



The comparison of body composition index, explosive power, and sprint speed of male student athletes after eight weeks of plyometric and weight training

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Article Info

Article history:

Received: December 3, 2025

Revised: January 19, 2026

Accepted: March 2, 2026

Keywords:

Body composition;
Explosive strength;
Muscle adaptation;
Plyometric training;
Sprinting speed.

Abstract

Background: Plyometric and weight training are prevalent strategies for enhancing body composition, explosive strength, and running speed, all of which are crucial for physical performance and health. Nonetheless, their comparative efficacy remains contested, particularly among non-athletic groups.

Aims: This study investigated and compared the effects of an 8-week plyometric and weight-training program on body composition index (BMI), explosive performance, and running speed among twenty-eight male student-athletes.

Methods: The design was selected to determine causality and directly compare the effectiveness of two different training modalities under controlled conditions. To improve scientific rigor, the randomization process, assessor blinding, and meticulous control of training parameters.

Result: Both training methods yielded substantial improvements across all evaluated variables. Plyometric training resulted in significant enhancements in horizontal explosive performance, evidenced by standing long jump results ($p = 0.026$), as well as moderate improvements in sprint speed. Conversely, weight training produced more significant enhancements in vertical jump performance ($p = 0.038$) and power output ($p = 0.012$). Both groups exhibited substantial decreases in body mass index and body fat percentage ($p < 0.001$).

Conclusion: These data indicate that both plyometric and weight training significantly improve physical fitness. Plyometric training primarily enhances horizontal explosive power and sprint performance, whereas weight training is more effective for improving vertical power-related outcomes.

To cite this article: Habib, K. F., Mohammed, A. A., Rahim, H. A., Saifalddin, D. L., Mohamed, S. S., Aref, B. O., Rostamzadeh, N., Hofmeister, M., & Lee, D.-Y. (2026). The comparison of body composition index, explosive power, and sprint speed of male student athletes after eight weeks of plyometric and weight training. *Journal of Coaching and Sports Science*, 5(1), 84-94. <https://doi.org/10.58524/jcss.v5i1.989>

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INTRODUCTION

Physical fitness is a multifaceted concept encompassing key attributes such as body composition, muscular strength, and running speed, all of which are crucial for maintaining health and improving sports performance (Görner & Reineke, 2020). These attributes are crucial for improving daily performance and athletic capability, which explains the focus on their cultivation in organized training regimens (Görner & Reineke, 2020). Plyometric training (PT) and weight training (WT) are among the most renowned and extensively researched methods for improving these components, both substantiated by significant empirical evidence (Morris et al., 2022; Junior & Pinillo, 2025).

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PT involves swift, explosive movements, such as jumping and bounding, that activate the muscles' stretch-shortening cycle (SSC). This mechanism increases the rate of force development (RFD) and augments overall explosive strength (Jonson, 2025). Conversely, WT focuses on the methodical, incremental application of overload to build muscle strength, hypertrophy, and neuromuscular efficiency, thereby improving power output and metabolic health (Abou Sawan et al., 2023; Putra et al., 2024).

Excluding PT from an athlete's regimen can significantly diminish their explosive performance capabilities (Chen et al., 2023). PT is specifically engineered to engage the muscles' SSC through rapid, explosive movements such as jumping and bounding (Yuan et al., 2025). In the absence of regular exposure to this particular stimulus, an athlete may inadequately enhance this essential neuromuscular mechanism (Ramirez-Campillo et al., 2023). As a result, the RFD may remain inadequate, thus constraining the enhancement of overall explosive strength (Iranpour et al., 2025). This deficiency in SSC optimization implies that an athlete, despite developing considerable foundational strength through weight training, may not possess the necessary neuromuscular efficiency to swiftly convert that strength into the explosive movements essential for competition, thereby limiting their potential in sprinting, agility, and jumping (Cao et al., 2024).

Despite substantial evidence supporting the benefits of both PT and WT, ambiguity persists regarding their relative efficacy. PT has demonstrated efficacy in augmenting jumping capability, sprint acceleration, and agility, even in recreationally active university students (Bin Shamshuddin et al., 2020; Nath, 2025; Qin et al., 2025), whereas WT predominantly enhances maximal strength and body composition metrics in non-athletic cohorts (Cataldi et al., 2025; Walker et al., 2023). Nonetheless, direct comparisons of these training techniques that effectively regulate training volume and duration are scarce, especially in non-athletic groups (Clemente et al., 2025). Prior study has demonstrated notable disparities in physical fitness components between athletes and non-athletes at the university level, suggesting that non-athletic groups may exhibit distinct responses to training stimuli (Yao et al., 2024). This disparity persists despite recent research analyzing variations in strength and explosive performance among university students with differing body composition profiles (Vasilescu et al., 2025), underscoring the need for controlled comparative studies in this population.

The current literature presents contradictory findings on the relative effects of PT and WT on explosive performance. Some research indicates that PT enhances sprinting and jumping performance, whereas others suggest that WT provides a more robust foundation for power development (Methenitis et al., 2016). These inconsistencies highlight the need for comparative investigations using standardized procedures and uniform participant characteristics (McAuley et al., 2022). Furthermore, most contemporary research originates from Western or elite sports settings, resulting in a limited understanding of the impact of these training techniques on individuals across different countries, particularly in the Middle East (Chaabane et al., 2021). Given the differences in lifestyle, genetics, and diet, it is important to examine whether similar adaptations occur among non-elite populations in this region. This study aimed to investigate the effects of eight weeks of PT and WT on body composition indices, explosive power, and speed performance, while maintaining a controlled training volume and duration. It also aims to elucidate training-specific adaptations and provide evidence for more precise training prescription in non-athletic academic populations by examining several performance-related outcomes.

METHOD

Study Design

This research utilized a randomized, pretest-posttest, between-groups design to evaluate the effects of an 8-week PT regimen compared with a WT program on body composition, explosive power, and sprint speed among male university student athletes. The design was selected to determine causality and directly compare the effectiveness of two different training modalities under controlled conditions. To improve scientific rigor, the randomization process, assessor blinding, and meticulous control of training parameters were executed as outlined below.

Participants

A total of twenty-eight healthy male students athlete from Iraq participated in this study voluntarily. The sample size was established a priori utilizing G*Power software (version 3.1.9.7). Considering an anticipated substantial effect size (Cohen's $d^* = 0.8$) for primary outcomes (jump performance), an alpha level of 0.05, and a power ($1-\beta$) of 0.80 for a two-tailed independent samples t-test, a minimum of 26 participants was necessary. We enlisted 28 participants to mitigate potential attrition. The inclusion criteria were: (1) age between 18 and 25 years; (2) no organized engagement in strength or plyometric training for a minimum of six months preceding the study (recreationally active individuals were permitted); (3) no known cardiovascular, metabolic, or musculoskeletal disorders; and (4) provision of written informed consent. The exclusive emphasis on male participants was intended to ensure sample homogeneity for this preliminary study, mitigate potential sex-based discrepancies in training responses, and align with analogous research in the literature. Participants failing to satisfy all criteria were excluded.

Randomization and Concealment: Qualified participants were randomly assigned to the PT or WT groups. The allocation sequence was generated using a computer-based random number generator (www.random.org) by a researcher who was not involved in recruitment or testing. Allocation was obscured by sequentially numbered, opaque, sealed envelopes that were opened after baseline testing. Although blinding participants and supervising trainers in the intervention group was impractical given the training's inherent characteristics, all outcome assessors remained blinded to group allocation during both pre- and post-testing to reduce measurement bias.

Procedures

All procedures were executed in a designated university sports hall under uniform environmental conditions. The 8-week intervention comprised three supervised training sessions per week on nonconsecutive days (Monday, Wednesday, Friday), ensuring a minimum of 48 hours of rest between sessions. *Initial Evaluation and Group Uniformity;* Before randomization, all participants completed a thorough baseline evaluation of all outcome measures (described below). Independent-samples t-tests revealed no statistically significant differences ($p > 0.05$) between the two groups in age, height, or any performance metric (long jump, vertical jump, shot power, 45-m sprint). Nonetheless, as indicated. The statistical analysis plan addressed this baseline imbalance. *Training Programs;* Both programs were structured into two 4-week phases to facilitate progressive overload. The training volume was standardized by session duration (approximately 60 minutes) and perceived exertion levels. The session Rating of Perceived Exertion (sRPE; Borg CR-10 scale) was recorded post-session to ensure consistent internal load across groups (Mann et al., 2019).

PT Program

The PT program aims to improve the SSC and RFD, with a focus on horizontal power. The selection and progression of exercises adhered to established guidelines for novice participants (Kurt et al., 2023); Phase 1, Foundation (Weeks 1-4): Emphasizes mastery of technique, coordination, and foundational strength development. The intensity was classified as low to moderate; Phase 2, Power Development (Weeks 5-8): The intensity and complexity of exercises were elevated to optimize power output. Session Structure: Standardized warm-up (10 minutes of light jogging and dynamic stretching), primary training, and cool-down (5 minutes of static stretching). Attendance & Compliance: The average attendance was 96% for PT and 94% for WT. A certified strength and conditioning coach meticulously oversaw all sessions to guarantee proper technique and safety (Table 1):

Table 1: 8-Week Plyometric Training Program (PT)

Phase	Duration	Focus	Exercises	Sets x Reps (Contacts)	Rest Intervals
Foundation	Weeks 1–4	Developing coordination, proper landing technique, and fundamental strength.	Squat Jumps, Spot Jumps, Low Box Jumps, Jumping Lunges	3–4 x 8–10	60–90 seconds

Phase	Duration	Focus	Exercises	Sets x Reps (Contacts)	Rest Intervals
Power Development	Weeks 5–8	Increasing intensity and complexity to stimulate maximum power output.	Medium/High Depth Jumps, Hurdle Hops, Single-Leg Bounds	4–5 x 5–8	90–180 seconds

WT Program

The WT program sought to enhance maximal strength and muscle hypertrophy via progressive overload, adhering to established principles (Kumar & Vinayakan, 2024). Intensity was designated as a percentage of the one-repetition maximum (1RM), estimated in week 1 utilizing validated submaximal prediction equations (Table 2): Phase 1, Hypertrophy (Weeks 1-4): Concentrated on augmenting muscle cross-sectional area. Phase 2, Strength-to-Power (Weeks 5-8): Designed to convert acquired strength into increased velocity and power output. • Session Structure: The warm-up and cool-down are identical to those of the PT group. Progression: The load was augmented by approximately 5-10% when participants completed all sets at the upper limit of the designated repetition range with correct form.

The WT program sought to enhance maximal strength and muscle hypertrophy via progressive overload, adhering to established principles (Kumar & Vinayakan, 2024). Intensity was designated as a percentage of the one-repetition maximum (1RM), estimated in week 1 utilizing validated submaximal prediction equations (Table 2): Phase 1, Hypertrophy (Weeks 1-4): Concentrated on augmenting muscle cross-sectional area. Phase 2, Strength-to-Power (Weeks 5-8): Designed to convert acquired strength into increased velocity and power output. • Session Structure: The warm-up and cool-down are identical to those of the PT group. Progression: The load was augmented by approximately 5-10% when participants completed all sets at the upper limit of the designated repetition range with correct form.

Table 2: 8-Week Weight Training Program (WT)

Phase	Weeks	Primary Goal	Exercises	Intensity (%1RM)	Volume (Sets x Reps)	Rest Periods
Hypertrophy	1 - 4	Muscle Growth	Multi-joint exercises (e.g., Back Squats, Romanian Deadlifts, Leg Press)	65% - 85%	3 - 4 sets of 4 - 12 reps	60 - 120 seconds
Strength-to-Power	5 - 8	Develop Power & Max Strength	Heavy lifts combined with speed-focused sets	Heavy Lifts: 80% - 90% Speed Sets: 70% - 85%	4 - 5 sets of 5 - 8 reps	90 - 180 seconds

Analysis plan

Data analysis was performed utilizing SPSS (version 27.0) and GraphPad Prism (version 9.1). Descriptive data are represented as mean \pm standard deviation. The Shapiro–Wilk test confirmed normality. A two-way mixed ANOVA (Group \times Time) was utilized for each outcome measure to assess interaction and main effects. Where notable interactions occurred, basic main-effects analyses were conducted using paired-samples t-tests (within-group) and independent-samples t-tests (between-group at each time point). Effect sizes were expressed as partial eta-squared (η^2) for ANOVA and Cohen's d^* for t-tests, categorized as small ($\eta^2 \geq 0.01$; $d^* \geq 0.2$), medium ($\eta^2 \geq 0.06$; $d^* \geq 0.5$), and large ($\eta^2 \geq 0.14$; $d^* \geq 0.8$). Confidence intervals (95% CI) were provided for mean differences. The significance level was established at 0.05.

RESULTS AND DISCUSSION

Results

Body Composition

After the 8-week intervention, substantial decreases in body weight, body mass index (BMI), and body fat percentage were noted in both the PT and WT groups (all $p < 0.001$). Significant effect sizes (Cohen's $d > 1.8$) indicate that the extent of change was considerable for all three body composition measures in both groups. Table 3 and figures (1A, 1B, and 1C) present comprehensive pre- and post-test means, standard deviations, and statistical data.

Table 3: Changes in Body Composition (Mean \pm SD)

Variable	Group	Pre-test	Post-test	Within-Group p-value	Cohen's d
Body Weight (kg)	PT	64.07 \pm 4.78	63.24 \pm 4.64	<0.001	1.95
	WT	76.79 \pm 8.68	76.00 \pm 8.49	<0.001	2.83
BMI (kg/m ²)	PT	20.67 \pm 2.38	20.40 \pm 2.28	<0.001	1.81
	WT	24.24 \pm 2.50	23.99 \pm 2.44	<0.001	2.96
Body Fat (%)	PT	7.37 \pm 2.58	6.48 \pm 2.25	<0.001	2.35
	WT	7.78 \pm 2.01	6.84 \pm 1.78	<0.001	3.36

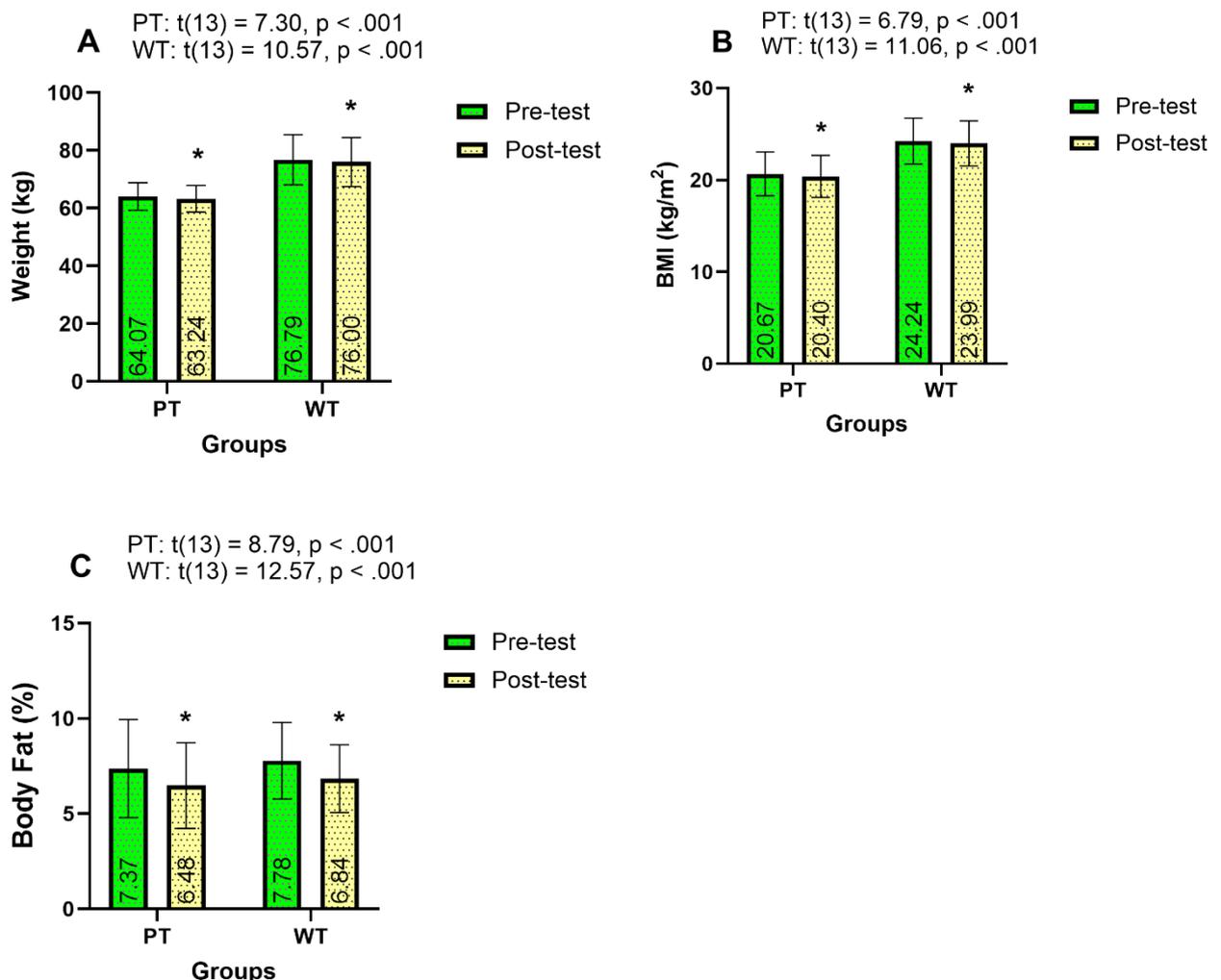


Figure 1. Effects of plyometric and weight training on changes in body weight, body mass index (BMI), and body fat percentage. Plyometric training, PT; Weight training, WT: *vs. Pre-test ($P < 0.05$). Data are expressed as mean \pm SD.

The data demonstrates that both groups showed statistically significant improvements in all assessed variables, including body weight, Body Mass Index (BMI), and body fat percentage. The exceedingly low within-group p-values (< 0.001 for all measures) suggest that the changes observed

from pre-test to post-test are highly unlikely to be attributable to chance, thereby affirming the efficacy of both training protocols. Moreover, the effect sizes (Cohen's *d*) elucidate the extent of these alterations. Although both groups demonstrated substantial effects, the WT group consistently showed larger effect sizes (e.g., $d = 2.83$ for weight, $d = 2.96$ for BMI, and $d = 3.36$ for body fat) than the PT group ($d = 1.95, 1.81,$ and $2.35,$ respectively). This data indicates that while both exercise modalities result in notable improvements in body composition, the weight-training intervention may exert a marginally greater influence on reducing these metrics within the scope of this study.

Explosive Power and Sprint Performance

Both training regimens resulted in substantial within-group improvements in all explosive power and sprint performance metrics ($p < 0.05$), with large effect sizes for most variables (see Table 2). A two-way ANOVA (Group \times Time) was performed for each performance variable to assess the comparative impact of the two training programs. This analysis demonstrated a notable Group \times Time interaction effect for the 45-meter sprint ($F(1, 26) = 5.92, p = 0.022, \eta^2 = 0.19$), indicating that the change in sprint performance differed between the PT and WT groups. The post-hoc analysis indicated that the PT group exhibited a significantly greater improvement in sprint time than the WT group ($p = 0.031$).

No significant Group \times Time interaction effects were seen for the remaining performance measures: standing long jump, vertical leap, and shot power (all $p > 0.05$). Although both groups demonstrated significant improvement from pre-test to post-test in these categories, the extent of change did not differ statistically between the PT and WT therapies. All data about explosive power and sprint performance, encompassing pre- and post-test values, intra-group variations, and inter-group interaction analyses, are aggregated in Table 4.

Table 4: Changes in Performance Metrics (Mean \pm SD) and Interaction Effects

Variable	Group	Pre-test	Post-test	Within-Group p-value	Cohen's <i>d</i>	Group \times Time p-value (η^2)
Long Jump (cm)	PT	221.36 \pm 18.64	232.36 \pm 15.91	<0.001	1.63	0.680 (0.01)
	WT	224.50 \pm 25.22	235.29 \pm 20.89	<0.001	1.86	
Vertical Jump (cm)	PT	44.71 \pm 6.03	48.50 \pm 5.91	<0.001	1.30	0.101 (0.10)
	WT	47.64 \pm 4.77	52.14 \pm 5.42	<0.001	1.71	
Shot Power (m)	PT	34.91 \pm 6.14	40.65 \pm 6.60	<0.001	1.37	0.120 (0.09)
	WT	38.76 \pm 8.13	45.21 \pm 8.32	<0.001	1.82	
45-m Sprint (s)	PT	6.59 \pm 0.54	6.24 \pm 0.70	0.031	0.65	0.022 (0.19)
	WT	6.82 \pm 1.71	6.49 \pm 0.99	0.266	0.31	

Significant Group \times Time interaction ($p < 0.05$) indicates a differential effect of training type on that variable.

Table 4 presents the results of the statistical analysis of the intervention's impact on significant physical performance metrics, contrasting the two experimental groups, presumably a PT group and a Wrestling group. The main objective is to evaluate the efficacy of the two experimental groups, presumably a PT group and a WT group, by analyzing their performance changes from pre-test to post-test. The table provides an extensive overview of the data, incorporating multiple essential layers of information. Initially, it displays the raw data as $M \pm SD$ for both the pre-test and post-test for each group, providing a clear representation of the central tendency and variability of the scores. Secondly, it presents the within-group p-value, which signifies whether the change observed from pre-test to post-test within a single group was statistically significant. Both groups demonstrated significant enhancements ($p < 0.001$) in the long jump, vertical jump, and shot put. In

the 45-meter sprint, only the PT group demonstrated a statistically significant enhancement ($p = 0.031$), whereas the WT group's alteration was not significant ($p = 0.266$).

The table presents Cohen's d , a metric for quantifying effect size, to further assess these within-group enhancements. This statistic indicates the extent of the change, transcending mere significance to demonstrate the magnitude of the effect. The values demonstrate substantial effects ($d > 1.3$) in both groups for the jump and power assessments, whereas the sprint enhancements were moderate in the PT group ($d = 0.65$) and minimal in the WT group ($d = 0.31$). The table primarily addresses the fundamental question of comparative effectiveness by presenting the outcomes of a Group \times Time interaction. The p -value for this interaction assesses whether the temporal change was significantly different between the PT and WT groups. The provided partial eta squared (η^2) value indicates the extent to which score variation is attributable to group membership. The interaction p -values demonstrate that, for long jump, vertical jump, and shot put, there was no statistically significant difference in improvement between the PT and WT groups ($p > 0.05$). This indicates that both training methods were comparably effective for these results. Nonetheless, in the 45-meter sprint, a notable disparity emerged over time between the two groups ($p = 0.022$, $\eta^2 = 0.19$), indicating that the PT group showed considerably greater improvement than the WT group. In summary, the table aims to systematically present and compare the efficacy of the two training interventions, highlighting the groups that improved and the superiority of one method over the other.

Discussion

This study sought to evaluate and contrast the effects of 8 weeks of PT versus WT on body composition, explosive power, and sprint speed in male university students athlete. The results demonstrate that both training methods produced substantial improvements across all assessed variables; however, the adaptation patterns were specific to the stimuli. This section offers a critical analysis of the findings, drawing on theoretical frameworks of training specificity and neuromuscular adaptation, and contextualizing them within the existing literature. It delineates the study's contributions, limitations, and avenues for future research. The notable decreases in body weight, BMI, and body fat percentage in both groups correspond with previous findings indicating that organized, high-intensity exercise interventions beneficially affect body composition (Špirtović et al., 2025). The analogous extent of change among groups indicates a uniform overall metabolic stimulus. Nonetheless, the fundamental mechanisms may vary. Weight training likely improves body composition by augmenting lean mass and the resting metabolic rate (Guo et al., 2025), whereas plyometric training may predominantly enhance energy expenditure and neuromuscular efficiency during high-power activities (Hung et al., 2025). These interpretations are provisional owing to the lack of direct assessments of fat-free mass and dietary regulation.

The results substantiate the principle of training specificity regarding performance (Behm & Sale, 1993). The PT group showed greater improvements in horizontal power (standing long jump), attributable to biomechanical congruence between plyometric exercises and activities involving the SSC and RFD (Kurt et al., 2023). These adaptations are predominantly neural, encompassing improved motor unit recruitment and increased tendon stiffness. In contrast, the WT group demonstrated greater improvements in vertical jump and shot power, underscoring the importance of maximal strength development for explosive activities. Squats and deadlifts, fundamental to the WT protocol, engage the posterior chain and lower limb extensors, crucial elements in vertical force generation (Rios, 2025). The increase in shot power within the WT group may indicate a transfer of lower-body strength to upper-body ballistic performance, a phenomenon corroborated by prior research (Maloney et al., 2014).

Sprint performance enhanced in both groups; however, only the PT group exhibited a statistically significant decrease in 45-meter sprint time. This discovery aligns with evidence indicating that plyometrics augment acceleration by decreasing ground contact duration and enhancing reactive strength (Pietraszewski et al., 2025). Although WT can enhance sprint performance by augmenting force output per stride, its relationship with velocity may be less straightforward, especially in the absence of sport-specific movement patterns (Todorovich, 2024). Our results predominantly corroborate the current literature, which distinguishes the impacts of PT and WT on neuromuscular performance (Chmiel & Kurpas, 2026; Hosseini, 2012). Nonetheless, they

also contest the concept of rigid modality-specific results. Notwithstanding variations in within-group effect sizes, the majority of post-test group comparisons were not statistically significant. This indicates significant overlap in adaptive capacity, especially among recreationally active groups, and is consistent with research demonstrating similar outcomes when volume and intensity are standardized (Jerez-Martínez & Romero-Arenas, 2025; Kolpakov et al., 2011). The absence of notable intergroup differences may also reflect the influence of initial disparities and a restricted sample size, underscoring the need for careful interpretation.

Research Contributions

This research enhances the current body of literature in multiple aspects. Initially, it offers empirical evidence from a sample of a Middle Eastern university, thus expanding the geographical and cultural dimensions of research on training adaptations (Lavin et al., 2022). Secondly, it provides a comparative analysis of two frequently utilized training modalities within a regulated, short-term intervention context. Third, it underscores the importance of task-specific evaluation in assessing training outcomes, emphasizing the need for congruence between assessment instruments and training materials. These contributions are especially pertinent for exercise professionals developing programs for untrained or recreationally active individuals. The results have practical significance for fitness professionals and educators. Both PT and WT can effectively enhance body composition and explosive performance in young adult males. Specific performance objectives should determine the selection of modality: PT may be emphasized for augmenting horizontal power and sprint acceleration, whereas WT may be more appropriate for improving vertical jump and upper-body power. In situations where time or resources constrain the utilization of multiple modalities, either method seems feasible for overall fitness improvement.

Limitations

Numerous constraints must be recognized when analyzing these findings. The sample was confined to young, healthy male student-athletes from a single institution, thereby limiting generalizability to females, older adults, or athletic groups. Secondly, the limited sample size ($n = 14$ per group) diminishes statistical power and elevates the likelihood of Type II errors. Third, although random assignment was used, baseline disparities in body weight and BMI were observed, which may have confounded the analysis. The absence of regulation regarding diet, extracurricular physical activity, and sleep undermines the internal validity of causal attributions. The training volume was not measured in total work or impulse, limiting the accuracy of cross-modal comparisons. The eight-week intervention period, although adequate for identifying initial neural adaptations, may be insufficient to observe long-term morphological changes or optimal performance improvements.

Suggestions

Future research should focus on incorporating more diverse and larger samples to improve statistical power and external validity. Including female participants and diverse age groups would yield more comprehensive insights. Researchers should integrate objective assessments of dietary intake, physical activity, and sleep to more effectively isolate the effects of training. Measuring training volume via mechanical or metabolic indicators would enhance the precision of inter-modal comparisons. Longitudinal designs lasting more than 8 weeks are advised to evaluate the sustainability and advancement of adaptations. Moreover, subsequent research should examine the interplay among training modality, genetic, nutritional, and cultural influences, especially in marginalized populations.

CONCLUSION

This study indicates that both eight-week PT and WT programs effectively enhance body composition and critical metrics of explosive power and speed in young, untrained men, despite the stated limitations. The adaptations noted align with the distinct physiological requirements of each modality. These findings indicate that exercise prescriptions for practitioners should correspond with performance objectives. Physical training is especially advantageous for goals focused on horizontal power, acceleration, and agility. WT is an effective method for enhancing maximal strength, vertical jump ability, and muscular hypertrophy. A periodized program that combines both

modalities is likely optimal for comprehensive athletic development, facilitating synergistic adaptations in structural (strength) and elastic-reactive (speed) performance components (Bompa & Buzzichelli, 2021; Gadiant & Deutsch, 2020). Subsequent research should use larger, more heterogeneous samples, incorporate direct assessments of body composition and mechanistic variables (e.g., tendon stiffness, EMG), rigorously control for confounding lifestyle factors, and employ longitudinal designs to investigate the enduring interplay between these training modalities.

ACKNOWLEDGMENT

The authors would like to thank the participants for their cooperation.

AUTHOR CONTRIBUTION STATEMENT

DLS, HAR, and SSM were the lead researchers responsible for study design, data collection, and statistical analysis. KFH, AAM, MH, BOA, DYL, and DLS contributed to the literature review, manuscript drafting, and overall study development. All authors reviewed and approved the final version of the manuscript.

AI DISCLOSURE STATEMENT

The author used [Grammarly, Turnitin] during the preparation of this work for [Text refinement and similarity checking]. After using the tool/service, the author thoroughly reviewed and edited the content as needed and takes full responsibility for the content of the publication.

CONFLICTS OF INTERES

The authors confirm the presence or absence of any potential conflicts of interest (financial, institutional, or personal) that could influence the conduct of this study, the analysis of data, the preparation of the manuscript, or its publication.

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