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Effects of Integrated Neuromuscular Training on Speed and Power in Male High School Soccer Players in Shandong, China

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ABSTRACT

This study examined the effects of integrative neuromuscular training (INT) on sprint speed and explosive power in high school male soccer players. A total of 20 participants were randomly assigned to either the experimental group (EG, n=10), which received an INT program, or the control group (CG, n=10), which followed regular physical fitness training. Pre- and post-intervention assessments included the 20-meter sprint and standing long jump tests. Generalized Estimating Equations (GEE) were used to analyze group-by-time interactions. Results showed that both groups significantly improved their sprint speed over time (EG: $p=0.047$; CG: $p=0.042$), with no significant differences in explosive power between groups ($p>0.05$). These findings suggest that while INT may enhance sprint performance, its short-term effect on explosive power appears limited. Further research with larger sample sizes and longer intervention periods is recommended.

Keywords: Integrated neuromuscular training, sprint speed, power, soccer

INTRODUCTION

Youth soccer players need to develop a range of physical attributes, including speed, power, coordination, and agility, to manage the high physical demands of competitive matches (Faude et al., 2012). Among these attributes, sprint speed and explosive power are especially important for key in-game actions, such as acceleration, ball chasing, and quick changes in direction (Clemente et al., 2025). Therefore, improving these skills during adolescence is crucial, as this period coincides with a critical phase of neuromuscular growth (Lloyd & Oliver, 2012).

Traditional training methods for youth soccer players often emphasize sport-specific skills or overall endurance but may lack a systematic approach to developing multiple physical qualities simultaneously. In contrast, Integrative Neuromuscular Training (INT) is a structured program that combines elements such as strength, balance, coordination, agility, and movement control. Its goal is to enhance both physical performance and injury

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resistance in youth athletes (Fort-Vanmeerhaeghe et al., 2016; Myer et al., 2011).

In this context, INT has evolved into a comprehensive method for enhancing athletic performance that encompasses strength, balance, coordination, agility, and movement quality (Myer et al., 2011). INT is based on the theoretical framework introduced by Fort-Vanmeerhaeghe et al. (2016), which promotes the gradual integration of general and sport-specific drills to improve overall movement efficiency and lower injury risk in youth athletes.

Although several studies have demonstrated the effectiveness of INT in enhancing physical performance in Western populations (Ahmed, 2015; Hammami et al., 2023; Pasanen et al., 2009), empirical evidence from Asian contexts, especially among Chinese high school soccer players, remains limited. Due to differences in training culture, competition level, and developmental environments, localized research is necessary. Therefore, this study aimed to examine the effects of a two-week integrative neuromuscular training program on sprint speed and lower-limb power among male high school soccer players in China. It was hypothesized that participants in the INT group would show greater improvements in sprint and power performance than those in the control group.

METHODOLOGIES

Twenty male high school soccer players were recruited from two regional teams in Jinan, Shandong Province, China. Participants were randomly assigned to either the experimental group (EG, n=10) or the control group (CG, n=10) through a simple coin toss. The EG received an INT intervention, while the CG continued their regular football training routines. The descriptive characteristics of the participants were as follows: EG: age=16.2±0.5 years, height=174.9±7.4 cm, body mass=67.9±7.1 kg; CG: age=16.0±0.7 years, height=172.9±7.4 cm, body mass=68.2±6.2 kg.

Inclusion criteria were: (1) male high school soccer players aged 15 to 17 years; (2) regular participation in soccer training without exposure to structured neuromuscular warm-up or integrative training in the past 12 months; (3) physically healthy and able to complete all physical performance tests; (4) voluntary informed consent and willingness to participate in all assessments and training sessions; and (5) a clear understanding of the study's objectives and procedures. Exclusion criteria included: (1) a history of significant musculoskeletal injuries (e.g., to the knee, ankle, or hip) within the past year; (2) current health conditions or medication use that could interfere with physical performance or muscular activity; (3) neurological disorders or chronic health issues that could affect participation in training or testing; (4) previous engagement in structured neuromuscular warm-up training in the past year; and (5) uncertainty about the ability to attend and complete training consistently due to personal or external factors.

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Human participation was approved by the Institutional Review Board of the local university (2024065) and was carried out in accordance with the Helsinki Declaration. The study has been registered at the Chinese Clinical Trial Registry (ChiCTR2500103945).

Testing procedures

Sprint

Sprint performance was measured with a 20-meter linear sprint test. Timing was recorded using a pair of infrared timing gates (Smart-Speed, Germany), positioned 1.0 meter above the ground. Each sprint began from a self-selected standing start, with the starting line 30 centimeters behind the initial timing gate. The timing system automatically activated when the athlete crossed the starting gate. Each participant completed three maximal 20-meter sprints, with 90 seconds of passive recovery between trials. The fastest time from the three sprints was used for subsequent analysis.

Standing Long Jump

Participants began the test by standing just behind the starting line and were instructed to leap forward with maximum effort. They had to land upright with both feet together, without swinging their arms to aid the jump. The jump distance was measured from the starting line to the furthest point of contact on landings, typically the heel. After two practice trials, each participant performed three recorded attempts. The longest distance from these attempts was used for further analysis.

Training program

This study's integrative neuromuscular training (INT) program was designed based on the theoretical framework proposed by Fort-Vanmeerhaeghe et al. (2016) and the Internal and External Training Load Model (Impellizzeri et al., 2019). An expert panel evaluated the program to ensure its suitability, safety, and effectiveness for adolescent male soccer players. The intervention combines various physical elements (strength, balance, agility, coordination, and endurance) into football-specific movements to gradually and systematically improve both physical fitness and sports performance.

i. Warm-up (10 minutes): Participants performed general and football-specific dynamic activities, including light jogging, multi-directional movements, and ball-handling drills. The warm-up also included joint mobility and core activation exercises (e.g., arm circles, trunk rotations, and hip mobility work) to prepare the body for the upcoming neuromuscular training phase and reduce injury risk.

ii. Main Intervention (40 minutes): The core part of the INT program focused on functional movement patterns that enhance lower-limb strength, trunk stability, coordination, and movement control. Training included multi-joint exercises (e.g., squats,

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lunges, jumps) combined with soccer-related drills (e.g., sprinting, T-agility, and high-speed dribbling). Intensity was kept at 55–65% of HRmax during the initial phase and gradually increased in accordance with the principle of progressive overload.

The following key exercises were incorporated and gradually adjusted according to participants' adaptation levels.

a) Single-leg static balance – to enhance postural control and proprioception.
b) Box jumps (30 cm) – to develop explosive leg power and reactive strength.
c) Single-leg lateral jumps (15 cm) – to improve lateral stability and agility.
d) Body-mass squats and single-leg squats – to strengthen the lower extremities while maintaining proper alignment.
e) Nordic hamstring exercises – to improve eccentric hamstring strength and reduce injury risk.
f) 20 m sprint and T-agility drills – to train acceleration, change of direction, and soccer-specific movement speed.

iii. Cool-down (10 minutes): Each session ends with static stretching for the lower and upper body, combined with deep breathing exercises to improve flexibility and support recovery.

iv. Frequency and Duration: The INT program lasted two weeks, conducted three times a week, with each session lasting about 60 minutes to ensure enough exposure and adaptation.

v. Instruction: All sessions were supervised by certified strength and conditioning specialists with over ten years of experience. Trainers provided individualized feedback on technique and posture to maximize performance benefits and ensure participant safety.

vi. Safety considerations: During the intervention, safety was a top priority. All exercises were performed under professional supervision in a fully equipped training facility, with appropriate rest periods (30–60 seconds) between sets and exercises to reduce fatigue and lower the risk of injury.

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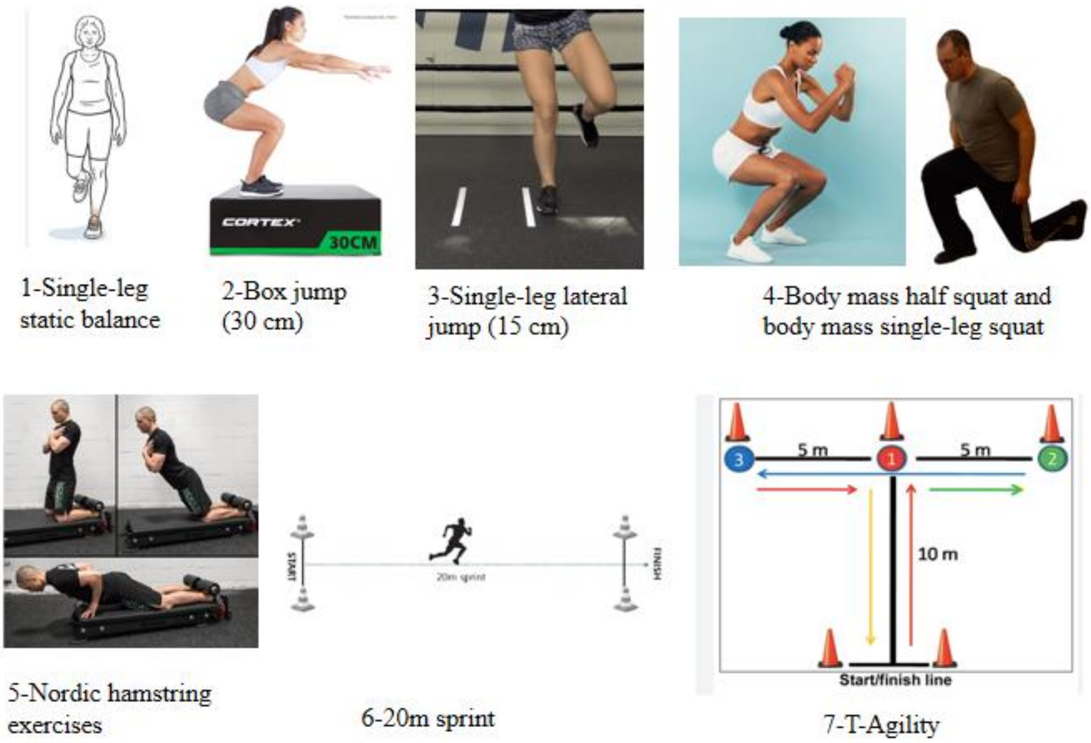

Figure 1: Key exercises were incorporated into the training program.

Statistical analysis

All quantitative data were analyzed using SPSS software (version 27.0; IBM, Chicago, USA). Descriptive statistics were calculated, and continuous variables were presented as mean ± standard deviation (SD). The Shapiro–Wilk test assessed normality, while Levene's test evaluated homogeneity of variances. A one-way ANOVA was performed to compare group differences. To analyze the longitudinal effects of the intervention, a Generalized Estimating Equation (GEE) model was applied. This method accounts for repeated measures and intra-subject correlations to detect changes in performance variables over time between groups. Statistical significance was defined as $p < 0.05$.

RESULT

Primary Outcomes

The Content Validity Index (CVI) is among the most widely used methods for assessing the adequacy of measurement content (Almanasreh et al., 2019). To ensure accuracy and consistency in this study, six experts with extensive experience in related research fields were invited to evaluate the content validity of each intervention component. The Item Content Validity Index (I-CVI) and the Kappa coefficient (Kappa) were used to assess agreement among experts. According to Lynn (1986), an I-CVI of 0.78 or higher and a

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Kappa value of 0.75 or higher indicate satisfactory content validity and agreement among raters. As shown in Table 2, both the speed and explosive power variables demonstrated acceptable content validity, with I-CVI values ranging from 0.833 to 1.000 and Kappa values ranging from 0.816 to 1.000. These findings suggest that the strength measurement tools are highly clear and consistent, making them suitable for evaluating adolescent student athletes.

Table 1. Correlation and consistency of sprint speed and power qualities

Variables	Measurement Method	Number in Agreement	Clarity	
			I-CVI	KAPPA
Sprint speed	20m sprint	6	1.000	1.000
Explosive power	Standing long jump	5	0.833	0.816

Noted: m: meter; I-CVI: Item-Content Validity Index

Reliability

Reliability refers to how consistently a measurement tool produces the same results under repeated conditions (Bolarinwa, 2015). In this study, the test–retest method was utilized to evaluate the reliability of strength quality measurements, as it provides a clear and effective way to assess measurement stability. According to Fleiss's criteria, the Intraclass Correlation Coefficient (ICC) was employed to measure reliability. As noted by Rodrigues et al. (2019), ICC values above 0.75 indicate excellent reliability, values between 0.40 and 0.75 suggest moderate to good reliability, and values below 0.40 denote poor reliability (Table 2).

Table 2. Results of the reliability of sprint speed and power quality

Variables	Items	Intra-class Correlation Coefficient
Sprint	20m	0.919
Explosive power	Standing long jump	0.910

Noted: m: meter

Data Analysis

This study used Generalized Estimating Equations (GEE) to determine whether the differences in speed and explosive power over time between the experimental group undergoing integrated neuromuscular training (EG) and the control group undergoing conventional training (CG) were statistically significant. Table 3 presents descriptive statistics (mean and standard deviation) for speed and explosive power in both groups, highlighting trends and differences in performance over time.

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Table 3. Descriptive statistics of the sprint speed and power qualities of each group in different periods (Mean±SD)

Variables	Time	EG Mean	CG Mean
Sprint speed: 20m sprint (s)	Pre-test	3.37(0.16)	3.49 (0.35)
	Post-test	3.27(0.14)	3.41(0.18)
Power: standing long jump (cm)	Pre-test	250.3(10.69)	244.3(16.55)
	Post-test	251.7(11.86)	244.8(16.25)

Noted: m: meter; EG: Experimental group; CG: Control group

GEE was used to analyze the effects of group (experimental vs. control), time (pre vs. post), and their interaction on speed and power performance outcomes. For speed performance measured by the 20-meter sprint, the main effect of time was statistically significant (Wald χ^2=14.238, df=1, p<0.001), revealing that overall sprint performance improved substantially across both groups after the intervention. However, neither the main effect of group (Wald χ^2=1.512, p=0.219) nor the group × time interaction (Wald χ^2=0.072, p=0.789) was statistically significant. This indicates that although participants improved over time, the degree of improvement did not differ significantly between the experimental and control groups. For power performance measured by the standing long jump, the effect of time nearly reached significance (Wald χ^2=2.956, p=0.084), hinting at a possible trend of improvement over time. Nonetheless, neither the group effect (Wald χ^2=1.176, p=0.278) nor the group × time interaction (Wald χ^2=0.670, p=0.413) was statistically significant. These results suggest there was no significant difference in power gains between groups or across the intervention period. See Table 4 for details (Table 4).

Table 4. Results of GEE on speed and power qualities

Variables	Measurement Method	Source	Wald-Chi-Square	df	p-value
Speed	20m sprint	Group	1.512	1	0.219
		Time	14.238*	1	<0.001
		Group*Time	0.072	1	0.789
Power	Standing long jump	Group	1.176	1	0.278
		Time	2.956	1	0.084
		Group*Time	0.670	1	0.413

Note: df: degree of freedom; EG: Experimental group; CG: Control group; *p<0.05 level of significance

Post Hoc testing (Bonferroni) was used to assess changes in sprint speed and explosive power. Changes in sprint speed and explosive power over time among high school soccer players in the experimental group (EG) and the control group (CG) are shown in Table 5. As shown, both groups experienced significant improvements in sprint performance over time. The mean difference in sprint speed was 0.098 (p=0.047) for the experimental group

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and 0.850 (p=0.042) for the control group. The 95% confidence intervals did not include zero, indicating statistical significance at the 0.05 level. Conversely, no significant changes in explosive power were observed in either group, as all p-values exceeded 0.05 (Table 5).

Table 5. Within Groups Comparison of speed and power qualities Across Time for Both Groups

Variable	Group	(I) Test	(J) Test	Mean Difference (I-J)	SE	p-value	95% CI for Difference	
							Lower	Upper
Speed	EG	Pre-test	Post-test	0.0980*	0.369	0.047	0.006	0.1954
	CG	Pre-test	Post-test	0.850*	0.314	0.042	0.002	0.168
Power	EG	Pre-test	Post-test	1.400	0.918	0.765	-1.023	3.823
	CG	Pre-test	Post-test	0.500	0.604	1.000	-1.093	2.093

Noted: SE: Standard Error * Mean difference is significant at the 0.05 level; EG: Experimental group; CG: Control group

Post hoc comparisons with the Bonferroni correction were conducted to compare mean values; the results are shown in Table 6. No significant differences were found in sprint speed or explosive power between the groups at either the pre-test or post-test. There were no significant differences between groups (p > 0.05) (Table 6).

Table 6. Between-Groups Comparison of Mean Score for speed and power qualities at Two Times

Variable	Time	(I) Test	(J) Test	Mean Difference (I-J)	SE	p-value	95% CI for Difference	
							Lower	Upper
Speed	Pre-test	EG	CG	-0.119	0.115	1.000	-0.422	0.184
	Post-test	EG	CG	-0.132	0.093	0.949	0.378	0.114
Power	Pre-test	EG	CG	6.900	6.030	1.000	-9.025	22.825
	Post-test	EG	CG	6.000	5.900	1.000	-9.590	21.590

Noted: SE: Standard Error * Mean difference is significant at the 0.05 level; EG: Experimental group; CG: Control group

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DISCUSSION

This pilot study aimed to examine the effects of a two-week INT program on sprint speed and explosive power in male high school soccer players from Shandong, China. The results showed that both the experimental group (EG) and the control group (CG) improved sprint performance over time, with no statistically significant difference between the groups. However, neither group experienced notable changes in explosive power.

The finding that sprint speed improved significantly over time in both groups coincides with previous research showing that short-term neuromuscular interventions can enhance movement efficiency and acceleration capacity (Hammami et al., 2023; Myer et al., 2011). However, the absence of a significant interaction between group and time indicates that these improvements may not be attributable solely to the INT intervention. Both groups benefited from their regular football-related physical activity or testing familiarity, which contributed to the overall time effect.

Unlike previous studies that reported significant gains in lower-limb power following integrative or neuromuscular training interventions, the current study found no significant change in standing long jump performance. One possible explanation is the short duration of the intervention. While earlier research typically conducted INT programs over 6 to 12 weeks (Fort-Vanmeerhaeghe et al., 2016), this study used a condensed two-week protocol. This relatively brief exposure might have been too short to produce substantial neuromuscular adaptations, especially for power-related tasks, which generally require longer training periods to show measurable improvements.

Another factor that may have influenced the findings is the small sample size. As a pilot study, the sample included only 20 participants, limiting statistical power to detect group differences. Additionally, the homogeneity of participants in terms of age, training background, and skill level may have reduced the observed variability in performance.

Despite these limitations, this study offers valuable initial data to the limited body of research on integrative neuromuscular training among Chinese youth athletes. It provides practical insights into how even a short-term program can enhance sprinting ability and encourages further exploration of longer-term, larger-scale interventions. Future research should consider extending the intervention period, increasing the sample size, and incorporating additional sport-specific power assessments to better evaluate INT's impact on performance.

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LIMITATIONS AND SUGGESTIONS FOR FUTURE STUDIES

Several limitations of this pilot study should be acknowledged. First, the small sample size (n=20) reduced statistical power to detect group differences, especially for explosive power outcomes. As a result, subtle but potentially significant effects of the INT program might have been missed. Future studies should consider recruiting larger samples to improve generalizability and statistical reliability.

Second, the intervention was quite brief (only two weeks), which might have been too short to produce significant neuromuscular adaptations, especially for power-related outcomes. Previous studies indicate that longer interventions (typically 6-12 weeks) are more effective in generating measurable changes in strength, power, and performance (Mendiguchia et al., 2015; Menezes et al., 2022; Nunes et al., 2021). Therefore, future research should lengthen the intervention period to evaluate the cumulative effects of INT.

Third, this study relied only on two performance indicators, the 20-meter sprint and the standing long jump, to evaluate training effects. While these tests are valid and frequently used, they may not fully capture the multidimensional nature of soccer performance. Future research should include additional variables such as change-of-direction speed, agility, balance, and sport-specific movement assessments to gain a more comprehensive understanding of performance improvements.

CONCLUSION

This study aimed to investigate the effects of INT on sprint speed and explosive power among Chinese high school soccer players. The findings indicated significant improvements in sprint speed in both the experimental and control groups, but no statistically significant changes in explosive power. These preliminary results suggest that INT may enhance sprint performance, though further research is needed to confirm its broader applicability.

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There was no financial sponsorship associated with this project.

Conflict of Interests

The authors declare no conflicts of interest.

Author Contributions

All authors shared responsibility for the conceptual design and writing of the manuscript.

Data Availability Statement

The datasets used and analyzed in this study are available from the corresponding author upon reasonable request.

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