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Biomechanical study of the place kick in rugby and its implications for the technical gesture

[*Estudio biomecánico del place kick en el rugby y sus implicaciones en el gesto técnico*]

[*Estudo biomecânico do chute colocado no rugby e suas implicações no gesto técnico*]

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ABSTRACT

Introduction: The place kick is crucial in high-performance rugby, accounting for between a quarter and half of a team's total score. However, how biomechanical variables combine to determine the effectiveness of place kickers is still not fully understood.

Objective: To analyze the influence of biomechanical variables of the place kick technique in rugby and its relationship with kick effectiveness in high-performance players.

Materials and methods: A cross-sectional descriptive study was conducted with 30 players from the metropolitan rugby league. The technical movement was recorded with high-speed cameras (60 fps) and analyzed using Kinovea software. Descriptive statistics, Spearman correlations, non-parametric tests (Mann-Whitney U, Kruskal-Wallis), and a logistic regression model with LASSO regularization were used.

Results: 66.7% of kicks were successful. Height showed the strongest correlation with maximum ball speed ($\rho=0.556$) and significant differences between successful and unsuccessful kicks ($p=0.033$). Approach speed was inversely correlated with the ball's launch angle ($\rho=-0.472$). The LASSO model identified height, support foot distance, and a smaller ankle flexion angle at impact as predictors of success.

Conclusions: Height offers a biomechanical advantage, but success depends on technical coordination, especially ankle control and stance distance. Individualized training based on playing position is recommended.

Keywords: place kick, rugby biomechanics, effectiveness, technique.

RESUMEN

Introducción: el place kick es determinante en el rugby de alto rendimiento, supone entre una cuarta parte y la mitad de la puntuación total de un equipo. Sin embargo, aún no se comprende cómo se combinan las variables biomecánicas para definir la efectividad de los pateadores.

Objetivo: analizar la influencia de las variables biomecánicas de la técnica del place kick en rugby y su relación con la efectividad de la patada en jugadores de alto rendimiento.

Materiales y métodos: estudio descriptivo transversal con 30 jugadores de la liga metropolitana de rugby. El gesto técnico se registró con cámaras de alta velocidad (60 fps) y se analizó con el software Kinovea. Se emplearon estadísticos descriptivos, correlaciones de Spearman, pruebas no paramétricas (Mann-Whitney U, Kruskal-Wallis) y un modelo de regresión logística con regularización LASSO.

Resultados: el 66.7% de las patadas fueron exitosas. La talla presentó la correlación más fuerte con la velocidad máxima del balón ($\rho=0.556$) y diferencias significativas entre patadas exitosas y fallidas (p=0.033). La velocidad de aproximación se correlacionó inversamente con el ángulo de salida del balón (ρ=-0.472). El modelo LASSO identificó la talla, la distancia del pie de apoyo y un menor ángulo de flexión del tobillo en el impacto como predictores del éxito.

Conclusiones: la talla ofrece una ventaja biomecánica, pero el éxito depende de la coordinación técnica, especialmente del control del tobillo y la distancia de apoyo. Se recomienda individualizar el entrenamiento según la posición de juego.

Palabras clave: place kick, biomecánica rugby, efectividad, técnica.

RESUMO

Introdução: O place kick é determinante no rugby de alto rendimento, representando entre um quarto e metade da pontuação total de uma equipe. No entanto, ainda não se compreende como as variáveis biomecânicas se combinam para definir a efetividade dos chutadores.

Objetivo: Analisar a influência das variáveis biomecânicas da técnica do place kick no rugby e sua relação com a efetividade do chute em jogadores de alto rendimento.

Materiais e métodos: Estudo descritivo transversal com 30 jogadores da liga metropolitana de rugby. O gesto técnico foi registrado com câmeras de alta velocidade (60 fps) e analisado com o software Kinovea. Foram empregados estatísticos descritivos, correlações de Spearman, testes não paramétricos (Mann-Whitney U, Kruskal-Wallis) e um modelo de regressão logística com regularização LASSO.

Resultados: 66,7% dos chutes foram bem-sucedidos. A estatura apresentou a correlação mais forte com a velocidade máxima da bola (ρ=0,556) e diferenças significativas entre chutes bem-sucedidos e falhos (p=0,033). A velocidade de aproximação correlacionou-se inversamente com o ângulo de saída da bola (ρ=-0,472). O modelo LASSO identificou a estatura, a distância do pé de apoio e um menor ângulo de flexão do tornozelo no impacto como preditores de sucesso.

Conclusões: A estatura oferece uma vantagem biomecânica, mas o sucesso depende da coordenação técnica, especialmente do controle do tornozelo e da distância de apoio. Recomenda-se individualizar o treinamento conforme a posição de jogo.

Palavras-chave: place kick, biomecânica rugby, efetividade, técnica.

INTRODUCTION

The term "place kick" refers to set-piece kicks in rugby. These kicks are used to score points through conversions and penalties, and their contribution ranges from a quarter to half of the points in high-performance sports. Therefore, the success rate directly impacts game strategies and the final result (Jones *et al.,* 2024; Pocock *et al.,* 2020). Some studies indicate that the success rate can reach up to 60% (Jones *et al.,* 2024).

On the other hand, there is a potential danger of injury during execution; the pelvic area and lower limb are the most affected (Lazarczuk) *et al.,* 2020).

Studies indicate that how a player stands and moves affects balance and kicking accuracy (Aedo-Muñoz *et al.,* 2020; Wang *et al.,* 2023; Yao, 2023; Belete *et al.,* 2024). Therefore, more attention should be paid to technique in order to create training programs aimed at reducing injuries and improving kicking effectiveness.

Over the years, various parameters have been used to measure performance in rugby. However, the technical aspect of the kick is often overlooked (Colomer *et al.,* 2020). A successful kick depends on movement, the environment, and the player's condition (Pocock *et al.,* 2020; Pocock *et al.,* 2021). It has also been suggested that positioning is more important than power for a successful kick (Atack *et al.,* 2021; Stalin *et al.,* 2022). Furthermore, it has been observed that the ball's orientation modifies the kinematics of the foot-ball impact, although it does not, on its own, predict the outcome of the kick (Jones *et al.,* 2022).

On the other hand, the role of the trunk and its coordination in kicking is known, and there is a contribution from rotations to increase the speed of the ball's exit, something not often seen in many training manuals (Chen *et al.,* 2024). This background positions biomechanical analysis as a connector between the understanding of the movement and the design of training programs (Pocock *et al.,* 2020; Pocock *et al.,* 2021; Augustus *et al.,* 2024).

Although the evidence identifies important variables of the technique, as well as its effect on efficacy and injury burden (Atack *et al.,* 2021; Jones *et al.,* 2022; Jones et al., 2024; Lazarczuk *et al.,* 2020; Pocock *et al.,* 2020; Pocock et al., 2021), it is unknown to what extent or how these variables relate to the effectiveness of rugby kickers.

Therefore, the research question that guides this work is:

How do the biomechanical variables of the place kick technique in rugby influence the effectiveness of high-performance kickers?

As far as the literature consulted allows, this question has not been answered in an integrated and specific way for the place kick in rugby.

That said, the objective of the present study is to analyze the biomechanical influence of the place kick technique in rugby and its relationship with the effectiveness of the kick.

MATERIALS AND METHODS

Design

To address this topic, a descriptive cross-sectional study with a correlational approach was conducted. Mathematical, empirical, and statistical methods were used. The sample consisted of players from the metropolitan rugby league.

Participants

Thirty athletes, all male with a mean age of 25 ± 2.49 years, were selected using non-probability convenience sampling. Participants were over 18 years of age at the time of the study, voluntarily declared the absence of physical or motor problems that could affect their performance, and were active in the metropolitan rugby league. Athletes who had experienced any injury in the previous four weeks that could influence the results were excluded.

Procedure and instruments

Data collection took place at the rugby field of the Villa María del Triunfo sports complex, located in the Villa María del Triunfo district of Lima, Peru. The tests were conducted between 8:00 and 10:00 a.m. on a single day. A total of 30 athletes participated.

Prior to the start of the evaluations, the necessary equipment for recording the kicking technique was set up. Two Canon 80D cameras with EF-S 10–22 mm ultrasonic lenses, 1920 × 1080-pixel resolution, and 60 fps frame rate were used. Both were positioned in the sagittal plane, one focused on the kicking technique and the other on the ball's trajectory. Each player's personal data was collected using a registration form. Weight was measured using a Tanita Innerscan ProRD-545HR digital scale with a precision of 0.1/kg, and height was measured using a SECA 213 portable stadiometer with a precision of 0.1 cm.

Subsequently, a specific 10-minute activation was performed to prepare the athlete for the kick. Once completed, markers were placed on the following anatomical points of the kicking foot: acromion, trochanter, lateral condyle of the femur, lateral malleolus, and proximal phalanx of the fifth toe. On the supporting foot, the medial malleolus was marked.

Once prepared, the player was asked to position the ball on the tee as they felt most comfortable. The tee remained in a fixed position throughout the evaluation. The athlete's step-back distance was recorded, and the distance between their supporting foot and the ball was measured. The shot was executed after a count of one to three.

For biomechanical analysis, Kinovea software version 0.9.5 was used. The database was compiled in an Excel spreadsheet, and the free software R version 4.4.1 was used for statistical analysis. Descriptive statistics (mean, standard deviation, range, 95% CI, frequencies) were applied, along with the Shapiro-Wilk and Levene tests. Inferential analysis included Spearman's rank correlation coefficient (ρ) with r^2 and non-parametric comparisons using the Mann-Whitney U and Kruskal-Wallis H tests, with corresponding effect sizes. Additionally, binary logistic regression with LASSO regularization (L1), validated with 5-fold and leave-one-out, was used, reporting accuracy, AUC-ROC, sensitivity, specificity, and odds ratios, with $\alpha = 0.05$.

RESULTS

Thirty rugby players from the metropolitan league were analyzed; the descriptive characteristics for anthropometric variables and angular and performance variables are shown in Tables 1 and 2.

Table 1. *- Descriptive statistics of anthropometric variables*

Variable	N	M	OF	Min	Max	95% CI
Age (years)	30	25.3	2.49	20.0	28.0	[24.37, 26.23]
Weight (kg)	30	78.5	5.44	71.0	88.0	[76.47, 80.53]
Size (cm)	30	172.1	5.33	165.0	180.0	[170.11, 174.09]
Experience (years)	30	7.7	2.37	3.0	10.0	[6.82, 8.58]
Distance from support foot (m)	30	3.58	0.88	2.35	5.5	[3.25, 3.91]
Approach speed (m/s)	30	7.19	1.49	5.03	10.88	[6.63, 7.75]

Note. M = Mean; SD = Standard Deviation; Min = Minimum Value; Max = Maximum Value; 95% CI = 95% Confidence Interval for the mean.

Table 2. - *Descriptive statistics of angular and performance variables*

Variable	N	M	OF	Min	Max	95% CI
External angle of countermovement of the hip (°)	30	24.11	2.28	19.2	27.3	[23.26, 24.96]
Angle of flexion of the knee against movement (°)	30	97.4	6.41	83.0	109.1	[95.0, 99.79]
Ankle flexion angle (°)	30	22.81	1.65	20.0	26.1	[22.19, 23.42]
flex angle (°)	30	26.06	6.0	12.1	38.0	[23.82, 28.3]
flex angle impact (°)	30	26.49	5.08	18.45	35.0	[24.59, 28.38]

Ankle flex angle (°)	30	21.77	1.41	19.9	24.0	[21.25, 22.3]
Max. impact foot speed (m/s)	30	15.5	3.54	4.3	22.85	[14.17, 16.82]
Ball launch angle (°)	30	36.9	4.39	25.2	47.0	[35.26, 38.54]
Maximum ball speed (m/s)	30	21.92	2.36	17.13	25.38	[21.03, 22.8]

Note. M = Mean; SD = Standard Deviation; Min = Minimum Value; Max = Maximum Value; 95% CI = 95% Confidence Interval for the mean.

Regarding categorical variables, 66.7% of the attempts were successful (20 out of 30), reflecting moderate effectiveness. 90% of the attempts were executed with the right foot. The most represented positions were scrum-half and fly-half (30% each), followed by center (20%), flanker, and fullback (10% each), as shown in Table 3.

Table 3. *- Distribution of categorical variables*

Variable	n	%
Playing position		
Scrum Medium	9	30
Opening	9	30
Center	6	20
3rd line	3	10
Fullback	3	10
Executing foot		
Right	27	90
Left	3	10
Kickoff results		
Goal	20	66.7
No goal	10	33.3

Note. Total N = 30. The percentages represent the proportion of the total sample for each category.

For correlational analysis, Spearman's correlation coefficient (ρ) was used with $\alpha = 0.05$. Four significant correlations were identified with moderate to large effect sizes (Table 4).

Table 4. *- Significant correlations between biomechanical variables and performance*

Predictor variable	Outcome	P	p-value	r^2	% Variation
Size (cm)	Maximum ball speed (m/s)	0.556	0.001	0.309	30.9%
Age (years)	Maximum ball speed (m/s)	0.522	0.003	0.272	27.2%
Approach speed (m/s)	Ball launch angle (°)	-0.472	0.009	0.223	22.3%
External angle of countermovement of the hip (°)	Maximum ball speed (m/s)	-0.435	0.016	0.189	18.9%

Note. ρ = Spearman's coefficient; r^2 = Explained variance. Magnitudes according to Cohen (1988): moderate (9-25%), large (> 25%).

Height emerged as the strongest predictor of ball speed (30.9% variance), followed by age (27.2%), suggesting biomechanical advantages of longer limbs and technical maturity. Approach speed was inversely associated with release angle (22.3% variance), indicating a trade -off between power and trajectory control. The countermovement hip extension angle showed an inverse relationship with ball speed (18.9% variance), suggesting that more upright postures optimize energy transfer, as shown in Table 4.

For the comparison between groups, non-parametric tests were used: Mann-Whitney U for two groups and Kruskal-Wallis for multiple groups ($\alpha = 0.05$) which are presented in Tables 5 and 6.

Table 5. - *Comparison of goal vs. no goal (Mann-Whitney U).*

Variable	Mdn goal	Mdn no goal	OR	p	r
Size (cm)	175.0	168.5	148.0	0.033	0.389

Note: Only size showed significant differences. The moderate effect (r = 0.389) indicates that size explains approximately 15% of the variability in success. No technical variables showed significant differences.

Table 6. - *Variables with significant differences between playing positions (Kruskal-Wallis).*

Variable	H	p-value	η^2	Magnitude
Weight (kg)	13,454	0.0093	0.378	Big
Size (cm)	22.233	0.0002	0.729	Big
Experience (years)	17,513	0.0015	0.541	Big
Approach speed (m/s)	20,891	0.0003	0.676	Big

Max. impact foot speed (m/s)	11,457	0.0219	0.298	Big

Note. H = Kruskal-Wallis statistic; η^2 = eta squared. Positions: Scrum-half (n=9), fly-half (n=9), center (n=6), back row (n=3), fullback (n=3). All with large effect sizes (η^2 > 0.25).

The analysis of physical characteristics shows clear variations according to each player's role: forwards are heavier, backs are lighter and taller. Kinematic variables (foot strike distance, approach speed) and angular variables (knee flexion) indicate that different positions develop distinct adaptive technical patterns, suggesting that individualized training could be considered according to position (Table 6).

Binary logistic regression with L1 regularization (LASSO) was also used to identify predictors of kick success. Regularization reduces overfitting and enables automatic variable selection. K- fold analysis was applied. cross-validation, dividing the data into 5 equal groups to select the optimal regularization parameter (C = 0.359) and leave one-out cross-validation (LOO-CV) to estimate actual performance, as shown in Table 7.

Table 7. - *LASSO model performance metrics*

Metrics	LASSO Model	LOO-CV
Accuracy	83.3%	66.7%
AUC-ROC	0.900	—
Sensitivity	90.0%	80.0%
Specificity	70.0%	40.0%

Note. AUC-ROC = Area under the ROC curve (>0.80 = good). LOO-CV = leave-one-out validation (more realistic estimate). A sensitivity of 80% indicates correct detection of 4 to 5 successful kicks.

Table 7 shows good performance in the training data (accuracy = 83.3%, AUC = 0.900), indicating discriminatory ability between successful and unsuccessful kicks. However, the LOO-CV cross-validation revealed more modest performance (accuracy = 66.7%), suggesting an overestimation of the training metrics due to the limited sample size. The 80% sensitivity in LOO-CV indicates that the model correctly detects 4 out of 5 successful kicks, while the 40% specificity suggests lower accuracy in detecting unsuccessful kicks.

This pattern is expected given the class imbalance (67% goal vs. 33% no goal) and reflects that the model tends to predict goals more frequently.

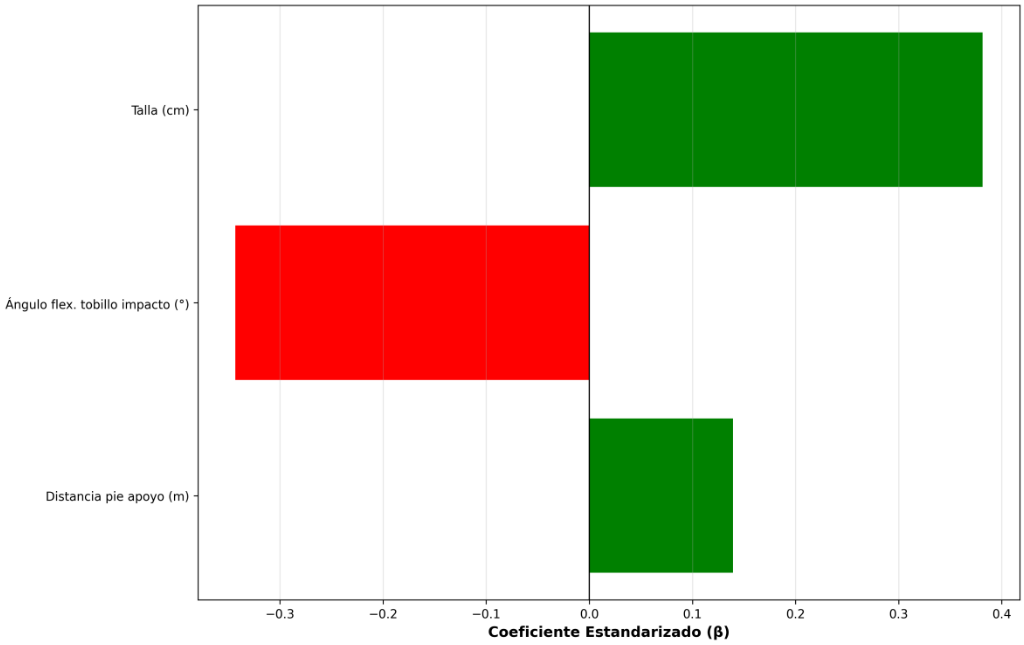

Fig. 1. *- Significant predictors selected by the LASSO model*

Note. Standardized coefficient magnitudes. Green = positive effect (increases goal probability); red = negative effect (decreases goal probability). Only variables with non-zero coefficients after LASSO regularization are shown.

In Figure 1, the LASSO model selected 3 of the original 13 variables, forcing the coefficients of the remaining 10 to exactly zero. This parsimonious selection reduces overfitting and facilitates interpretation.

1. Height (β = 0.381, OR = 1.464): Body height emerges as a positive predictor of success. Each increase of 1 standard deviation (approximately 5 cm) increases the odds of scoring by 46%. Biomechanically, greater height implies longer limbs that generate greater linear foot speed and angular momentum, both critical for energy transfer to the ball.

2. Ankle flexion angle at impact (β = -0.343, OR = 0.709): Negative predictor. Greater ankle flexion at the moment of contact reduces goal odds by 29%. This finding suggests that a more extended ankle (smaller flexion angle) at impact optimizes the stiffness of the foot-ankle complex, maximizing momentum transfer to the ball and minimizing energy losses due to joint deformation. Clinically, this implies that players should emphasize active ankle extension (plantar flexion) during contact.

3. Support foot distance (β = 0.139, OR = 1.150): A positive predictor with a minor effect. A greater distance between the support foot and the ball increases the odds of scoring by 15%. Although the effect is modest, it suggests that placing the support foot further away allows for a greater range of motion of the striking limb, potentially increasing foot speed at impact. However, excessive distances could compromise stability, explaining the moderate magnitude of the coefficient.

Methodological limitations, due to the sample size of n = 30 and 20 events (goal), result in an events-per-variable ratio (EPV) of 1.5 for the initial 13-predictor model, well below the recommended minimum of EPV ≥ 10. Although LASSO regularization partially mitigates this problem by reducing the number of predictors to 3 (EPV = 6.7), the model is still at risk of instability. The LOO-CV validation (accuracy = 66.7%) reflects this limitation.

External validation with independent data is required to confirm the model's generalizability to new players. All results are derived from internal validation (same sample).

The 67% goal vs. 33% non- goal ratio is moderately unbalanced, which explains the model's higher sensitivity (80%) than specificity (40%). Resampling techniques (SMOTE, subsampling) could improve the balance, but require larger samples.

DISCUSSION

This study analyzed how certain biomechanical factors of the place kick in rugby influence its effectiveness in high-level players, taking into account body measurements, movement patterns, and models that predict the outcome. Overall, the results confirm that the place kick is a complex skill, where success depends more on the combination of player characteristics, movement patterns, and the technical demands of the moment than on a single isolated variable.

A key finding was that a player's height is related to the speed the ball reaches and can help predict whether a strike will be successful. From a biomechanical perspective, this is explained by the principle that longer body levers, such as the legs, allow for greater foot speed if the movement technique is good (Atack *et al.,* 2021; Velkov, 2021). Strength matters, but body structure and the ability to transmit that force from the core are crucial. In other words, physical advantages alone are not enough; they need to be accompanied by good technique and coordination (Hébert-Losier et al., 2022). A successful strike, then, arises from a specific combination of various biomechanical elements.

It was also observed that the faster the run-up to the ball, the shallower the ball's launch angle. This demonstrates a balance between generating power and maintaining control of the trajectory. A faster run-up provides more energy to the strike, but it can also make the movement less precise and more variable (Atack *et al.,* 2021; Blair *et al.,* 2020). From a dynamic systems perspective, this compensation is interpreted as an adaptation by the athlete to the demands of the task, leading them to choose different motor solutions depending on their objective and what they perceive in the environment (Pocock *et al.,* 2020).

Furthermore, the inverse relationship found between hip extension angle and ball velocity indicates that hyperextending the hip can impair the efficiency of the entire kinematic chain. Sports biomechanics maintains that a coordinated sequence of flexion and extension transmits energy more effectively than simply aiming for maximum joint range of motion (Roger-Lund *et al.,* 2020; Chen *et al.,* 2024). This supports the idea that a wider range of motion is not always more effective; what truly matters is the synchronization between different body segments.

Our findings only partially coincide with those of Atack *et al.* (2021), because while player height has some influence, it is the approach to the ball and technical details that ultimately determine performance more than purely physical characteristics. The LASSO model applied in this study confirmed this, identifying relevant technical variables such as the distance at which the supporting foot is placed and the ankle angle at the moment of impact. This highlights the crucial importance of technical control just before impact. In fact, research such as that by Jones *et al.* (2022) already indicated that kickers tend to maintain stable technical patterns to preserve the efficiency of the foot-ball contact, even when external conditions vary.

The fact that no significant differences were found in most technical aspects between successful and unsuccessful kicks aligns with the findings of Hébert-Losier *et al.* (2022). This suggests that, essentially, the movement patterns are very similar in both cases, and success or failure is defined by very subtle combinations of these factors. Therefore, success is not a matter of achieving an ideal value in a specific variable, but rather of maintaining a stable technical pattern when performing the movement under real-world conditions. This idea is reinforced by Pocock *et al.* (2021) in their study of how factors such as fatigue and player expectations affect performance.

The differences found in physical and movement measurements between players in different positions (forwards and backs) are consistent with the literature. These players develop different physical and technical profiles, leading them to use movement strategies adapted to the demands placed upon them on the field (Colomer *et al.*, 2020; Gilham *et al.*, 2024). This reinforces the idea that a single technical model cannot be applied to everyone. Therefore, place kick training should be tailored to the specific characteristics of each position and each individual player.

From a mechanical perspective, the fact that ankle flexion angle appears to negatively influence success could be due to the role of stiffness in force transmission. When the ankle is more stable at the moment of impact, contact is generally more efficient and less energy is lost (Velkov, 2021; Aedo-Muñoz *et al.,* 2020). Meanwhile, the positive effect of the distance between the supporting foot and the ball of the foot is likely due to the increased stability it provides to the body, allowing for better control of the impact moment (Atack *et al.,* 2024; Gilham *et al.,* 2024). To date, research has not yet determined the ideal values for this distance.

It is important to mention the limitations of this study. The small number of participants reduces the power of the statistical analyses and makes the predictive models used less robust. Furthermore, as a cross-sectional study, it is not possible to establish cause-and-effect relationships between the biomechanical variables analyzed and striking accuracy. Additionally, the two-dimensional analysis does not accurately capture more complex trunk and pelvic movements, something that is possible with three-dimensional studies (Chen *et al.,* 2024; Augustus et al., 2024). Finally, the fact that the measurements were taken in a controlled environment prevents replicating the real conditions of a competition, where factors such as psychological pressure or fatigue can significantly affect performance (Pocock *et al.,* 2020; Pocock *et al.,* 2021).

In short, the results obtained support the idea that the place kick is a complex skill involving physical, technical, and environmental factors. In practical terms, these findings indicate that it is more useful to focus on improving body position, stability of the movement, and coordination between different body parts than on trying to gain strength or increase running speed separately. The differences observed according to playing position reinforce the need for more personalized training programs. Finally, the technical variables that the LASSO model indicates should be considered can serve as a starting point for developing tools to help evaluate and monitor performance, which will need to be validated in future studies with larger samples and in other situations.

CONCLUSIONS

The results indicate that height plays a significant role, as it is related to both achieving greater ball speed and a higher probability of accurate striking. This suggests a biomechanical advantage, associated with longer body levers and more efficient force transmission. However, this advantage alone does not explain everything; it also depends on good technical coordination.

It was also observed that there is a balance between running speed towards the ball and trajectory control: sometimes, seeking more power can lead to a loss of precision in the exit angle.

Regarding technique, it was observed that aspects such as the distance at which the supporting foot is placed, and especially maintaining a more closed ankle flexion angle at the moment of impact, result in a more rigid ankle, which helps to better transmit energy to the ball and increases the chances of success. Conversely, when comparing kicks that resulted in a goal with those that did not, most of the technical variables showed no significant differences. This reinforces the idea that success depends more on the stability and overall coordination of the movement than on achieving specific values in isolated aspects.

Finally, clear differences were found between players in different positions, both in their physical characteristics and in the way they execute the movement. This confirms the need to adapt technical training to each position and the specific demands it entails.

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