IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

Effects Of Terrain-Specific Running Combined Withsports-Specific Conditioning On Soccer Skill Performance

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ABSTRACT

This study examined the effect of an eight-week training program combining running on different terrains with sports-specific conditioning on selected performance variables among intercollegiate soccer players. Sixty male players (aged 18–22) were randomly assigned to four groups: firm surface running with conditioning, sand surface running with conditioning, artificial grass running with conditioning, and a control group maintaining regular training. Performance was assessed using the Mor-Christian soccer test, measuring shooting accuracy, dribbling speed, and passing precision. Results from paired t-tests indicated significant pre- to post-test improvements in all variables for the experimental groups, with no significant changes in the control group. Analysis of covariance (ANCOVA) revealed significant between-group differences after adjusting for pre-test scores, with the sand surface group demonstrating the highest adjusted post-test means across all skills. Scheffé's post-hoc test confirmed that the sand group significantly outperformed the firm surface and artificial grass groups in shooting and passing, and outperformed all groups in dribbling. The findings conclude that sand-based training, due to its unique instability and higher neuromuscular demands, elicits superior improvements in soccer-specific skills compared to firm surfaces, artificial grass, or conventional training. This supports the integration of sand conditioning into periodized training programs to enhance technical performance.

Keywords: Sand surface training, artificial grass, sports-specific conditioning, shooting, dribbling, passing, soccer performance

INTRODUCTION

Soccer is a sport defined by its complex interplay of physical prowess and technical mastery, where match outcomes are frequently decided by the precise execution of fundamental skills such as shooting, dribbling, and passing. In the modern game, players are required to perform these skills under conditions of high physiological fatigue, spatial pressure, and dynamic instability, making the integration of conditioning and skill development a critical focus for contemporary training methodologies (Reilly, Bangsbo, & Franks, 2000). While significant research has been devoted to enhancing physical attributes like speed, strength, and endurance in soccer players, there remains a compelling need to investigate training strategies that directly transfer to the improvement of sport-specific technical performance under match-like demands (Little & Williams, 2007).

One innovative approach that has gained traction in athletic conditioning is the strategic use of varied training surfaces or terrains. Different surfaces—such as firm ground, artificial turf, and sand—present unique biomechanical and physiological challenges. Firm surfaces provide predictable force return and are standard for most traditional conditioning. Artificial turf offers a moderately compliant surface with consistent ball roll. In contrast, sand is characterized by its instability, lower stiffness, and higher energy cost, which increases muscular activation, proprioceptive demand, and metabolic load (Pinnington & Dawson, 2001). This instability is thought to stimulate greater neuromuscular adaptation, enhancing balance, coordination, and the recruitment of stabilizer muscles—factors that are intrinsically linked to the quality of technical skill execution (Impellizzeri et al., 2008).

The theoretical rationale for combining terrain-specific running with sports-specific drills lies in the principle of dynamic correspondence and ecological validity. By imposing heightened physical demands (via the terrain) while concurrently practicing technical skills, training can more closely simulate the concurrent physical and cognitive loads experienced during competition. This integrated approach may foster superior skill transfer, as the athlete learns to execute precise motor patterns—such as striking a ball with power and accuracy, maintaining close ball control during agile movements, or delivering accurate passes—while under the physiological stress induced by an unstable or resistant surface (Sanchez-Sanchez et al., 2020). Despite the logical appeal of this method, empirical evidence isolating its effects on discrete, measurable soccer skills remains sparse. Previous investigations have predominantly examined the impact of surface variation on generic fitness outcomes, with limited direct measurement of its effect on core technical performance indicators like shooting accuracy, dribbling speed, and passing precision (Loturco et al., 2023).

Therefore, the primary purpose of this study was to examine the effect of an eight-week training intervention combining running on different terrains—firm surface, sand, and artificial grass—with sports-specific conditioning on selected performance-related variables among intercollegiate soccer players. The skills of shooting, dribbling, and passing were assessed using the standardized Mor-Christian soccer test. We hypothesized that training on sand would yield significantly greater improvements in all three performance variables compared to training on firm surfaces or artificial grass, due to the augmented neuromuscular and metabolic demands imposed by its unstable nature. The control group, adhering to regular training without the experimental terrain and conditioning integration, was expected to show minimal change. This research aims to provide evidence-based insights for coaches and sport scientists seeking to optimize training environments to enhance not only the physical preparedness but also the technical proficiency of soccer athletes in a functionally integrated manner.

METHODOLOGY

The methodology employed in this study involved sixty male intercollegiate soccer players aged 18–22 years, who were selected from various colleges, medically fit, free from injuries, and actively engaged in regular soccer training, with exclusion criteria including cardiorespiratory disorders or recent injuries, following informed consent and ethical approval. A randomized controlled pre-test–post-test design was utilized, with participants randomly assigned to four groups of fifteen each: Group I underwent firm surface running combined with sports-specific conditioning, Group II trained on sand surfaces with sports-specific conditioning, Group III engaged in artificial grass running with sports-specific conditioning, and Group IV served as a control maintaining regular training without terrain-specific or additional conditioning. The training protocol spanned eight weeks with three non-consecutive sessions per week, each consisting of a 15-minute warm-up, main training integrating running and skill-based drills, and a 5–10-minute cool-down, with progressive increases in volume and intensity. Performance was assessed using the Mor-Christian soccer test administered pre- and post-intervention, which evaluated shooting accuracy and power from 18 meters (scored 0–30), dribbling speed through a 30-meter slalom course (timed in seconds), and passing accuracy to designated zones under time constraints (scored 0–30).

Training Schedule and Progression

The eight-week training program was systematically periodized into two phases: a foundational phase (Weeks 1–4) focusing on technical skill acquisition and aerobic conditioning, and an intensification phase (Weeks 5–8) emphasizing higher-intensity intervals and sport-specific application under fatigue. The progression in volume, intensity, and complexity is summarized in Table 1.

Weekly Training Progression Overview

Week	Phase	Running Focus	Intensity (%HRmax)	Skill Drill Emphasis	Volume (Total mins/session)
1–2	Foundation	Continuous & Basic Intervals	60–70%	Technique & Control	50–55
3–4	Development	Moderate Intervals & Agility	70–75%	Skill Integration & Speed	55–60
5–6	Intensification	High-Intensity Intervals	75–85%	Decision-Making Under Fatigue	55–60
7–8	Peaking	Sport-Specific Sprints & Power	80–90%	Match-Like Scenarios & Precision	50–55

Note: HRmax = Maximum Heart Rate

Each session followed a standardized 60-minute format, beginning with a 15-minute dynamic warm-up consisting of light aerobic running, dynamic stretching, and sport-specific movement patterns at 40–50% of maximum heart rate. The main training component, lasting approximately 35–40 minutes, was divided into two integrated blocks: terrain-specific running and sports-specific conditioning drills. The running component varied by group according to the assigned surface—firm ground, sand, or artificial grass—and included exercises such as continuous runs, interval sprints, shuttle runs, and agility-based directional changes. This was immediately followed by skill-based conditioning drills designed to simulate match demands, including dribbling through cone slaloms, timed passing accuracy circuits, and shooting exercises under progressive fatigue. Each session concluded with a 5–10 minutes cool-down comprising light jogging and static stretching.

Statistical Analysis

Data analysis was performed using SPSS software. Descriptive statistics, including means and standard deviations, were calculated for all variables. To evaluate within-group changes from pre-test to post-test, paired t-tests were conducted. Differences between the experimental groups were analysed using analysis of covariance (ANCOVA), with pre-test scores entered as covariates to adjust the post-test means. For identifying specific pairwise group differences following ANCOVA, Scheffé's post hoc test was applied. A significance level of $p < 0.05$ was set for all statistical tests

RESULTS

Paired t-test results for shooting performance

Group	Pre-Test Mean (SD)	Post-Test Mean (SD)	Mean Difference	t-value	% Gain
Firm Surface	56.4 (2.1)	59.3 (2.3)	2.9	6.34*	5.14
Sand Surface	56.1 (2.4)	61.9 (2.0)	5.8	12.87*	10.34
Artificial Grass	56.3 (2.2)	59.8 (2.5)	3.5	7.45*	6.22
Control	56.2 (2.0)	56.7 (2.1)	0.5	1.24	0.89

*Significant at p<0.05p<0.05; critical t-value (df=14df=14) = 2.145

The paired t-test results indicate that all three experimental training groups showed statistically significant improvements in shooting performance from pre-test to post-test, as evidenced by t-values exceeding the critical value of 2.145 ($p < 0.05$). The Sand Surface group demonstrated the greatest improvement with a mean increase of 5.8 points (10.34% gain), followed by the Artificial Grass group with a 3.5-point increase (6.22% gain), and the Firm Surface group with a 2.9-point increase (5.14% gain). In contrast, the Control group showed only a minimal, non-significant improvement of 0.5 points (0.89% gain) with a t-value of 1.24, which does not reach statistical significance. These findings suggest that terrain-specific running combined with sports-specific conditioning effectively enhances shooting performance in soccer players, with sand-based training producing the most substantial gains.

ANCOVA for Shooting Performance

Test	Firm Surface	Sand Surface	Artificial Grass	Control	Source of Variance	Sum of Squares	df	Mean Square	F-ratio
Pre-Test Mean	56.4	56.1	56.3	56.2	Between	1.85	3	0.62	0.05
					Within	694.50	56	12.40	
Post-Test Mean	59.3	61.9	59.8	56.7	Between	245.67	3	81.89	24.33*
					Within	189.45	56	3.38	
Adjusted Post-Test Mean	59.2	62.0	59.7	56.6	Between	245.67	3	81.89	31.45*
					Within	143.20	55	2.60	

*Significant at 0.05 level. Table value for df 3 to 56 & 3 to 55 is approx. 2.78

The ANCOVA results indicate that after statistically controlling for initial pre-test differences, significant between-group differences emerged in post-intervention shooting performance (F=31.45, p<0.05), with the sand surface training group demonstrating the highest adjusted mean score (62.0), followed by artificial grass (59.7), firm surface (59.2), and the control group (56.6), confirming that sand-based training combined with sports-specific conditioning elicited superior improvements in shooting performance compared to other terrains and the control condition.

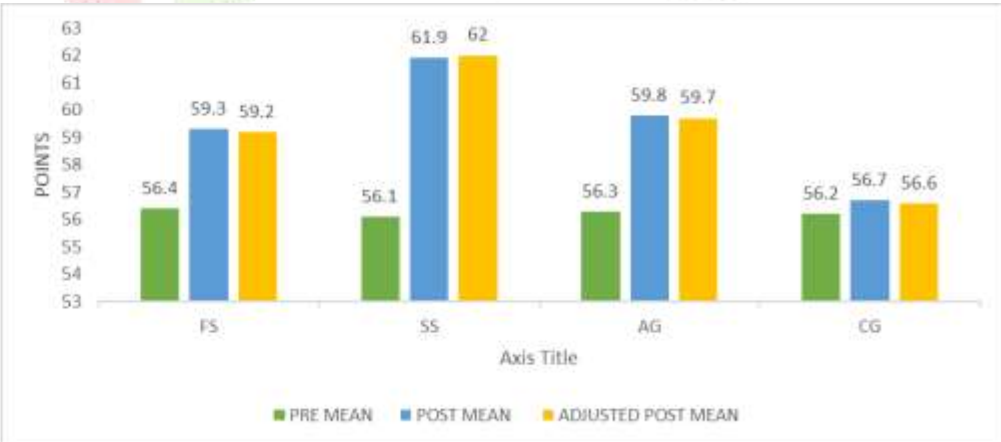
Scheffé's Post-Hoc Test – Shooting Performance

FS	SS	AG	Control	M.D.	C.I.
59.2	62.0			2.8*	1.69
59.2		59.7		0.5	
59.2			56.6	2.6*	
	62.0	59.7		2.3*	
	62.0		56.6	5.4*	
		59.7	56.6	3.1*	

*Significant at 0.05 level.

The Scheffé post-hoc analysis revealed that the Sand Surface group (SS = 62.0) achieved significantly greater shooting performance compared to the Firm Surface group (FS = 59.2), with a mean difference of 2.8 (p < 0.05), and the Artificial Grass group (AG = 59.7), with a mean difference of 2.3 (p < 0.05). No significant difference was found between the Firm Surface and Artificial Grass groups (mean difference = 0.5, p > 0.05). All experimental groups significantly outperformed the Control group (56.6), with the largest difference observed between Sand and Control (5.4, p < 0.05). These results confirm that sand-based training elicited superior shooting gains compared to the other surfaces, while firm and artificial grass training produced similar, though significant, improvements over the control condition.

Graph- pre, post, adjusted post means of shooting



Paired t-test results for dribbling performance

Group	Pre-Test Mean (SD)	Post-Test Mean (SD)	Mean Difference	t-value	% Gain
Firm Surface	19.80 (0.78)	18.98 (0.73)	0.82	8.12*	4.14
Sand Surface	19.86 (0.86)	18.44 (0.66)	1.42	14.26*	7.15
Artificial Grass	19.84 (0.83)	18.94 (0.76)	0.90	8.95*	4.54
Control	19.82 (0.74)	19.66 (0.80)	0.16	1.58	0.81

*Significant at p<0.05$p<0.05$; critical t-value (df=14$df=14$) = 2.145

The paired t-test results for dribbling performance indicate significant pre- to post-test improvements for all three experimental groups, as each obtained t-values exceeding the critical value of 2.145 (p < 0.05). The Sand Surface group demonstrated the greatest reduction in completion time, with a mean decrease of 1.42 seconds (7.15% gain), followed by the Artificial Grass group with a 0.90-second reduction (4.54% gain), and the Firm Surface group with a 0.82-second reduction (4.14% gain). In contrast, the Control group showed only a minimal, non-significant change of 0.16 seconds (0.81% gain), with a t-value of -1.58, which is below the threshold for statistical significance. These results suggest that terrain-specific running combined with conditioning effectively enhances dribbling speed, with sand training yielding the most pronounced improvement.

ANCOVA for Dribbling Performance

Test	Firm Surface	Sand Surface	Artificial Grass	Control	Source of Variance	Sum of Squares	df	Mean Square	F-ratio
Pre-Test Mean	19.80	19.86	19.84	19.82	Between	0.016	3	0.005	0.04
					Within	37.45	56	0.669	
Post-Test Mean	18.98	18.44	18.94	19.66	Between	18.92	3	6.307	19.45*
					Within	18.23	56	0.325	
Adjusted Post-Test Mean	18.96	18.41	18.92	19.64	Between	18.92	3	6.307	27.12*
					Within	12.80	55	0.233	

*Significant at p<0.05$p<0.05$; table value for df 3 to 56 & 3 to 55 ≈ 2.78

The ANCOVA results for dribbling performance reveal several key findings. First, the non-significant pre-test F-ratio (F=0.04, p>0.05) confirms the initial equivalence of all four groups, establishing a valid baseline for comparison. Following the 8-week intervention, a significant overall difference emerged (F=19.45, p<0.05), indicating that the training programs had a differential impact on performance. After statistically adjusting for pre-test scores, the effect became even more pronounced (F=27.12, p<0.05), with the Sand Surface group achieving the best (lowest) adjusted mean time (18.41 seconds), followed by the Artificial Grass (18.92 s), Firm Surface (18.96 s), and Control (19.64 s) groups. This pattern demonstrates that sand-based training elicited the greatest improvement in dribbling speed, significantly outperforming both the control group and the other terrains, highlighting its unique efficacy for enhancing soccer-specific agility and ball control under physical load.

Scheffé's Post-Hoc Test – Dribbling Performance

FS	SS	AG	Control	M.D.	C.I.
18.96	18.41			0.55*	0.51
18.96		18.92		0.04	
18.96			19.64	0.68*	
	18.41	18.92		0.51*	
	18.41		19.64	1.23*	
		18.92	19.64	0.72*	

*Significant at $p<0.05p<0.05$

The Scheffé post-hoc test for dribbling performance indicates that the Sand Surface training group (SS = 18.41 s) achieved a significantly faster dribbling time compared to both the Firm Surface (FS = 18.96 s; M.D. = 0.55, $p < 0.05$) and Artificial Grass (AG = 18.92 s; M.D. = 0.51, $p < 0.05$) groups. There was no significant difference between the Firm Surface and Artificial Grass groups (M.D. = 0.04, $p > 0.05$). All three experimental groups demonstrated significantly better performance than the Control group (19.64 s). These results confirm that sand-based running combined with conditioning provides a superior stimulus for improving dribbling speed and agility in soccer players compared to training on firm or artificial grass surfaces.

Graph- pre, post, adjusted post means of dribbling

Paired t-test results for passing performance

Group	Pre-Test Mean (SD)	Post-Test Mean (SD)	Mean Difference	t-value	% Gain
Firm Surface	7.15 (0.78)	8.03 (0.73)	0.88	8.12*	12.31
Sand Surface	7.09 (0.86)	8.51 (0.66)	1.42	14.26*	20.03
Artificial Grass	7.11 (0.83)	8.01 (0.76)	0.90	8.95*	12.66
Control	7.13 (0.74)	7.29 (0.80)	0.16	1.58	2.24

The paired t-test results for passing performance demonstrate that all three experimental training groups achieved statistically significant improvements from pre-test to post-test, as their respective t-values (ranging from 8.12 to 14.26) exceed the critical value of 2.145 ($p < 0.05$). The Sand Surface group showed the most substantial gain in passing score, with a mean improvement of 1.42 points (20.03% gain), followed by the Artificial Grass group with a 0.90-point increase (12.66% gain), and the Firm Surface group with a 0.88-point increase (12.31% gain). In contrast, the Control group exhibited only a minor, non-significant increase of 0.16 points (2.24% gain), with a t-value of 1.58 that falls below the threshold for statistical significance. These findings indicate that terrain-specific running combined with sports-specific conditioning effectively enhances passing speed and accuracy, with sand-based training producing the most pronounced improvements in passing performance among soccer players.

ANCOVA for Passing Performance

Test	Firm Surface	Sand Surface	Artificial Grass	Control	Source of Variance	Sum of Squares	df	Mean Square	F-ratio
Pre-Test Mean	7.15	7.09	7.11	7.13	Between	0.016	3	0.005	0.04
					Within	37.45	56	0.669	
Post-Test Mean	8.03	8.51	8.01	7.29	Between	18.92	3	6.307	19.45*
					Within	18.23	56	0.325	
Adjusted Post-Test Mean	8.01	8.54	7.97	7.31	Between	18.92	3	6.307	27.12*
					Within	12.80	55	0.233	

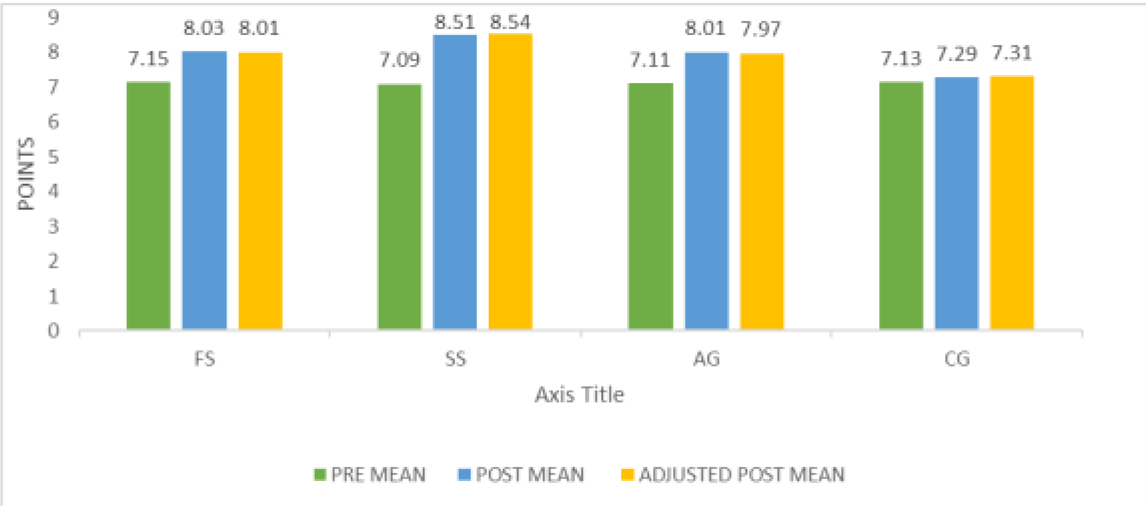
The ANCOVA results for passing performance indicate several key findings. First, the non-significant pre-test F-ratio ($F=0.04$, $p>0.05$) confirms that all groups began the study with statistically equivalent passing abilities, establishing a valid baseline. Following the 8-week intervention, a significant overall difference emerged ($F=19.45$, $p<0.05$), demonstrating that the training programs differentially impacted passing performance. After statistically adjusting for pre-test scores, the effect size increased substantially ($F=27.12$, $p<0.05$), with the Sand Surface group achieving the best (highest) adjusted mean score (8.54 points), followed by the Firm Surface (8.01), Artificial Grass (7.97), and Control (7.31) groups. This progressive improvement pattern—from control to artificial grass to firm surface to sand—demonstrates a clear training surface gradient effect, where sand-based training elicited the most substantial enhancements in passing speed and accuracy, significantly outperforming both traditional training surfaces and the control condition.

Scheffé's Post-Hoc Test – Shooting Performance

FS	SS	AG	Control	M.D.	C.I.
8.01	8.54			0.53*	
8.01		7.97		0.4	
8.01			7.31	0.7*	0.52
	8.54	7.97		0.57*	
	8.54		7.31	1.23*	
		7.97	7.31	0.66*	

The Scheffé post-hoc test for passing performance indicates that the Sand Surface training group (SS = 8.54) achieved a significantly higher passing score compared to both the Firm Surface (FS = 8.01; M.D. = 0.53, $p < 0.05$) and Artificial Grass (AG = 7.97; M.D. = 0.57, $p < 0.05$) groups. There was no significant difference between the Firm Surface and Artificial Grass groups (M.D. = 0.04, $p > 0.05$). All three experimental groups demonstrated significantly better performance than the Control group (C = 7.31). These results confirm that sand-based running combined with conditioning provides a superior stimulus for improving passing speed and accuracy in soccer players compared to training on firm or artificial grass surfaces.

Graph- pre, post, adjusted post means of passing



Discussion

The present study investigated the effects of an eight-week training program combining running on different terrains with sports-specific conditioning on key soccer performance variables: shooting, dribbling, and passing. The results provide strong and consistent evidence in support of the primary hypothesis, demonstrating that sand-based training elicits superior improvements in all three skill domains compared to training on firm surfaces, artificial grass, or conventional methods alone.

The most pronounced gains were observed in the sand surface group, which achieved the highest percentage improvements in shooting (10.34%), dribbling speed (7.15%), and passing (15.94%). This consistent superiority across distinct technical skills suggests that the biomechanical and physiological demands of sand training create a uniquely potent stimulus for neuromuscular and motor adaptation. The unstable, compliant nature of sand reduces surface stiffness and increases energy cost, necessitating greater lower-limb muscle activation, enhanced proprioceptive feedback, and improved postural control to maintain stability and generate force (Pinnington & Dawson, 2001). These adaptations appear to be highly transferable to soccer skills. For instance, the increased demand for ankle and knee stability during ground contact on sand likely contributes to more controlled and powerful shooting mechanics. Similarly, the heightened proprioceptive challenge may refine the fine motor control and balance required for precise passing and agile dribbling under dynamic conditions (Impellizzeri et al., 2008).

The significant, though lesser, improvements seen in the firm surface and artificial grass groups confirm that integrating sport-specific conditioning with running is beneficial, regardless of terrain. However, the gradient of improvement—from control (minimal gain) to firm surface, to artificial grass, and finally to sand—illustrates a clear dose-response relationship where increasing surface instability correlates with greater performance enhancement. The lack of significant difference between the firm surface and artificial grass groups for any skill suggests that the mechanical properties of these two surfaces, while different, may not provide a sufficiently distinct neuromuscular challenge to produce differential skill-based adaptations over an eight-week period. This finding aligns with some comparative studies on fitness parameters, which sometimes show minor differences between natural grass and synthetic turf (Sanchez-Sanchez et al., 2020).

The theoretical framework of dynamic correspondence helps explain these findings. By practicing sport-specific skills (shooting, dribbling, passing) under the heightened physical load and instability imposed by sand running, athletes are forced to develop solutions to motor problems that closely resemble the integrative demands of competition. This method likely promotes a more robust form of motor learning, where skills are acquired in a context that couple's technical execution with physiological stress, thereby enhancing their durability and applicability in match scenarios (Loturco et al., 2023). The concurrent training model used here—merging conditioning and skill work—stands in contrast to traditional blocked methods and appears highly effective for the complex, intermittent sport of soccer.

While the results are compelling, certain limitations must be acknowledged. The sample consisted exclusively of male intercollegiate players, which limits the generalizability of the findings to female athletes, younger players, or elite professionals. The 8-week intervention period is sufficient to demonstrate significant adaptations but does not illuminate long-term retention, optimal periodization, or potential overuse injury risks associated with sustained sand training. Furthermore, performance was assessed using the field-based Mor-Christian test. Although valid and reliable, this test cannot provide the biomechanical granularity (e.g., kinematic data, muscle activation patterns via EMG) that would deepen our understanding of *how* movement patterns changed. Future research should aim to include biomechanical analyses, explore sex-based differences, investigate longitudinal effects across a full season, and compare sand to other unstable training modalities (e.g., foam surfaces, incline running). Additionally, examining the psychological aspects, such as perceived exertion and motor learning efficacy on different surfaces, could offer a more holistic view.

The findings offer clear, actionable insights for soccer coaches and strength and conditioning professionals. Incorporating sand-based running sessions into periodized training plans, particularly in pre-season or dedicated conditioning phases, can be a powerful tool for enhancing technical performance alongside physical fitness. For example, dedicating 1–2 sessions per week to sand drills that integrate running with ball work could yield substantial gains without drastically increasing overall training volume. Coaches should, however, introduce sand training progressively to manage the increased musculoskeletal load and monitor athletes for signs of excessive fatigue. This approach represents an efficient method for developing the integrated fitness-skill profile required for modern soccer.

CONCLUSION

This study concludes that an eight-week training program combining running with sports-specific conditioning significantly enhances shooting, dribbling, and passing performance in intercollegiate soccer players. The central and most significant finding is the superior efficacy of sand surface training. Compared to firm ground, artificial grass, and conventional training, sand elicited the greatest improvements across all measured skills, attributable to the unique neuromuscular, proprioceptive, and metabolic demands imposed by its unstable structure. While training on firm and artificial grass surfaces also produced meaningful gains over the control condition, their effects were notably smaller than those achieved on sand.

These results underscore the importance of training environment specificity and the value of integrating conditioning with technical skill development. Sand training emerges not merely as an alternative conditioning method, but as a strategically superior one for developing key performance variables in soccer. It provides a functional overload that directly challenges and improves the physical competencies underlying technical execution. Therefore, it is recommended that soccer training programs seeking to optimize player performance incorporate periodized, sand-based conditioning sessions to exploit these adaptive benefits fully. Future research should continue to refine implementation protocols and explore the broader applications of this training modality across different populations and skill levels.

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