

Effects of A 12-Week Sand-Based Training Program on Physical Fitness and Football-Specific Skills in Young Male Players: A Randomized Controlled Study

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Abstract: *This study examined the effectiveness of a twelve-week sand training package on selected physical and football skill performance variables among college-level football players aged 17–20 years. Seventy-five male players were randomly assigned to Hill Training, Sand Training, and active Control groups (n = 25 each). All groups trained three non-consecutive days per week; the Sand Training Group completed progressively overloaded sprint, agility, plyometric, and football-specific drills on dry uncompacted sand, whereas the Control Group completed volume-matched conditioning on flat natural grass. Eleven outcomes were assessed before and after training. Analysis of covariance, with the corresponding pre-test score as covariate, showed significant adjusted group effects for all outcomes ($p < .001$). Compared with the Control Group, the Sand Training Group demonstrated better adjusted performance in acceleration, maximum sprint speed, speed endurance, leg explosive power, muscular endurance, agility, dribbling, passing, shooting, and right- and left-leg kicking ability. The results indicate that a structured sand training package can be an effective supplementary method for developing physical fitness and football-specific performance, although findings should be interpreted within the study design and model diagnostics.*

Keywords: Sand training, football conditioning, acceleration, agility, explosive power, technical performance

I. INTRODUCTION

Football performance depends on the coordinated development of acceleration, sprint speed, speed endurance, explosive power, muscular endurance, agility, and football-specific technical skills. During competition, players repeatedly sprint, decelerate, change direction, jump, dribble, pass, shoot, and kick under conditions of incomplete recovery. Conditioning programmes should therefore develop physical capacity while supporting the execution of technical actions.

Sand provides a compliant and deformable training surface. Part of the force applied during stance is dissipated through surface deformation, reducing elastic energy return and increasing active muscular and energetic demands. Acute studies have shown that running on sand generally produces lower external velocity but higher physiological demand than running on firm surfaces [1]–[4]. This combination provides a rationale for using sand as a natural resistance medium in football conditioning.

Previous longitudinal research indicates that sand-based programmes can improve selected sprint, jump, change-of-direction, endurance-related, and football-skill outcomes [5]–[8]. However, responses depend on programme duration,



exercise selection, training frequency, surface condition, participant characteristics, and the test employed. Short standing-start sprints, for example, primarily represent acceleration and should not automatically be interpreted as maximum sprint speed.

The present paper was developed from a doctoral investigation comparing hill training, sand training, and an active grass-based control condition. The paper focuses specifically on the Sand Training Group and evaluates whether a progressive twelve-week sand training package produced superior physical and football skill outcomes to volume-matched conditioning on flat natural grass.

A. Objectives

The study sought to determine the effects of sand training on acceleration, maximum sprint speed, speed endurance, leg explosive power, muscular endurance, agility, dribbling, passing, shooting, and kicking ability using the right and left legs. It also compared adjusted post-test performance of the Sand Training Group with the active Control Group after accounting for the corresponding pre-test scores.

B. Hypothesis

It was hypothesized that the Sand Training Group would demonstrate superior adjusted post-test performance to the Control Group across the selected physical and football skill variables.

II. METHODOLOGY

A. Research Design and Participants

A randomized pre-test–post-test control-group design was employed. Seventy-five male football players aged 17–20 years were recruited from Dhadsakhai Stars Football Club, Marcel, Goa, and Agasaim Youth Club, Goa. Participants were randomly assigned to the Hill Training Group, Sand Training Group, or Control Group, with 25 players in each group. The present paper emphasizes the Sand Training and Control conditions while retaining the full three-group ANCOVA framework used in the thesis.

B. Training Conditions

Training was conducted three days per week on non-consecutive days for twelve weeks. Every session included an identical 15-minute warm-up and 10-minute cool-down. The Sand Training Group trained on dry, uncompacted sand maintained at an approximate depth of 20–30 cm. The Control Group completed an equated volume of sprint and plyometric conditioning on flat natural grass. Sets, repetitions, exercise distances, work-to-rest ratios, weekly frequency, session duration, warm-up, and cool-down were matched as closely as possible.

TABLE I
TWELVE-WEEK SAND TRAINING PACKAGE

Phase	Training focus	Exercises	Volume	Work:Rest
Weeks 1–4	Adaptation and stability	Straight sprints; lateral shuffles; squat jumps	$2 \times 5 \times 15$ m; $2 \times 4 \times 10$ m; 3×8 repetitions	1:4
Weeks 5–8	Reactive power and agility	Sand sprints; T-drill; tuck jumps	$3 \times 5 \times 20$ m; 3×3 repetitions; 3×10 repetitions	1:4
Weeks 9–12	Football-specific power	Resisted sand sprints; dribbling slalom; drop jumps	$3 \times 6 \times 30$ m; $3 \times 5 \times 20$ m; 4×5 repetitions	1:5

Note: Progressive overload was achieved through increases in sprint distance, sets, repetitions, and movement complexity.



C. Variables and Tests

Acceleration was assessed with the 35 Metre Run Test; maximum sprint speed with the timed 20–50 m flying section of a 50 m sprint; speed endurance with the 150 Metre Run Test; leg explosive power with the Vertical Jump Test; muscular endurance with the One-Minute Sit-Ups Test; and agility with the Illinois Agility Test. Dribbling, passing, and shooting were assessed using components of the Mor-Christian General Soccer Ability Test. Right- and left-leg kicking distance were assessed using the Warner Fundamental Skill Test.

D. Reliability and Data Collection

The same instructions, equipment, course dimensions, trial allowances, testing order, and scoring rules were used during pre-test and post-test assessment. Test–retest reliability coefficients for the eleven variables ranged from ICC = 0.82 to 0.93. Testing was distributed across three days to reduce fatigue and preserve consistency.

E. Statistical Analysis

Means and standard deviations summarized observed pre-test and post-test scores. Separate ANCOVA models compared adjusted post-test scores among the three groups using the corresponding pre-test value as covariate. Homogeneity of regression slopes, residual normality, variance equality, heteroscedasticity, and influential observations were examined. Scheffé-adjusted comparisons were used following significant omnibus effects. HC3 heteroscedasticity-robust omnibus tests were reported as sensitivity analyses when appropriate. Paired-samples t-tests and Cohen's *d* described supplementary within-group change. Statistical significance was assessed at 0.05.

III. RESULTS

A. Pre-test to Post-test Performance in the Sand Training Group

The Sand Training Group improved significantly from pre-test to post-test on all eleven outcomes (all $p < .001$). For timed variables, negative changes represented improvement; for jump, repetition, point, and distance variables, positive changes represented improvement.

TABLE II
PRE-TEST AND POST-TEST RESULTS FOR THE SAND TRAINING GROUP (n = 25)

Variable	Pre-test Mean $\pm$ SD	Post-test Mean $\pm$ SD	Direction	Cohen's <i>d</i>
Acceleration (s)	5.304 $\pm$ 0.176	4.967 $\pm$ 0.188	Improved	–4.075
Maximum sprint speed (s)	4.073 $\pm$ 0.153	3.860 $\pm$ 0.167	Improved	–6.758
Speed endurance (s)	21.800 $\pm$ 0.673	20.248 $\pm$ 0.852	Improved	–4.417
Leg explosive power (cm)	47.401 $\pm$ 3.748	52.437 $\pm$ 3.854	Improved	4.679
Muscular endurance (reps)	35.680 $\pm$ 3.497	42.840 $\pm$ 3.145	Improved	4.802
Agility (s)	16.444 $\pm$ 0.628	15.808 $\pm$ 0.631	Improved	–4.508
Dribbling (s)	18.515 $\pm$ 0.821	17.372 $\pm$ 0.819	Improved	–5.435
Passing (points)	7.200 $\pm$ 1.443	9.120 $\pm$ 1.536	Improved	2.528
Shooting (points)	25.360 $\pm$ 4.232	32.080 $\pm$ 4.377	Improved	4.146
Right-leg kicking (m)	47.640 $\pm$ 4.898	52.000 $\pm$ 5.025	Improved	4.054
Left-leg kicking (m)	44.000 $\pm$ 5.164	48.720 $\pm$ 5.311	Improved	5.041

*Note: All paired-samples comparisons were significant at $p < .001$. Negative *d* values for timed tests reflect lower, better post-test times.*



B. Adjusted Sand Training versus Control Comparisons

ANCOVA produced significant adjusted group effects for every outcome (all omnibus $p < .001$). The Sand Training Group also differed significantly from the Control Group in each conventional Scheffé-adjusted comparison. Table III presents the adjusted means and the Sand-minus-Control difference. Negative differences favour sand for timed tests; positive differences favour sand for score- and distance-based tests.

TABLE III
ANCOVA-ADJUSTED SAND TRAINING AND CONTROL GROUP MEANS

Variable	Sand adjusted mean	Control adjusted mean	Sand – Control	Scheffé p
Acceleration (s)	4.975	5.303	-0.328	< .001
Maximum sprint speed (s)	3.869	4.065	-0.196	< .001
Speed endurance (s)	20.494	21.926	-1.432	< .001
Leg explosive power (cm)	52.065	46.769	+5.297	< .001
Muscular endurance (reps)	42.926	36.295	+6.631	< .001
Agility (s)	15.830	16.437	-0.606	< .001
Dribbling (s)	17.452	18.533	-1.081	< .001
Passing (points)	9.120	7.556	+1.564	< .001
Shooting (points)	31.620	26.237	+5.383	< .001
Right-leg kicking (m)	52.013	47.815	+4.199	< .001
Left-leg kicking (m)	48.507	44.024	+4.483	< .001

Note: Adjusted means were estimated within the original three-group ANCOVA models. Conventional Scheffé pairwise probabilities should be interpreted with the model diagnostics reported in the thesis.

C. Summary of Findings

The sand package produced favourable changes across all selected physical outcomes. Relative to the active Control Group, sand training was associated with faster acceleration, maximum sprint speed, speed endurance, agility, and dribbling; greater vertical-jump performance and muscular endurance; higher passing and shooting scores; and longer right- and left-leg kicking distances. The most direct interpretation is that the complete sand programme was more effective than volume-matched flat-grass conditioning for the field tests used in this study.

The thesis also found that the Hill Training Group recorded the most favourable adjusted mean on all eleven outcomes. Accordingly, the present results establish the effectiveness of sand training relative to the active Control Group, but they do not establish sand as the superior terrain-based method within the full experiment.

IV. DISCUSSION

The findings support the use of sand as a natural resistance surface in football conditioning. Surface deformation increases energetic demand and reduces elastic energy return, requiring greater active muscular contribution [1]–[4]. Repeated exposure to this stimulus may help explain the observed improvements in short sprinting, speed endurance, explosive power, muscular endurance, and planned change-of-direction performance.

The acceleration findings are consistent with football-specific studies in which sand-based sprint or plyometric programmes improved short-distance sprint performance [5], [7]. Nevertheless, these studies do not consistently demonstrate statistical superiority of sand over grass. The present study differs by using a twelve-week progressive programme and an active, volume-matched grass condition. Maximum sprint speed was assessed through a flying segment, which is methodologically distinct from the standing-start short sprints used in much of the literature.



Improvements in leg explosive power and agility are also consistent with evidence that compliant-surface training can stimulate neuromuscular adaptation and change-of-direction performance [5]–[7]. The effect appears outcome-specific: sand may favour some horizontal power and change-of-direction measures while firm surfaces may be equally or more effective for selected reactive or vertical-jump variables. Programme design should therefore follow the targeted performance quality rather than treating sand as universally superior.

The improvements in dribbling, passing, shooting, and bilateral kicking distance are practically relevant but require cautious interpretation. Technical performance depends on coordination, motor learning, task familiarity, and football-specific practice in addition to physical capacity. The study establishes improvement on standardized skill tests; it does not independently prove improved competitive match decision-making, pass completion, shot conversion, or tactical performance.

Several ANCOVA models in the thesis showed residual heteroscedasticity or non-normality. HC3 robust omnibus sensitivity tests continued to support overall group differences, but conventional Scheffé pairwise tests were not themselves heteroscedasticity-robust. In addition, multiple outcomes and comparisons increase the study-wide risk of false-positive findings. The large and uniform effects should therefore be verified using raw-data auditing, confidence intervals, robust pairwise procedures, and independent replication.

V. CONCLUSION

Within the conditions of this investigation, a progressive twelve-week sand training package performed three times per week was effective in improving selected physical and football skill performance variables among male football players aged 17–20 years. Compared with volume-matched conditioning on flat natural grass, sand training produced superior adjusted outcomes in acceleration, maximum sprint speed, speed endurance, leg explosive power, muscular endurance, agility, dribbling, passing, shooting, and right- and left-leg kicking ability.

Sand training may therefore be incorporated as a supplementary component of collegiate football conditioning. Implementation should be progressive, supervised, and coordinated with technical training, match load, recovery, footwear, and surface safety. The conclusions apply to the participants, programme, terrain, duration, and field tests used in this study and should not be generalized automatically to other populations or competitive match outcomes.

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