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RESEARCH ARTICLE

# Comparative Analysis of Plyometric Training Protocols in Volleyball: A Meta-Analysis

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**Abstract**

**Purpose:** This meta-analysis synthesizes findings from 40 research studies to comprehensively examine the impact of plyometric training protocols on overall performance outcomes in volleyball athletes. **Method:** A systematic search identified relevant studies on plyometrics and volleyball performance. Data on training programs, performance measures, and outcomes were extracted. Statistical analysis assessed the overall effect size and addressed potential variation between studies. **Findings:** The constant-effects version revealed a giant wonderful common impact (Fisher r-to-z converted correlation coefficient = 0.7531, 95% CI: 0.6952 to 0.8110), affirming the fine relationship between plyometrics and volleyball overall performance. However, the random-effects model indicated giant heterogeneity among authentic effects ($I^2$ = 78.53%), prompting a radical exploration of ability sources of variability. Despite diagnosed limitations, inclusive of heterogeneity and ability publication bias, this meta-analysis underscores the want for standardized protocols and in addition studies to refine training strategies. **Conclusion:** The importance of this analysis lies in its contribution to proof-primarily based practices, providing valuable insights to coaches and practitioners in search of to optimize plyometric training for volleyball athletes. As a complete reference, it courses destiny research endeavors and advances know-how within the nuanced courting between plyometrics and volleyball.

**Keywords**
Plyometric Training, Volleyball Overall Performance, Athletic Training, Sports Science

## INTRODUCTION

Volleyball has modified beyond recognition within the beyond three a long time from an unorganized recreation into a relatively competitive sport, requiring a excessive level of bodily fitness, mental alertness and mastery over strategies. Volleyball has developed into a exceedingly competitive sport which requires a excessive stage of physical, physiological and psychological health. The sport at a excessive degree of competition calls for faster unexpected moves and speedy reaction (Vassil & Bazanovk, 2012). Volleyball fits have no time restrict and suits can last for numerous hours, if the teams are calmly matched. Successful play in volleyball isn't always the final results of strength by myself however it's far the made from the mixed show of energy and tactical competencies. Modern game of volleyball is characterized by using accuracy, concentration and cleverness (Peitz et al., 2018).

Volleyball athletes frequently engage in plyometric training to beautify their electricity and agility on the court. Plyometric physical games, characterized by using speedy stretching and contracting of muscular tissues, aim to enhance muscle energy, explosiveness, and common overall performance in sports activities (Sarkar et al., 2020). In the context of volleyball, the needs of the sport require athletes to execute powerful jumps,

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fast directional changes, and precise actions, making plyometric education a important thing in their conditioning routine (Muanjai & Namsawang, 2015). While the benefits of plyometric Training in volleyball are extensively stated, there exists a want for a complete analysis of various plyometric Training protocols. Previous studies has provided treasured insights into the efficacy of plyometrics in improving vertical bounce top and agility in volleyball players (Stojanović et al., 2017). However, a comparative analysis of various plyometric education methods is lacking, leaving coaches and practitioners with constrained steering on the most suitable protocols for maximizing athletic overall performance in volleyball.

Plyometrics, derived from the Greek word 'plethyoin' (meaning 'same period'), involves exercises that enhance muscle power through rapid lengthening followed by a strong contraction. The term 'plyo' signifies 'greater,' and 'metric' indicates a 'measured amount,' emphasizing the technique's foundation and a quick muscle stretch preceding a contraction yields a significantly stronger response (Rocha Henrique et al., 2023). Plyometric exercises, including depth jumping, hopping, and bouncing drills, utilize gravitational force and the contractile and elastic properties of muscle tissues to enhance muscle strength and performance. This dynamic training method, which increases strain on targeted muscles, can be seen as an advanced form of the 'shock' method for boosting athletic performance (Ramírez-Campillo et al., 2016). The surprise technique recommended by Verkhoshansky involves rebounded jumps from a peak to enhance the athlete's reactive neuromuscular system. Plyometric exercises, derived from the Greek words for "increase" and "measure," involve muscles working both concentrically and eccentrically. The principle behind plyometrics is that a rapid muscle lengthening immediately before contraction leads to a significantly stronger contraction (Ali et al., 2023; ALi et al., 2023; Almeida et al., 2021). Other phrases used alongside plyometric are depth jumping, box leaping and bounce Training. The delivered contraction electricity is thought to be due to a energy of muscle spindles involving the reflex and resulting in an growth frequency of motor unit discharge.

Depth leaps, a type of plyometric exercise, involve an athlete standing on a platform and stepping off to immediately execute a maximal vertical or horizontal jump upon landing (Vadivelan & Sudhakar, 2015). Plyometric education is one of the high-quality methods of developing explosive power in sports activities. Basically, plyometrics offer a way of Training for the highest quality relationship between electricity and pace with the intention to ultimately show up itself as explosive power. Today plyometric actions are carried out in almost all sports. Basic strength level ought to be attained earlier than beginning plyometric Training programmer. The preference of exercising need to correspond to age, sex and biological improvement of sports activities person (A. Ali et al., 2023; ALi et al., 2023; S. L. Ali et al., 2023; Dinh et al., 2023; Saleem Naz Babari et al., 2024). These should progressively increase the stress at some point of an entire training cycle. Body weight have to be the figuring out aspect in assigning the cost of jumps in workout (Bedoya et al., 2015). Generally, the number of sessions to be dedicated to the plyometric Training is 2 or 3 instances according to week Plyometric exercising is a fairly new concept of education that applies the precise precept concerning the existing energy situations of the muscle prior to explosive contraction. The effect of plyometric physical games in increasing vertical jumping potential has beens studied experimentally, but no try has been made if they're extra effective than the kinetic exercise (Beato et al., 2018).

Plyometric education, a shape of exercising characterized with the aid of speedy muscle lengthening and contraction, has turn out to be a distinguished thing within the conditioning regimens of volleyball athletes. The fundamental precept underlying plyometrics is the usage of the stretch-shortening cycle, wherein muscle mass are unexpectedly stretched and straight away shrunk to generate maximal force (Kobal et al., 2017). In the context of volleyball, plyometric physical activities intention to decorate precise components of athletic performance important to the game. Volleyball is characterized through explosive actions together with leaping, spiking, and speedy lateral transitions, all of which demand an excessive degree of energy and agility. Plyometric education is specifically relevant to volleyball gamers because it targets the neuromuscular device, enhancing the efficiency of muscle contractions and improving the pressure manufacturing required for dynamic movements at the court (di Cagno et al., 2020; Shafiq et al., 2024). Common plyometric sports in volleyball education

encompass intensity jumps, bounding, and box jumps, all designed to mimic the demands of the sport and improve talents like vertical bounce top and short directional modifications. Incorporating plyometric training into volleyball conditioning has proven effective outcomes on overall performance outcomes. Studies have tested upgrades in vertical bounce peak, spiking strength, and average agility among volleyball athletes who go through systematic plyometric training interventions (Giovanelli et al., 2017). The transferability of plyometric variations to the unique demands of volleyball makes it a treasured Training modality for coaches and athletes striving to optimize on-court carry out.

The present literature on plyometric Training in volleyball lacks a comprehensive synthesis of studies that immediately compares distinctive Training protocols. Although several studies have for my part investigated the impact of plyometric Training on various overall performance results in volleyball athletes, there stays a superb gap inside the literature regarding the comparative analysis of these protocols (Nwanna et al., 2024; Sporri et al., 2018). This gap in knowledge poses a task for coaches and practitioners seeking proof-based guidance on the simplest plyometric education strategies for volleyball athletes.

Identify the Gap or Controversy within the Existing Literature and Current studies in plyometric education for volleyball predominantly includes person research analyzing particular factors of overall performance, along with vertical soar top or agility. However, a comprehensive understanding of the relative effectiveness of different plyometric education protocols is missing. Some studies may emphasize one type of plyometric exercising over any other, creating a capacity controversy in the literature concerning the most advantageous technique for volleyball. This gap in know-how necessitates a meta-analysis which can systematically assessment and synthesize the present evidence, supplying a more nuanced attitude at the comparative efficacy of numerous plyometric training interventions.

Highlight the Need for a Comparative Analysis of Plyometric Training Protocols in Volleyball The want for a comparative analysis arises from the numerous natures of plyometric sporting events hired in volleyball Training and the absence of consensus at the most useful protocols. Coaches and athletes currently lack a complete aid that directly compares the effects of various plyometric education strategies, hindering the improvement of proof-primarily based Training packages (Chu, 1998; Gjinovci et al., 2017) By conducting a meta-analysis, we purpose to deal with this hole with the aid of offering a synthesized view of existing research, taking into consideration a better-informed expertise of which plyometric education protocols yield the most sizeable improvements in volleyball performance.

The number one goals of this meta-analysis are to systematically review and synthesize present studies on plyometric training protocols in volleyball. The desires and specific targets of the meta-analysis are as follows:

Evaluate the Comparative Efficacy of Plyometric Training Protocols, Address Methodological Variability Across Studies, Quantify the Magnitude of Plyometric Training Effects, Explore Subgroup Analyses to Identify Moderators, Assess Publication Bias and Study Quality Provide Evidence-Based Recommendations for Coaches and Practitioners.

## MATERIALS AND METHODS

This meta-analysis was conducted in accordance with the guidelines specified in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement (Figure 1).

***Inclusion Criteria***

The meta-analysis will encompass various take a look at designs, with a primary emphasis on randomized controlled trials (RCTs) to make certain a higher degree of methodological rigor. Additionally, observational studies, and systematic reviews/meta-analyses may be taken into consideration to offer a comprehensive evaluate of the available proof. Inclusion criteria will contain studies presenting members identified as volleyball athletes. This consists of people actively engaged in volleyball Training or competitive play, irrespective of age, gender, or skill degree. The numerous inclusion of contributors aims to capture a vast representation of the volleyball populace. The intervention of hobby may be plyometric training protocols. This encompasses quite a few physical games designed to decorate muscular strength, agility, and other performance-associated attributes specific to volleyball. Plyometric sporting activities may additionally consist of but are not confined to depth jumps, container jumps, and bounding

sporting activities. Selected research should record quantitative statistics on overall performance indicators directly relevant to volleyball. Key outcome measures encompass, however are not limited to, vertical soar height, agility (e.G., travel run instances), spiking energy, and different generally assessed metrics reflective of volleyball performance.

***Exclusion Criteria***

Exclusion criteria applied to research that lack enough records for effect size calculations or exhibit methodological flaws that compromise the inner validity of the consequences. This ensures that covered research make contributions sturdy and dependable facts to the meta-analysis. Studies that do not explicitly check out the results of plyometric Training on volleyball overall performance may be excluded. This criterion guarantees that the meta-analysis remains centered on the particular studies query concerning the effect of plyometrics in the context of volleyball.

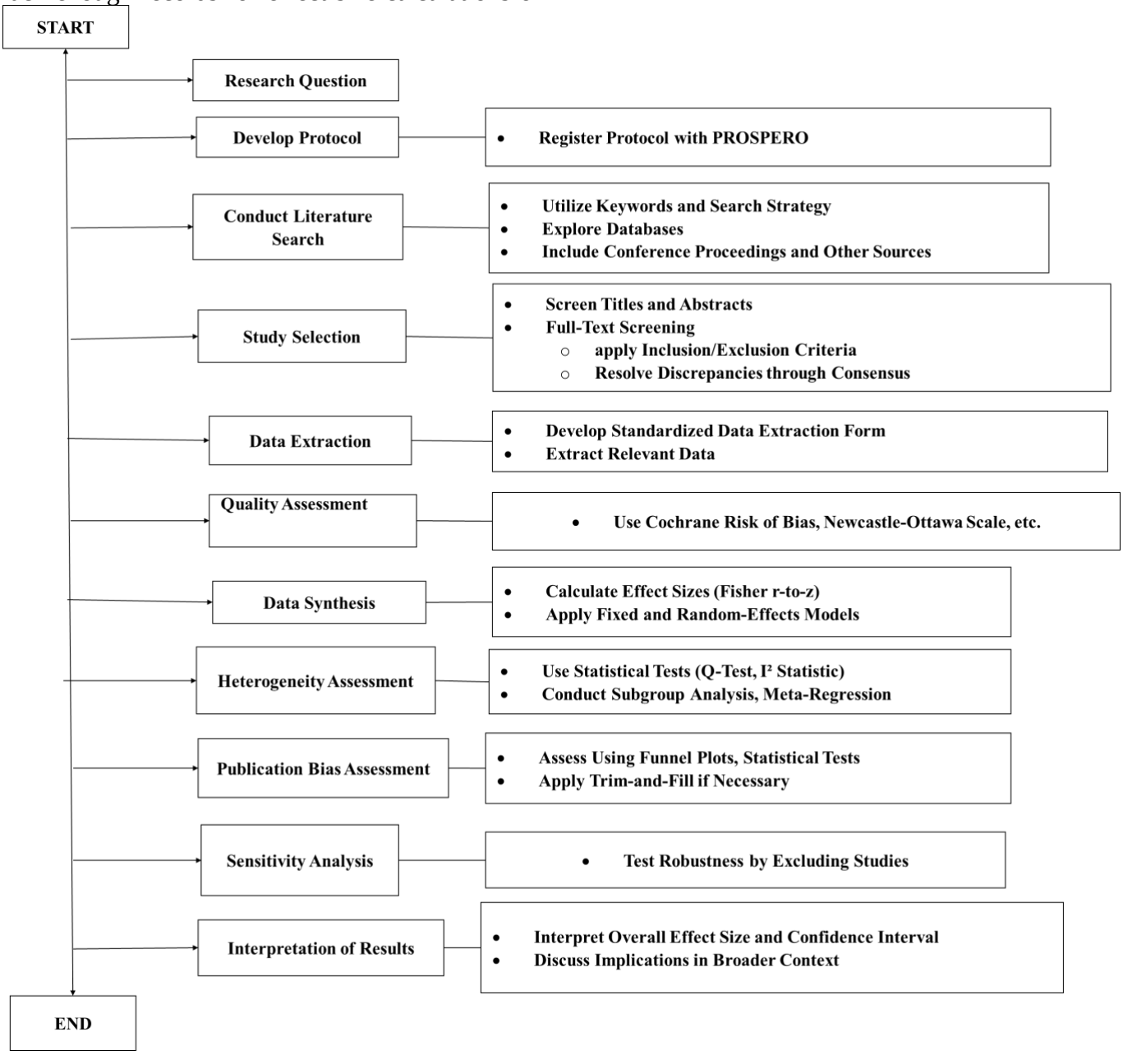


**Figure 1.** PRISMA Flow diagram of meta-analysis

***Search Strategy***

Electronic databases, including PubMed, Scopus, SPORT Discus, and PsycINFO, can be systematically searched the use of a combination of controlled vocabulary terms and relevant key phrases. Inclusion criteria could be implemented to

filter out outcomes, making sure alignment with the observe kinds, individuals, interventions, and final results measures outlined above. Exclusion standards could be used to dispose of research that fall outdoor the scope of the research question, preserving the specificity of the meta-analysis. The literature search will encompass research posted within 2015-2022 years. This time-frame moves a stability between capturing current advancements and practices in plyometric education at the same time as maintaining a sufficiently robust body of literature for analysis.

***Data Extraction and Quality Assessment***

Clearly distinguish among various observe designs, presenting insights into the strengths and barriers related to every layout. For instance, RCTs provide excessive inner validity, while observational studies may additionally offer treasured actual-international context (Table 1).

**Table 1.** Previous study results

| Study | Participants | r | N |
|---|---|---|---|
| (Alp & Mansuroglu, 2021) | Male | 0.4 | 20 |
| (Harmandeep et al., 2015) | Male & Female | 0.1 | 10 |
| (Mroczek et al., 2017) | Female | 0.4 | 60 |
| (SHAIK MANNAN, 2015) | Male & Female | 0.3 | 62 |
| (Rao & Rao, 2016) | Male | 0.8 | 14 |
| (Ahmad & Jain, 2020) | Female | 0.8 | 21 |
| (Novita et al., 2022) | Female | 0.3 | 25 |
| (Gjinovci et al., 2017) | Male | 0.6 | 60 |
| (Kumar & Jadia, 2021; Shoukat et al., 2024) | Male & Female | 0.8 | 50 |
| (shaık mannan, 2015) | Male | 0.4 | 26 |
| (Vadivelan & Sudhakar, 2015) | Male | 0.2 | 34 |
| (Mroczek et al., 2017; Riaz et al., 2024) | Male | 0.7 | 14 |
| (Çimenli et al., 2016) | Male & Female | 0.9 | 15 |
| (Mroczek et al., 2017) | Male | 0.7 | 12 |
| (shaık mannan, 2015) | Female | 0.9 | 23 |
| (Krzysztofik et al., 2021) | Female | 0.6 | 17 |
| (Mroczek et al., 2017) | Male | 0.2 | 19 |
| (Çimenli et al., 2016) | Female | 0.5 | 30 |
| (Vassil & Bazanovk, 2012) | Male & Female | 0.7 | 63 |
| (Maciejczyk et al., 2021) | Male | 0.9 | 41 |
| (Zghal et al., 2019) | Male | 0.7 | 43 |
| (Machado et al., 2019) | Male | 0.2 | 23 |
| (Fischetti et al., 2018) | Female | 0.4 | 34 |
| (Weeks et al., 2023) | Male & Female | 0.5 | 36 |
| (Bianchi et al., 2018) | Male | 0.8 | 29 |
| (Becerra-Patiño et al., 2023) | Female | 0.9 | 31 |
| (Alp & Mansuroglu, 2021) | Female | 0.3 | 37 |
| (Sporri et al., 2018) | Male | 0.6 | 26 |
| (Giovanelli et al., 2017) | Female | 0.5 | 29 |
| (di Cagno et al., 2020) | Male | 0.8 | 31 |
| (Kobal et al., 2017) | Male | 0.9 | 22 |
| (Beato et al., 2018) | Male | 0.3 | 51 |
| (Bedoya et al., 2015) | Male & Female | 0.9 | 34 |
| (Vadivelan & Sudhakar, 2015) | Female | 0.7 | 40 |
| (Almeida et al., 2021) | Female | 0.5 | 56 |
| (Ramírez-Campillo et al., 2016) | Female | 0.8 | 18 |
| (Rocha Henrique et al., 2023) | Male | 0.5 | 22 |
| (Stojanović et al., 2017) | Female | 0.7 | 26 |
| (Muanjai & Namsawang, 2015) | Male & Female | 0.9 | 20 |
| (Sarkar et al., 2020) | Male | 0.7 | 42 |

Delve into player characteristics to recognize the variety of the look at populace. Document any versions in age, gender, skill stage, or different applicable elements that might impact the generalizability of the findings. Extract detailed records about the plyometric Training protocols,

which include the specific physical activities worried, training frequency, period, and any variations throughout interventions. Systematically categorize the effects measured in each take a look at. This can also involve performance indicators unique to volleyball, as well as any secondary results that contribute to a holistic know-how of the intervention's effect.

Assess the adequacy of randomization approaches and participant allocation, emphasizing research with robust strategies to reduce choice bias. Evaluate whether or not blinding turned into carried out effectively, considering both participant blinding and final results assessment blinding. Blinding complements the reliability of examine consequences by decreasing the potential for bias. Examine how research address player dropouts and withdrawals. Transparent reporting and appropriate dealing with of missing statistics contribute to the overall methodological first-class. Employ the Cochrane Risk of Bias tool for RCTs, considering domains together with random collection generation, allocation concealment, blinding, incomplete final results statistics, and selective reporting. Utilize the Newcastle-Ottawa Scale for observational research, comparing selection, comparability, and outcome assessment to gauge observe nice. Which includes systematic reviews/meta-analyses, apply AMSTAR 2 (A Measurement Tool to Assess Systematic Reviews) to evaluate the methodological first-rate of those higher-degree evidence syntheses. For drawing the forest plot, the "metafor" library in R was employed. The statistical analyses were conducted using R (version 2023.09.1+494), and the specific functions within the "metafor" package were utilized for effect size estimation and forest plot generation (Supplemrtry file 1).

## RESULTS

### *Correlation Coefficients (r, N)*

The fixed-effects model, implemented to the records with k=40 research, revealed an anticipated average Fisher r-to-z transformed correlation coefficient of 0.7531 (ninety-five% CI: 0.6952 to 0.8110) (Table 2). The intercept had a good sized advantageous estimate of zero.753, indicating that, on common, plyometric education protocols have been associated with a advantageous effect at the outcome measure. The Z-check for the intercept changed into notably significant (Z = 25.5, p < 0.001), indicating that the found impact differed drastically from zero. The random-effect model, additionally carried out to the same dataset, yielded an anticipated average Fisher r-to-z converted correlation coefficient of zero.781 (ninety five% CI: zero.655 to zero.908). The intercept, with a advantageous estimate of 0.781, remained substantial (Z = 12.1, p < 0.001). The $Tau^2$ estimator the usage of the Hunter-Schmidt technique became said as 0.000, indicating no observed heterogeneity table 3.

The model fit statistics and information criteria offer valuable insight into the appropriateness of statistical model under meta-analysis (table 4). The maximum-likelihood model demonstrates a advanced match, as indicated by using its lower log-chance, deviance, AIC, BIC, and AICc values compared to the restricted maximum-likelihood model. While the reduction in deviance and lower AIC and BIC values in the maximum-probability version suggest a higher balance between goodness of fit and model complexity, warning is warranted in deciding on the version entirely based totally on these metrics. It is crucial to do not forget the theoretical context and capability overfitting, as overly complicated models might not generalize well to new statistics. Therefore, a comprehensive interpretation entails weighing statistical standards in opposition to the great implications of the fashions in the particular context of the meta-evaluation.

**Table 2.** Fixed and random effect model

| Fixed-Effects Model (k = 40) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Estimate | se | Z | p | CI Lower Bound | CI Upper Bound |
| Fixed Effect Model | Intercept | 0.753 | 0.0295 | 25.5 | < .001 | 0.695 | 0.811 |
| Random Effect Model | Intercept | 0.781 | 0.0645 | 12.1 | < .001 | 0.655 | 0.908 |

**Table 3.** Heterogeneity statistics.

| Heterogeneity Statistics | | | | | |
|---|---|---|---|---|---|
| Tau | Tau² | I² | H² | R² | df |
| 0.000 | 0 (SE= NA ) | 78.53% | 4.657 | . | 39.000 |

**Table 4.** Model Fit Statistics and information.

| Model Fit Statistics and Information Criteria | | | | | |
|---|---|---|---|---|---|
| | Log-Likelihood | Deviance | AIC | BIC | AICc |
| Maximum-Likelihood | -63.160 | 181.636 | 128.321 | 130.009 | 128.426 |
| Restricted Maximum-Likelihood | -63.919 | 127.838 | 129.838 | 131.501 | 129.946 |

***Visualization through Forest Plot and Funnel Plot Analysis***

Various studies have been performed to assess online publication bias the Fail-Safe N, a measure of the wide variety of extra studies with null findings required to make the discovered effect non-large, was 9405 (table 5). The Begg and Mazumdar Rank Correlation test and Egger's Regression test indicated no massive book bias, despite the fact that Egger's Regression recommended some asymmetry (p = 0.017), The statistical analyses for publication bias were conducted using R scripts with the "metafor" library. The forest plot generated using R is presented in Figure 5, illustrating effect sizes and confidence intervals for each study. The Trim and Fill manner advised the capability addition of 2 studies to regulate for asymmetry.

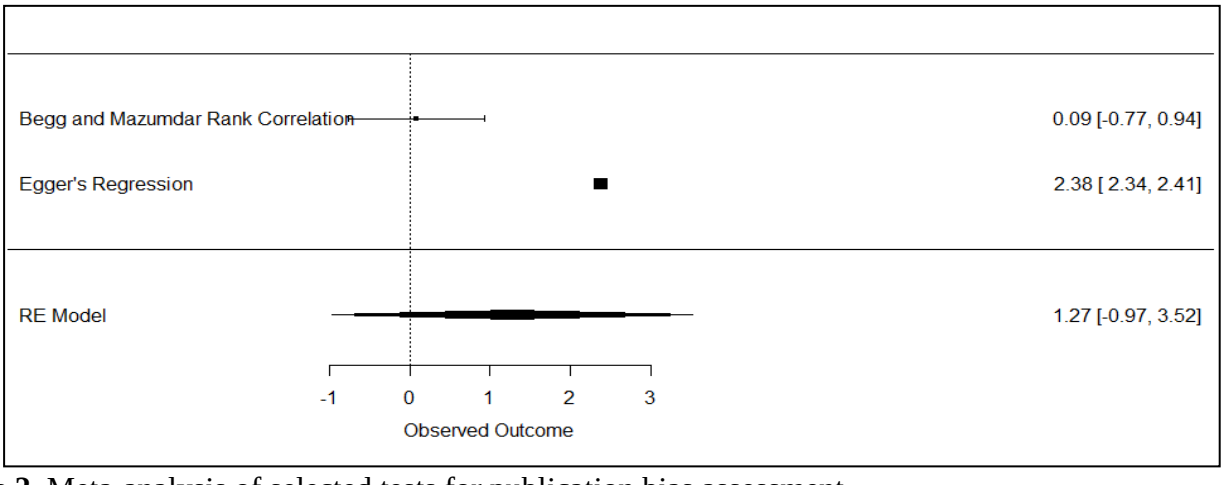


**Figure 2.** Meta-analysis of selected tests for publication bias assessment

**Table 5.** Key statistical metrics for publication bias assessment

| r | | |
|---|---|---|
| Test Name | Value | p |
| Fail-Safe N | 9405.000 | < .001 |
| Begg and Mazumdar Rank Correlation | 0.087 | 0.435 |
| Egger's Regression | 2.377 | 0.017 |
| Trim and Fill Number of Studies | 2.000 | . |

The analysis utilized the Fisher r-to-z transformed correlation coefficient to measure outcomes in the meta-analysis of polymetric training protocols. Applying a fixed-effects model, the results included the Q-test for heterogeneity (Cochran 1954) and the I² statistic (Table 4). To

identify potential outliers or influential studies, studentized residuals and Cook's distances were evaluated, with studies surpassing the Bonferroni-corrected threshold for studentized residuals (100 x (1 - 0.05/(2k)) Outliers in the data, defined as values exceeding the median plus six times the interquartile range in Cook's distances (a measure of influence in regression analysis), were identified. Funnel plot asymmetry was assessed using rank correlation and regression tests, with observed outcome standard errors as predictors, to detect potential biases (Figure 3).

The analysis comprised 40 studies, with Fisher r-to-z transformed correlation coefficients observed ranging from 0.1003 to 1.4722, predominantly positive across all estimates (100%). The fixed-effects model yielded an estimated average Fisher r-to-z transformed correlation coefficient of \(\hat{\theta} = 0.7531\) (95% CI: 0.6952 to 0.8110), indicating a significant deviation from zero (z = 25.4948, p<0.0001). The Q-test suggested heterogeneity among the true outcomes (Q(39) = 181.6355, p < 0.0001, $I^2$ = 78.5284%).

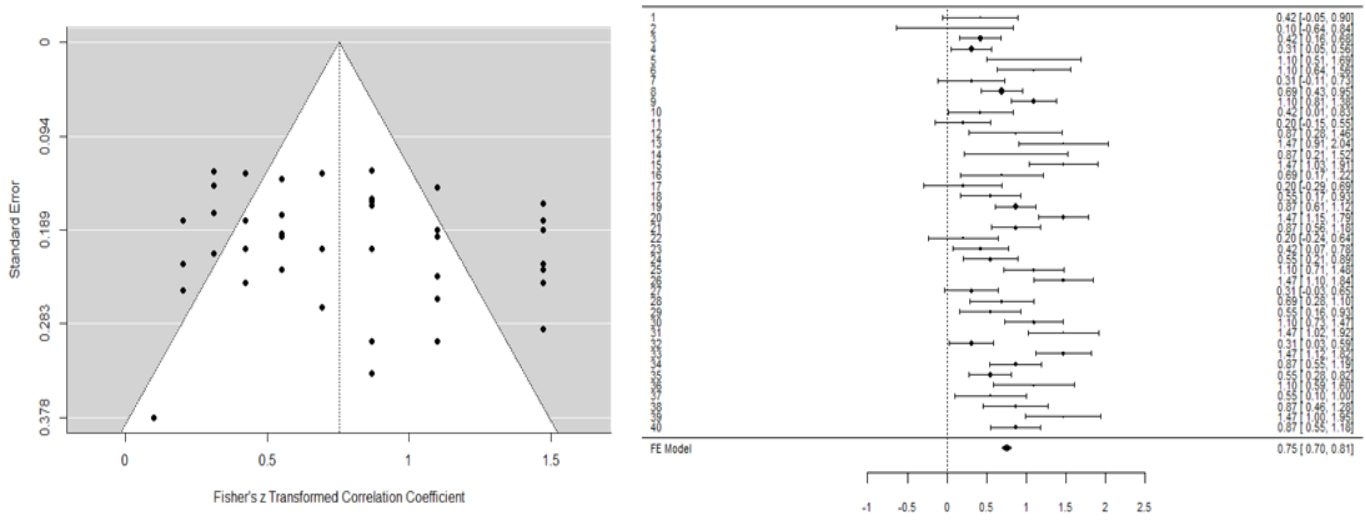


**Figure 3**. Result of a meta-analysis

The Q-test suggested heterogeneity among the true outcomes (Q(39) = 181.6355, p < 0.0001, $I^2$ = 78.5284%). Analysis of the studentized residuals identified potential outliers in studies 4, 15, 20, 26, and 33, with values exceeding ±3.2272. However, Cook's distance analysis revealed no studies with excessive influence. The regression test showed funnel plot asymmetry (p = 0.0175), whereas the rank correlation test did not indicate such asymmetry (p = 0.4346).

## DISCUSSION

This meta-analysis underscores the significant positive impact of plyometric training on volleyball athletes' performance, as reflected in the strong overall effect size (Fisher r-to-z converted correlation coefficient = 0.7531, 95% CI: 0.6952 to 0.8110). Our results align with previous studies that demonstrate the effectiveness of plyometric training in enhancing explosive power, agility, and vertical jump height—critical attributes for success in volleyball (de Villarreal et al., 2021). The notable heterogeneity observed ($I^2$ = 78.53%) suggests that variations in training protocols, participant characteristics, and outcome measures may have contributed to the observed disparities between studies, consistent with findings from similar meta-analyses in sports science (Moran et al., 2021; Ramirez-Campillo et al., 2023).

The fixed-effects model highlighted a robust positive relationship between plyometric training and volleyball performance outcomes. However, the random-effects model, with its larger variance, suggests that the effect size may not be uniform across all contexts, reflecting the need for tailored training protocols that consider individual athlete needs and volleyball positions. For instance, setters, spikers, and blockers may benefit from specialized plyometric regimens targeting specific motor abilities (Vychodilová, 2023).

Despite the strong positive correlation, the considerable heterogeneity observed signals the necessity for further standardization in plyometric training regimens (Si et al., 2024). The variability among studies may be attributable to differences in training volume, intensity, and duration, as well as in participant demographics such as age, experience level, and physical conditioning. Similar heterogeneity was reported in studies of other sports disciplines, indicating that a one-size-fits-all approach may not be ideal for plyometric training (Liu et al., 2024).

Furthermore, the potential presence of publication bias, although relatively minor, suggests that some studies with null or negative results might not have been included in the analysis. This highlights the importance of continued, comprehensive reporting of all findings, regardless of statistical significance, to ensure a more balanced understanding of the true effects of plyometric training (Kons et al., 2023; Sanchez-Sanchez et al., 2024).

This meta-analysis provides compelling evidence supporting the effectiveness of plyometric training in volleyball, future research should focus on refining and standardizing protocols to mitigate the variability across studies. Coaches and practitioners are encouraged to adopt evidence-based practices that consider the unique physiological demands of volleyball, contributing to optimized performance and injury prevention. Continued exploration of individualized and position-specific training methods will be crucial in advancing the science of athletic conditioning.

***Conclusion***

In end, our meta-analysis sheds mild on the connection between plyometric Training protocols and overall performance results in volleyball. The found fine common effect underscores the capability benefits of incorporating plyometrics into Training regimens. However, the large heterogeneity recognized among real effects necessitates a cautious interpretation. Despite diligent efforts to cope with capacity sources of bias and variability, our findings are concern to the inherent challenges of synthesizing diverse research. The mentioned obstacles, such as heterogeneity, e-book bias worries, and variability in have a look at fine, underscore the complexity of the field and the need for refined methodologies in destiny research. Nonetheless, this meta-analysis provides a foundational information of the impact of plyometric education on volleyball performance and offers valuable insights for coaches and practitioners searching for proof-primarily based methods. As the sphere progresses, ongoing studies endeavors can build upon these findings, fostering a nuanced knowledge of most effective plyometric training strategies tailor-made to the dynamic desires of volleyball athletes.

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***Declaration of Interest Statement***

The authors declare that they have no competing interests regarding the publication of this manuscript

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***Ethical Approval***

The study titled “Comparative Analysis of Plyometric Training Protocols in Volleyball: A Meta-Analysis” was approved from the Abdul wali khan university Mardan. [Ref: AWKUM-23123451.

***Author Contibution***

Study Design, S.A., I.B.B. and A.C.G.; Data Collection, S.A.; Statistical Analysis, S.A., I.B.B.; Data Interpretation, S.A., and I.B.B.; Manuscript Preparation, S.A., I.B.B.; Literature Search, S.A., I.B.B and A.C.G. All authors have read and agreed to the published version of the manuscript.

***Data Availability Statement***

The dataset used in this study, involving genetic identification and parasite determination in wild rats, is outlined within the manuscript.

## REFERENCES

Ahmad, T., & Jain, D. R. (2020). Effects of lower body plyometric training in young Kashmiri female volleyball players. *Int. J. Phys. Educ. Sports Health*, *7*, 151–156. [CrossRef]

ALi, A., Manzoor, U., Ali, S. L., Marsool, M. D., Parida, P. K., Marsool, A. D., & Swathi, N. L. (2023). Currently trendıng and futurıstıc bıologıcal modalıtıes ın the management of dıfferent types of dıabetes: a comprehensıve revıew. *Journal of Population*

*Therapeutics and Clinical Pharmacology*, *30*(18), 2948–2970. [CrossRef]

Ali, A., Manzoor, U., Ali, S. L., Nousheen, R., Ullah, W., & Adil, K. (2023). Analysis of the capability of IgG antibodies and receptors with their relationships to food tolerance and autoimmune disorders. *International Journal of Natural Medicine and Health*, *3*(1), 25–32. [CrossRef]

Ali, S. L., Ali, A., Alamri, A., Baiduissenova, A., Dusmagambetov, M., & Abduldayeva, A. (2023). Genomic annotation for vaccine target identification and immunoinformatics-guided multi-epitope-based vaccine design against Songling virus through screening its whole genome encoded proteins. *Frontiers in Immunology*, *14*, 1284366. [CrossRef] [Pubmed]

Almeida, M. B. de, Leandro, C. G., Queiroz, D. da R., José-da-Silva, M., Pessoa dos Prazeres, T. M., Pereira, G. M., das-Neves, G. S., Carneiro, R. C., Figueredo-Alves, A. D., & Nakamura, F. Y. (2021). Plyometric training increases gross motor coordination and associated components of physical fitness in children. *European Journal of Sport Science*, *21*(9), 1263–1272. [CrossRef] [Pubmed]

Alp, M., & Mansuroglu, M. (2021). Effects of Regional Plyometric Trainings on Agility Performance of Male Volleyball Players. *Journal of Educational Issues*, *7*(1), 449–457. [CrossRef]

Beato, M., Bianchi, M., Coratella, G., Merlini, M., & Drust, B. (2018). Effects of plyometric and directional training on speed and jump performance in elite youth soccer players. *The Journal of Strength & Conditioning Research*, *32*(2), 289–296. [CrossRef] [Pubmed]

Becerra-Patiño, B., Ospina-Leon, M. Á., Macías-Quecan, J. D., Cárdenas-Castiblanco, J. A., & LÓPez-Mosquera, Y. D. (2023). Effects of plyometric training in Colombian soccer players (17-18 years old) according to their position in the field of play. *Journal of Physical Education and Sport*, *23*(1), 41–51. [CrossRef]

Bedoya, A. A., Miltenberger, M. R., & Lopez, R. M. (2015). Plyometric training effects on athletic performance in youth soccer athletes: a systematic review. *The Journal of Strength & Conditioning Research*, *29*(8), 2351–2360. [CrossRef] [Pubmed]

Bianchi, M., Coratella, G., Dello Iacono, A., & Beato, M. (2018). Comparative effects of single vs. double weekly plyometric training sessions on jump, sprint and COD abilities of elite youth football players. *Journal of Sports Medicine and Physical Fitness*, *Aug 18*. [Pubmed]

Chu, D. A. (1998). *Jumping into plyometrics*. Human Kinetics. [CrossRef]

Çimenli, Ö., Koç, H., Çimenli, F., & Kaçoğlu, C. (2016). Effect of an eight-week plyometric training on different surfaces on the jumping performance of male volleyball players. *Journal of Physical Education & Sport*, *16*(1). [CrossRef]

di Cagno, A., Iuliano, E., Buonsenso, A., Giombini, A., Di Martino, G., Parisi, A., Calcagno, G., & Fiorilli, G. (2020). Effects of accentuated eccentric training vs plyometric training on performance of young elite fencers. *Journal of Sports Science & Medicine*, *19*(4), 703. [CrossRef] [Pubmed]

Dinh, P., Tran, C., Dinh, T., Ali, A., & Pan, S. (2023). Hsa_circRNA_0000284 acts as a ceRNA to participate in coronary heart disease progression by sponging miRNA-338-3p via regulating the expression of ETS1. *Journal of Biomolecular Structure and Dynamics*, 1–14. [CrossRef] [Pubmed]

Fischetti, F., Alessio, V., Cataldi, S., & Greco, G. (2018). Effects of plyometric training program on speed and explosive strength of lower limbs in young athletes. *Journal of Physical Education and Sport*, *18*(4), 2476–2482. [CrossRef]

Giovanelli, N., Taboga, P., Rejc, E., & Lazzer, S. (2017). Effects of strength, explosive and plyometric training on energy cost of running in ultra-endurance athletes. *European Journal of Sport Science*, *17*(7), 805–813. [CrossRef] [Pubmed]

Gjinovci, B., Idrizovic, K., Uljevic, O., & Sekulic, D. (2017). Plyometric training improves sprinting, jumping and throwing capacities of high level female volleyball players better than skill-based conditioning. *Journal of Sports Science & Medicine*, *16*(4), 527. [CrossRef] [Pubmed]

Harmandeep, S., Satinder, K., Amita, R., & Anupriya, S. (2015). Effects of six-week plyometrics on vertical jumping ability of volleyball players. *Research Journal of Physical Education Sciences*, *2320*, 9011. [CrossRef]

Kobal, R., Loturco, I., Barroso, R., Gil, S., Cuniyochi, R., Ugrinowitsch, C., Roschel, H., & Tricoli, V. (2017). Effects of different combinations of strength, power, and plyometric training on the physical performance of elite young soccer players. *The Journal of Strength & Conditioning Research*, *31*(6), 1468–1476. [CrossRef] [Pubmed]

Krzysztofik, M., Kalinowski, R., Filip-Stachnik, A., Wilk, M., & Zajac, A. (2021). The effects of plyometric conditioning exercises on volleyball performance with self-selected rest intervals. *Applied Sciences*, *11*(18), 8329. [CrossRef]

Kumar, A., & Jadia, M. K. (2021). The Effect of Plyometric Training and Strength Training among Male College Volleyball Players-A Comparative Study. *Indian Journal of Youth and Adolescent Health (E-ISSN: 2349-2880)*, *8*(3), 15–19. [CrossRef]

Liu, J., Lei, S., & Yu, H. (2024). The Effects of Functional Training on Muscle Strength in Athletes: A Meta-Analysis. *BioRxiv*, 2006–2024. [CrossRef]

Machado, A. F., De Castro, J. B. P., Bocalini, D. S., JUNIOR, A. J. F., Nunes, R. D. A. M., & Vale, R. G. D. S. (2019). Effects of plyometric training on the performance of 5-km road runners. *Journal of Physical Education and Sport*, *19*(1), 691–695. [CrossRef]

Maciejczyk, M., Błyszczuk, R., Drwal, A., Nowak, B., & Strzała, M. (2021). Effects of short-term plyometric training on agility, jump and repeated sprint performance in female soccer players. *International Journal of Environmental Research and Public Health*, *18*(5), 2274. [CrossRef] [Pubmed]

Mroczek, D., Superlak, E., Seweryniak, T., Mackala, K., Konefal, M., Chmura, P., Borzucka, D., Rektor, Z., & Chmura, J. (2017). The effects of a Six-week plyometric training program on the stiffness of anterior and posterior muscles of the lower leg in male volleyball players. *Central European Journal of Sport Sciences*

*and Medicine*, *20*(4). [CrossRef]

Moran, J., Ramirez-Campillo, R., Liew, B., Chaabene, H., Behm, D. G., García-Hermoso, A., Izquierdo, M., & Granacher, U. (2021). Effects of vertically and horizontally orientated plyometric training on physical performance: A meta-analytical comparison. *Sports Medicine*, *51*, 65–79. [CrossRef] [Pubmed]

Muanjai, P., & Namsawang, J. (2015). Effects of stretching and cold-water immersion on functional signs of muscle soreness following plyometric training. *Journal of Physical Education and Sport*, *15*(1), 128. [CrossRef]

Novita, N., Harahap, P. O., Sagala, R. S., & Pasaribu, A. M. N. (2022). Effect of plyometric exercises on limb muscle power in volleyball players. *Jurnal SPORTIF: Jurnal Penelitian Pembelajaran*, *8*(1), 131–144. [CrossRef]

Nwanna, E., Ojo, R., Shafiq, N., Ali, A., Okello, E., & Oboh, G. (2024). An In Silico In Vitro and In Vivo Study on the Influence of an Eggplant Fruit (Solanum anguivi Lam) Diet on Metabolic Dysfunction in the Sucrose-Induced Diabetic-like Fruit Fly (Drosophila melanogaster). *Foods*, *13*(4), 559. [CrossRef] [Pubmed]

Peitz, M., Behringer, M., & Granacher, U. (2018). A systematic review on the effects of resistance and plyometric training on physical fitness in youth-What do comparative studies tell us? *PloS One*, *13*(10), e0205525. [CrossRef] [Pubmed]

Ramírez-Campillo, R., Vergara-Pedreros, M., Henríquez-Olguín, C., Martínez-Salazar, C., Alvarez, C., Nakamura, F. Y., De La Fuente, C. I., Caniuqueo, A., Alonso-Martinez, A. M., & Izquierdo, M. (2016). Effects of plyometric training on maximal-intensity exercise and endurance in male and female soccer players. *Journal of Sports Sciences*, *34*(8), 687–693. [CrossRef] [Pubmed]

Ramirez-Campillo, R., Sortwell, A., Moran, J., Afonso, J., Clemente, F. M., Lloyd, R. S., Oliver, J. L., Pedley, J., & Granacher, U. (2023). Plyometric-jump training effects on physical fitness and sport-specific performance according to maturity: a systematic review with meta-analysis. *Sports Medicine-Open*, *9*(1), 23. [CrossRef] [Pubmed]

Rao, N. R. C., & Rao, R. R. (2016). Specific influence of selected plyometric training exercises on jump serve among inter collegiate men volleyball players. *International Journal of Physical Education, Sports and Health*, *3*(6), 143–147. [CrossRef]

Rocha Henrique, J., Ramirez-Campillo, R., Afonso, J., Miguel Silva, R., Moran, J., & Manuel Clemente, F. (2023). Plyometric training programs in handball: A systematic scoping review. *Kinesiology*, *55*(2), 298–336. [CrossRef]

Saleem Naz Babari, I., Islam, M., Saeed, H., Nadeem, H., Imtiaz, F., Ali, A., Shafiq, N., Alamri, A., Zahid, R., & Ahmad, I. (2024). Design, synthesis, in-vitro biological profiling and molecular docking of some novel oxazolones and imidazolones exhibiting good inhibitory potential against acetylcholine esterase. *Journal of Biomolecular Structure and Dynamics*, 1–18. [CrossRef] [Pubmed]

Sarkar, S., Dasgupta, S., Meitei, K. K., Adhikari, S., Bandyopadhyay, A., & Dey, S. K. (2020). Effect of eccentric cycling and plyometric training on physiological and performance related parameters of trained junior track cyclists. *Polish Journal of Sport and Tourism*, *27*(1), 14–20. [CrossRef]

Shafiq, N., Arshad, M., Ali, A., Rida, F., Mohany, M., Arshad, U., Umar, M., & Milošević, M. (2024). Integrated computational modeling and in-silico validation of flavonoids-Alliuocide G and Alliuocide A as therapeutic agents for their multi-target potential: Combination of molecular docking, MM-GBSA, ADMET and DFT analysis. *South African Journal of Botany*, *169*, 276–300. [CrossRef]

Sanchez-Sanchez, J., Rodriguez-Fernandez, A., Granacher, U., Afonso, J., & Ramirez-Campillo, R. (2024). Plyometric Jump Training Effects on Maximal Strength in Soccer Players: A Systematic Review with Meta-analysis of Randomized-Controlled Studies. *Sports Medicine-Open*, *10*(1), 52. [CrossRef] [Pubmed]

Si, X. W., Yang, Z. K., & Feng, X. (2024). A meta-analysis of the intervention effect of mindfulness training on athletes' performance. *Frontiers in Psychology*, *15*, 1375608. [CrossRef] [Pubmed]

Shaık Mannan, D. P. (2015). Impact of volleyball specific plyometric training on arm and leg explosive power of male volleyball players. *Asian Journal of Applied Research (AJAR)*, *7*(1), 1–11. [CrossRef]

Sporri, D., Ditroilo, M., Pickering Rodriguez, E. C., Johnston, R. J., Sheehan, W. B., & Watsford, M. L. (2018). The effect of water-based plyometric training on vertical stiffness and athletic performance. *PLoS One*, *13*(12), e0208439. [CrossRef] [Pubmed]

Stojanović, E., Ristić, V., McMaster, D. T., & Milanović, Z. (2017). Effect of plyometric training on vertical jump performance in female athletes: a systematic review and meta-analysis. *Sports Medicine*, *47*, 975–986. [CrossRef]

Vadivelan, K., & Sudhakar, S. (2015). To compare the effects of sprint and polymetric training program on anaerobic power and agility in collegiate male football players. *International Journal of Physiotherapy*, *2*(3), 535–543. [CrossRef]

Vassil, K., & Bazanovk, B. (2012). The effect of plyometric training program on young volleyball players in their usual training period. *Journal of Human Sport and Exercise*, *7*(1), S34–S40. [CrossRef]

Vychodilová, R. (2023). *of Thesis: Effect of Movement Intervention of Fascial Fitness Method on Jumping Performance in Volleyball*. [CrossRef]

Weeks, C., Thompson, B. J., Spencer, S. B., Fisher, C., Althouse, D., Louder, T. J., & Bressel, E. (2023). Effects of Multi-joint Eccentric Training on Muscle Function When Combined With Aquatic Plyometric Training: A Minimal Dose, Mixed Training Study. *Journal of Musculoskeletal & Neuronal Interactions*, *23*(4), 386. [CrossRef] [Pubmed]

Zghal, F., Colson, S. S., Blain, G., Behm, D. G., Granacher, U., & Chaouachi, A. (2019). Combined resistance and plyometric training is more effective than plyometric training alone for improving physical fitness of pubertal soccer players. *Frontiers in Physiology*, *10*, 455009. [CrossRef]