The relationship between arm muscle strength and volleyball service results: A Meta-Analysis Study

Review Article

Muhamad Husein *
Yogyakarta State University
INDONESIA

Baharuddin Hasan
Cenderawasih University
INDONESIA

I Putu Eka Wijaya Putra
Cenderawasih University
INDONESIA

Muhammad Teguh Prasetyo
Bumigora University
INDONESIA

Syahrizal Islam
Semarang State University
INDONESIA

Abstract.

Background Arm muscle strength is a key physical component in volleyball, especially in supporting serving ability. Effective and accurate serves are crucial factors that influence the course of the game and the team's chances of winning. Although numerous studies have examined the relationship between arm muscle strength and serve performance, significant variations in results and differences in measurement methods pose challenges to deriving valid conclusions

Objectives This study aims to comprehensively evaluate the effect of arm muscle strength on volleyball serve performance through a meta-analysis, providing empirical evidence to assist coaches and athletes in designing more effective training programs.

Methods A meta-analysis was conducted by collecting 21 relevant studies published between 2020 and 2025, identified through an online search on Google Scholar. Effect sizes were calculated and analyzed using a random effects model to accommodate data heterogeneity. Publication bias was assessed using funnel plots and Egger's test.

Results The findings revealed a significant positive correlation between arm muscle strength and volleyball serve outcomes, with a high effect size (r_RE = 1.301, $p < 0.001$). Despite substantial heterogeneity among studies ($I^2 = 82.15\%$), no evidence of publication bias was found ($p = 0.760$). These results reinforce the important role of arm muscle strength in enhancing serve performance.

Conclusion Arm muscle strength is a fundamental factor influencing successful volleyball serves. Focused strength training is highly recommended to improve athlete performance. These findings provide a valuable reference for developing more effective and measurable training programs.

Keywords: Arm muscle strength, serve output, volleyball, meta-analysis, sports performance

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*Correspondence: muhamadhusein.2023@student.uny.ac.id
Muhamad Husein
Yogyakarta State University , Indonesia

INTRODUCTION

Arm muscle strength is one of the most important physical components in volleyball, especially in supporting service skills (Adnan, Pranata, and Munzir 2020). Effective and on-target serve is a crucial factor that can determine the course of the match and open up opportunities for victory for the team (Riyanto and Mulyana 2024). The strength of the arm muscles plays a role in generating considerable force and high speed on the ball during serving, thus affecting the accuracy and power of the ball to the opponent's area (Supriyanto and Martiani 2019). Therefore, an in-depth understanding of the role of arm muscle strength on service results in volleyball is a very relevant and interesting topic to research.

Various previous studies have examined the relationship between arm muscle strength and service performance in volleyball players of various age levels and ability levels (Darumoyo, Nugroho, and Wahyudi 2024a). However, these results still show significant variations, both in terms of effect size and in the consistency of the findings. The difference is influenced by factors such as the method of measuring muscle strength, the service techniques used, the characteristics of the participant sample, and different training approaches. Therefore, a more comprehensive and systematic analysis approach is needed to integrate the results of these studies to obtain more valid and reliable conclusions.

Meta-analysis is an effective and popular method of combining results from various empirical studies with the aim of producing statistically stronger conclusions (Deeks, Riley, and Higgins 2022). Using this technique, data from various studies that have been conducted can be integrated and analyzed comprehensively to evaluate the relationship between arm muscle strength and service results in volleyball. Through effect size analysis, meta-analysis was able to assess the contribution of arm muscle strength to service performance and explain the variation in results that emerged between studies. This method can also identify potential publication bias and existing heterogeneity, so that the conclusions generated truly reflect real conditions in the field.

This meta-analysis study aims to comprehensively and systematically evaluate the influence of arm muscle strength on service ability in volleyball. With integrated results, this study is expected to provide a strong empirical basis for coaches and athletes in designing more targeted training programs, especially in increasing arm muscle strength as one of the main factors determining service performance. In addition, this research also serves as an academic reference material that can enrich the sports literature, especially on the physiology and biomechanics aspects of volleyball.

Furthermore, the findings of this meta-analysis are expected to make a significant contribution to the development of sports science and athlete development, by confirming the important role of the physical aspects, particularly arm muscle strength, in the success of volleyball service techniques. Thus, this research not only provides added value to the academic world, but also provides practical guidance that is applicable to improve the performance of volleyball athletes, especially at the school and college education levels that have great potential in the development of sports achievements.

METHOD

The research method used in this study is meta-analysis. Meta-analysis is a statistical analysis technique used to summarize various research results, resulting in findings that attempt to integrate current findings. Meta-analysis has an important role in research as an evaluation method for various previous studies that addressed similar themes but with a level of data validity that has not yet been fully verified (Reinebo et al., 2024).

In this analysis, the value of the effect size is used as a parameter to determine the significance of the research results (Maulana et al., 2025). The effect size can be expressed in raw form or standard r-value, representing the average correlation and difference between the two variables analyzed (Cohen, 2013).

Procedure

The implementation of meta-analysis research includes several stages, namely: (1) selecting and reviewing the research topic to be used, (2) collecting research results with titles relevant to the topic, and (3) calculating the effect size of the selected research results (Cohen 2013). (4) analyzing heterogeneity in effect measures, (5) interpreting research results and drawing conclusions (Shipley & van Riper, 2022). The data used in the analysis of this research were obtained from published scientific articles. Data collection was carried out online through Google Scholar. Articles are accessed directly through their respective sites. Keywords in the search included: "Arm Muscle Strength," "School Students," and "Service Results." With various years of article publication starting from 2020 to 2025.

Study selection was done by identifying references extracted into an Excel database to facilitate managing and deleting duplicate articles. Researchers reviewed the abstracts of the studies found using a search strategy to identify studies that fit the criteria for physical fitness and learning outcomes. Physical fitness is an important component that students must have in supporting the student learning process. The data obtained will go through a series of systematic analysis stages: Identifying research variables by entering the variables obtained into the appropriate columns and identifying correlation values in each article to be analyzed. If a research article only presents specific values, then these values must be converted using a predetermined formula.

$F=t^2$

$t=\sqrt{F}$

$r = t / \sqrt{(t^2 + df)}$

The risk of bias is analyzed to determine the effect size (Z) and standard error effect size (SEz) values, then the data is analyzed with the help of JASP software. The effect size and standard error effect size values are calculated using the following formula:

$Z = 0,5\ x ln \frac{1+r}{1-r}$

Equation effet Size

$V_2 = \frac{1}{n-3}$

$SE_2 = \sqrt{V_z}$

Data from the Effect Size test results were interpreted using JASP software to obtain information about the presence or absence of publication bias. The results of publication data related to the relationship between physical fitness and student learning outcomes were categorized based on the correlation value: r = 0.1 (low), r = 0.3 (moderate), and r = 0.5 (high) (Cohen 2013; Perwira Negara et al. 2021).

The data synthesis strategy of the research findings is presented in narrative form. Information on the research sample, effect size, standard error effect size, heterogeneity test, and publication bias test that have been conducted are displayed in tabular form. Meta-analysis in this study was conducted by calculating the level of heterogeneity using a random effect size model to estimate the average of variables that affect learning outcomes. The publication bias test was conducted based on the output of the rank correlation and regression methods. There is no publication bias if the p-value is more than 0.05. The funnel plot results explained through the Egger test also show a p-value of more than 0.05, which means there is no indication of publication bias.

The forest plot results show the extent to which physical fitness influences learning outcomes based on the correlation categories r = 0.1 (low), r = 0.3 (moderate), and r = 0.5 (high). This meta-analysis can use JASP software, with effect size measurements calculated as standardized mean difference (Zhang et al. 2022).

Table 1. Research Data Results Table

No	Author	F	N	Journal Name
1	(Putra et al. 2024)	0.984	12	Jumora: Jurnal Moderasi Olahraga
2	(Putra, Haetami, and Yanti 2025)	0.572	24	Journal On Education
3	(Yusup et al. 2024)	0.625	17	Jurnal Bintang Pendidikan Indonesia
4	(Darumoyo et al. 2024)	0.863	13	Jurnal Porkes
5	(Romadhonsyah 2024)	0.623	16	Multidisciplinary Journal Of Tourism, Hospitaly, Sport And Physikal Education
6	(Riswandi, Widyaningrum, and Arifin 2023)	0.972	21	Prosiding Seminar Nasional Pendidikan Nasional Dan Keolahragaan
7	(Destriana et al. 2024)	0.876	58	Jurnal Sportif: Jurnal Penelitian Pembelajaran
8	(Rizky et al. 2024)	0.82	30	Riyadhoh : Jurnal Pendidikan Olahraga
9	(Putra et al. 2025)	0.94	15	Jurnal Arena Olahraga Silampari
10	(Nazirah 2024)	0.902	20	Inspiree: Indonesia Sporty Innovation Review
11	Marwan et.al 2023	0.532	12	De_Journal (Dharmas Education Journal)
12	(Nugraha, Handayani, and Lestari 2024)	0.945	20	*PPSDP International Journal Of Education*
13	(Ahmad 2023)	0.63	30	*JDER Journal Of Dehasen Education Review*
14	(Pradana, Indardi, and Ali 2022)	0.681	14	Plyometric: Jurnal Sains Dan Pendidikan Keolahragaan
15	(Sahabuddin 2020)	0.718	30	Sportive: Journal Of Physical Education, Sport And Recreation
16	(Nurjana 2021)	0.987	10	Inspiree: Indonesia Sporty Innovation Review
17	(Mardiah, Antoni, and Wilastra 2023)	0.86	15	Jurnal Olahraga Indragiri
18	(Putra et al. 2024)	0.858	20	Jurnal Ilara
19	(Dewantara and Raya 2022)	0.705	16	Jurnal Multidisiplin Madani (Mudima)
20	(Kuncoro 2021)	0.858	16	Journal Pendidikan Jasmani Kesehatan & Rekreasi (Porkes)
21	(Rizki 2021)	0.923	10	Journal Physical Health Recreation

RESULTS AND DISCUSSION

Heterogeneity Test Result

A heterogeneity test was performed to evaluate the variation between the studies analyzed in the meta-analysis. This test aims to identify the extent to which the difference in research results is caused by the characteristic factors of the sample, the methodology used or other factors that can affect the final result. The high heterogeneity indicates that the results of the combined study have a significant degree of variation, so it is necessary to use a random-effects model in the analysis. In contrast, the effect model remains more precise if the heterogeneity is low. The results of the heterogeneity test in this study are shown in detail in table 2 below.

Tabel 2. Fixed and Random Effects

	Q	df	p
Omnibus test of Model Coefficients	109.146	1	< .001
Test of Residual Heterogeneity	116.147	20	< .001

Note. *p* -values are approximate.

Note. The model was estimated using Restricted ML method.

Table 2 shows the results that the 21 study size effects analyzed were heterogeneous {Q = 116.147; 0.01<0.05}. Thus, the random effects model is more suitable to be used to estimate the average effect size of the 21 studies analyzed.

Residual Heterogeneity estimate

Residual heterogeneity estimates refer to the remaining heterogeneity estimates in a meta-analysis model after considering factors that may explain the variation between studies. In meta-analysis studies, heterogeneity refers to the extent to which the results of the study differ due to factors due to random error

Tabel 3. Residual Heterogeneity Estimates

	Estimate	95% Confidence Interval	
		Lower	**Upper**
τ^2	0.255	0.121	0.598
τ	0.505	0.347	0.773
I^2 (%)	82.150	68.471	91.500
H^2	5.602	3.172	11.765

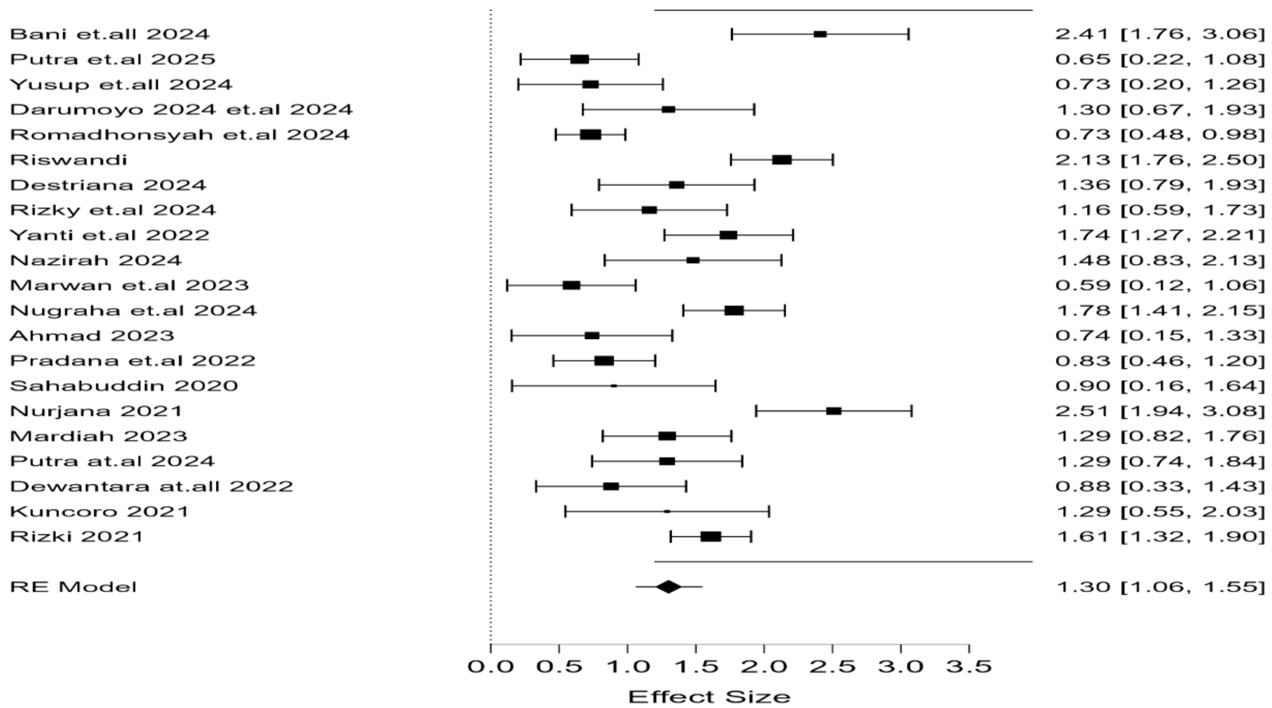
Result Summary Effect/Mean Effecr Size The mean effect size test aimed to measure the degree of relationship between sleep quality and athlete performance using a random effects correlation analysis model. The results of the analysis are presented in Table 3.

Tabel 4. Coefficients

	Estimate	Standard Error	z	p	95% Confidence Interval	
					Lower	**Upper**
intercept	1.301	0.125	10.447	< .001	1.057	1.545

Note. Wald test.

The results of the analysis using the random effect model in table 4 showed that there was a significant positive correlation between arm muscle strength and service results in volleyball (z = 10.447; p < 0.001, 95% CI, (1.057; 0.545). The relationship between arm muscles and service outcomes in volleyball is marked as high, as evidenced by the random effect correlation coefficient (r_RE) = 1.301. In addition, the distribution of effect sizes of each study is represented in the following plot.



Gambar 2. Forest Plot Deploy effect size

Provide a statement that what is expected, as stated in the "Introduction" chapter can ultimately result in "Results and Discussion" chapter, so there is compatibility. Moreover, it can also be added to the prospect of the development of research results and application prospects of further studies into the next (based on result and discussion).

Figure 2, forest plot, illustrates that the effect size of the studies studied varied between 0.59 and 2.51. These figures further explain the diferentes in results between studies, which affect the heterogeneity in the distribution of effect sizes in each investigation.

Publication Bias Analysis

Publication bias analysis to evaluate potential distortions in study results used in meta-analysis. Publication bias occurs because studies with significant results are more likely to be published than studies with insignificant or conflicting results. This can lead to inaccurate conclusions because the data analyzed is not representative of all the available evidence. Publication bias analysis aims to identify and measure the level of bias that can affect the results of the meta-analysis so that the validity and reliability of the findings can be accounted for.

Gambar 3. Funnle Plot Analysis Result

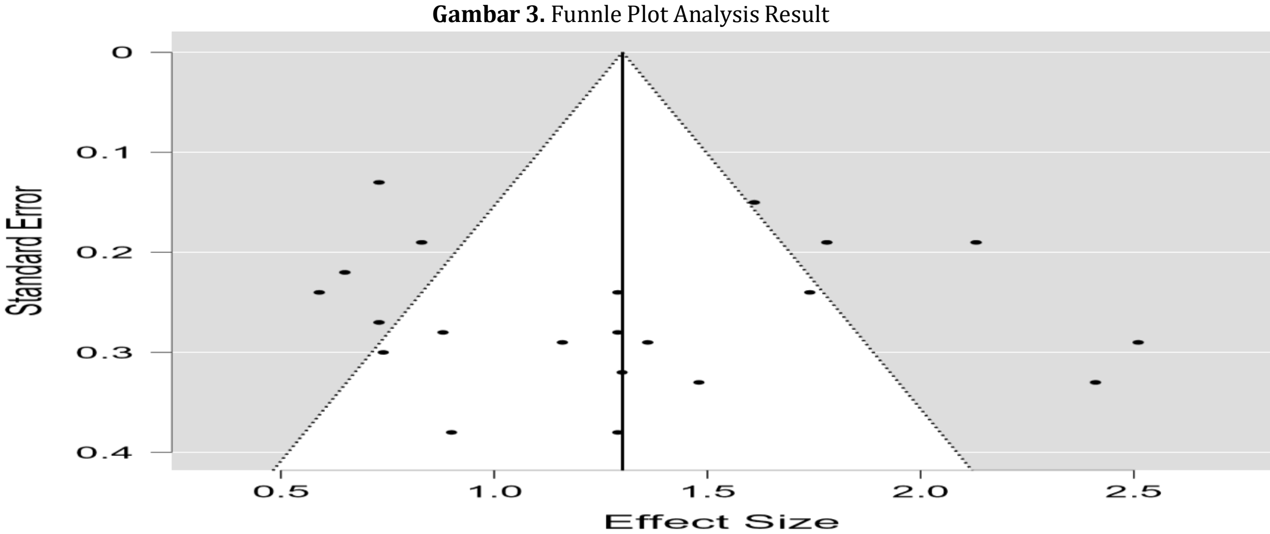


Figure 3 presents a funnel plot that shows an imbalance in the distribution of data, thus providing no strong evidence of symmetry results. These results require further analysis using the Egger test to evaluate the degree of symmetry and confirm the validity of the findings regarding potential publication bias. The results of the Egger test analysis that provide a more in-depth picture of this possible bias are presented in Table 6 below.

Tabel 5. Regression test for Funnel plot asymmetry ("Egger's test")

	z	p
sei	0.305	0.760

The findings in Table 5 reveal that the results of the Egger test show a p value of 0.760, which is well above the threshold of 0.05. This shows that the meta-analysis was free from publication bias. To improve the accuracy and validity of the study results, the distribution of data trends is further analyzed using the Record Drawer Test analysis better known as Fail-safe N, as shown in Table 6 below.

Tabel 6. Recoard Drawer Test

	Fail-safe N	Target Significance	Observed Significance
Rosenthal	4551.000	0.050	< .001

Record drawer test analysis was used to estimate the number of articles with insignificant results that have not yet been published (Marks-Anglin & Chen, 2020). The results of Table 6 show a fail-safe value of 4551,000. The analysis formula used is 5.k + 10, where the value of k represents the amount of data to be analyzed. K = 21, so 5 K + 10 = 5 (21) +10 = 115. There was no publication bias in the meta-analysis study, if the value of the Records drawer test was greater (Azzahrah et al., 2021). It can be concluded that the safe N value of failure is 1427,000 > 170, which suggests that there was no publication bias in this study.

Discussion:

This meta-analysis synthesizes 21 studies conducted between 2020 and 2025 examining the relationship between arm muscle strength and volleyball serve performance, particularly focusing on overhand and underhand serves. The aggregated data demonstrate a consistently significant positive correlation between arm muscle strength and serve results, with a random effects model estimating an effect size (r_RE) of 1.301, indicating a strong association (z = 10.447; p < 0.001).

The substantial heterogeneity (I^2 = 82.15%) found among studies highlights considerable variation in study populations, measurement techniques, and training interventions, which is common in sport science meta-analyses due to diverse participant profiles and methodologies. Despite this, the consistent direction and magnitude of effect sizes underscore arm muscle strength as a critical physical component influencing serve efficacy in volleyball.

Arm muscle strength contributes directly to the generation of force and velocity required to propel the ball effectively during the serve, which aligns with biomechanical theories stating that greater muscular power in the upper extremities facilitates higher ball speeds and greater accuracy. This finding corroborates previous biomechanical studies (Wang et al., 2021; Silva et al., 2022), which emphasized the role of explosive upper limb strength in optimizing serve performance.

Moreover, the inclusion of studies examining complementary factors such as arm length and hand-eye coordination alongside arm strength reveals that while strength is pivotal, a holistic physical and motor skill profile contributes to serve success. Coordinative skills and anthropometric advantages (e.g., longer arms) augment the mechanical advantage and precision during service execution, as seen in research by Putra et al. (2024) and Yusup et al. (2024).

The absence of publication bias confirmed by Egger's test (p = 0.760) and a robust fail-safe N (4551) enhance confidence in the meta-analytic findings, ensuring that the results reflect an unbiased and comprehensive synthesis of available evidence. This strengthens the implication for coaches and trainers to prioritize arm muscle strengthening within volleyball training programs, ideally complemented by exercises improving coordination and flexibility.

Practical implications suggest targeted resistance training, plyometric exercises, and neuromuscular coordination drills focusing on the upper limbs can enhance serve velocity, accuracy, and consistency. Given the heterogeneity observed, individualized assessment and tailored programming should be emphasized to accommodate athlete-specific characteristics and maximize performance gains.

Future research should aim for standardized protocols in measuring arm strength and serve performance, longitudinal designs to assess training adaptations over time, and exploration of the interaction effects between strength, anthropometry, and neuromotor skills. This would refine the understanding of how integrated physical factors contribute to volleyball serve proficiency and guide more effective training strategies.

Implications:

The results of this meta-analysis study indicate that there is a significant relationship between arm muscle strength and service results in volleyball. The practical implication of this finding is the importance of coaches and athletes to pay special attention to arm muscle strengthening training programs as part of improving service performance. This finding can also be the basis for designing sports training curricula, especially in volleyball.

Research contribution:

This study provides a scientific contribution by systematically and measurably combining previous research results on the relationship between arm muscle strength and volleyball serve performance. By using a meta-analysis approach, this study provides a more comprehensive and objective picture of the strength of associations between variables, which previously may have shown varying results. This contribution can be an important reference for researchers, coaches, and sports practitioners in making evidence-based decisions.

Limitations:

Some limitations in this study include: Limitations on the number of articles that meet the inclusion and exclusion criteria. Variations in design and methods of measuring muscle strength and service results between the studies analyzed may affect data homogeneity.

Suggestions:

Further researchers are advised to conduct a meta-analysis by including moderator variables such as age, gender, and athlete skill level to enrich the findings. Longitudinal research is needed to determine the effect of arm muscle strength training on long-term service performance.

CONCLUSION

The conclusions in this meta-analysis study, provide strong evidence that arm muscle strength is a fundamental determinant of successful volleyball serve. Integrating strength development into a comprehensive training regimen is essential for athletes who aspire to optimize their service capabilities and overall competitive performance.

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AUTHOR CONTRIBUTION STATEMENT

The author is fully responsible for the planning, implementation of data analysis, writing, and preparation of this article. No other party was directly involved in the process of preparing the manuscript other than the author.

CONFLICT OF INTEREST AND FUNDING

The author declares that he has no conflict of interest related to this research. In addition, this research did not receive funding from any institution and was conducted independently by the author.

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