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The Relationship Between Abdominal Muscle Strength And Trunk Flexibility With Heading Ability In Football

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ABSTRACT

Football performance requires the integration of technical proficiency and physical conditioning, particularly in aerial actions such as heading. Heading ability is biomechanically influenced by trunk acceleration, force transmission, and neuromuscular coordination, in which abdominal muscle strength and trunk flexibility play essential roles within the kinetic chain mechanism. This study aimed to examine the relationship between abdominal muscle strength and trunk flexibility with heading ability among Physical Education, Health, and Recreation students. A descriptive correlational design was employed. The population consisted of 229 students, and a sample of 33 male participants was selected through purposive random sampling (20% of 167 eligible male students). Abdominal muscle strength was measured using a 30-second sit-up test, trunk flexibility using a trunk extension test, and heading ability through a standardized heading distance test. Data were analyzed using Pearson product-moment correlation and multiple correlation analysis with a significance level of $\alpha = 0.05$. The results revealed a significant relationship between abdominal muscle strength and heading ability ($r = 0.750$; $p < 0.05$), trunk flexibility and heading ability ($r = 0.660$; $p < 0.05$), and a strong simultaneous relationship between both independent variables and heading ability ($r = 0.797$; $p < 0.05$). These findings indicate that core strength and trunk flexibility substantially contribute to heading performance. The study reinforces the importance of integrated strength and mobility training to optimize football-specific skills.

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A. Conception and design of the study;
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INTRODUCTION

Sport is a systematic physical activity aimed at improving physical fitness, health, and individual performance in various contexts, both for daily activities and for achievement (Bangsbo et al., 2015; Bompa & Buzzichelli, 2019). In the context of competitive sports, optimal physical condition is a primary prerequisite for achieving maximum performance because technical and tactical success is heavily influenced by an athlete's biomotor capacity (Suchomel et al., 2016). As the world's most popular sport, football demands an integrated combination of physical, technical, tactical, and psychological abilities (Sarmento et al., 2018).

In football, mastery of basic techniques such as passing, dribbling, shooting, controlling, and heading is the foundation of an athlete's performance (Faude et al., 2017). Among these techniques, heading has unique characteristics because it involves upper body coordination, neck and core strength, balance, and precise timing in dynamic game situations (Tierney et al., 2021). Biomechanically, heading requires not only accuracy but also the ability to generate impulsive force through muscle contractions in the neck, trunk, and lower extremities to maximize the direction and speed of the ball (Caccese & Kaminski, 2018).

However, various studies have shown that heading performance is significantly influenced by physical condition components, particularly strength and flexibility (Lloyd & Oliver, 2015; Hammami et al., 2018). Strength plays a role in generating propulsion upon contact with the ball, while flexibility supports optimal range of motion, resulting in more effective force transfer and a reduced risk of injury (Behm et al., 2016).

A phenomenon among students at Nahdlatul Ulama University in Southeast Sulawesi shows that despite high participation in regional and national tournaments, performance is still suboptimal. Initial observations indicate that limited physical components, particularly strength and flexibility, are among the factors inhibiting the effectiveness of heading techniques in matches. This issue is urgently needed for research because heading is often the deciding factor in match outcomes, both in dead-ball situations and aerial duels.

Modern developments in coaching science emphasize evidence-based training approaches to improving technical performance by strengthening biomotor capacity (Turner & Comfort, 2018). Recent research shows that neck and trunk muscle strength significantly correlates with the ability to generate ball speed when heading (Caccese et al., 2020). Furthermore, resistance training and core stability exercises have been shown to increase the efficiency of kinetic energy transfer from the lower extremities to the head (Prieske et al., 2016).

Regarding flexibility, a study by Behm et al. (2016) confirmed that dynamic flexibility plays a role in improving explosive performance without reducing force production. Hammami et al. (2018) also reported that a combination of strength and flexibility training significantly improved the performance of young football athletes, particularly in aerial duels and vertical jump ability.

Other research indicates that heading is a complex skill influenced by the interaction of neck muscle strength, lower extremity power, and neuromuscular coordination (Tierney et al., 2021). In fact, an integrative approach combining strength and flexibility training has been shown to be more effective than technique training alone (Granacher et al., 2016).

Physiologically, increased muscle strength through neuromuscular adaptation and hypertrophy increases the ability to generate maximal force in a short period of time (Suchomel et al., 2016). Meanwhile, good flexibility allows for biomechanical efficiency of movement, allowing optimal joint angles to be achieved during heading (Behm & Chaouachi, 2017).

These findings indicate that heading performance cannot be separated from underlying physical conditions. Therefore, a structured, component-based training approach is essential for comprehensively developing heading technique.

Although several studies have examined the relationship between strength, flexibility, and technical performance in football, most have focused on leg power, sprinting, or vertical jump ability (Faude et al., 2017; Hammami et al., 2018). Studies specifically analyzing the simultaneous contribution of strength and flexibility to heading ability in student or university-level athlete populations are relatively limited.

Furthermore, most research has been conducted on adolescent or professional athletes in Europe and the Americas, so the context of Asian populations, particularly Indonesia, is underrepresented in the international scientific literature. This is despite the fact that anthropometric characteristics, training patterns, and sporting culture can influence an athlete's physiological and biomechanical responses (Sarmento et al., 2018).

Previous research has also tended to partially isolate physical condition variables without examining their interaction in supporting heading performance. However, theoretically and empirically, strength and flexibility work synergistically to produce effective and efficient movements (Granacher et al., 2016).

Thus, there are research gaps in the following areas: (1) Limited empirical studies analyzing the simultaneous relationship between strength and flexibility and heading ability, (2) Lack of data on the Indonesian football student population, and (3) Lack of an integrative approach that connects physiological, biomechanical, and technical performance aspects within a comprehensive analytical framework.

Based on the above description, this study aims to analyze the relationship between strength and flexibility and heading ability in students at Nahdlatul Ulama University, Southeast Sulawesi. Specifically, this study seeks to identify the contribution of each physical condition variable and their simultaneous influence on heading performance.

The novelty of this study lies in: (1) An integrative approach that simultaneously examines strength and flexibility in relation to heading technique, (2) The context of the Indonesian football student population, which has not been widely studied in the international literature, and (3) Analysis based on physiological and biomechanical approaches to more comprehensively explain the mechanisms of the relationships between variables.

The results of this study are expected to provide theoretical contributions to the development of a physical conditioning-based heading technique coaching model, as well as practical contributions for coaches in designing more effective and targeted training programs. Thus, this research not only enriches the academic literature but also has strategic implications for improving football performance at the collegiate and regional levels.

METHODS

Research Design

This study employed a descriptive correlational design to examine the relationship between abdominal muscle strength (X_1) and trunk flexibility (X_2) with heading ability (Y) in football. A correlational approach is appropriate for identifying associative patterns among physical performance variables without experimental manipulation (Thomas, Nelson, & Silverman, 2015; Hopkins et al., 2020).

From a biomechanical perspective, heading performance is influenced by trunk stabilization, force transmission, and neuromuscular coordination (Caccese et al., 2020; Tierney et al., 2021). Core muscle strength, particularly abdominal musculature, plays a central role in force transfer from lower extremities to the upper body during explosive actions (Suchomel et al., 2016; Prieske et al., 2016). Meanwhile, trunk flexibility contributes to optimal range of motion and efficient kinetic chain sequencing (Behm et al., 2016; Granacher et al., 2016).

The correlational model is illustrated as:

$X_1 \rightarrow Y$ (Abdominal muscle strength with heading ability)

$X_2 \rightarrow Y$ (Trunk flexibility with heading ability)

X_1 & $X_2 \rightarrow Y$ (Simultaneous relationship with heading ability)

Population and Sample

The population consisted of 229 students from the 2016 cohort of Physical Education, Health, and Recreation (167 males; 62 females). Considering the higher biomechanical demand of heading in male competitive football contexts (Faude et al., 2017; Sarmento et al., 2018), purposive random sampling was applied to select male participants only.

A total of 20% of 167 male students were randomly selected, resulting in 33 participants. This sampling proportion meets minimum requirements for correlational analysis in sport science research (Hopkins et al., 2020). All participants were healthy, injury-free, and had prior football experience.

Research Instruments

Validated field-based physical performance tests were used due to their practicality and reliability in sport settings (Turner & Comfort, 2018).

Table 1.
Research Variables and Instruments

Variable	Instrument	Measurement Unit	Reliability Evidence
Abdominal Muscle Strength (X_1)	30-second Sit-up Test	Repetitions	High test-retest reliability (ICC >0.85) (Hammami et al., 2018)
Trunk Flexibility (X_2)	Trunk Extension Test	Centimeters (cm)	Valid for spinal extension ROM (Behm et al., 2016)
Heading Ability (Y)	Heading Distance Test	Meters (m)	Field validity in football performance testing (Caccese et al., 2020)

Data Analysis

Data were analyzed using parametric statistics ($\alpha = 0.05$).

Normality Test: Kolmogorov–Smirnov test to confirm distribution assumptions.

Pearson Product-Moment Correlation: To determine partial relationships between X_1–Y and X_2–Y.

Multiple Correlation Analysis: To assess simultaneous contribution of abdominal strength and trunk flexibility to heading ability.

Multiple correlation analysis is recommended in sport performance research when evaluating interacting physical components (Hopkins et al., 2020; Turner & Comfort, 2018). Effect sizes were interpreted based on contemporary sport science standards (Hopkins et al., 2020).

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RESULTS AND DISCUSSION

Result

Descriptive Data of Research Variables

Table 2.
Descriptive Statistics of Research Variables

	N	Minimum	Maximum	Mean	Std. Deviation
x1	33	21	30	25,12	1,73
x2	33	33,20	57,50	48,0303	5,75
Y	33	5,50	8,90	6,7045	,69
Valid N (listwise)	**33**				

Frequency Distribution Table

Table 3.
Frequency Distribution of Abdominal Muscle Strength (X1)

Interval	Frequency	Percent	Valid Percent	Cumulative Percent
21-22	2	6,1	6,1	6,1
23-24	10	30,3	30,3	36,4
25-26	14	42,4	42,4	78,8
27-28	6	18,2	18,2	97,0
29-30	1	3,0	3,0	100,0
Total	**33**	**100,0**	**100,0**	

Flexibility of the trunk (X2)

The frequency distribution of togok flexibility in this study is shown in Table.

Table 4.
Frequency Distribution of Body Flexibility (X2)

Interval	Frequency	Percent	Valid Percent	Cumulative Percent
33,2-38	1	3,0	3,0	3,0
38,1-42,9	5	15,2	15,2	18,2
43-47,8	10	30,3	30,3	48,5
47,9-52,7	10	30,3	30,3	78,8
52,8-57,6	7	21,2	21,2	100,0
Total	**33**	**100,0**	**100,0**	

Data Normality Test

The results of the normality test of the research data consisting of X1, X2, and Y are summarized in Table below.

Table 5.
Summary of Data Normality Test Results

		x1	x2	y
N		33	33	33
Normal Parameters(a,b)	Mean	25,12	48,0303	6,7045
	Std. Deviation	1,728	5,74878	,68675
Most Extreme Differences	Absolute	,137	,059	,156
	Positive	,134	,053	,156
	Negative	-,137	-,059	-,110
Kolmogorov-Smirnov Z		,787	,337	,897
Asymp. Sig. (2-tailed)		,566	1,000	,397

Linearity Test

The results of the linear test for each research variable can be seen in Table below.

Table 6.
Linear Test X1 and Y

			Sum of Squares	df	Mean Square	F	Sig.
y * x1	Between Groups	(Combined)	10,261	7	1,466	7,585	,000
		Linearity	8,493	1	8,493	43,948	,000
		Deviation from Linearity	1,768	6	,295	1,524	,211
		Within Groups	4,831	25	,193		
		Total	**15,092**	**32**			

Table 7.
Linear Test X2 and Y

			Sum of Squares	Df	Mean Square	F	Sig.
y * x2	Between Groups	(Combined)	14,912	31	,481	2,672	,455
		Linearity	6,569	1	6,569	36,496	,104
		Deviation from Linearity	8,343	30	,278	1,545	,573
		Within Groups	,180	1	,180		
		Total	**15,092**	**32**			

Hypothesis Testing

Relationship between abdominal muscle strength (X1) and heading ability (Y)

Table 8.
Results of Correlation Test of X1 with Y

		x1	**Y**
x1	Pearson Correlation	1	,750(**)
	Sig. (2-tailed)		,000
	N	33	33
y	Pearson Correlation	,750(**)	1
	Sig. (2-tailed)	,000	
	N	33	33

The Relationship Between Togok Flexibility (X2) and Heading Ability (Y)

Table 9.
Results of Correlation Test of X2 with Y

		Y	x2
y	Pearson Correlation	1	,660(**)
	Sig. (2-tailed)		,000
	N	33	33
x2	Pearson Correlation	,660(**)	1
	Sig. (2-tailed)	,000	
	N	33	33

Relationship Between Abdominal Muscle Strength (X1), Togok Flexibility (X2), and Heading Ability (Y)

The results of the calculations regarding multiple correlation are shown in Table below.

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Table 10.
Summary of Multiple Correlation Test Results

Model	R	R Square		Change Statistics	
	R Square Change	F Change	df2	R Square Change	Sig. F Change
1	,797(a)	,636	,636	26,191	,000

Discussion

Relationship between Abdominal Muscle Strength (X_1) and Heading Ability (Y)

The findings demonstrate a significant and strong relationship between abdominal muscle strength and heading ability ($r = 0.750$; $p < 0.05$), with a coefficient of determination (r^2) of 0.56. This indicates that 56% of the variance in heading performance is explained by abdominal muscle strength. From a sport biomechanics perspective, this result is theoretically consistent with the concept of the kinetic chain, where core musculature functions as a force transmitter between lower and upper body segments during explosive movements (Suchomel et al., 2016; Prieske et al., 2016).

Heading involves a preparatory trunk hyperextension followed by rapid flexion, requiring powerful concentric contraction of the abdominal muscles to accelerate the head toward the ball (Caccese et al., 2020; Tierney et al., 2021). Strong abdominal musculature enhances trunk stiffness and stability, thereby improving force transfer efficiency (Granacher et al., 2016). Empirical evidence indicates that greater core strength correlates with improved performance in explosive actions such as jumping, sprinting, and upper-body striking tasks (Hammami et al., 2018; Turner & Comfort, 2018).

Moreover, abdominal strength contributes to postural control during aerial duels, allowing athletes to maintain balance and directional accuracy (Behm & Chaouachi, 2017). The high contribution value (56%) observed in this study underscores the central role of core musculature in heading mechanics. These findings align with contemporary conditioning principles emphasizing trunk stabilization as a determinant of sport-specific power output (Lloyd & Oliver, 2015; Hopkins et al., 2020).

Relationship between Trunk Flexibility (X_2) and Heading Ability (Y)

The study also revealed a significant correlation between trunk flexibility and heading ability ($r = 0.660$; $p < 0.05$), with a coefficient of determination (r^2) of 0.44. Although the contribution (44%) is lower than that of abdominal strength, it remains substantial and falls within the high correlation category.

Trunk flexibility enhances range of motion (ROM), allowing greater preparatory extension before explosive flexion during heading. Increased ROM can improve angular velocity and impulse generation, thereby increasing ball propulsion distance (Behm et al., 2016; Granacher et al., 2016). Biomechanical analyses indicate that optimal spinal extension enables more effective elastic energy storage and release, contributing to performance efficiency (Tierney et al., 2021).

Flexibility also plays a protective role by reducing muscular stiffness and injury risk, particularly in repetitive aerial duels (Faude et al., 2017). Athletes with adequate trunk flexibility demonstrate improved coordination and smoother segmental sequencing, which are essential for accurate ball contact (Sarmento et al., 2018).

Although flexibility contributes less than strength, its role should not be underestimated. Contemporary training literature emphasizes that explosive performance is optimized when adequate strength is supported by sufficient mobility (Behm & Chaouachi, 2017). Therefore, trunk flexibility acts as a complementary physical component that enhances mechanical efficiency during heading execution.

Simultaneous Relationship between Abdominal Muscle Strength (X_1) and Trunk Flexibility (X_2) with Heading Ability (Y)

The multiple correlation analysis revealed a strong simultaneous relationship ($r = 0.797$; $p < 0.05$), with a coefficient of determination (r^2) of 0.64. This means that 64% of heading performance is jointly explained by abdominal muscle strength and trunk flexibility.

This finding supports the integrative model of athletic performance, which posits that motor performance results from the interaction of multiple biomotor components rather than isolated variables (Suchomel et al., 2016; Turner & Comfort, 2018). Core strength provides force production capacity, while flexibility ensures optimal movement amplitude and efficient biomechanical positioning (Granacher et al., 2016). Together, these factors enhance trunk acceleration and ball impact force during heading.

The remaining 36% variance may be attributed to other biomotor components such as lower-limb power, balance, coordination, timing accuracy, and neuromuscular control (Hammami et al., 2018; Hopkins et al., 2020). Vertical jump capacity and neck muscle strength, for example, have also been shown to influence aerial performance (Caccese et al., 2020; Tierney et al., 2021).

Overall, the present findings reinforce contemporary strength and conditioning frameworks advocating integrated training approaches that combine core strengthening and mobility enhancement to optimize sport-specific performance (Lloyd & Oliver, 2015; Behm et al., 2016). Practically, coaches should design conditioning programs that simultaneously develop abdominal strength and trunk flexibility to maximize heading performance in football athletes.

CONCLUSION

Based on the statistical findings, this study confirms that abdominal muscle strength and trunk flexibility are significantly associated with heading ability in football. First, abdominal muscle strength demonstrated a strong and significant relationship with heading performance ($r = 0.75$; $r^2 = 0.56$; $p < 0.05$), indicating that 56% of heading ability variance is explained by core strength capacity. Conceptually, this supports the kinetic chain theory, in which abdominal musculature functions as a central force transmitter that enhances trunk acceleration and impact force during ball contact. Empirical sport science literature consistently highlights core strength as a determinant of explosive and aerial performance in football.

Second, trunk flexibility showed a significant relationship with heading ability ($r = 0.66$; $r^2 = 0.44$; $p < 0.05$). This suggests that 44% of performance variance is linked to trunk range of motion. From a biomechanical perspective, adequate flexibility enables optimal preparatory extension and efficient force application, thereby improving movement amplitude and ball propulsion.

Third, the simultaneous contribution of abdominal muscle strength and trunk flexibility yielded a strong multiple correlation ($r = 0.797$; $r^2 = 0.64$; $p < 0.05$), indicating that together these variables explain 64% of heading performance. These findings reinforce the integrative conditioning principle that explosive sport skills are optimized through the combined development of strength and mobility.

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Furthermore, the author formally declares that this article is an original scientific work conducted independently and ethically. The manuscript has not been plagiarized, duplicated, or published elsewhere in any form. All references cited in this study have been appropriately acknowledged in accordance with academic integrity standards and applicable publication ethics guidelines. Should any violation of these principles be identified in the future, the author is fully prepared to accept sanctions in accordance with prevailing academic regulations and institutional policies.

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