, estimating the regression coefficients with their respective 95% confidence intervals to evaluate the relationship between the independent and dependent variables. For all analyses, a p-value $\leq 0.05$ was considered statistically significant.

**Ethical Aspects**

This study adhered to the criteria stipulated in the Declaration of Helsinki for studies conducted on humans (15). Approval was obtained from the FiXU sports medical center management, as well as the ethics and research committee of the Universidad San Juan Bautista. The study's purpose and procedures were explained to each participant. Following the implementation of informed consent, data evaluation and collection proceeded. To maintain participant confidentiality and privacy, only the principal author and the statistician had access to the data and individual identifiers.

## RESULTS

Seventy-nine non-professional tennis players who regularly participate in national tournaments were analyzed. The mean age of the tennis players was 26.33 (5.47) years, with an average of 20.42 (2.05) weekly playing hours and 12.59 (5.21) years of experience. Regarding anthropometric characteristics, the average height of the players was 174.61 (4.17) cm, and the average weight was 72.20 (6.97) kg. The average BMI was 23.67 (2.04) kg/m$^2$. Body segment lengths were 33.22 (1.49) cm for the arm, 26.18 (1.04) cm for the forearm, 40.98 (1.48) cm for the thigh, and 41.63 (1.22) cm for the leg. The average serve speed was 94.38 (9.98) km/h. (Table 1).

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**Table 1.** Descriptive Statistics.

| Variables | Mean (Standard Deviation) |
|---|---|
| Serve speed (km/h) | 94.38 +/- 9.98 |
| Height (cm) | 174.61 +/- 4.17 |
| Weight (kg) | 72.20 +/- 6.97 |
| Body mass index | 23.67 +/- 2.04 |
| Arm (cm) | 33.22 +/- 1.49 |
| Forearm (cm) | 26.18 +/- 1.04 |
| Thigh (cm) | 40.98 +/- 1.48 |
| Leg (cm) | 41.63 +/- 1.22 |
| Age | 26.33 +/- 5.47 |
| Weekl playing hours | 20.42 +/- 2.05 |
| Years of experience | 12.59 +/- 5.21 |

Correlation tests revealed several significant relationships between the studied variables. Height showed a very strong positive correlation with serve speed ($r = 0.796$, $p < 0.001$). Weight also presented a significant correlation ($r = 0.533$, $p < 0.001$), as did arm circumference ($r = 0.583$, $p < 0.001$), forearm ($r = 0.627$, $p < 0.001$), thigh ($r = 0.436$, $p < 0.001$), and leg ($r = 0.585$, $p < 0.001$). Weekly playing hours ($r = 0.611$, $p < 0.001$) and years of experience ($r = 0.435$, $p < 0.001$) also positively correlated with serve speed. However, BMI ($r = 0.161$, $p = 0.158$) and age ($r = 0.192$, $p = 0.090$) did not show significant correlations. These results suggest that both physical characteristics and the time dedicated to training are important for serve performance (Table 2).

**Table 2.** Correlation tests of predictor variables with serve speed.

| VARIABLES | CORRELATION COEFFICIENT | P-VALUE |
|---|---|---|
| Height (m) | 0.796 | < 0.001 |
| Weight (kg) | 0.533 | < 0.001 |
| Body Mass Index | 0.161 | 0.158 |
| Arm (cm) | 0.583 | < 0.001 |
| Forearm (cm) | 0.627 | < 0.001 |
| Thigh (cm) | 0.436 | < 0.001 |
| Leg (cm) | 0.585 | < 0.001 |
| Age | 0.192 | 0.090 |
| Weekly playing hours | 0.611 | < 0.001 |
| Years of experience | 0.435 | < 0.001 |

The linear regression analysis identified several significant predictors of serve speed among the studied tennis players. Height (B = 1.91, p < 0.001), weight (B = 0.76, p < 0.001), arm circumference (B = 3.88, p < 0.001), forearm (B = 6.00, p < 0.001), thigh (B = 2.94, p < 0.006), and leg (B = 4.79, p < 0.001) were significantly associated with higher serve speed. Additionally, weekly playing hours (B = 2.97, p < 0.001) and years of experience (B = 0.83, p < 0.001) also proved to be important predictors. On the other hand, BMI and age did not show a significant association in this model. These findings highlight the importance of specific physical dimensions and experience in serve performance among non-professional tennis players, emphasizing the need for personalized approaches in training to enhance performance (Table 3).

**Table 3.** Linear regression model of predictor variables for serve speed.

| PREDICTOR | B COEFFICIENT | T VALUE | P-VALUE | 95% CI |
|---|---|---|---|---|
| Height | 1.91 | 11.55 | <0.001 | 1.58 – 2.23 |
| Weight | 0.76 | 5.52 | <0.001 | 0.49 – 1.04 |
| BMI | 0.78 | 1.43 | 0.158 | -0.31 –1.88 |
| Arm | 3.88 | 6.29 | <0.001 | 2.65 – 5.10 |
| Forearm | 6.00 | 7.07 | <0.001 | 4.31 – 7.69 |
| Thigh | 2.94 | 4.25 | <0.006 | 1.56 – 4.31 |
| Leg | 4.79 | 6.33 | <0.001 | 3.29 – 6.31 |
| Age | 0.35 | 1.71 | 0.0899 | - 0.06–0.76 |
| Weekly playing hours | 2.97 | 6.78 | <0.001 | 2.10 – 3.84 |
| Years of experience | 0.83 | 4.23 | <0.001 | 0.44 – 1.22 |



## DISCUSSION

The study analyzed 79 male tennis players, finding that height (r = 0.796) and weight (r = 0.533) are significant predictors of serve speed. Other anthropometric measures, such as arm and forearm length, also showed significant correlations. Weekly playing hours and years of experience correlated positively with serve speed. Linear regression analysis showed that height (B = 1.91, p < 0.001), weight (B = 0.76, p < 0.001), and forearm length (B = 6.00, p < 0.001) are significant predictors of serve speed. Weekly playing hours (B = 2.97, p < 0.001) and years of experience (B = 0.83, p < 0.001) also positively influenced.

Villouta et al. studied the anthropometric characteristics of elite young tennis players in Chile, finding that in males, the average weight was 64.3 kg, height was 1.74 m, and body fat percentage was 16.6%. In our study with Peruvian tennis players, the average weight was 72.20 kg, height was 174.61 cm, and the average BMI was 23.67. Additionally, we found significant correlations between height, weight, and limb dimensions with serve speed[16].

Sanchez-Pay found that body mass (r = 0.934), height (r = 0.914), and BMI (r = 0.330) had significant correlations with serve speed in national tennis players. Similarly, arm (r = 0.818), forearm (r = 0.858), and leg (r = 0.773) measurements showed positive correlations. These results are consistent with previous findings on the relevance of height and limb measurements for serve speed. However, they differ regarding the correlation of BMI, as our results did not find a significant relationship for this variable[6]. Vaverka et al. identified that body height had a significant correlation with the fastest serve speed (r = 0.52), the average first serve (r = 0.55), and the average second serve (r = 0.37).

Similarly, the results of this study also support the importance of height in serve speed [10]. Wong et al. reported a positive correlation between height (r = 0.542) and BMI (r = 0.577) with serve speed, with the BMI correlation being significant. Similar to what Wong et al. observed, this study identified height as a significant factor in serve speed. However, in contrast, this study did not find a significant correlation for BMI, highlighting a notable discrepancy in findings related to this variable[17].

Hayes et al. found a significant correlation between body weight (r = 0.68) and serve speed but a non-significant correlation for BMI (r = 0.31). Consistent with these findings, the present study also identified body weight as a significant factor, and similar to Hayes et al., did not find a significant correlation for BMI[3]. Fett et al. reported positive and significant correlations for height (r = 0.31), body mass (r = 0.44), BMI (r = 0.40), and the medicine ball throw (r = 0.52) with serve speed. While the results of this study agree on the importance of height and body mass, there is a notable discrepancy regarding BMI, as this study did not find a significant correlation for this variable [18]. Bonato et al. found significant correlations between height and the speed of the first (r = 0.79) and second serve (r = 0.80), supporting the findings of this study on the importance of height in serve speed [19]. Finally, Baiget et al. found that height had significant correlations with the speed of the first (r = 0.503) and second serve (r = 0.486), while BMI did not show significance (r = 0.26 and r = 0.125). Similar to the results of this study, they reinforce the importance of height and agree that the correlation of BMI is not significant[20].

Among the limitations in interpreting the results, the sample size, although calculated to ensure statistical power, is limited to 79 tennis players from a single sports center, restricting the generalizability of the findings. Furthermore, the cross-sectional observational design prevents establishing causal relationships, allowing only the identification of associations. Anthropometric and serve speed measurements can vary between evaluators, despite using certified anthropometrists and calibrated equipment. The study did not consider factors such as individual technique, specific training level, and environmental conditions. The lack of diversity in the sample, composed exclusively of male tennis players from Lima, Peru, limits the applicability of the results. Variables of weekly playing hours and years of experience were self-reported, affecting their accuracy. Evaluation in a controlled environment might not fully reflect real playing conditions or capture the consistency of the serve during a match. Recognizing these limitations is crucial for the appropriate interpretation of the results and planning of future studies.

## CONCLUSIONS

In conclusion, this study identified height and weight as significant predictors of serve speed in Peruvian tennis players. Additionally, limb measurements and years of playing experience positively influence, while BMI did not show a significant correlation.



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***Correspondence:*** *Juan Carlos Ezequiel Roque Quezada.*
***Address:*** *Mariano Cornejo 1609 Pueblo libre.*
***Telephone:*** *945558094*
***Email:*** ***robert.vega1@unmsm.edu.pe***

## REFERENCES

1.Colomar J, Corbi F, Brich Q, Baiget E. Determinant Physical Factors of Tennis Serve Velocity: A Brief Review. Int J Sports Physiol Perform. 2022 Jul 5;17(8):1159-1169. doi: 10.1123/ijspp.2022-0091. PMID: 35894981.

2.Roetert EP, Ellenbecker TS, Reid M. Biomechanics of the Tennis Serve: Implications for Strength Training. Strength Cond J. agosto de 2009;31(4):35. DOI:10.1519/SSC.0b013e3181af65e1

3.Hayes MJ, Spits DR, Watts DG, Kelly VG. Relationship Between Tennis Serve Velocity and Select Performance Measures. J Strength Cond Res. 2021;35(1):190–7. doi:10.1519/JSC.0000000000002440

4.Colomar J, Corbi F, Baiget E. Improving Tennis Serve Velocity: Review of Training Methods and Recommendations. Strength Cond J. agosto de 2023;45(4):385. DOI:10.1519/SSC.0000000000000733

5.Kovacs M, Ellenbecker T. An 8-stage model for evaluating the tennis serve: implications for performance enhancement and injury prevention. Sports Health. 2011 Nov;3(6):504-13. doi: 10.1177/1941738111414175. PMID: 23016050; PMCID: PMC3445225.

6.Sánchez-Pay A, Ramón-Llin J, Martínez-Gallego R, Sanz-Rivas D, Sánchez-Alcaraz BJ, Frutos S. Fitness testing in tennis: Influence of anthropometric characteristics, physical performance, and functional test on serve velocity in professional players. PLoS ONE. 2021;16(11):e0259497. doi:10.1371/journal.pone.0259497

7.Fernandez-Fernandez J, Nakamura FY, Moreno-Perez V, Lopez-Valenciano A, Del Coso J, Gallo-Salazar C, Barbado D, Ruiz-Perez I, Sanz-Rivas D. Age and sex-related upper body performance differences in competitive young tennis players. PLoS One. 2019 Sep 3;14(9):e0221761. doi: 10.1371/journal.pone.0221761. PMID: 31479492; PMCID: PMC6719856.

8.De Jesus-Leite MAF, Sasaki JE, Lourenço CLM, Zanetti HR, Mota GR, Mendes EL. Rev Bras Cineantropom Desempenho Hum 2020, 22:e63286. DOI:http://dx.doi.org/10.5007/1980-0037.2020v22e63286

9.Canós J, Corbi F, Colomar J, Cirer-Sastre R, Baiget E. Effects of isoinertial or machine-based strength training on performance in tennis players. Biol Sport. 2022 Sep;39(3):505-513. doi: 10.5114/biolsport.2022.107020. Epub 2021 Jul 3. PMID: 35959344; PMCID: PMC9331344.

10.Vaverka F, Cernosek M. Association between body height and serve speed in elite tennis players. Sports Biomech. 2013;12(1):30–7. doi:10.1080/14763141.2012.670664

11.Liang Z, Wu J, Yu J, Ying S, Liu Z, Zhang Y, et al. Comparison and analysis of the biomechanics of the lower limbs of female tennis players of different levels in foot-up serve. Front Physiol. 24 de febrero de 2023;14:1125240.

12.Tomlinson DJ, Erskine RM, Morse CI, Winwood K, Onambélé-Pearson GL. Combined effects of body composition and ageing on joint torque, muscle activation and co-contraction in sedentary women. Age. junio de 2014;36(3):9652.

13.Wood CT, Truong T, Skinner AC, Armstrong SC, Perrin EM, Woo JG, et al. Timing and Magnitude of Peak Body Mass Index and Peak Weight Velocity in Infancy Predict Body Mass Index at 2 Years in a Retrospective Cohort of Electronic Health Record Data. J Pediatr. 1 de junio de 2023;257:113356.

14.Cuschieri S. The STROBE guidelines. Saudi J Anaesth. 2019 Apr;13(Suppl 1):S31-S34. doi: 10.4103/sja.SJA_543_18. PMID: 30930717; PMCID: PMC6398292.

15.WMA - The World Medical Association-WMA Declaration of Taipei on Ethical Considerations regarding Health Databases and Biobanks [Internet]. [citado 9 de octubre de 2023]. Disponible en: https://www.wma.net/policies-post/wma-declaration-of-taipei-on-ethical-considerations-regarding-health-databases-and-biobanks/

16.Villouta PL, Correia-de-Campos LFC, Paredes-Arias M, Vargas-Vitoria R, Martínez-Salazar C, Araneda-Garces N. Caracterización Antropométrica y Composición Corporal de Tenistas de Elite Varones y Damas de Chile. Int J Morphol. 2021;39(1):84–9. doi:10.4067/S0717-95022021000100084

17.Wong FK, Keung JH, Lau NM, Ng DK, Chung JW, Chow DH. Effects of Body Mass Index and Full Body Kinematics on Tennis Serve Speed. J Hum Kinet. 2014;40:21–8. doi:10.2478/hukin-2014-0003

18.Fett J, Ulbricht A, Ferrauti A. Impact of Physical Performance and Anthropometric Characteristics on Serve Velocity in Elite Junior Tennis Players. J Strength Cond Res. 2020;34(1):192. doi:10.1519/JSC.0000000000002641

19.Bonato M, Maggioni MA, Rossi C, Rampichini S, La Torre A, Merati G. Relationship between anthropometric or functional characteristics and maximal serve velocity in professional tennis players. J Sports Med Phys Fitness. 2015;55(10):1157–65.

20. Baiget E, Corbi F, López J. Influence of anthropometric, ball impact and landing location parameters on serve velocity in elite tennis competition. Biol Sport. 2022;40(1):273–81. doi:10.5114/biolsport.2023.112095