Transformations in muscular mechanical properties and the impact of dynamic balance on free kick accuracy in elite football players

Transformaciones en las propiedades mecánicas musculares y el impacto del equilibrio dinámico en la precisión de los tiros libres en jugadores de fútbol de élite

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Abstract

Introduction: This study examines the influence of dynamic balance and muscle mechanical properties on the accuracy of free kicks in elite football players. Skeletal muscles, critical for movement, possess mechanical properties such as stiffness, strength, and elasticity, which are pivotal for maintaining balance and executing accurate kicks.
Objective: The objective of this research was to explore how these biomechanical factors impact free kick performance, with a focus on identifying significant relationships.
Methodology: The study employed a descriptive methodology, analyzing data from six elite players in the Iraqi Stars League using tools like the Myoton device and Y-Balance test. Players underwent specialized training, and assessments were conducted pre- and post-training.
Results: Results indicated a strong correlation between enhanced muscle stiffness, dynamic balance, and free kick accuracy. Key findings demonstrated that quadriceps and gastrocnemius muscle properties significantly influenced performance.
Discussion: The discussion highlighted how these findings align with existing literature, emphasizing the biomechanical underpinnings of dynamic balance and muscle efficiency.
Conclusions: It is suggested that targeted training focusing on muscle mechanical properties and balance enhancement can effectively improve football performance, particularly in free kicks.

Keywords

Dynamic balance, muscle properties, free kick accuracy, football, biomechanics.

Resumen

Introducción: Este estudio analiza la influencia del equilibrio dinámico y las propiedades mecánicas musculares en la precisión de los tiros libres en jugadores de fútbol de élite. Los músculos esqueléticos, fundamentales para el movimiento, poseen propiedades como rigidez, fuerza y elasticidad, esenciales para mantener el equilibrio y ejecutar tiros precisos.
Objetivo: El objetivo de la investigación fue explorar cómo estos factores biomecánicos afectan el rendimiento en tiros libres, centándose en identificar relaciones significativas.
Metodología: Se utilizó una metodología descriptiva, analizando datos de seis jugadores élite de la Liga de Estrellas de Irak mediante herramientas como el dispositivo Myoton y la prueba Y-Balance. Los jugadores se sometieron a un entrenamiento especializado y se realizaron evaluaciones antes y después del entrenamiento.
Resultados: Los resultados mostraron una correlación sólida entre el aumento de la rigidez muscular, el equilibrio dinámico y la precisión en los tiros libres. Los hallazgos principales destacaron que las propiedades de los músculos del cuádriceps y gastrocnemio influyen significativamente en el rendimiento.
Discusión: La discusión contrastó estos resultados con investigaciones previas, resaltando los fundamentos biomecánicos del equilibrio dinámico y la eficiencia muscular.
Conclusiones: Se concluye que un entrenamiento dirigido a mejorar las propiedades mecánicas musculares y el equilibrio puede mejorar eficazmente el rendimiento en fútbol, especialmente en tiros libres.

Palabras clave

Biomecánica; equilibrio dinámico; fútbol; precisión en tiros libres; propiedades musculares.

Introduction

Skeletal muscles are essential tissues that enable human movement, relying on physiological and mechanical properties to perform their functions. Properties such as stiffness, strength, and elasticity are critical in sports performance, particularly in activities requiring precision and dynamic control like football. The ability to maintain stability and control during high-speed, repetitive actions relies heavily on these muscular attributes (Bonato, P.et al., 2001). Muscle stiffness plays a vital role in maintaining stability, reducing deformation under stress, and ensuring effective force transmission. Previous studies have highlighted its importance in executing complex motor tasks in football (Dankel & Razzano, 2020). Similarly, muscle strength and elasticity contribute to force production and rapid recovery from deformation, enhancing athletic performance (Clancy, E. A.et al., 2005). These mechanical properties, combined with dynamic balance, are key to achieving precision and stability in free kicks (Morales-Sánchez et al., 2022). Dynamic balance, defined as the ability to maintain stability while in motion, has been identified as a significant factor in football performance. Research has emphasized its role in optimizing posture and movement coordination during critical actions, such as free kicks (Scurr et al., 2011). Despite the recognized importance of these factors, there is limited research addressing the interplay between muscle mechanical properties, dynamic balance, and free kick accuracy. This study aims to fill this gap by examining how dynamic balance and specific mechanical properties of the quadriceps and gastrocnemius muscles influence free kick performance in elite football players. The research provides valuable insights into targeted training programs, emphasizing the importance of muscle characteristics and balance for improving athletic performance (Ettema & Huijing, 1994).

Method

This research adopted a descriptive quantitative methodology to analyze the relationship between dynamic balance, muscle mechanical properties, and free kick accuracy in elite football players. The scope of the study was correlational, seeking to identify significant relationships among these variables through structured assessments and controlled conditions.

Population and Sample

The study population consisted of elite football players from the Iraqi Stars League, specializing in free kicks. A purposive sampling method was used, selecting six players from three prominent clubs: Al-Zawraa, Al-Shorta, and Al-Quwa Al-Jawiya. Each club contributed two players based on coach recommendations. Players with recent injuries or chronic conditions were excluded to ensure the validity of results.

Techniques and Instruments

Data collection involved three main tests:

1. Dynamic Balance Assessment: The Y-Balance test was utilized to measure the players' ability to maintain balance during controlled movements. This test evaluates anterior, posterolateral, and posteromedial reach distances, providing a comprehensive measure of dynamic balance.
2. Muscle Mechanical Properties Measurement: The Myoton device was employed to assess stiffness, elasticity, and tone in the quadriceps and gastrocnemius muscles. Measurements were taken under standardized conditions to ensure accuracy.
3. Free Kick Accuracy Test: Players were tested on their ability to score goals from a set distance using the inside of the foot, with accuracy evaluated based on predefined target zones.

Procedure

The research was conducted over three months, from March to June 2022. Pre-training assessments were conducted to establish baseline values for dynamic balance, muscle properties, and free kick accuracy. Participants underwent a specific training program designed to improve these attributes. Post-training assessments were performed under identical conditions to evaluate improvements.

Data Analysis

The data collected were organized and analyzed using statistical methods to determine the relationships and significance among variables. The correlation coefficients and regression analyses were interpreted to understand the impact of dynamic balance and muscle mechanical properties on free kick accuracy. This methodological approach ensures that the findings are reproducible, offering valuable insights for improving football performance through targeted training strategies.

Results

This section presents the findings of the study, which aimed to analyze the impact of muscular mechanical properties and dynamic balance on the accuracy of free kicks in elite football players. The results were obtained using advanced tools such as the Myoton device to measure muscle properties and the Y-Balance test to assess dynamic balance. The data analysis revealed significant improvements in free kick accuracy following targeted training, with key findings indicating strong positive correlations between enhanced muscle stiffness, dynamic balance, and accuracy. The results align with the objectives set forth in the study, emphasizing the importance of muscle characteristics such as stiffness and tone, as well as the role of dynamic balance in maintaining body stability during high-performance tasks.

Table 1. Statistic descript

	N	Min.	Max.	Mean	Standard deviation	Variance	Skewness
ACC.Indx	6	1.74	2.37	2.20	0.237	.057	-2.133
Y_Balance	6	86.30	95.08	90.67	3.229	10.433	-.236
Qud.Rt.F	6	12.00	15.00	13.16	1.169	1.367	0.668
Qud.Lt.F	6	11.00	14.00	12.50	1.048	1.100	0.000
Gast.Rt.F	6	8.00	9.00	8.50	0.547	.300	0.000
Gast.Lt.F	6	8.00	10.00	9.3333	0.81650	.667	-.857
Qud.Rt.S	6	223.00	251.00	236.50	9.544	91.100	0.276
Qud.Lt.S	6	324.00	352.00	336.83	11.143	124.167	0.044
Gast.Rt.S	6	223.00	390.00	315.00	68.931	4751.6	-.392
Gast.Lt.S	6	299.00	375.00	332.83	25.301	640.16	0.656

Table 2. Multiple correlation coefficients among the research variable

Var.	ACC.Indx	Y_Balance	Qud.Rt.F	Qud.Lt.F	Gast.Rt.F	Gast.Lt.F	Qud.Rt.S	Qud.Lt.S	Gast.Rt.S	Gast.Lt.S
Correlation	1	0.731	0.812	0.376	0.752	0.537	0.863	0.842	0.712	0.682
Standard error	0.00	0.043	0.023	0.093	0.036	0.056	0.011	0.021	0.034	0.079
significance		Significant	Significant	Un.sig.	Significant	Un.sig.	Significant	Significant	Significant	Un.sig.

The findings underscore the significant impact of targeted training programs in enhancing muscle properties and dynamic balance, which collectively contribute to improved athletic performance, particularly in football free kicks.

The results from Table 2 highlight the significant role of muscle characteristics and dynamic balance in free kick accuracy. Dynamic balance and the stiffness of key muscles, especially the right quadriceps and gastrocnemius, show a strong positive influence on performance. Muscle frequency also demonstrates varying degrees of impact, with the right-side muscles contributing more significantly compared to the left. These findings emphasize the importance of targeted training to enhance specific muscle properties and dynamic stability for improved athletic performance.

Table 3. Collinearity Diagnostics

Dimensions	Eigenvalue	Condition Index	Variance Proportions					
			constant	Y-Balance	Qud.Lt.F	Gast.Lt.F	Gast.Rt.S	Gast.Lt.S
1	5.954	1.000	0.00	0.00	0.00	0.00	0.00	0.00
2	0.033	13.504	0.00	0.00	0.00	0.01	0.62	0.01
3	0.009	25.419	0.00	0.00	0.13	0.10	0.15	0.03
4	0.002	50.615	0.00	0.00	0.02	0.67	0.03	0.67
5	0.001	79.679	0.18	0.27	0.85	0.22	0.19	0.28
6	0.001	107.427	0.81	0.73	0.00	0.00	0.01	0.01

Table 4. Coefficients

		B	Std. Error	Beta	Tolerance	VIF
1	(Constant)	-3.543	0.000			
	Y_Balance	0.023	0.000	0.314	0.788	1.268
	Qud.Lt.F	0.156	0.000	0.688	0.429	2.332
	Gast.Lt.F	0.162	0.000	0.555	0.561	1.782
	Gast.Rt.S	0.001	0.000	0.340	0.682	1.466
	Gast.Lt.S	-0.001	0.000	-0.055	0.597	1.675

Discussion

The results of the multiple linear regression analysis presented in Table 5 highlight the effects of various independent variables on the accuracy index (ACC.Indx) of free kick performance. Among the variables, the frequency of the left quadriceps (Qud.Lt.F) and the frequency of the left gastrocnemius (Gast.Lt.F) demonstrate strong positive impacts on free kick accuracy, with high Beta values indicating their significant contributions to performance. Specifically, Qud.Lt.F shows the strongest effect, underscoring the importance of quadriceps frequency in enhancing kick accuracy. Dynamic balance (Y_Balance) also contributes positively, albeit to a lesser extent, with a moderate Beta value indicating a smaller but notable role in improving accuracy. On the other hand, the strength of the right gastrocnemius (Gast.Rt.S) and the strength of the left gastrocnemius (Gast.Lt.S) exhibit weak effects. While Gast.Rt.S shows a minimal positive influence, Gast.Lt.S has a negligible negative impact, suggesting that the strength of the left gastrocnemius does not significantly affect free kick accuracy in this context. The multicollinearity analysis, reflected by the Tolerance and VIF values, suggests that while there is some correlation between variables, it does not reach levels that would compromise the integrity of the regression model. The moderate multicollinearity present in certain variables, particularly between Qud.Lt.F and Gast.Lt.F, does not significantly influence the model's accuracy, allowing for reliable interpretation of the results. Overall, the findings indicate that muscle frequency, particularly in the quadriceps and gastrocnemius, along with dynamic balance, play crucial roles in enhancing the accuracy of free kicks, while muscle strength, especially in the left gastrocnemius, appears to be less influential. These insights can guide the design of training programs aimed at improving specific muscle functions to optimize performance in football.

Conclusions

The results of the study suggest that the accuracy of free kicks in elite football players is significantly influenced by certain muscle properties and dynamic balance. Specifically, the frequency of the left quadriceps and gastrocnemius, along with dynamic balance, have the strongest positive effects on free kick accuracy. Muscle stiffness, particularly in the quadriceps, also plays a crucial role in enhancing performance. However, the strength of the left gastrocnemius muscle appears to have a minimal impact on accuracy, indicating that certain muscle properties are more critical than others. The findings underscore the importance of targeted training to improve muscle frequency, stiffness, and balance, which collectively contribute to better performance in high-intensity sports like football.

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