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Effects of speed, agility, and quickness training on grass versus sand surface on sprinting, jumping, and change of direction performance of amateur male soccer players

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Abstract

Study aim: The study compared the effects of speed, agility, and quickness (SAQ) training performed on grass *versus* sand surfaces on improvements in sprinting, jumping, and change of direction speed (CODS).
Materials and methods: Twenty-four male university soccer players were randomly assigned to SAQ training on grass or sand surfaces. The intervention lasted four weeks with a weekly frequency of two sessions. The variables assessed were 30-m linear sprint, CODS, countermovement jump (CMJ), drop jump (DJ; jump height, ground contact time [GCT], reactive strength index [RSI]), squat jump (SJ), standing long jump (SLJ), and triple-hop distance. A two-by-two mixed design ANOVA was used to analyze the training effects.
Results: A significant positive main effect of time was observed for CMJ, DJ, and SJ height ($p < 0.001$) and triple-hop distance, with significant pre-to-post improvement in both groups (all $p < 0.001$). In addition, a negative main effect of time was observed for DJ GCT and DJ RSI ($p = <0.001–0.024$), with a significant increase in DJ GCT for both groups but a significant decrease in DJ RSI only for the group training on sand. No main effect of time was found for the 30-m linear sprint, CODS, or SLJ distance ($p = 0.080–0.792$). An interaction effect on CMJ height was noted ($p = 0.027$), favoring the group training on the sand surface.
Conclusion: SAQ training on grass and sand surfaces showed similar improvements in the DJ, SJ, and triple-hop performance. However, compared to the grass surface, training on the sand surface induced greater improvements in CMJ but showed negative effects on DJ RSI.

Keywords: Plyometric exercise – Football – Athletic performance – Team sports – Muscle strength

Introduction

Soccer is an intermittent team sport that requires players to perform numerous high-intensity efforts such as sprinting, jumping, or changing directions during a competitive match [40]. Various resistance-training methods have been studied to improve these high-intensity efforts (e.g. using linear sprints, jumps, and change of direction speed [CODS]) in soccer players [30, 43, 44, 49]. One of the methods is speed, agility, and quickness (SAQ) training, which is performed with a combination of linear sprints, multi-directional movements, and jumps in a rapid motion [19, 49]. SAQ training has been reported to promote musculoskeletal and neuromuscular adaptations [6, 19]. The musculoskeletal adaptations may include muscle hypertrophy or increased cross-sectional area [3]. The neuromuscular adaptations result in an increased motor unit firing rate and motor unit recruitment, leading to improved inter – and intra-muscular coordination (i.e., enhanced stretch-shortening cycle function) [26]. These positive musculoskeletal and neuromuscular adaptations enhance force production, thereby improving the performance of activities such as sprinting, jumping, or CODS [19, 26].

Furthermore, SAQ training requires less expensive equipment and can be performed on different surfaces (e.g., gym floor, natural grass, sand). However, SAQ training is commonly performed on hard surfaces (e.g., wooden

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floors) [10] due to the rationale that soft surfaces such as sand are more compliant and store the generated muscle energy (i.e., less rebound force) [5]. Moreover, in a recent meta-analysis [31], the authors reported that similar physical fitness improvement can be achieved through both hard and sand surfaces. Indeed, the sand surface, due to its compliant nature (i.e., absorptive characteristics), is associated with lower impact forces, leading to lower stress on joints and muscles compared to hard surfaces [16]. In addition, training on sand surfaces is associated with higher energy cost [23], greater lactate accumulation, and higher muscle activation of lower limbs [28] compared to hard surfaces [4]. Thus, training on the sand surface seems to be an effective way to increase muscle activation demands while reducing the load on the joints.

However, the effects of performing SAQ training on sand surfaces among amateur soccer players is unknown. Most previous studies have been conducted on firm surfaces (e.g., natural grass surfaces) [49]. Therefore, it is important to understand the differences in adaptations for SAQ training when performed on grass or sand surfaces. Moreover, establishing the minimal effective duration for SAQ training on these surfaces is also important, considering the short duration of the pre-season period in soccer [49]. The current study compares the effects of SAQ training on grass versus sand surfaces. Based on evidence [31], SAQ training on both grass and sand surfaces should be equally effective in improving the physical fitness of amateur soccer players.

Materials and methods

Participants

The participants of the study were selected from the same soccer team practicing for inter-university competitions (n = 24). The participants were selected based on the convenience sampling method, and sample size estimation was not performed *a priori*. The inclusion criteria for the participants selected for the study were as follows: (i) being an outfield player of the university male soccer team (goalkeepers were considered outliers as they were involved in a different training program than the outfield players and thus excluded from the study); (ii) having no record of recent injury that could impose a limit on maximal effort in training or testing sessions; (iii) willingness to attend all the SAQ training sessions on either grass or sand; and (iv) to be available for assessment at pre-and post-intervention. The participants practiced at least three soccer training sessions and one friendly match (this includes matches played within the training group, i.e., two teams were created, and a 90-minute match was played) per week. The participants were explained the training protocol, its benefits, and potential risks associated with the study. The participants then signed informed consent forms. Eligible participants were then randomly assigned to either grass (n = 12) or sand (n = 12) training groups following an allocation ratio of 1:1 (Figure 1). Anthropometric and demographic details are described in Table 1. The study was approved by the internal

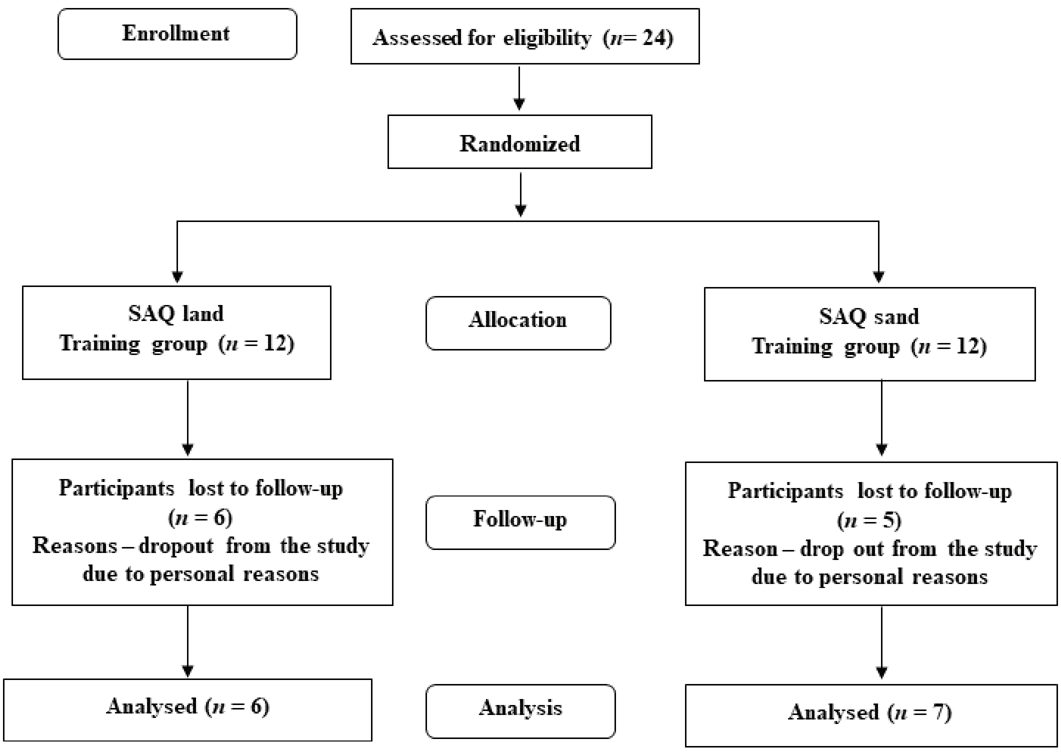

Figure 1. CONSORT flowchart for the present study. Note: SAQ – sand, agility, and quickness

Table 1. Demographics of the participants in experimental training groups

Variables	Grass training group (n = 6)	Sand training group (n = 7)	*P*-value*
	Mean ± SD		
Age [yrs]	19.3 ± 1.8	20.3 ± 1.5	0.312
Height [cm]	171.2 ± 6.8	172.7 ± 7.2	0.698
Body mass [kg]	60.8 ± 7.6	67.9 ± 9.4	0.170

*Independent t-test.

review board of Amity School of Physical Education and Sports Sciences, Amity University (approval number: AS-PESS/IRB/2023/01, dated 03/11/2023) and adhered to the Helsinki Declaration principles.

Study design

A two-by-two mixed design was adopted in this study to investigate the effects of training surfaces during SAQ on physical performance. The pre- and post-intervention assessments were included as the within-subject factors. The two training groups were included as the between-subject factors. The testing sessions for data collection were conducted at similar times of the day (i.e., between 16:00 and 19:00 hours) during pre- and post-intervention assessments. Participants were instructed to avoid strenuous physical activity 48 hours before the testing days. In addition, participants were also instructed to avoid alcohol for 48 hours and heavy meals for three hours before testing. A standardized warm-up protocol of ~10 minutes duration was conducted before each testing session [42]. The warm-up also included sub-maximal trials for the test being conducted (e.g., sub-maximal linear sprints).

Data collection

Physical fitness outcomes were assessed using the 30-m linear sprint test, CODS, countermovement jump (CMJ), drop jump (DJ), squat jump (SJ), standing long jump (SLJ), and triple-hop test. Linear sprint and CODS tests were conducted on outdoor natural surfaces, and the timings were measured using reliable single-beam photocell timing gates (Cronox, Madrid, Spain) [46]. The participants were instructed to start 0.3 m behind the first timing games for both tests, and a self-selected start was allowed. For CODS, the modified agility T-test was used, following the protocol described by Sassi & colleagues [39]. The CMJ, SJ, and DJ were conducted on a reliable contact platform (Chronojump, Spain) [32]. All three vertical jump tests were conducted with hands on hips. For CMJ and SJ, verbal instructions were given to jump as high as possible, with the SJ being performed with a 3-second pause at ~90° angle at the knee joint. The DJ was performed from a 30 cm box, and verbal instructions were given to minimize the ground contact time and jump as high as possible. The SLJ and triple-hop distance were performed on a natural grass surface with measurement tape attached to the ground. Verbal instructions were given to jump as far as possible [41, 45]. Three successful trials with a between-trial rest period of 3 minutes were conducted for all the tests mentioned above. The same assessors were involved during both pre – and post-intervention testing sessions. The test-retest reliability for the variables is presented in Table 2.

Training protocol

Before the start of the training interventions, SAQ familiarization sessions were conducted for two weeks, with the training performed on a grass surface in the first week (i.e., two sessions) and training performed on a sand surface in the second week (i.e., two sessions). These sessions were also used to familiarize the testing assessment protocols in order to reduce the learning effects. After that, in the next week, the baseline assessments were conducted. Thereafter, a four-week training intervention was conducted. The post-intervention assessments were conducted 72 hours after the last training session. The exercises and training load were similar for both the intervention groups, with the training surface being the only exception

Table 2. Interclass correlation coefficient (ICC) with 95% confidence interval (CI)

Variables	ICC (95% CI)
30 m sprint [s]	0.63 (0.43–0.80)
CODS [s]	0.68 (0.49–0.83)
CMJ height [cm]	0.96 (0.93–0.98)
DJ height [cm]	0.85 (0.73–0.93)
DJ ground contact time [ms]	0.84 (0.72–0.92)
DJ RSI [au]	0.68 (0.49–0.83)
SLJ distance [m]	0.82 (0.70–0.91)
SJ height [cm]	0.92 (0.85–0.96)
Triple–hop distance [m]	0.90 (0.82–0.95)

Note: au – arbitrary units, CODS – change-of-direction speed, CMJ – countermovement jump, DJ – drop jump, RSI – reactive strength index, SLJ – standing long jump, SJ – squat jump.

Table 3. Training protocol used in the study

Exercise	Week 1		Week 2		Week 3		Week 4	
	Set	Reps#	Set	Reps#	Set	Reps#	Set	Reps#
Single-leg standing long jump	2	8	3	8	3	8	3	8
Single-leg tuck jump (cluster)* Single-leg tuck jump (repeated)*	1	8	1	8	1	8	2	8
Tuck jump (repeated)	2	6	2	6	2	6	2	6
Alternate leg hop	1	5	1	5	2	5	2	5
Single-leg repeated hop	2	6	2	6	2	6	2	6
Shuffle with lateral hop	1	5	1	5	1	5	1	5
Zig-zag run	1	4	1	4	1	4	1	5
Sprint + shuffle + sprint	1	2	1	2	1	3	1	4
Acceleration and deceleration runs	1	4	1	4	1	5	1	5

Note: rest period between exercises were 75 seconds, and between repetitions were 30 seconds; * single-leg tuck jump (cluster) was conducted on week 1 and week 2 and single-leg tuck jump (repeated) was conducted on week 3 and week 4; # – the repetitions for single-leg jumps is mentioned for each leg.

(i.e., grass or sand surface). A progressive overload was applied during the intervention. The volume of jumps during the SAQ was 58 foot contacts at week 1, progressively increasing to 79 foot contacts at week 4, as suggested by previous studies [33]. All sessions were conducted by an accredited strength and conditioning coach. The sand pit that was used for training was 20 cm in depth. All the sessions were conducted in the afternoon hours of the day (between 15:00 hours and 18:00 hours), depending on the schedule of soccer training. The detailed training protocol used in the study is provided in Table 3. The participants were also involved in regular soccer training and were part of the same training group that practiced for the inter-university competition. The soccer training involved both technical and tactical sessions.

Statistical analysis

Data were analyzed using the SPSS software (version 26.0, IBM, USA). The normality of the data was verified using the Shapiro-Wilk test. The data are presented as mean and standard deviation. A two-by-two repeated measures analysis of variance with the pre-and post-data as within-subject factors and intervention groups (i.e., grass versus sand) as between-subject factors was applied to evaluate the interaction effect. Post-hoc tests using independent samples *t*-tests were applied to find between-group differences in pre- and post-intervention, while paired *t*-tests were applied to find within-group differences from pre-to-post intervention in each training group. Percent change differences from the pre-to-post intervention were calculated for each variable using the formula: [(post-pre)/pre] × 100. Effect sizes were calculated for pre-to-post changes for each variable using Hedge's *g* and were interpreted as trivial (<0.2), small (0.2–0.6), moderate (>0.6–1.2), or large (>1.2–2.0) [15]. Effect sizes for the main and interaction effects were calculated using partial eta squared and interpreted as small (<0.06), moderate (≥0.06–0.13), or large (≥0.14) [9]. In addition, the reliability of the data was assessed using the interclass correlation coefficient with a 95% confidence interval and interpreted as poor (<0.5), moderate (0.5–0.75), good (0.75–0.9), or excellent (>0.9) reliability based on the lower bound of the 95% CI [21]. The significance level was set at $p \leq 0.05$ for all the statistical analyses.

Results

No significant differences between the groups were found at baseline for any dependent variables. An interaction effect was detected only for CMJ height, favoring the group training on the sand surface. No interaction effect was observed for other dependent variables. Furthermore, a significant main effect of time emerged for multiple variables, with positive improvements observed in CMJ height, DJ height, SJ height, and triple-hop distance, and negative effects observed for DJ contact time and DJ RSI. No main effect of time was noted for the 30 m linear sprint, CODS, or SLJ distance. Both intervention groups showed significant pre-to-post improvement in CMJ height, DJ height, SJ height, and triple-hop distance, suggesting a positive effect of SAQ training. However, DJ RSI significantly decreased (i.e. negative effects) only for the group training on the sand surface. Statistical analyses are presented in Table 4, and within-group effect sizes and percentage changes are presented in Table 5.

Table 4. Comparisons for changes in outcome variables between SAQ training on sand and land

Variables	Sand training group (n = 7)		Grass training group (n = 6)		Time effect P-value (η_p^2)	Group × time *P*-value (η_p^2)
	Pre	Post	Pre	Post		
	Mean ± SD		Mean ± SD			
30 m sprint [s]	4.37 ± 0.21	4.28 ± 0.23	4.30 ± 0.11	4.22 ± 0.15	0.080 (0.25)	0.869 (<0.01)
CODS [s]	5.89 ± 0.57	5.85 ± 0.47	5.76 ± 0.27	5.77 ± 0.29	0.792 (0.01)	0.758 (0.01)
CMJ height [cm]	34.9 ± 6.1	39.0 ± 5.2*	31.9 ± 4.5	33.6 ± 5.0*	<0.001(0.78)	0.027 (0.37)
DJ height [cm]	31.6 ± 3.8	37.13 ± 5.2*	26.8 ± 4.0	32.9 ± 6.2*	<0.001(0.67)	0.833 (<0.01)
DJ contact time [ms]	0.31 ± 0.11	0.46 ± 0.35*	0.34 ± 0.08	0.47 ± 0.05*	<0.001(0.78)	0.657 (0.02)
DJ RSI [au]	1.10 ± 0.37	0.79 ± 0.19*	0.84 ± 0.23	0.69 ± 0.19	0.024 (0.39)	0.358 (0.08)
SLJ distance [m]	2.30 ± 0.22	2.34 ± 0.21	2.23 ± 0.12	2.29 ± 0.22	0.299 (0.10)	0.935 (<0.01)
SJ height [cm]	34.1 ± 6.4	37.7 ± 6.4*	29.9 ± 4.8	32.2 ± 5.9*	<0.001(0.75)	0.296 (0.10)
Triple-hop distance [m]	6.07 ± 0.62	6.81 ± 0.76*	5.54 ± 0.32	6.42 ± 0.33*	<0.001(0.78)	0.628 (0.02)

Note: au – arbitrary units, CODS – change-of-direction speed, CMJ – countermovement jump, DJ – drop jump, RSI – reactive strength index, SLJ – standing long jump, SJ – squat jump, * – significantly different from pre-intervention levels.

Table 5. Hedge's g effect size and percentage change from pre – to post-intervention

Variables	Sand training group		Grass training group	
	Hedge's g	Percentage changes (%)	Hedge's g	Percentage changes (%)
30 m sprint [s]	0.39	–2.1	0.58	–1.9
CODS [s]	0.07	–0.7	0.03	0.2
CMJ height [cm]	0.69	11.8	0.35	5.4
DJ height [cm]	1.17	17.6	1.11	22.7
DJ contact time [ms]	0.55	48.4	1.87	38.2
DJ RSI [au]	1.00	–28.2	0.68	–17.9
SLJ distance [m]	0.18	1.7	0.32	2.7
SJ height [cm]	0.50	9.9	0.41	7.7
Triple-hop distance [m]	1.01	10.9	2.59	13.7

Note: au – arbitrary units, CODS – change-of-direction speed, CMJ – countermovement jump, DJ – drop jump, RSI – reactive strength index, SLJ – standing long jump, SJ – squat jump.

Discussion

The aim of the study was to compare the effects of SAQ training on grass versus sand surfaces on the physical fitness abilities of amateur male soccer players. The findings suggest significant improvements in jump height in CMJ, DJ, and SJ, as well as triple-hop distance for both training groups. In addition, the findings suggest a negative effect of SAQ training on DJ contact time for both groups. Meanwhile, negative effects were observed only in the sand training group for DJ RSI. Furthermore, when both training groups were compared, the CMJ height significantly improved after SAQ training on sand compared to the grass surface.

The significant improvement in the jump height across all the vertical jump tests (i.e., CMJ, DJ, and SJ) and triple-hop distance in both training groups may be attributed to the musculoskeletal and neuromuscular adaptations that may have occurred due to the SAQ training [19, 26, 49]. The SAQ training protocol in the current study included jump-based exercises that have previously been shown to improve various physical fitness characteristics [29, 34, 35]. These jump-based exercises may have enhanced the inter – and intra-muscular coordination of the lower limb via improvements in the motor unit firing rate and recruitment (i.e., higher-order motor unit recruitment), thus improving the stretch-shortening cycle function of the lower limbs [26, 48]. Furthermore, studies have shown that jump-based exercises induce hypertrophy and increase muscles' cross-sectional area (e.g., girth size) [3], which is associated with increased force production [12]. In support of this, a recent meta-analysis also reported increased maximal strength after jump-based training compared to control conditions [38]. In addition, jump-based exercises have been shown to increase type II muscle fiber recruitment [24], which is associated with an improved rate of force development [25], essential in improving jump height [27].

Furthermore, no beneficial effect of SAQ training was observed in improving 30 m linear sprint time, CODS time, or SLJ distance. This contradicts the conclusion of a recent meta-analysis in favor of improvements in linear sprints, CODS, and jumps after SAQ training [49]. One plausible reason for the lack of improvement in the sprinting performance may relate to the specificity of the training stimulus. For example, all the SAQ training sessions were completed in an area of 12 m × 5 m; i.e., the maximal space for sprinting was limited to 12 m. Similarly, it may be possible that the directional change stimulus was insufficient to improve the CODS time. Moreover, it may also be due to the selection of CODS tests and the training stimulus. During SAQ training, the participants performed quick directional changes that required them to cross agility poles in a step or two. However, the CODS test chosen in this study was a modified agility T-test, which required participants to shuffle sideways and included backward running [39]. It is possible that the neuromuscular stimulus with the SAQ training was not sufficiently specific to improve the modified agility T-test [36]. In addition, the study included unilateral SLJ exercises in the SAQ training, while the SLJ test was conducted bilaterally, possibly affecting the training specificity principle between training and testing [36].

In addition, negative effects of SAQ training were observed for DJ ground contact time and DJ RSI. The ground contact time significantly increased in addition to the jump height for both groups, indicating that the participants changed the jump strategy during the DJ test (i.e., compromising the ground contact time to increase the vertical jump height) [18]. A previous study reported that greater depth (i.e., eccentric muscle action) produced greater jump height [18]. A greater depth is associated with a longer ground contact time [7]. Furthermore, it should be noted that specific instructions to minimize the ground contact time and increase the jump height were provided; however, no trials were discarded based on ground contact time (despite the ground contact time data being directly available to the assessors). Therefore, it may be plausible that SAQ training that does not include jump exercises aiming to decrease the ground contact time (e.g., DJ) does not improve the ground contact but instead increases the ability to use the stretch-shortening cycle function by altering the jumping strategy. A more detailed interpretation can be observed from the DJ RSI data, which show no changes for the grass training group but a significant decrease in the sand training group. This indicates that, although there is a change in jump strategy during DJ in both groups, the sand training has a negative effect on the reactive strength abilities of the lower limbs. This may be due to the compliant nature of the sand, which may not have allowed the application of high-ground reaction forces during the jump exercises [17]. One study [2] that compared jump training on sand versus a rigid surface showed a non-significant decrease in the DJ RSI for the sand training group (–3.9%), and a non-significant increase was observed for the rigid surface training group (11.5%).

Of note, a significantly greater improvement in CMJ height was observed for the group performing SAQ training on the sand surface compared to the grass surface. This may be due to the compliant nature of the sand surface, which allows leg extensor muscles to generate excess force in an active state, resulting in an increased contraction time [4]. This increase in the contraction time enables participants to produce more work on sand compared to the grass surface [23, 50]. A previous study also reported a significant increase in CMJ peak force and rate of force development, resulting in greater CMJ height after jump training on sand compared to rigid surfaces [2]. In addition, a recent meta-analysis [31] that compared training on sand versus hard surfaces on jump performance of team sports athletes reported a favoring effect on CMJ improvement for sand surfaces, although the result was non-significant. However, the meta-analysis included only five studies; thus, more studies are required to strengthen the evidence. Moreover, sand-based training has also reported lesser muscle damage compared to grass surfaces [8], implicating its effectiveness and usefulness as a training consideration.

Limitations

Firstly, although the study included 24 participants from an amateur university soccer training group (12 in each experimental group), the attrition of participants from the study led to the final participant number of 13. The most commonly given reason for not completing the study was academic-related concerns at the university (e.g., assignments). Therefore, future studies may be conducted on participants from full-time soccer academies or professional soccer clubs to avoid attrition and reduced sample size. Indeed, the current findings may serve as a proof-of-concept for future studies. Secondly, the study included only male participants, so the results cannot be extrapolated to the female population. Thirdly, not all the participants were familiar with the assessments before the start of the intervention. Although sufficient familiarization sessions were conducted before the assessment sessions, it is worth noting that the study was conducted on participants unfamiliar with the assessment protocols. Future studies may take this point into consideration. Fourthly, the participants did not show improvement in CODS with the incorporated test in the protocol. More ecologically valid tests may be added to the testing protocol (e.g., a 5-0-5 test or a zigzag running test). Lastly, no control group could be included due to the limited number of participants. The inclusion of a control group would allow comparison of the improvements in both the training groups against the control condition.

Conclusion

In conclusion, compared to baseline, SAQ training in general (i.e., both grass and sand) effectively improved jump height during CMJ, SJ, and DJ, and triple-hop distance. However, greater improvement was observed with SAQ training on the sand surface for CMJ height compared to the grass surface. Furthermore, SAQ training, in general, did not improve 30-m linear sprint time, CODS time, or SLJ distance. In addition, DJ GCT increased after SAQ training on both surfaces, highlighting the changes in participants' jump strategy. Lastly, DJ RSI decreased after SAQ on sand but not on grass surfaces, showing the adverse effects of training on sand on the reactive strength abilities. A practical recommendation to mediate these adverse effects on RSI would be to use a combination of training on both grass and sand surfaces. However, whether this combined training approach would improve the RSI should be researched using larger sample size studies.

Conflict of interest: Authors state no conflict of interest

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