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Effects of a volleyball-specific plyometric and spike training program (the "mega trend" program) on smash performance in youth female club athletes: a one-group pretest–posttest study

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ABSTRACT

In volleyball, a smashing performance relies on explosive power, coordination and perfect technical execution. To find out whether a 16- session volleyball-specific plyometric and spike-training program resulted in greater smash performance a study was carried out with eight youth female club volleyball athletes. Through a one-group pretest post- test quasi-experimental method, participants underwent plyometric routines combining hurdle, cone, box and pipe jumps with the spike-specific drills. The main variable here was the smash accuracy measured by the Nurhasan test across five sets where total scores were recorded against the target area before and after the program. The statistical techniques were paired- samples t test, Cohen's dz, 95 percentile CI, Wilcoxon test. From an average smash score of 5.25 ± 1.75, post-trainingscore was 8.75 ±1.58, a mean increase of 3.50 (95% CI [1.40, 5.60]), t(7)=3.95, p=.006, d z=1.40.Each player's level was enhanced. Our results point out a significant enhancement but a lack of control in the experimental design limits the establishment of an actualcausal relationship.

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Introduction

Volleyball is decided by a small number of terminal actions, and the attack, executed through the spike (smash), is consistently among the strongest discriminators between winning and losing teams across elite competition (Giatsis et al., 2023; Mikolajec et al., 2025). Because the spike is the primary means of converting an offensive sequence into a point, its effectiveness is a central training priority for players at every level of the game, from national squads to community clubs. Improving the quality of the spike, therefore, offers one of the most direct routes to raising a team's offensive output.

Mechanically, the spike is a whole-body, sequentially organized skill. The approach run converts horizontal momentum into vertical velocity at take-off (Tai et al., 2021), the jump itself relies on the stretch–shortening cycle and the rapid force production of the lower limbs (Gupta et al., 2021), and the arm swing transfers momentum along the kinetic chain to the point of ball contact, where hand and ball velocity are decisive (Slovak et al., 2023). Effective spiking thus depends jointly on explosive lower-limb power, jump height, intra- and inter-muscular coordination, movement speed, and refined technical execution, and studies of young players confirm that jumping ability and coordination together explain a meaningful portion of spike performance (Guntur et al., 2022; Irawan et al., 2023).

Plyometric jump training is one of the most strongly evidenced methods for developing the neuromuscular qualities that underpin jumping and spiking. Meta-analyses show that plyometric training improves squat-jump, countermovement-jump, and sport-specific spike-jump performance in volleyball players regardless of age or sex (Ramirez-Campillo et al., 2021; Sole et al., 2021; Novita et al., 2022), and recent syntheses focused specifically on female athletes report moderate-to-large gains in jumping, sprinting, and change-of-direction performance (Zhao et al., 2025; Lin et al., 2025). Controlled trials in youth volleyball reinforce these conclusions, with large within-group improvements in jump and service performance emerging after only four to eight weeks of training (Hernandez-Martinez et al., 2023; Longakit et al., 2025; Raiola et al., 2025; Sylvester et al., 2024; Kürkçü Akgönül et al., 2025). Reviews of applied training interventions similarly conclude that plyometric and combined regimens enhance the explosive power, agility, and strength relevant to volleyball (Keoliya et al., 2024).

Against this evidence, the practical situation of many community clubs is markedly different. The KTC Pakandangan women's club in Padang Pariaman, West Sumatra, is representative: coaches observed that the team's spikes were frequently driven out of bounds or intercepted, and they attributed this low effectiveness to insufficient lower-limb explosive power and limited hand–eye coordination. In such settings, training tends to emphasize match play and generic drills, with little structured, progressively overloaded conditioning, and jump ability and physical condition are known to constrain spike ability in comparable Indonesian youth populations (Siregar et al., 2023). An accessible, equipment-light program that can be delivered on an ordinary court is therefore attractive for this context.

Two gaps motivate the present study. First, although plyometric training reliably increases jump height, comparatively fewer studies quantify its transfer to spike accuracy, an outcome that captures the technical–tactical goal of the skill rather than jump capacity alone; combining plyometric drills with spike-specific repetition may target this transfer more directly than plyometrics in isolation (Anggraini et al., 2023; Akhmad et al., 2022). Second, much applied work in this population reports results only through the comparison of a calculated t value against a tabulated critical value, without effect sizes or confidence intervals, which limits interpretability and cumulative synthesis (Lakens, 2013). Evaluating a real-world, multimodal program with transparent effect estimates addresses both gaps.

Accordingly, this study evaluated a locally developed multimodal program, termed the "Mega Trend" program, that integrates plyometric and spike-specific drills within an authentic coaching environment, and reported its effect using recomputed statistics, effect sizes, and confidence intervals. The purpose was to determine whether smash performance changed from pre- to post-intervention. We hypothesized that smash performance would improve significantly following the 16-session program.

Method

Study Design

A one-group pretest–posttest quasi-experimental design was used. Smash performance was measured once before the intervention (pretest) and once after the 16-session program (posttest), with each athlete serving as her own reference. No control or comparison group was included, and participants were not randomized; consequently, the design supports statements of association between the program and the observed change rather than definitive causal claims, and rival explanations such as maturation, concurrent training, or familiarization cannot be excluded. This limitation is addressed explicitly in the Discussion.

Participants

Participants were eight female athletes of the KTC Pakandangan volleyball club (Padang Pariaman, West Sumatra, Indonesia). Because the accessible population comprised exactly these eight registered players, total (census) sampling was used, and the sample equaled the population. The athletes were youth players (age = 17.6 ± 1.7 years, range 15–20; height = 154.5 ± 3.9 cm; body mass = 45.1 ± 5.2 kg; body mass index = 18.8 ± 1.3 kg□ m^{-2}) with ongoing club training experience (Table 1). Individual identities are not reported; athletes are labeled P1–P8. The study followed the ethical principles of the Declaration of Helsinki; players and, where applicable, guardians were informed of the procedures, and consent to participate was obtained through the club.

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Table 1. Participant Characteristics (N = 8)

Participant	Age (years)	Height (cm)	Body mass (kg)	BMI (kg□m^{-2})
P1	18	150	40	17.8
P2	19	158	50	20.0
P3	20	158	47	18.8
P4	17	150	40	17.8
P5	19	159	52	20.6
P6	17	157	50	20.3
P7	16	152	40	17.3
P8	15	152	42	18.2
M (SD)	17.6 (1.7)	154.5 (3.9)	45.1 (5.2)	18.8 (1.3)

Note. BMI = body mass index. Anthropometric values were provided by the club. The final row shows the sample mean and standard deviation.

Intervention

The Mega Trend program was a 16-session, volleyball-specific training block that combined lower-limb plyometric drills with spike-specific drills. Although the program name derives from an admired elite spiker, its content is described here in operational, reproducible terms: it is best characterized as a volleyball-specific, explosive-power-oriented plyometric and spike-drill program. Each session followed a fixed structure: an opening (≈5 min), a general warm-up of stretching, jogging, and calisthenics (≈20 min), a core block of plyometric and spike drills (≈35–70 min), a small-sided game (≈15 min), and a cool-down (≈10 min). Thus, session duration was approximately 85–120 min. The 16 sessions were delivered three times per week over approximately five to six weeks. The core drills comprised hurdle jumps, front cone hops, crow jumps (bilateral horizontal bounds), box jumps, pipe jumps, a spike drill, and a combination drill in which a pipe jump was immediately followed by a spike from four court positions, linking explosive take-off to the attacking action. Training load progressed through increases in repetitions (from 6–8 to 12–15 per set), sets (from 2–3 to 3–4), and inter-set recovery (from 15 to 20–25 s), consistent with established plyometric progressive-overload principles (Ramirez-Campillo et al., 2020). Training load progressed across the block through increases in repetitions (from 6–8 to 12–15 per set), sets (from 2–3 to 3–4), and inter-set recovery (from 15 to 20–25 s), consistent with established plyometric progressive-overload principles (Ramirez-Campillo et al., 2020). The session-by-session prescription is summarized in Table 2. The program was delivered by the club coaching staff on the club's outdoor court; session frequency followed the club's regular schedule, and the 16 sessions were completed over approximately five to six weeks.

Table 2. Mega Trend Program: Core-Block Drills and Progression Across the 16 Sessions

Session	Core-block drills	Load (reps × sets)	Recovery
1	Hurdle jump; front cone hop; crow jump	6–8 × 2–3	15 s
2	Hurdle jump; front cone hop; crow jump	8–10 × 2–3	15 s
3	Box jump; spike drill; pipe jump + spike (4 positions)	2–8 × 2–3	15 s
4	Box jump; spike drill; pipe jump + spike (4 positions)	3–10 × 2–3	15 s
5	Front cone hop; pipe jump	5–8 × 2–3	15 s
6	Front cone hop; pipe jump	5–10 × 2–3	15 s
7	Hurdle jump; crow jump; box jump	10 × 3	15 s
8	Hurdle jump; crow jump; box jump	12 × 3	20 s
9	Pipe jump; pipe jump + spike (4 positions)	10 × 3	15 s
10	Pipe jump; pipe jump + spike (4 positions)	12 × 3	20 s
11	Box jump; crow jump	12–15 × 3	25 s
12	Box jump; crow jump	15 × 3–4	25 s
13	Front cone hop; spike drill; pipe jump + spike (4 positions)	12 × 3	20 s
14	Front cone hop; spike drill; pipe jump + spike (4 positions)	12 × 4	20 s
15	Hurdle jump; spike drill; pipe jump	5–15 × 3–4	20 s
16	Hurdle jump; spike drill; pipe jump	6–15 × 3–4	20 s

Note. Each session also included an opening (≈5 min), a general warm-up (≈20 min), a small-sided game (≈15 min), and a cool-down (≈10 min). Where the source prescription listed slightly different loads for individual drills within a session, the representative range is shown. "Pipe jump + spike (4 positions)" denotes a combination drill in which a plyometric jump is immediately followed by a spike from four court positions.

Outcome Measure

Smash performance was assessed with the spike (smash) accuracy test described by Nurhasan (2001), a standard instrument in Indonesian physical-education testing. On a full court with a regulation net, the athlete received an open set near the top of the net and, with or without an approach, jumped and struck the ball over the net into the opponent's court, where numbered target zones were marked on the floor. Each athlete performed five attempts; the score for each attempt was the value of the target zone in which the ball landed, and a ball that struck the net or landed out of bounds scored zero. The outcome for each athlete was the sum of the five attempts, so higher totals indicate greater spiking accuracy and control. Balls set inappropriately for the athlete were not counted and were repeated. The same court, net height, testing protocol, and scoring were used at pretest and posttest. No formal reliability coefficient was calculated in the present sample; therefore, inter-rater reliability and test-retest reliability are not claimed. The same court, net height, testing protocol, and scoring rules were used at pretest and posttest.

Data Collection Procedure

The procedure followed three phases. At the pretest, each athlete completed the five-attempt smash test under the conditions described above, and scores were recorded on a standardized sheet. The 16-session Mega Trend program was then delivered. At the posttest, the smash test was repeated using an identical protocol. Testing was conducted on the club's outdoor court; environmental conditions (for example, wind and surface) therefore reflect an applied, ecologically valid setting but could not be fully standardized, a point considered in the Limitations.

Statistical Analysis

All analyses were computed from the raw individual scores rather than transcribed from the original report, and the paired t statistic reproduced the value reported in the source thesis ($t = 3.95$), supporting the integrity of the dataset. Descriptive statistics are presented as mean, standard deviation, minimum, and maximum. The pre-to-post change was evaluated with a paired-samples t-test on the summed smash scores, accompanied by the mean difference, its 95% confidence interval, and the percentage change in means. Because both measurements came from the same athletes, a between-groups homogeneity-of-variance test was not treated as a prerequisite for the paired test and is not reported as such. The distributional assumption was checked with the Shapiro–Wilk test; given the small sample ($n = 8$), normality results were interpreted cautiously and were supplemented by a Wilcoxon signed-rank sensitivity analysis. Effect size was quantified with Cohen's d_z (the standardized mean difference for paired data), with a small-sample (Hedges) correction and a 95% confidence interval obtained by noncentral-t inversion; d_z values of about 0.2, 0.5, and 0.8 denote small, medium, and large effects, respectively (Cohen, 1988; Lakens, 2013). The alpha level was set at .05.

Results and Discussions

All eight athletes completed the pretest, the 16-session program, and the posttest, with no dropouts. The study design and testing sequence are summarized in Figure 1.

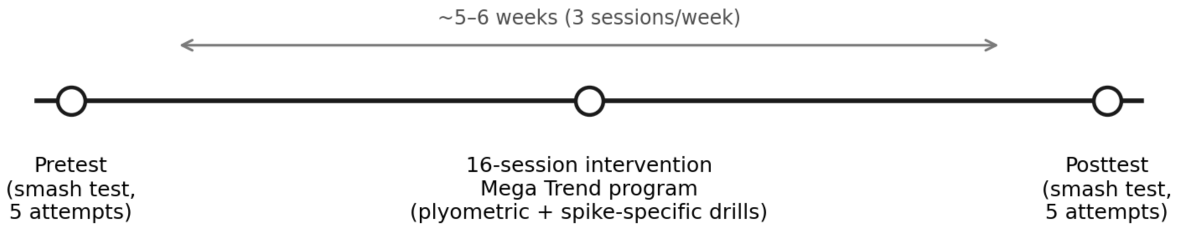

Figure 1. Study Design and Intervention Timeline

Note. Smash performance was measured before and after a 16-session volleyball-specific plyometric and spike training program.

Smash performance increased from a pretest mean of 5.25 ± 1.75 points (range 3–7) to a posttest mean of 8.75 ± 1.58 points (range 7–11). The mean improvement was 3.50 points (95% CI [1.40, 5.60]), corresponding to a 66.7% increase in the group mean. The paired-samples t-test indicated a statistically significant change, $t(7) = 3.95$, $p = .006$, with a large effect size, $d_z = 1.40$ (95% CI [0.38, 2.37]; Hedges-corrected $d_z = 1.24$). Descriptive and inferential results are reported in Table 3 and displayed in Figure 2.

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The Shapiro–Wilk test was consistent with normality for the pretest (W = .85, p = .089), posttest (W = .88, p = .175), and change scores (W = .90, p = .27). Because of the small sample, a Wilcoxon signed-rank test was also conducted as a sensitivity analysis and corroborated the parametric finding (p = .008).

Table 3. Descriptive and Inferential Statistics for Smash Performance (N = 8)

Measure	Pretest M (SD)	Posttest M (SD)	Mean change [95% CI]	t	df	p	dz
Smash score	5.25 (1.75)	8.75 (1.58)	3.50 [1.40, 5.60]	3.95	7	.006	1.40

Note. M = mean; SD = standard deviation; CI = confidence interval; dz = Cohen's dz for paired data. The percentage change in the group mean was +66.7%. A Wilcoxon signed-rank sensitivity analysis yielded p = .008.

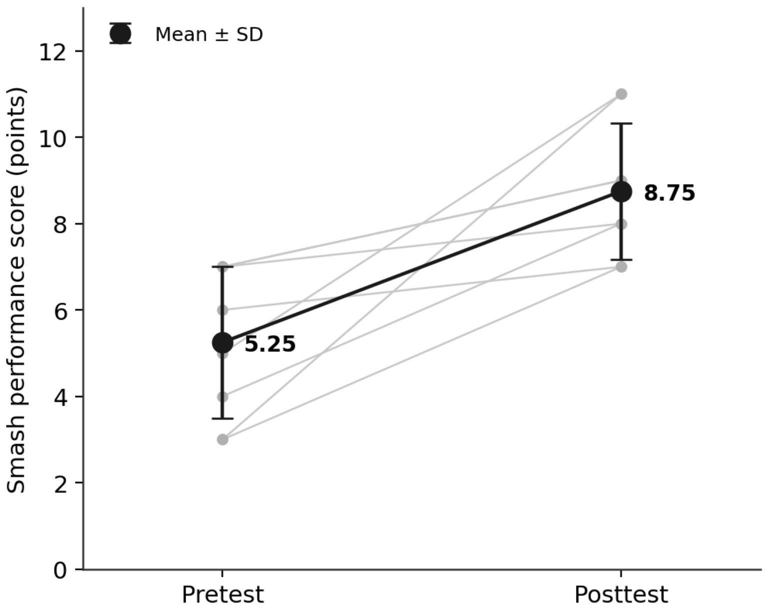

Figure 2. Pretest and Posttest Smash Performance

Note. Black markers show the group mean ± SD; grey lines and points show individual athletes. Higher scores indicate greater spiking accuracy.

The improvement was consistent across the group: every athlete scored higher at posttest than at pretest, with individual gains ranging from 1 to 8 points (Table 4; Figure 3). The largest absolute gains occurred in athletes with lower pretest scores (for example, P5 improved from 3 to 11 points), whereas athletes already near the upper end of the pretest range showed smaller gains (for example, P8 improved from 7 to 8 points), a pattern consistent with a larger ceiling for improvement among lower-scoring players.

Table 4. Individual Pretest–Posttest Smash Scores and Change

Participant	Pretest	Posttest	Change	Change (%)
P1	7	9	+2	+29
P2	3	7	+4	+133
P3	5	11	+6	+120
P4	6	7	+1	+17
P5	3	11	+8	+267
P6	4	8	+4	+100
P7	7	9	+2	+29
P8	7	8	+1	+14
M	5.25	8.75	+3.50	+66.7

Note. Participants are labeled P1–P8. All eight athletes improved from pretest to posttest.

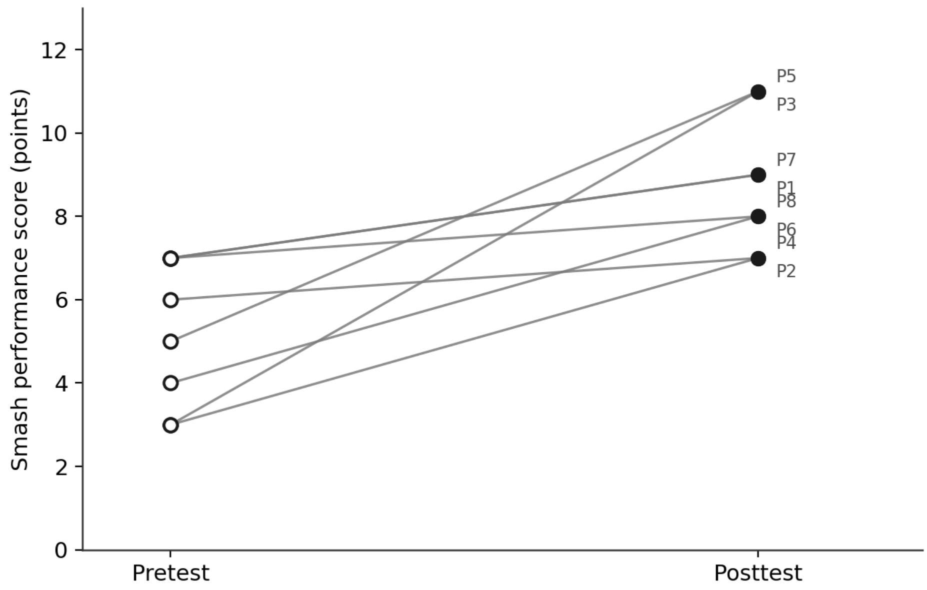

Figure 3. Individual Changes in Smash Performance

Discussion

Principal Finding

Following the 16-session Mega Trend program, smash performance improved by a mean of 3.50 points (+66.7%), a statistically significant change with a large effect size (dz = 1.40) that was consistent across all eight athletes and robust to a nonparametric sensitivity analysis. Within the constraints of an uncontrolled design, the program was thus associated with a substantial and uniform improvement in spiking accuracy in youth female club players.

Comparison With Previous Research

The direction of the effect aligns with the wider literature, but its magnitude and outcome warrant careful comparison. Controlled trials of plyometric training in youth volleyball report large within-group standardized gains in jump and service performance; for example, Hernandez-Martinez et al. (2023) observed dz values of roughly 1.3 to 2.2 for squat-, countermovement-, and drop-jump performance and about 1.5 for service speed after progressive plyometric training, and aquatic plyometric training improved spike height with a large effect (Hedges' g $\approx$ 1.09) in youth female players (Dell'Antonio et al., 2022). The present effect size (dz = 1.40) sits within this range. However, two features distinguish the current result. First, the outcome here was spike accuracy rather than jump height, so the improvement reflects transfer to the attacking action itself, plausibly aided by the spike-specific drills embedded in the program rather than by plyometrics alone (Anggraini et al., 2023; Raiola et al., 2025). Second, and in the opposite direction, the absence of a control group means that part of the observed change may reflect factors other than the training stimulus, so the effect is likely an upper-bound estimate relative to the net gains reported in controlled trials.

The present effect is also broadly consistent with the wider plyometric literature. Ramirez-Campillo et al. (2021) synthesized evidence showing beneficial effects of plyometric jump training on physical fitness in amateur and professional volleyball players. Sylvester et al. (2024) reported improvements in stretch-shortening-cycle function and physical qualities in female volleyball players, while Raiola et al. (2025) documented performance-related benefits of plyometric training in youth volleyball. Broader syntheses by Lin et al. (2025) and Zhao et al. (2025) likewise indicate moderate-to-large improvements in physical performance among female team-sport athletes. The present study extends this literature by examining smash accuracy rather than jump height or general physical performance. However, because the current intervention also included spike-specific drills, the observed change cannot be attributed to plyometric training alone. The program was also delivered on an outdoor court and used a summed target-zone accuracy score rather than instrumented jump height or ball velocity. Therefore, differences in sample, training dose, drill selection, testing protocol, and outcome measure caution against treating the 66.7% change as directly comparable with effect estimates for other performance outcomes. The uncontrolled design further means that maturation, concurrent training, familiarization, and other contextual factors may have contributed to the observed gain.

Possible Mechanisms

Because the study did not measure physiological or biomechanical variables, the following mechanisms are offered as plausible explanations rather than demonstrated pathways. The improvement may reflect neuromuscular adaptations commonly associated with plyometric training, including enhanced rate of force development, improved intra- and inter-muscular coordination, and greater efficiency of the stretch–shortening cycle and muscle–tendon stiffness during the take-off (Ramirez-Campillo et al., 2021; Sylvester et al., 2024; Iranpour et al., 2025). Such adaptations could raise lower-limb explosive power and jump quality, which are known contributors to spiking in young players (Guntur et al., 2022). The gains could also be explained in part by improved coordination of the approach–jump–swing sequence and by sport-specific technical repetition, given that the program repeatedly linked explosive take-offs to spikes from multiple court positions; more effective momentum transfer along the kinetic chain and higher hand and ball velocity at contact would be consistent with this account (Tai et al., 2021; Gupta et al., 2021; Slovak et al., 2023). These explanations are consistent with the data but were not directly tested.

Practical Implications

For coaches in resource-limited club settings, the program has a practical advantage because it uses simple court-based drills and does not require laboratory or wearable technology. A 16-session block delivered three times per week, with progressive repetitions, sets, and recovery, can be incorporated into routine training while linking explosive take-off directly to spike execution. Coaches should nevertheless individualize workload, emphasize safe landing mechanics, provide adequate recovery, and avoid interpreting the present 66.7% change as a guaranteed training effect because the estimate comes from an uncontrolled study.

Limitations

Several limitations qualify these results. The one-group pretest–posttest design lacked a control group and randomization, so maturation, concurrent volleyball training, and familiarization with the test cannot be separated from the program's effect, and causal interpretation is not warranted. The sample was small ($n = 8$) and drawn from a single team, which limits precision and generalizability, as reflected in the wide confidence intervals. Testing took place outdoors, where wind and surface conditions could not be fully standardized and may have influenced scores. Reliability and validity of the smash test were not established in this sample, and psychological and physiological factors, as well as day-to-day variation, were not controlled; the original thesis likewise noted psychological, physiological, weather, and time constraints as limitations. Finally, only spike accuracy was measured, so the study cannot speak to jump height, ball velocity, or match-play outcomes.

Future Research

Future studies should employ randomized controlled designs with adequate sample sizes and, where possible, multiple teams, to isolate the program's effect. Comparisons between female and male athletes, longer intervention periods, and retention or follow-up testing would clarify the durability of any gains. Incorporating biomechanical and physiological measures, such as jump height, approach velocity, ball velocity, force-plate kinetics, electromyography, or wearable-sensor data, would allow the proposed mechanisms to be tested directly, and linking training-induced changes to match-performance outcomes would strengthen the practical relevance of this line of work.

Conclusions

In eight youth female club volleyball athletes, a 16-session volleyball-specific plyometric and spike training program was associated with a significant, large, and consistent pre-to-post improvement in smash performance (5.25 to 8.75 points; +66.7%; $t(7) = 3.95$, $p = .006$, $dz = 1.40$). Because the study used a one-group pretest–posttest design without a control group, these findings should be interpreted as preliminary evidence of association rather than proof of a causal effect. The findings nevertheless provide applied support for combining plyometric and spike-specific drills in youth female club volleyball. Future controlled trials should recruit substantially larger samples and determine sample size a priori using power analysis; as a pragmatic planning target, at least 25–30 athletes per group would provide a stronger basis for estimation than the present sample of eight. Future studies should also incorporate objective performance measures and follow-up testing.

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