Analysis of dominant physical factors in volleyball skills: confirmatory analysis of the Bahana Muda volleyball team

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ABSTRACT

Background: Physical condition is an important determinant of volleyball skill performance, but few studies have empirically tested the structure of its dominant factors using a confirmatory approach.

Objectives: This study aims to identify the dominant physical condition factors that influence the playing skills of Bahana Muda Club volleyball athletes using Confirmatory Factor Analysis (CFA).

Methods: This study used a quantitative descriptive design. The sample consisted of 20 male volleyball athletes from the Bahana Muda Club who were selected through purposive sampling. The physical condition variables measured included speed (30-meter run), endurance (beep test), arm muscle strength (push-ups), abdominal muscle strength (sit-ups), leg muscle power (vertical jump), and agility (shuttle run). The analysis was conducted through an initial exploratory analysis and continued with CFA using IBM SPSS AMOS version 26. The goodness-of-fit model was evaluated using the CFI, TLI, and RMSEA indices.

Results: The CFA results show that leg muscle power ($\lambda = 0.791$), arm muscle strength ($\lambda = 0.742$), endurance ($\lambda = 0.732$), and agility ($\lambda = 0.606$) have significant factor loadings on volleyball skills ($p < 0.05$), while abdominal muscle speed and strength did not show significant contributions. The CFA model showed good data fit (CFI = 0.986; TLI = 0.978; RMSEA = 0.050).

Conclusions: Leg muscle power, arm muscle strength, endurance, and agility are the dominant physical factors in volleyball skills. Training programs should prioritize these components, and further research should involve larger samples and cross-clubs.

Keywords: confirmatory factor analysis, physical condition, playing skills, volleyball.

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INTRODUCTION

Volleyball is a team sport with high physical demands, especially in terms of muscle strength, explosive power, agility, and endurance (Bojanic, Bjelica, & Georgijev, 2016). At the competitive level, volleyball athletes are required to perform explosive jumps, quick changes of direction, and repeated technical actions during matches of uncertain duration. International literature indicates that volleyball performance is significantly influenced by specific physical capacities, particularly lower-body and upper-body muscle strength, which are directly related to smashing, blocking, and serving abilities (Sheppard et al., 2020; Kitamura et al., 2020; Radu, Făgăraş, & Graur, 2015; Wang et al., 2025). Additionally, agility and change of direction ability are reported as important predictors in defensive responses and game transitions, distinguishing elite and non-elite athletes (de la Rubia et al., 2025).

A number of empirical studies have examined the relationship between physical condition components and volleyball performance. Research on young volleyball athletes shows that leg muscle strength, explosive power, and aerobic endurance contribute significantly to movement efficiency and technical performance during matches (López-Serrano et al., 2024; Keoliya et al., 2024). Other studies report that upper body strength has a positive relationship with hitting accuracy and power, while agility plays an important role in passing and defense quality (Lidor & Ziv, 2010; Duarte et al., 2019). However, most previous studies still focus on descriptive approaches or variable correlation analysis (Anza, Denis, & Silva, 2013; Farley et al., 2020; Khoirudin et al., 2023; Olivar et al., 2025; Raga & lasma, 2025), while the application of confirmatory factor analysis to test the suitability of physical condition construct structures in an integrated measurement model is still relatively limited, especially in the context of volleyball clubs in Indonesia.

Based on this gap, this study aims to identify and validate the dominant physical condition factors that influence volleyball skills in athletes of the Bahana Muda Club in Malang City using Confirmatory Factor Analysis (CFA). The application of CFA allows testing the suitability between the theoretical model of physical condition and empirical data of athletes, as well as providing estimates of the contribution of each physical component simultaneously. The novelty of this study lies in the use of CFA to validate physical condition constructs in the context of local volleyball clubs in Indonesia, an approach that is still rarely used in national volleyball research. The findings of this study are expected to provide a scientific basis for coaches in prioritizing evidence-based training programs and enriching the international literature on the physical performance of volleyball athletes.

METHODS

Study Design and Participants

This study uses a quantitative descriptive design with exploratory factor analysis (EFA) as the main analysis, supplemented by exploratory confirmatory factor analysis (preliminary CFA) to evaluate the initial suitability of the measurement model. This approach was chosen given the relatively small sample size, so that CFA was used in a limited manner and its interpretation was carried out with caution.

The study was conducted at the Bahana Muda Volleyball Club, Malang City. There were 20 male volleyball athletes participating in the study, selected using purposive sampling. The inclusion criteria were: (1) active athletes of the Bahana

Muda Club, (2) having experience participating in regional competitions (Porprov), and (3) being in good physical condition at the time of data collection. The exclusion criteria included athletes who were injured or unable to complete the entire series of tests.

Although factor analysis generally recommends using a larger sample size, this study is exploratory in nature and aims to identify initial patterns of physical condition structures in the context of local clubs. Therefore, the CFA results in this study are not intended as final validation of the construct, but rather as an initial evaluation that requires confirmation in subsequent studies with larger sample sizes.

Ethical approval statement

This study has been approved by the Research Ethics Committee of Malang State University with approval number 05.11.03/UN32.14.2.8/LT/2025. All participants provided written consent before participating in the study.

Research Instruments

Physical condition measurements of athletes were conducted using a series of standard sports testing instruments commonly used in coaching and sports science research. Speed was measured using a 30-meter sprint test, with the best time from two trials recorded as the final score. Aerobic endurance was measured using the Léger bleep test to estimate the athletes' aerobic capacity. Arm muscle strength and abdominal muscle strength were measured using the push-up test and sit-up test for 60 seconds, respectively. Leg muscle explosive power was measured through a vertical jump test using the Sargent jump method, while agility was measured using a 4 × 10-meter shuttle run test (Susilawati, 2018).

Volleyball skills were measured using the AAHPERD Volleyball Skill Test, which included serving, passing, and smashing tests (Baumgartner et al., 2015). This instrument has been widely used in physical education and sports research and has been reported to have adequate content validity for evaluating basic volleyball skills.

Data Analysis

Data analysis was conducted in several stages. First, descriptive analysis was performed to describe the characteristics of the data. Next, statistical assumption tests were conducted, including checking for missing data, univariate normality (skewness and kurtosis), and identifying outliers before factor analysis. Second, Exploratory Factor Analysis (EFA) was performed using the Principal Component Analysis (PCA) method with Varimax rotation. Data feasibility was evaluated using the Kaiser–Meyer–Olkin (KMO) and Bartlett's Test of Sphericity. Factors were retained based on the criteria of eigenvalue > 1, minimum factor loading ≥ 0.50, and conceptual interpretability. Third, confirmatory factor analysis (CFA) was conducted exploratorily using IBM SPSS AMOS version 26 to evaluate the initial suitability of the model generated from EFA. The goodness-of-fit indices reported included χ^2/df, Comparative Fit Index (CFI ≥ 0.90), Tucker–Lewis Index (TLI ≥ 0.90), and Root Mean Square Error of Approximation (RMSEA ≤ 0.08). Given the limited sample size, the CFA results were interpreted cautiously and were not used as the basis for final construct validation.

RESULTS

This study aims to identify the physical condition components that contribute to volleyball skills in athletes of the Bahana Muda Club. Descriptive statistics for each

physical condition variable are presented in Table 1. In general, the mean values and data distribution show reasonable variation in accordance with the characteristics of the physical tests used. All variables are reported according to their respective units of measurement, namely seconds for speed and agility, repetitions for muscle strength tests, and centimeters for leg muscle explosive power.

Table 1. Results of Descriptive Analysis of Physical Factors in Bahana Muda Volleyball Athletes

Test Item	N	Min	Max	Mean	SD
Arm muscle strength	20	25	28	26.45	1.146
Endurance	20	8	9	8.21	.128
Explosive power	20	56	60	58.75	1.293
Abdominal muscle strength	20	34	38	35.75	1.293
Agility	20	12.38	12.50	12.45	.03395
Speed	20	4	5	40.50	.043

Data suitability testing for factor analysis showed a Kaiser–Meyer–Olkin (KMO) value of 0.584 and a significant Bartlett's Test of Sphericity result ($\chi^2 = 18.918$; df = 10; p = 0.041) (Table 2). The KMO value, which is slightly below the threshold of 0.60, indicates that the sample adequacy is in the borderline category, so the results of the factor analysis need to be interpreted carefully and are exploratory in nature.

Table 2. Output Results of Bartlett's KMO Test in Factor Analysis of the Most Dominant Physical Conditions on Volleyball Playing Skills

Kaiser-Mayer-Olkin Measure of Sampling Adequacy.		**.584**
Bartlett's Test of Sphericity	Approx. chi-Square	18.918
	Df	10
	Sig.	.041

Table 3. Anti-Image Correlation Results

Anti-image Correlation	Explosive Power	Arm muscle strength	Agility	Endurance	Volleyball Skills
Explosive Power	.548[a]	-.428	-.545	.025	.028
Arm muscle strength	-.428	.527[a]	.156	-.112	.013
Agility	-.545	.156	.594[a]	-.258	-.082
Endurance	.025	-.112	-.258	.626[a]	-.482
Volleyball Skills	.028	.013	-.082	-482	.614[a]

The Anti-Image Correlation results show that most variables have a Measure of Sampling Adequacy (MSA) value ≥ 0.50, except for the variables of speed and abdominal muscle strength. Therefore, these two variables were not included in the further factor analysis. The retained variables were then analyzed using Principal Component Analysis (PCA) with Varimax rotation. The communalities values (Table 4) show that leg muscle power (0.791), endurance (0.732), and skill (0.744) have relatively high contributions to the factor structure, while arm muscles (0.554) and agility (0.595) show moderate contributions.

Table 4. Communalities Results

	Initial	*Extraction*
Explosive Power	1.000	.791
Arm muscle strength	1.000	.554
Agility	1.000	.595
Endurance	1.000	.732
Volleyball Skills	1.000	.744

Table 5. Rotated Component Matrix Results

	Component	
	1	2
Explosive Power	.876	
Arm muscle strength	.742	
Agility	.606	.477
Endurance		.838
Volleyball Skills		.862

The rotated component matrix (Table 5) identifies two main components. The first component is dominated by leg muscle explosive power (loading = 0.876), arm muscle strength (0.742), and agility (0.606), while the second component is mainly determined by endurance (0.838). These findings indicate that explosive ability and muscle strength play a more dominant role than other components in the physical condition of volleyball athletes in the context of this study.

As a complementary analysis, exploratory confirmatory factor analysis (CFA) was conducted using AMOS to evaluate the initial suitability of the measurement model generated from the previous factor analysis. The CFA results showed a χ^2 value of 18.862; df = 17; $\chi^2/df = 1.11$; p = 0.400, with model fit indices of CFI = 0.986, TLI = 0.978, RMSEA = 0.050, and GFI = 0.819 (Table 6). These values indicate that the model shows adequate to good data fit, although the GFI value is in the borderline category. Given the small sample size, these CFA results are not intended as final construct validation, but rather as an initial evaluation that needs to be confirmed in studies with larger sample sizes.

Table 6. Good of Fit Model

Index	Score	Compatibility Criteria	Description
Chi-square	18.862	-	The model matches the data.
Probability	0.400	> 0.05	There is no significant difference between the model and the actual data.
RMSEA	0.050	≤ 0.80	The model has a good fit.
GFI	0.819	≥ 0.80	The model is quite good.
CFI	0986	≥ 0.90	The model is very good.
TLI	0.978	≥ 0.90	The model is excellent.

Table 7. Summary of Dominant Physical Condition Factors

Factors	Highest Loading	Communalities	Interpretation
Leg muscle power	0.876	0.791	Major contributor to explosive physical factors
Arm muscle strength	0.742	0.554	Moderate contributor to technical ability
Agility	0.606	0.595	Supports movement response and transition
Endurance	0.838	0.732	Dominant in sustained physical capacity factors

Dominant physical condition factors are outlined in Table 7, these having been identified by exploratory factor analysis. One variable, leg strength, had the largest correlation with the factor, explaining 771 of the variance, and a high level of commonality with the factor. The explosive capacities of the lower limbs are of vital importance in defining the physical qualities of the volleyball players under study here.

With a moderate factor loading of 0.742, muscle strength in the arm correlated significantly with physical condition, albeit with a communality of 0.554. This was the lowest correlation of all the variables considered. Agility showed a reasonable loading on the factor of 0.606 and a communality of 0.595, implying that it makes a contribution to the factors of movement response and play transition.

This study found a strong correlation between endurance and the second component (0.838) of physical condition, with a high degree of commonality (0.732). This suggests that endurance is a key element of an individual's overall physical condition. Given the results it appears that power and stamina are vital components of physical fitness in the current scenario, despite it being early days in research.

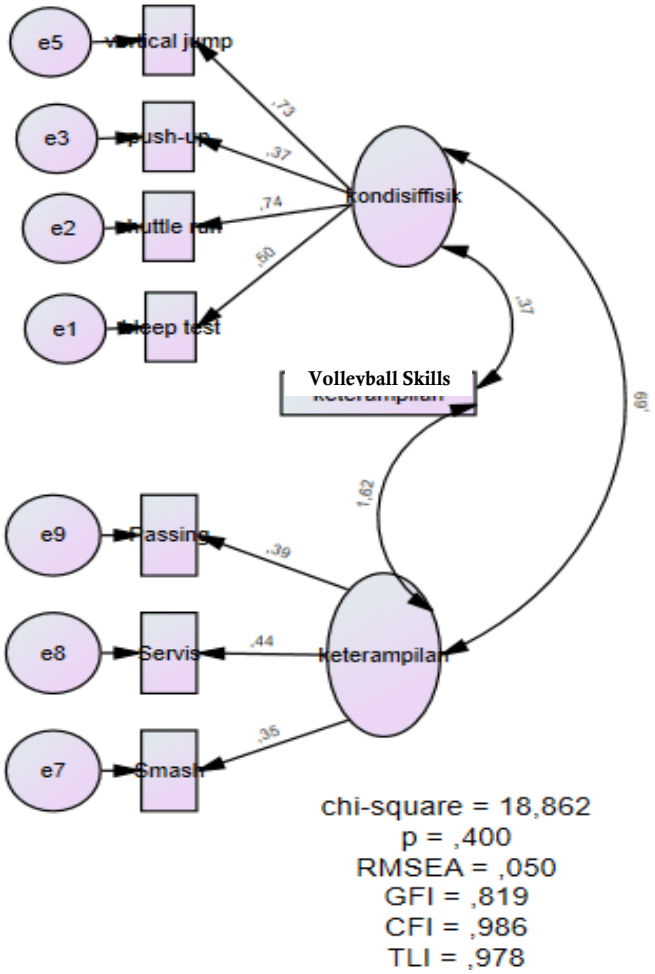

Figure 1. Exploratory confirmatory factor analysis (CFA) model of physical fitness and volleyball skill performance (AMOS 26)

Note. Values represent standardized factor loadings. Model fit indices indicate acceptable to good fit (χ^2 = 18.862, p = .400; RMSEA = .050; CFI = .986; TLI = .978).

The exploratory measurement model presented in Figure 1 shows the relationship between the skill performance in volleyball and physical fitness. This study of physical fitness was found to be heavily influenced by four different parameters - muscular strength as demonstrated by a push-up test, the power of the leg muscles as measured by a vertical jump, cardiovascular endurance measured by the bleep test and finally speed and agility as demonstrated by a 25 yard shuttle run.

The volleyball skill factor comprised variables for service, the spike and pass. These had low to moderate loadings on the factor, suggesting they contained some, but not all of the information of the factor. In the present sample, a positive

correlation was found between physical fitness and the performance of volleyball skills. This suggests a relationship between physical condition and the execution of technical skills in volleyball.

The fit statistics suggested that the model was a reasonable representation of the data however due to the low general fit index of 0.819 and the sample size the results should be treated with caution and viewed as exploratory rather than confirmatory.

DISCUSSION

This study aims to explore the structure of dominant physical condition components related to volleyball skill performance in the context of local clubs. The main findings indicate that leg muscle strength contributes most to physical fitness (loading = 0.876; communality = 0.791), followed by endurance (loading = 0.838; communality = 0.732), arm muscle strength (loading = 0.742; communalities = 0.554), and agility (loading = 0.606; communality = 0.595). On the other hand, linear speed (30 m sprint) and abdominal muscle strength did not meet the criteria for inclusion in the factor structure and were therefore excluded from further analysis. These results suggest that explosive and sustained physical capacity may represent important components of physical fitness related to volleyball skill performance in the sample studied.

The dominance of leg muscle strength observed in this study is consistent with international evidence emphasizing the importance of lower body explosive strength in volleyball performance. Previous studies have shown that vertical jump ability has a strong relationship with smash height, block efficiency, and overall performance in volleyball matches among volleyball athletes (Sheppard et al., 2006; Keoliya et al., 2024). Lower body explosive capacity allows athletes to generate rapid force production, which is essential for offensive and defensive actions at the net.

Similarly, the contribution of arm muscle strength aligns with findings indicating that upper body strength plays a crucial role in serve speed and spike execution (Lidor & Ziv, 2010; Duarte et al., 2019). While arm strength alone does not determine technical skill, it provides the mechanical foundation that supports effective force transfer during overhead actions.

Endurance emerges as a separate and significant component, consistent with studies reporting that volleyball matches impose intermittent yet prolonged physiological demands, particularly during extended rallies and multi-set matches (López-Serrano et al., 2024). Adequate aerobic and anaerobic endurance enables athletes to maintain technical execution quality under fatigue conditions.

Agility shows a moderate contribution, supporting literature that highlights the role of the ability to change direction in defense, transition play, and positional adjustments, especially for libero and wing players (de la Rubia et al., 2025). However, agility appears to function as a complementary rather than dominant component compared to explosive power and endurance.

The exclusion of linear speed and abdominal muscle strength can be explained by the principle of exercise specificity. The 30-meter sprint primarily measures linear acceleration, while volleyball performance relies more on short, multi-directional movements and reactive agility (Weldon et al., 2021). Therefore, linear sprint speed may not adequately describe the movement demands of volleyball.

Abdominal muscle strength, although important for core stability, may have an indirect rather than a dominant influence on volleyball skill execution. Core strength

contributes to postural control and force transmission; however, its effects may be overshadowed by more task-specific physical attributes such as leg strength and agility (de Bruin, Coetzee, & Schall, 2021). This may explain its limited statistical contribution in the current exploratory model.

Limitations of the study

Several methodological limitations should be considered when interpreting these findings. First, the small sample size (N = 20) and KMO value close to the threshold (0.584) indicate that the factor structure identified in this study should be interpreted with caution. A small sample can reduce factor load stability and limit generalization (Schreiber, 2021). As a result, factor analysis and CFA are treated as exploratory rather than confirmatory analyses.

Second, the use of purposive sampling from a single club may introduce selection bias, as the physical and technical profiles of athletes can vary significantly across clubs, competition levels, and training systems. Third, the unavailability of raw datasets limits the possibility of re-analysis and cross-validation, further highlighting the preliminary nature of these findings.

This study did not control for several variables that could interfere with the relationship between physical condition and volleyball skill performance. These variables include training experience, weekly training volume, playing position (e.g., setter, libero, wing spiker), anthropometric characteristics (height, reach, body mass), technical skills, nutritional status, and injury history. Previous studies have shown that these factors can significantly influence physical test results and match performance indicators (Duarte et al., 2019; Vanrenterghem et al., 2017). Future studies should include these variables to gain a more comprehensive understanding of the determinants of performance.

Despite these limitations, the findings have several practical implications for training practices. Training programs for volleyball players should prioritize lower body explosive strength, upper body strength, endurance, and agility. Specifically, plyometric exercises (e.g., depth jumps, contraction jumps) can be used to increase leg strength; resistance exercises targeting the upper body can support serving and smashing movements; and anaerobic endurance exercises (e.g., repeated shuttle runs) can help maintain performance throughout a set. Training effectiveness should be evaluated using pre-post measures, such as changes in vertical jump height, repeated sprint ability, and match performance metrics.

Future research should use larger and more diverse samples, adopt longitudinal designs, and consider mixed approaches to understand the mechanisms linking physical condition and volleyball skill performance. Confirmatory factor analysis with an adequate sample size is essential to validate the initial structure identified in this study. Additionally, integrating objective match performance data and qualitative insights from coaches can strengthen the ecological validity of future research.

CONCLUSIONS

Based on the results of factor analysis on a sample of athletes from the Bahana Muda Volleyball Club, it can be concluded that leg muscle power, arm muscle strength, endurance, and agility are physical condition components that contribute relatively more to volleyball skills than other components. Conversely, linear speed

(30-meter run) and abdominal muscle strength did not meet the criteria for inclusion in the factor structure, thus not showing a dominant role in the context of this study.

These findings indicate that volleyball skills in club athletes are more related to the ability to produce explosive movements, maintain physical capacity during the game, and respond to game situations quickly and agilely. Therefore, training programs are recommended to place more emphasis on developing leg muscle power, arm muscle strength, endurance, and agility as part of efforts to improve volleyball skills.

However, considering that this study was conducted at a single site with a relatively small sample size (n = 20) and used an exploratory factor analysis approach, the results of this study should be interpreted with caution. Further studies with larger samples, involving various clubs or competition levels, and using longitudinal or training intervention designs are needed to more strongly test the relationship between physical conditioning development and improvements in volleyball playing skills and match performance.

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DATA AVAILABILITY

The data supporting this study's findings are available on request from the corresponding author. The data are not publicly available because they contain information that could compromise the privacy of research participants

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CONFLICT OF INTEREST

The author officially certifies that there are no conflicts of interest with any party with respect to this research.

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