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The Effects of Ten Weeks of Lower-Body Unstable Surface Training on Markers of Athletic Performance

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Abstract. Cressey, E.M., C.A. West, D.P. Tiberio, W.J. Kraemer, and C.M. Maresh. The effects of ten weeks of lower-body unstable surface training on markers of athletic performance. *J. Strength Cond. Res. 21(2):561–567. 2007.*—Initially reserved for rehabilitation programs, unstable surface training (UST) has recently grown in popularity in strength and conditioning and general exercise scenarios. Nonetheless, no studies to date have examined the effects of UST on performance in healthy, trained individuals. The purpose of this study was to determine the effects of 10 weeks of lower-body UST on performance in elite athletes. Nineteen healthy, trained members (ages 18–23 years) of a National Collegiate Athletic Association Division I collegiate men's soccer team participated. The experimental (US) group (n = 10) supplemented their normal conditioning program with lower-body exercises on inflatable rubber discs; the control (ST) group (n = 9) performed the same exercises on stable surfaces. Bounce drop jump (BDJ) and countermovement jump (CMJ) heights, 40- and 10-yard sprint times, and T-test (agility) times were assessed before and after the intervention. The ST group improved significantly on predicted power output on both the BDJ (3.2%) and CMJ (2.4%); no significant changes were noted in the US group. Both groups improved significantly on the 40- (US = −1.8%, ST = −3.9%) and 10-yard sprint times (US = −4.0%, ST = −7.6%). The ST group improved significantly more than the US group in 40-yard sprint time; a trend toward greater improvement in the ST group was apparent on the 10-yard sprint time. Both groups improved significantly (US = 2.9%, ST = −4.4%) on T-test performance; no statistically significant changes were apparent between the groups. These results indicate that UST using inflatable rubber discs attenuates performance improvements in healthy, trained athletes. Such implements have proved valuable in rehabilitation, but caution should be exercised when applying UST to athletic performance and general exercise scenarios.

Key Words. instability, stability, balance, power, proprioception, stretch-shortening cycle

Introduction

Unstable surface training (UST) has recently grown in popularity in strength and conditioning and general exercise scenarios. Although UST has proved valuable in rehabilitation settings, especially with respect to addressing proprioceptive deficits related to functional ankle instability (25, 39), little research has examined how UST affects healthy, trained athletes. Nonetheless, many companies and strength and conditioning professionals have capitalized on this trend by promoting UST products as useful for improving performance.

Unstable training implements, including stability balls, wobble boards, foam pads, and balance discs, reduce (or eliminate) an individual's points of contact with solid ground. Unstable surface training proponents assert that such training will enhance performance via improvement of balance, kinesthetic sense, proprioception, and gradation of force (8, 27). These supporters claim that because all movement requires both stability and mobility, it is valuable to train the 2 qualities simultaneously (8, 27). Both efferent and afferent processes modulate neuromuscular function, yet little research has focused on the efferent component. Unstable surface training aims to develop afferent efficiency to reduce injury risk and improve performance (8, 14, 27); such training may help to establish proper agonist-antagonist cocontraction for joint stability and improve rate of force development (14). Efficient afferent function is crucial to neuromuscular excitation; potential improvements in this regard include more rapid proprioceptive input collection, information transmission to the central nervous system, and information processing by the central nervous system (15).

Afferent efficiency is valuable in injury prevention, because short latency periods before muscle activity allow for rapid stiffening of joint complexes (14). In limited research, wobble board training has improved discrimination of ankle inversion movements in already-stable ankles of athletes and the elderly (36); however, control groups did not exercise in these studies. Similar results were noted in youth soccer players (35), but previous injury history was not considered; some subjects may have simply been correcting existing injury-related proprioceptive deficits. Regarding performance, UST improved rate of force development without a concurrent increase in maximal static leg press strength in untrained subjects (14), although no control groups were used to allow for comparison to stable surface exercise. Conversely, Bruhn and others (9) found a stable surface program to be superior to UST with respect to postural stabilization, maximal voluntary isometric contraction, and countermovement jump (CMJ) height.

There remains considerable opposition to using UST outside of rehabilitation settings in spite of its purported benefits; opponents speculate that UST may undermine training specificity, lead to unfavorable biomechanical compensations, and impair the development of athletic qualities. Unstable surface training has been shown to increase core musculature activation when compared with stable surface exercises (6, 22), but these studies have been performed with the torso on the unstable surface (i.e., exercises targeting the trunk) rather than the lower extremity; such results may not be applicable to the present study. Increasing core stabilizer activation with lower-body UST may not favorably influence dynamic movements; standing UST exercises do not stress the core in a similar manner to trunk-specific exercises (e.g., curl-ups), in which the overall stability challenge is less difficult. Swiss ball training improved core stability in young athletes but did not favorably affect abdominal and erector spinae electromyographic activity, $\dot{V}O_2$max, running economy, or running posture (31). Likewise, no correlation existed between wobble board performance and hockey skating speed in players older than age 19 years (7). These findings support previous evidence (13) that there is little carryover from static to dynamic balance. Balance and stability are skill specific; UST, which necessitates predominantly static balance, may not transfer to most athletics, which require more dynamic balance (10). Finally, incorporating UST to a neuromuscular recruitment pattern for a given activity (e.g., throwing on an unstable surface) may negatively affect chronic performance of that skill (39).

Core musculature activation is significantly greater under unstable squat conditions than stable conditions (2), and instability with trunk-strengthening exercises increased activation of the lower abdominal muscles (6). However, force production under stable conditions is markedly greater than under unstable conditions, and antagonist activity is significantly higher with instability (5). Behm and colleagues (5) attributed this altered recruitment to "excess stress associated with the increased postural demands" (muscles stabilizing joints rather than promoting movement) and "the dispersion of concentration [neural drive] in attempting to control 2 limbs with differing responsibilities [balance and force]." Overall electromyographic activity is unchanged because limb musculature is called upon to aid in maintaining joint stability with instability (3, 6, 20).

Although stable surface free weight exercises have been proved safe (41), no studies have examined injury rates with UST. More attention is devoted to maintenance of balance with UST, so one may pay less attention to actual performance of the dynamic component of movements, leading to potentially unsafe exercise technique. One may also question UST injury prevention benefits; in one study, fewer ankle sprains were observed in volleyball players who trained on balance boards, but this reduction was confined to those with previous ankle sprains. No preventive effect was noted in healthy athletes, and the incidence of overused knee injuries actually increased in the balance board group (34). Balance board training was also ineffective at decreasing traumatic lower-extremity injury rate in elite female soccer players, and the frequency of major injuries was significantly higher in the UST group (30). Static balance cannot be used to predict ankle injury in soccer players (19), indicating that methods to improve static balance may not help to reduce injury rate in dynamic activities, especially when dealing with athletes without recent lower extremity injuries.

With this debate in mind, the purpose of this study was to determine the effects of 10 weeks of lower-body unstable surface training on performance indices of the short- and long-lasting stretch-shortening cycle (SSC), sprinting speed, and agility in elite collegiate soccer players. To our knowledge, this is the first study to examine an UST intervention in healthy, trained athletes with no recent history of injury. The research hypothesis was that there would be significantly different changes in performance on jumping tests of the short- and long-lasting SSC, sprinting speed, and agility between subjects who did not undergo a lower-body UST intervention and those who did.

Methods

Experimental Approach to the Problem

A pretest, posttest control group design was utilized for this study. Subjects were matched for age and position (goalkeeper, defender, midfielder, and forward to account for varying activity levels during training and competition) and then randomly assigned into either the experimental (US, $n = 10$) or control (ST, $n = 9$) group.

Subjects

Nineteen members of a National Collegiate Athletic Association Division I collegiate men's soccer team (ages 18–23 years) with considerable resistance training experience were chosen to participate in this study. All subjects had a minimum of 6 months of resistance training experience but no involvement in UST or ankle sprain history over the previous 6 months. Each subject provided written informed consent prior to entry in the study, which was approved by the institutional review board of the University of Connecticut.

Pretesting

All subjects took part in pretesting during their normally scheduled January testing week. The testing was carried out in 1 day in the following order: bounce drop jump (BDJ), CMJ, 40-yard sprint test (with assessment of a 10-yard sprint time), and T-test. The testing session took approximately 1 hour, and subjects were given ample time to recover between each test. All subjects were proficient with each of the tests, so no familiarization session was necessary. Prior to testing, each subject's fully clothed body weight was recorded. As a general warm-up, subjects jogged lightly for 5 minutes and then participated in a team dynamic warm-up directed by their strength and conditioning coach.

Bounce Drop Jump. The BDJ test assessed the subjects' proficiency with the short ($<$250 ms contact time) SSC, also known as fast reactive strength (17, 18). Subjects were instructed to drop from a 12-inch box onto the floor and rapidly perform a rebound jump to maximize jump height while minimizing ground contact time and avoiding heel contact with the floor. Jump height was determined using the Vertec Jump Training System (Sports Imports, Columbus, OH). Subjects completed as many trials as needed to determine the maximum jump height. The subjects' reaches were subtracted from these heights to attain the net jump height, and this number was converted to predicted power as described by Sayers and others (29) to account for differences in body mass among subjects.

Counter Movement Jump. The CMJ assessed the subjects' proficiency with the long ($>$250 ms contact time) SSC, also known as slow reactive strength (17, 18). Subjects were instructed to rapidly descend to a self-selected squat depth and immediately attempt a maximal vertical jump, the height of which was determined using the Vertec Jump Training System (Sports Imports). Subjects completed as many trials as needed to determine the maximum jump height. The subjects' reach was subtracted from these heights to attain the net jump height, and this number was converted to predicted power as described by Sayers and others (29) to account for differences in body mass among subjects.

TABLE 1. Sample training day: week 1, day 1.

Team dynamic flexibility warm-up
A) Speed deadlifts: 4 × 2, 55% 1RM
B) Barbell deadlifts: 3 × 5
C) Dynamic dumbbell lunges (stable/unstable*): 3 × 8 right and left
D1) Low-incline barbell press: 3 × 5
D2) One-arm bent-over dumbbell row: 3 × 6 right and left
E) Side bridges: 3 × 40 seconds right and left

* The experimental/unstable group performed these lunges with the front foot stepping onto a Dyna-Disc. The control/stable group performed the exercise while stepping directly onto the floor. All other exercises were the same for both groups.

Forty- and Ten-Yard Sprint. After the jumping assessments, the subjects completed 2 submaximal 40-yard sprints as extended warm-ups. The subjects then took part in 3 maximal-effort 40-yard sprints on an indoor track with a rubberized surface. Approximately 3 minutes of rest separated each trial, and the fastest time was used for data analysis. An automatic digital timer linked to sensors (Brower Timing Systems, Draper, UT) at the 0-, 10-, and 40-yard marks was utilized to assess total time as well as 10-yard sprint times. The 10-yard sprint time that corresponded to the fastest overall time was used for data analysis. Subjects started from self-selected positions with the foot within 1 inch of the starting line.

T-Test. The T-test was used to assess agility. This test required the subjects to sprint from the starting point to a cone 10 yards away, turn and sprint to the left 5 yards to touch a line cone, turn and sprint to the right 10 yards to touch another line, turn again and sprint to the left 5 yards, turn at the center cone, and sprint back through the starting line. Each subject completed the test 3 times with approximately 3 minutes of rest between each trial; the fastest time was used for data analysis. An automatic digital timer linked to sensors (Brower Timing Systems) at the start and finish points was utilized to assess time to completion.

Training Intervention

Between pre- and posttesting, all subjects completed their normal spring strength and conditioning programming, but the US group performed the UST intervention on one of the exercises in each resistance training session over the course of the intervention (Table 1). In all, the intervention lasted 10 weeks (including a 1-week break after week 4) and comprised 27 sessions. The intervention occurred during the off-season period to avoid any potential conflicts with in-season preparation and competition; however, the last 4 weeks coincided with the team's spring schedule.

All UST was performed on 1-2 Dyna-Discs (Exertools, Inc., Novato, CA); these inflatable rubber discs are 14 inches in diameter and widely used in rehabilitation settings. Training was structured such that volume was identical between the 2 groups, but 1 supplemental lower-body exercise in each resistance training session was performed on different training surfaces (unstable or stable). These exercises, which were performed for 2 to 5 sets of 5 to 15 repetitions (or for a certain duration, with balance exercises) in a manner consistent with the team's normal nonlinear periodization parameters at the time of the session, consisted of variations of exercises, such as squats, deadlifts, lunges (Figures 1 and 2), single-leg squats, and single-leg balances.

FIGURE 1. Unstable surface dumbbell lunge.

The US group performed the exercises on an unstable surface with body weight or body weight plus a load prescribed as a percentage of estimated 1 repetition maximum (1RM) for the given unstable surface exercise (Figure 1). Conversely, the ST group simply performed the same exercises on stable surfaces (i.e., the ground or a bench); the same percentage of 1RM was prescribed for loading, but it was based on the estimated 1RM for stable conditions (Figure 2). All estimations of 1RM were based on pilot data by the investigators, as well as the experience of the certified strength and conditioning specialists. This design effectively accounted for the reduction in force output one experiences with UST compared with stable surface training (3, 5) and therefore replicated what occurs when UST is implemented in lieu of stable surface training. Because UST is generally implemented as an assistance or supplemental exercise in programming, including these exercises at the end of the training

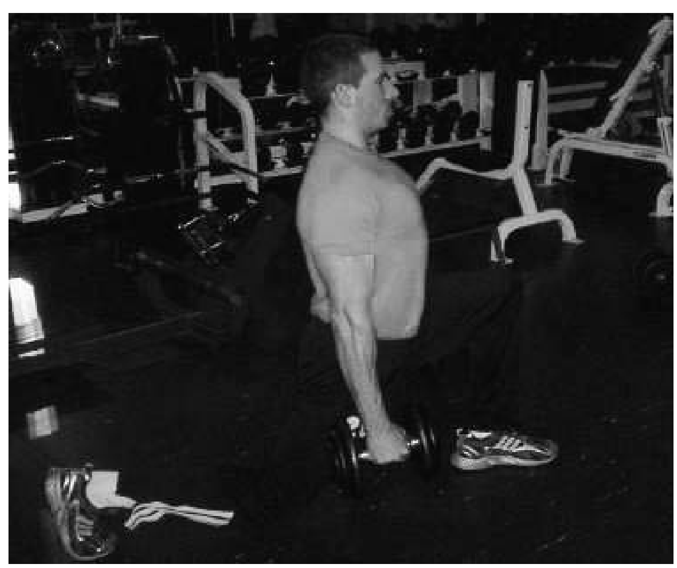

FIGURE 2. Stable surface dumbbell lunge.

TABLE 2. Mean (± *SD*) bounce drop jump and countermovement jump predicted peak power for pre- and posttest and % change.

Assessment	Pretest	Posttest	% change
Bounce drop jump predicted power (W)			
Unstable	5,067.8 (387.8)	5,109.5 (384.0)	0.8%
Stable	5,156.3 (642.8)	5,324.1 (602.57)	3.2%*†
Countermovement jump predicted power (W)			
Unstable	5,088.6 (390.6)	5,088.6 (404.1)	0.0%
Stable	5,174.5 (588.7)	5,302.7 (545.8)	2.4%*†

* Significant difference within groups over pretesting at $p < 0.05$.
† Significant difference between groups at $p < 0.05$.

session better carried over to the real-world applications. Perhaps more important, incorporating the movements at the end of the sessions disrupts the continuity of the team's training by having athletes performing different exercises from the beginning of the sessions.

Posttesting

Posttesting occurred 11 weeks after pretesting during the team's normal April testing week. All tests conducted during pretesting were repeated in the same order, with specific attention paid to standardizing footwear and test timing to pretesting conditions. Changes to body weight and reach height were noted and factored into statistical analyses of the data.

Statistical Analyses

All data were analyzed using a SPSS 10.0 statistical software package (SPSS, Inc., Chicago, IL). Independent sample *t*-tests were conducted before the 10-week study to determine if any significant differences existed between the 2 groups. Each data set was tested for outliers and statistical assumptions, and a Log_{10} transformation of data was used to meet assumptions. Outliers were removed from the data set. After meeting all statistical assumptions for linear statistics, a 2 × 2 (group × time) repeated measures analysis of variance was used to determine if significant differences existed between the mean changes for each group on each of the dependent variables. Five paired-sample *t*-tests with alpha level corrections were conducted to follow up on significant interactions. Using nQuery Advisor software (Statistical Solutions, Saugus, MA) the statistical power for the *n* size used ranged from 0.67 to 0.82. Statistical significance was set at $p \leq 0.05$. All data are presented as means ±1 *SD*.

RESULTS

Jumping Assessments

Independent sample *t*-tests demonstrated no significant preintervention differences between the 2 groups for predicted power on the BDJ or CMJ. Pretreatment means for all jumping measures for both groups are presented in Table 2. In contrast to the ST group, which demonstrated significant improvements in both BDJ and CMJ, the US group did not demonstrate significant improvements in BDJ or CMJ at posttesting. The ST group showed significantly greater improvements than the US group in both BDJ and CMJ performance. Postintervention means and percent change for the BDJ and CMJ power output for both groups are presented in Table 2.

TABLE 3. Mean (± *SD*) 40- and 10-yard sprint times for pre- and posttest and % change.

Assessment	Pretest	Posttest	% change
40-yard sprint(s)			
Unstable	5.02 (0.11)	4.93 (0.11)	−1.8%*
Stable	5.06 (0.24)	4.87 (0.16)	−3.9%*†
10-yard sprint(s)			
Unstable	1.73 (0.04)	1.67 (0.07)	−4.0%*
Stable	1.75 (0.09)	1.63 (0.08)	−7.6%*

* Significant difference within groups over pretesting at $p < 0.05$.
† Significant difference between groups at $p < 0.05$.

Sprinting Assessments

Independent sample *t*-tests demonstrated no significant preintervention differences between the 2 groups for 40-yard sprint time or 10-yard sprint time. Pretreatment means for all jumping measures for both groups are presented in Table 3. Significant improvements were observed on the 40- and 10-yard sprint tests in both the ST and US groups. The ST group showed significantly greater improvements than the US group in 40-yard sprint time and a trend ($p = 0.06$) toward greater improvement in 10-yard sprint time. Postintervention means and percent change for the 40- and 10-yard sprint times are presented in Table 3.

Agility Assessment

Independent sample *t*-tests revealed no significant preintervention difference between the 2 groups for T-test time. Pretreatment means for all jumping measures for both groups are presented in Table 4. Significant improvements were observed in both the ST and the US groups over baseline. No statistically significant ($p > 0.05$) differences were apparent between groups. Postintervention means and percent change for the T-test times are presented in Table 4.

DISCUSSION

Unstable surface training has emerged from the world of rehabilitation to become a popular initiative in the world of strength and conditioning, and numerous companies have capitalized on this trend by introducing a wide variety of UST products. In doing so, they have asserted that UST is an outstanding way to develop general fitness; reduce the risk of injury; and, most applicable to the present study, improve athletic performance. In spite of these claims, no scientific evidence exists to support UST for improving athletic performance in healthy, trained populations. The literature to date has only examined the effects of UST on untrained (and sometimes completely deconditioned) subjects, many of whom were injured prior to the intervention.

This uncertainty is in complete contrast to the knowl-

TABLE 4. Mean (± *SD*) T-test times for pre- and posttest and % change.

Assessment	Pretest	Posttest	% change
T-test(s)			
Unstable	8.33 (0.15)	8.09 (0.21)	−2.9%*
Stable	8.42 (0.37)	8.06 (0.24)	−4.4%*

* Significant difference within groups over pretesting at $p < 0.05$.

edge surrounding traditional stable surface resistance training, which has proved effective in healthy, trained subjects in enhancing such athletic qualities as muscular strength (4), power (4), aerobic endurance (26), anaerobic endurance (4), rate of force development (40), hypertrophy (4), reactive strength (40), and agility (21). These qualities transfer to improved performance in a variety of sporting tasks, including vertical jump (32), throwing velocity (33), sprinting speed (12), and running economy (26). In contrast to the inconclusive research with respect to UST's effect on explosive strength, several studies have demonstrated the efficacy of stable surface resistance training in improving the rate of force development without altering firing patterns (16). In spite of the lack of scientific data to validate or refute the value of UST in athletic populations, considerable debate, based largely on theoretical knowledge, occurs regarding its utility.

The primary findings of this study were that 10 weeks of lower-body UST attenuated improvements in both short- and long-lasting SSC jumping performance and 40-yard sprint time when compared with a stable surface program identical in all other programming variables. A trend toward similar attenuation in 10-yard sprint time was also apparent. No significant difference between groups was noted on an agility measure, however.

In a broad sense, the differential training effect between groups can be considered fundamentally related to the fact that UST undermines the principle of specificity of training. It is important to differentiate between instability at the foot, which is accustomed to stable surfaces in closed-chain motion, and instability at the torso and arms, which often encounter instability while the base is stable. Most athletic endeavors occur in a standing position on stable surfaces, and instability is applied further up the kinetic chain. In this regard, UST training may prove more useful in measures aimed at training the core and upper body musculature (e.g., movements seated on or lying across a stability ball with or without added resistance) than with exercises targeting the lower body. Instability can, however, be imposed in a more sport-specific context with unilateral exercises (6), destabilizing torques to regions above the feet, and lifting of awkward objects (e.g., strongman training) (37).

Most athletic movements are performed at high velocities and heavily depend on the SSC. Given that UST interventions delay the amortization phase of SSC movements, one can infer that subsequent force production due to release of stored energy from eccentric preloading would be markedly compromised on such training surfaces (18). Although UST may have favorable impacts on afferent functioning in injured subjects with proprioceptive deficits, it may chronically impair optimal SSC function via both mechanical (loss of stored energy as heat) and psychological (tentative movement) factors in healthy subjects. Effectively, by training slowly and tentatively, the athlete may be conditioned to perform in the same slow manner when faced with athletic challenges. Antagonist activity is heightened during UST to maintain joint stability (5), so it is not unreasonable to conjecture that such a training effect could be detrimental to optimal rate and magnitude of force production when applied for an extended training period. Although increased antagonist activation may assist in maintaining joint stability, it can be counterproductive in strength and power tasks. Torque developed by the antagonists decreases net torque in the desired direction and, through reciprocal inhibition, may impair an individual's ability to completely activate the agonists (28). Therefore, UST may create a hesitant athlete for whom stability is gained at the expense of mobility and force production. Sale (28) noted that 2 muscular activation alteration patterns emerge with prolonged (stable surface) resistance training: (a) "a decrease in absolute antagonist activation in conjunction with either an increase or no change in agonist activation" and (b) no change in "absolute antagonist activation but increased agonist activation, decreasing the antagonist/agonist ratio." Muscular activation patterns with UST work contrary to both of these outcomes.

The opportunity cost of the athletes' training time may also have been an issue in this study. With a limited time available to train, athletes must be provided with exercises and program variables that yield the most results in the least amount of time. In light of the findings of the current study, it appears that the UST group would have benefited more from more sport-specific training emphasizing dynamic muscle actions (as was used in the stable surface group). Additionally, Gruber (15) recently found that UST enhanced neuromuscular activation in untrained subjects only in the earliest phases (<50 ms) of muscular action. One must therefore question if exercises that improved neuromuscular function throughout the entire duration of muscle action were in fact superior in this case; previous research (1) has established the efficacy of stable surface heavy and explosive resistance training with respect to this more extensive training effect. Also of note, the early-phase training effect (increased rate of force development) observed in previous studies of untrained subjects may not be applicable in trained subjects.

A correlation exists between BDJ (short SSC) performance and 30- to 100-m sprint performances, whereas the CMJ (long SSC) has correlated to sprinting distances up to 300 m (17). Nicol and Komi (24) noted that contact time and impact loads increase due to contractile failure (because of repeated stretch loads) and accumulated metabolic fatigue. As a result, the neuromuscular system alters the musculotendon stiffness by increasing the preactivation level, leading to a reduced tolerance to stretch and, in turn, loss of elastic recoil capabilities. This corresponds to an increased need for work during push-off (24), verifying that the SSC takes on a less important role as duration of exercise increases. Given that negative alterations to SSC function may have been a major contributing factor to the attenuation of performance improvements in the UST group, it follows that more marked differences would be observed between groups on short SSC movements (those most correlated with short sprint performances under nonfatigued conditions, e.g., BDJ, 40-yard sprint) than on long SSC tasks (e.g., CMJ). The latter category of movements is characterized by a longer amortization phase.

The trend toward statistical significance in 10-yard sprint times may have been related to increases in maximal strength and power, both of which have been verified as important for the initial acceleration of sprint performance (23). Given that UST compromises exercise intensity vs. performing the same exercises under stable conditions, it is likely that the stable surface group had a greater stimulus for increases in maximal strength as a result of the intervention. Both maximal strength and power are influenced by the SSC, the function of which appeared to be negatively affected by the UST. Cronin and Hansen (11) found that CMJ performance was significantly correlated with the initial acceleration of sprinting performance. This trend has direct implications in terms of a coach's decision to use UST as assistance exercises, because both groups performed traditional stable surface heavy resistance training exercises (e.g., squats, deadlifts) prior to the exercises specific to the training intervention. Therefore, these results suggest that it would be ideal to maintain specificity (with stable surface exercises) throughout the entire training session.

Although the stable surface group improved more than the UST group on the T-test, a measure of agility, this difference was not significant. Because the T-test is similar to the other tests utilized in that it is heavily reliant on the SSC, this lack of significant finding underscores the need for future research with larger sample sizes.

PRACTICAL APPLICATIONS

One existing criticism of UST is that such training does not allow for sufficient loading to induce strength gains; the results of this study not only verify that assertion but also demonstrate that UST actually attenuates power (and presumably strength) gains derived from concurrent stable surface training. As such, coaches applying UST with a proprioceptive training effect in mind may in fact be impairing the development of important athletic qualities; this finding demonstrates that proprioception is likely best trained in a specific sense with stable surface initiatives.

As initially proposed by Anderson and Behm (3), UST may prove valuable in situations in which one would want to maintain activation of muscles but reduce joint torque to lessen the stress on the articular system. Although electromyography has traditionally been used to measure changes in externally measurable force, muscles used to aid in joint stability can contribute significantly to electromyographic signals without altering measurable force (6). Applicable situations may include "backoff" or "regeneration" phases during which athletes' bodies are given a chance to recuperate from high-force, high-velocity movement. It would appear that such UST interventions would be best utilized in the upper body, which typically operates in an open-chain fashion in the majority of sporting movements. Conversely, based on the results of the present study, similar interventions could prove to negatively affect performance in the lower extremities, which typically operate in a closed-chain fashion in most athletics.

The rehabilitation value of UST training cannot be ignored, however. In addition to proprioceptive reeducation after injuries (especially ankle injuries), UST may be of value in scenarios in which muscles are not yet capable of unrestricted loading through a full range of motion (which would involve significant joint torques). There may also be value to UST as preventative maintenance training for presently healthy individuals with a history of ankle sprain or other lower extremity trauma. Nonetheless, with the present results in mind, there appears to be a point of diminishing and even negative returns on such a training investment, so fitness professionals and coaches would be wise to utilize such interventions in extreme moderation outside of rehabilitation settings. Instead, program design with healthy athletes should adhere to the principle of specificity with respect to training surfaces just as it would for other characteristics of muscular actions. Although there may be certain sports (e.g., surfing, snowboarding) for which UST may offer appreciable carryover to performance, the results of the present study suggest that for most athletes, instability should be applied to training in more sport-specific contexts. These contexts include the application of destabilizing torques applied further up the kinetic chain, just as athletes would encounter in sporting environments where they move on fixed contact surfaces. Examples of such destabilizing torques include unilateral exercises (6), lifts performed with nonsymmetrical objects and uneven loading (38), and change-of-direction drills performed at progressively higher speeds. Such initiatives constantly fluctuate an athlete's center of gravity within his or her base of support, thereby imposing instability and, over time, a training effect that enables an athlete to better regain stability in athletic contexts.

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