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Development of Predictive Models for Power Performance Based on Anthropometric Variables in Amateur Football Players

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ABSTRACT

This study aims to determine the correlation between selected anthropometric variables and power ability, and to develop predictive models for power ability. Fifteen male players from UiTM Perlis FC (aged 20.87 ± 1.19 years) were recruited for this study. The anthropometric variables were measured using different instruments, including body weight, height, body mass index, body fat percentage, waist circumference, hip circumference, calf circumference, thigh circumference, ankle circumference, leg length, foot length and fat-free mass. Power ability was assessed using the countermovement jump (CMJ) test. Pearson correlation was used to analyze relationships between anthropometric variables and power, while multiple regression was applied to develop predictive models for power. The results showed that there was a significant relationship between power ability and body weight ($r = 0.79$), fat-free mass ($r = 0.83$), body mass index ($r = 0.64$), waist circumference ($r = 0.66$), hip circumference ($r = 0.69$), calf circumference ($r = 0.58$), thigh circumference ($r = 0.67$), and ankle circumference ($r = 0.61$), $p \leq 0.05$. The predictive model for power ability is = 315.819 - (18.572) body weight + (57.922) fat-free mass + (83.478) body mass index - (1.095) waist circumference - (36.472) hip circumference + (4.107) thigh circumference. In conclusion, anthropometric variables significantly correlate with amateur football players' power ability. Therefore, coaches and practitioners should emphasize developing these variables to enhance power performance.

Keywords: *amateur athletes, anthropometric measurements, muscular power, predictive modeling, performance prediction*

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INTRODUCTION

Football is the most widely played and followed sport globally, with an estimated 260 million players (Junge & Dvorak, 2004). A standard football match involves two 45-minute halves and prolonged physical movement, making the aerobic energy system the predominant energy provider (Stølen et al., 2005). However, football is also characterized by its intermittent nature, requiring players to engage in high-intensity movements such as sprints, tackles, and jumps. These actions place a substantial demand on the anaerobic energy system, with average and highest heart rates reported to reach approximately 85% and 98% of an athlete's maximum, respectively (Ali & Farrally, 1991).

The physical demands of football extend beyond endurance; players must also generate rapid bursts of force, often repeatedly throughout a match. On average, athletes perform between 150 and 250 intense actions per game, including sprints, directional changes, headers and jumps (Stølen et al., 2005). These efforts rely heavily on lower-limb neuromuscular strength and anaerobic power. Vertical jumping capability is crucial in several game situations, such as contesting aerial balls, defending set pieces, and executing goal-scoring opportunities. It is a key indicator of explosive lower-body power (Haugen, Tønnessen & Seiler, 2012).

Power, the product of speed and force, is essential for executing explosive movements in sport. Developing such power requires both strength and speed, particularly in the muscles of the lower extremities (Cometti et al., 2001). Regardless of similarly structured training programs coaches provide, players often demonstrate varying levels of power performance. This variation raises questions about the role of individual physical characteristics, specifically anthropometric variables, in determining power ability. For instance, past studies have shown that vertical jump heights of football players ranged from 38 to 55 cm, with differences observed across playing positions: strikers and defenders often surpass midfielders in jump performance (Wisloeff, Helgerud, & Hoff, 1998; Cometti et al., 2001).

Anthropometry is the method of measuring the human body or individual parts of the body that includes a quantitative definition of morphological characteristics and insight into an objective image of the growth condition of the person being tested (Gusic et al., 2017). In recent years, the integration of anthropometric and performance data to develop predictive models has gained substantial attention in football performance analytics. Studies have shown that morphological characteristics, such as limb girth, body composition, and lean mass, significantly influence explosive movements like jumping and sprinting (França et al., 2021; Martins et al., 2022). For example, França et al. (2021) developed predictive equations for vertical jump performance in elite players, identifying thigh girth and fat-free mass as key predictors. Similarly, Martins et al. (2022) utilized regression-based approaches to associate anthropometric and fitness markers with injury risk, demonstrating the value of predictive modeling for applied football settings. Moreover, recent developments have explored the relationship between countermovement jump (CMJ) performance and sprinting ability (Oleksy et al., 2024), highlighting how neuromuscular power measures can be used not only to assess performance but also to inform training strategies. Study by Woods et al. (2015) and others have found that elite football players with greater body size and ideal anthropometric characteristics tend to exhibit higher power ability. The literature suggests that morphological traits may play a substantial role in power performance differences, even among players receiving similar structured training.
Based on this foundation, the present study aims (1) to investigate the relationship between selected anthropometric variables and power ability in football players and (2) to develop predictive models for power ability based on these variables.

METHODS

Participants

The Power and Sample Size Calculation software determined the sample size. Fifteen male football players (age: 20.87 ± 1.19 years) from UiTM Perlis FC voluntarily participated in this study. All participants had at least one competitive season's playing experience with the team and engaged in structured football training two to three times per week. Inclusion criteria required participants to be free from injury and actively involved in regular training and competition during the study period. Before data collection, all participants provided informed consent.

Procedure

Each participant visited the Human Performance Laboratory during two separate sessions. Participants were briefly informed about the study's purpose and experimental procedure during the initial visit. The participants provided written informed consent and completed the Physical Activity Readiness Questionnaire (PAR-Q) (Warburton, Jamnik, Bredin, Shephard, & Gledhill, 2018) as part of the screening process. Subsequently, selected anthropometric variables were measured. On the second visit, participants performed a standardized warm-up before completing the countermovement jump test using an electronic jump mat to assess power ability.

Anthropometric measurement

The anthropometric variables included body weight, height, body mass index, body fat percentage, waist circumference, hip circumference, calf circumference, thigh circumference, ankle circumference, leg length, foot length, and fat-free mass, which were measured using different instruments. All measurements were taken twice, and the mean value was used for data analysis. Measurement procedures followed the standards set by the International Society for Advancement in Kinanthropometry (ISAK) (Stewart, Marfell-Jones, Olds, & Ridder, 2011).

Countermovement Jump Test

Power ability was assessed using an electronic jump mat (Ezejump; Swift Performance Equipment, Lismore, Australia). Before testing, a standardized warm-up protocol was implemented to reduce the risk of injury and enhance test reliability. The countermovement jump was performed with arms swing, and participants were instructed to initiate the jump from a static position on the jump mat, without any preparatory step. They were asked to quickly squat down, followed by an explosive vertical jump to achieve maximum height. Each participant completed two trials, with a three-minute rest interval between attempts. The highest jump was recorded for analysis.

Statistical analysis

Data were analysed using the Statistical Package for Social Sciences (SPSS) version 25.0 (IBM Corp., Chicago, IL, USA). Descriptive statistics were reported as mean and standard deviation (SD). Pearson's correlation was used to determine the relationship between anthropometric variables and power ability. Multiple regression analysis was applied to develop predictive models for power ability. The significance level was set at $p \leq .05$.

RESULTS

Table 1 presents the descriptive statistics for age, independent variables (body weight, height, body mass index, body fat percentage, fat-free mass, waist circumference, hip circumference, thigh circumference, calf circumference, ankle circumference, leg length, and foot length) and dependent variables (power ability). All the values are presented as means and standard deviations.

Table 1: Descriptive Data of The Participants

Variables	Mean	Standard Deviation
Age (year old)	20.87	1.19
Power (w)	1030.00	171.49
Bodyweight (kg)	63.86	7.52
Height (cm)	174.44	5.53
Body mass index (kg/m²)	20.97	2.12
Body fat percentage (%)	9.25	3.41
Fat free mass (kg)	57.77	5.16
Waist circumference (cm)	75.12	6.95
Hip circumference (cm)	91.44	4.71
Thigh circumference (cm)	53.84	3.62
Calf circumference (cm)	36.60	1.72
Ankle circumference (cm)	21.72	0.88
Leg length (cm)	95.05	5.05
Foot length (cm)	26.21	1.17

Table 2 presents the Pearson correlation coefficients between power ability and anthropometric variables. The analysis showed a strong and statistically significant positive correlation between power ability and fat-free mass ($r = .83$, $p < .05$) and body weight ($r = .79$, $p < .05$). Moderate significant correlations were observed with hip circumference ($r = .69$, $p < .05$), thigh circumference ($r = .67$, $p <.05$), waist circumference ($r = .66$, $p <.05$), BMI ($r = .64$, $p <.05$), ankle circumference ($r = .61$, $p <.05$), and calf circumference ($r = .58$, $p <.05$). In contrast, height ($r = .46$, $p >.05$), body fat percentage ($r = .43$, $p >.05$), foot length ($r = .27$, $p >.05$), and leg length ($r = .17$, $p >.05$) showed not statistically significant associations with power ability. These findings suggest that power is more closely related to muscularity and body size measures than to linear body dimensions.

Table 2: Correlation Between Dependent Variable and Independent Variables

Dependent variable	Independent variables	r	Sig
Power	Fat-free mass	.83	.00
	Bodyweight	.79	.00
	Hip circumference	.69	.00
	Thigh circumference	.67	.01
	Waist circumference	.66	.01
	Body mass index	.64	.01
	Ankle circumference	.61	.02
	Calf circumference	.58	.03
	Height	.46	.09
	Body fat percentage	.43	.11
	Foot length	.27	.33
	Leg length	.17	.55

A multiple linear regression was conducted to examine whether body weight, fat-free mass, body mass index, waist circumference, hip circumference, and thigh circumference significantly predict power ability. The results are presented in Tables 3, 4, and 5. The overall regression model was statistically significant, $F (6, 8) = 5.009$, $p < 0.05$. The regression model accounted for approximately 79.0% of the variance in power ability ($R^2 = .790$). All six variables added statistically significantly to the prediction, indicating a good fit of the model to the data.

The multiple regression equation to predict power ability is as follows:

Power ability = 315.819 - 18.572 (body weight) + 57.922 (fat-free mass) + 83.478 (body mass index) - 1.095 (waist circumference) - 36.472 (hip circumference) + 4.107 (thigh circumference)

Table 3: Model Summary of Pearson Correlation Between Power Ability and Selected Anthropometric

Model	R	R square	Adjusted R square
1	.889[a]	.790	.632
a. Predictors: (Constant), Thigh Circumference, Fat Free Mass, Waist Circumference, Hip Circumference, Body Mass Index, Bodyweight			

Table 4: The ANOVA Table of The Linear Regression Model About Speed Ability Based on Selected Anthropometric Variables

Model		Sum of Square	df	Mean Square	F	Sig.
1	Regression	325160.55	6	54193.43	5.009	.02
	Residual	86547.45	8	10818.43		
	Total	411708.00	14			
a. Dependent Variable: Power b. Predictors: (Constant), Thigh Circumference, Fat Free Mass, Waist Circumference, Hip Circumference, Body Mass Index, Bodyweight						

Table 5: Regression Coefficient of Selected Anthropometric Variables in Predicting Power Ability

Model		Unstandardized Coefficients	
		B	Std. Error
1	(Constant)	315.819	1392.138
	Bodyweight	-18.572	28.741
	Fat Free Mass	57.922	27.569
	Body mass index	83.478	56.238
	Waist circumference	-1.095	14.936
	Hip circumference	-36.472	24.038
	Thigh circumference	4.107	20.874

DISCUSSION

The findings of this study reinforce the importance of key anthropometric variables, such as fat-free mass, body weight, and lower limb circumferences, in determining lower-limb power among amateur football players. This aligns with previous work by França et al. (2021) and Oleksy et al. (2024), who demonstrated strong associations between body composition and explosive strength performance in elite and semi-elite football populations. Furthermore, the current model's explained variance (R^2 = 0.79) is comparable to other recent predictive approaches that emphasize the role of morphology in forecasting physical output (Martins et al., 2022; Sneha et al., 2024).

The outcome revealed significant correlations between specific anthropometric variables and power ability, supporting preceding research and highlighting the importance of body composition in performance outcomes. Not all anthropometric variables showed substantial relationships, indicating that only specific physical characteristics may influence power ability. Notably, variables such as fat-free mass, body weight, BMI, and lower limb circumferences (thigh, hip, waist, calf, and ankle) demonstrated significant associations with power performance.

These findings are consistent with those of Mielgo-Ayuso et al. (2015), who reported strong positive correlations between vertical and squat jump performance and mid-thigh and calf girths. Similarly, Oliver et al. (2015) emphasized the contribution of calf girth to jumping ability, attributing this to increased muscle cross-sectional area and sarcomere content, which enhance contractile force and power generation. This physiological basis aligns with the force-velocity relationship, whereby greater muscular force production can overcome external load more effectively, although at lower shortening velocities.

The current study also supports the findings of Panoutsakopoulos et al. (2014), who demonstrated a significant association between higher lean body mass and improved jump performance. Similarly, Clemente-Suarez et al. (2017) observed that body mass and BMI were significant predictors of vertical jump ability in volleyball players. These consistent results suggest that lean mass and overall body size are relevant indicators of explosive strength.

However, divergent findings in the literature highlight the complex nature of these relationships. For instance, Nikolaidis et al. (2015) reported a negative association between BMI and CMJ performance, demonstrating that excess body mass may hinder jump ability, especially if it is not primarily lean tissue. This finding is echoed by Johnson and Bahamonde (1996), who noted that individuals with higher body mass must produce more force to achieve similar jump heights, underscoring the importance of the force-to-mass ratio in power performance.

Studies examining body fat percentage also show contradicting results. While Abidin and Adam (2013) found no significant relationship between body fat and jump performance, Dizon and Grimmer-Somers (2012) reported that individuals with lower body fat tended to perform better in vertical jump tests. This may likely be attributed to reduced non-functional mass, which increases relative power output. Roschel et al. (2009) also suggest that lower fat mass facilitates greater jump height by improving the efficiency of muscular power transmission.

In contrast to body composition, body height was not significantly associated with jump performance in this study, in line with previous research by Davis et al. (2003) and Abidin and Adam (2013). While taller athletes may possess mechanical advantages in some contexts, height is a non-modifiable factor, and its impact may be offset by superior technique, strength, and neuromuscular coordination (Dizon & Grimmer-Somers, 2012).

Nonetheless, the study's limitations must be acknowledged. The small sample size (n=15) limits the generalizability of the results and raises the potential for model overfitting. Future research should replicate these findings using larger and more diverse samples, including athletes from various performance levels and positional roles. Additionally, integrating biomechanical and neuromuscular assessments may yield more comprehensive models and deepen the understanding of the determinants of power performance in football. To enhance predictive accuracy and applicability across various performance contexts, the advanced modeling techniques, such as machine learning approaches (Sneha et al., 2024) was suggested to applied in the future study.

CONCLUSION

This study demonstrated that selected anthropometric variables, particularly fat-free mass, body weight, body mass index, and lower limb circumferences, are significantly associated with lower-limb power performance, as measured by the countermovement jump (CMJ) test, among amateur football players. The predictive model developed in this study accounted for 79% of the variance in power ability, underscoring the substantial influence of specific morphological characteristics on explosive performance.

From a practical standpoint, these findings offer coaches and talent scouts a non-invasive, cost-effective approach to evaluating and enhancing player performance. By prioritizing the development of lean body mass and targeted muscle hypertrophy, training programs can be more individualized and aligned with the physical characteristics that contribute most to lower-limb power. This model may also assist in early talent identification and long-term athlete development planning.

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AUTHORS' CONTRIBUTION

Nik Suzairan Nik Zahib was responsible for conducting the study and drafting the initial manuscript. Harith Rusydin Abd Rahman supported the conceptualisation of the research design and formulation of the research objectives and questions. Nur Amirah Zaker developed the methodology and assisted with interpreting the data. Masshera Jamaludin developed the research idea, conceptualised the study design, formulated the research objectives and questions. Al Hafiz Abu Bakar contributed to the study design and coordinated the data collection process. Ahmad Dzulkarnain Ismail participated in designing the study and performed data analysis. Zulkifli Ismail contributed to the study design, interpreted data, and writing the manuscript. All authors read and approved the final manuscript.

CONFLICT OF INTEREST DECLARATION

We certify that the article is the Authors' and Co-Authors' original work. The article has not received prior publication and is not under consideration for publication elsewhere. This manuscript has not been submitted for publication nor has it been published in whole or in part elsewhere. We testify to the fact that all Authors have contributed significantly to the work, validity and legitimacy of the data and its interpretation for submission to Jurnal Intelek.

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