

## Effects of Core Strength Training Using Stable and Unstable Surfaces on Physical Fitness and Functional Performance in Professional Female Futsal Players

by

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The aim of this study was to assess the effect of core strength training performed on a stable surface (CTS) compared with core strength training performed on an unstable surface (CTU) on physical fitness (jump performance, sprint, and repeated sprint ability (RSA)) and quality of movement (Fundamental Movement Screen) in professional female futsal players. Fourteen professional female futsal players (mean age:  $23.7 \pm 5.1$  years, age range: 18-28 years) were randomly assigned to a CTS ( $n = 7$ ) or a CTU ( $n = 7$ ) group. The intervention program was carried out 3 times a week over 6 weeks. Players of both groups performed the same four core-strengthening exercises. The only difference between the two interventions was that the CTU group performed all exercises (i.e., shoulder bridge, side bridge, prone plank, and crunch) on an unstable surface (Togu® Dyn-Air). Within-group analysis showed significant improvements ( $p < 0.001$ ) in 10 m sprint performance from the pre- to post-test in the CTS (+4.37%) and CTU (+5.00%) groups. Players in both the CTS (+10.39%) and CTU (+11.10%) group also showed significant enhancement in the Functional Movement Screen total score, from the pre-test to post-test. In addition, a significant time effect was also observed for the CTU group in the relative score of the RSA test decreasing from the pre- to post-test (-30.85%). In the between-groups analysis, there were no significant differences between the core strength training groups (CTS vs CTU) in any variable. To conclude, sprint and Functional Movement Screen performance improved following CTS and CTU when conducted in combination with regular futsal training. In addition, CTU had limited benefit in RSA compared to CTS.

**Key words:** resistance training, trunk stability, Functional Movement Screen, explosive strength, repeated sprint ability.

### Introduction

Competitive futsal can be characterized as an intermittent high-intensity strenuous sport (Barbero et al., 2009; Dogramaci et al., 2011). Time-motion analysis studies have demonstrated that professional futsal players spend >22% of total match time undertaking high-intensity running (Barbero et al., 2008). Due to the smaller court dimensions compared to soccer, the unlimited number of substitutions, and the inclusion of attacking and defensive tasks, competitive futsal

players are required to perform a great number of sprints throughout a game that are typically present in short bursts (Dogramaci et al., 2011). Moreover, as in soccer, decisive actions of futsal games occur during high-intensity activities (Barbero et al., 2009; Dogramaci et al., 2011). Thus, it can be argued that anaerobic performance is crucial in competitive futsal, particularly for elite players.

It is well known that anaerobic

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performance can be improved by means of strength training (Bompa, 1999). As a consequence, training programs to promote strength adaptations in futsal players should be prioritized (Paz-Franco et al., 2017), in this regard, core strength training has been advocated as a means to prevent and rehabilitate injuries, and as a way to increase athletic performance (Akuthota and Nadler, 2004). However, a recent systematic review and meta-analysis have showed that core strength training is associated with only limited gains in physical fitness and athletic performance (Prieske et al., 2016a). Functionally, core strength may help transmitting the energy efficiently from the lower to upper extremity and also the other way around, it improves body control, body balance and efficiency between movement transitions that is of vital importance for sport-specific activities (Akuthota and Nadler, 2004; Granacher et al., 2014).

Remarkably, performance in several futsal actions often occurs on relatively unstable surfaces (e.g. kicking a ball while being impeded by an opponent). Thereby, according to the training specificity principle (Behm et al., 2010), core strength training must attempt to closely address the demands of the respective sport-specific activity using unstable surfaces (Behm et al., 2015). It is well documented that trunk muscle activity is higher when using unstable surfaces during the execution of core exercises (Vera-García et al., 2000). Thus, the integration of unstable surfaces in core strength training could generate superior neuromuscular adaptations compared with training using stable surfaces (Behm et al., 2010). However, to the best of our knowledge, there is only one study available that has investigated the effect of core strength training on stable vs. unstable surfaces in team sport athletes (i.e. youth soccer players) (Prieske et al., 2016b). As a result, the authors found that trunk muscle strength, sprint, and kicking performance improved following 9 weeks of core strength training on unstable and stable surfaces, without differences between groups (Prieske et al., 2016b).

Traditionally, core strength training is frequently used as a prophylactic strategy in an attempt to improve neuromuscular control and ineffective movement patterns (Huxel Bliven and Anderson, 2013). However, there is no clear scientific evidence to date that supports the

relationship between core strength and effective movement proficiency. Thus, core exercises are implemented according to the theoretical framework that these exercises can restore as well as enhance muscle strength and endurance, contribute to regaining posture along with balance through the regulation of the neuromuscular control system for overall improvements in function (Huxel and Anderson, 2013). In this regard, the Functional Movement Screen (FMS) is a test that was developed with the goal of identifying limitations or asymmetry in core strength, coordination, balance, range of motion, and general movement proficiency that may predispose an athlete to injuries during activity (Cook et al., 2006). Previous studies suggest that the FMS demonstrates excellent interrater and intrarater reliability (Bonazza et al., 2016), and as a screening tool, is habitually used within both applied and clinical settings. However, although the ability of the FMS protocol to determine the effectiveness of training interventions has been examined (Bodden et al., 2015; Kiessel et al., 2011), no studies have assessed whether or not changes in an individual's FMS score can be achieved with a core strength training program using stable and unstable surfaces.

Therefore, the aim of this study was to examine the effects of core training performed on stable (CTS) vs. unstable surfaces (CTU) when conducted in combination with regular futsal training on physical fitness and FMS scores in professional female futsal players. We hypothesized that CTU would provide greater improvements in physical fitness (i.e. speed, strength, and repeated sprint ability) and functional performance (i.e. FMS) than CTS.

## **Methods**

### *Participants*

Fourteen female professional futsal players competing in the Spanish First Division Professional Futsal League participated in this study. The players regularly performed 5-6 weekly futsal sessions with their team and on average exercised  $10.3 \pm 0.9$  h·wk<sup>-1</sup> in their standard training cycle. The team also regularly played one official match per week. Only players who participated in full training were considered for inclusion. Exclusion criteria were injuries resulting in loss of one or more futsal matches/training sessions in the

preceding 3 months prior to the initiation of the study. All the subjects were informed of the purpose of the study and gave their informed consent according to the Declaration of Helsinki. The study was approved by the Investigational Review Committee of the Department of Physical Education and Sport Sciences. The subjects were randomized by a co-author not directly involved in testing or the training intervention into one of the two groups, the CTS group ( $n = 7$ ; age:  $23.6 \pm 4.8$  years; body height:  $166.5 \pm 5.9$  cm; body mass:  $63.9 \pm 7.5$  kg) and the CTU group ( $n = 7$ ; age:  $23.8 \pm 5.8$  years; body height:  $164.8 \pm 4.8$  cm; body mass:  $63.9 \pm 6.8$  kg). No significant baseline differences were found between groups in terms of age, body mass, body height, body mass index, and performance measures. The randomization was computer generated.

### **Design and procedures**

A randomized controlled trial design was used to determine the effects of core strength training performed on stable (CTS) and unstable (CTU) surfaces when conducted in combination with regular futsal training on physical fitness and FMS performance. The intervention program of each group was added to their daily training routines. The experimental intervention consisted of 1 session of the pre-test, 6 weeks of supervised training intervention, 3 days of rest and 1 session of the post-test (Figure 1). During testing sessions, the participants were required to wear the same athletic equipment and measurements were conducted at the same time of the day to minimize the effect of diurnal variations on the selected variables during the two experimental sessions. To reduce the influence of uncontrolled variables, all futsal players were instructed to maintain their habitual lifestyle and normal dietary intake before and during the study. All data collection and test sessions were performed in an indoor court where ambient temperature ranged from 18 to 21°C.

### **Measures**

To determine training effects, the following tests were selected: (a) FMS, (b) countermovement jump (CMJ), (c) 10 m sprint, and (d) repeated sprint ability (RSA) test. All tests were performed after 72 hours of rest and at the same venue under identical conditions and supervised by the same test leaders. The subjects were told to consume their last (caffeine-free) meal at least 3 hours before the scheduled test time. After FMS, all participants

performed 10 min of a standardized warm-up comprising 2 min of light active static stretching (10 repetitions for hamstrings, quadriceps, and calf muscles) and 5 min jogging, followed by short distance accelerations (3 submaximal sprints, progressing to 90% of their maximal velocity for the shuttle distance [30 + 30 m]). This routine was supervised by the team's physical coach before the tests.

*Functional Movement Screen.* The FMS consists of 7 movement patterns that include an overhead deep squat, a hurdle step, an in-line lunge, shoulder mobility exercise, active straight leg raise, rotary stability exercise, and a push-up. Details of each task have been published previously (Cook et al., 2006). The administration of the FMS was carried out in accordance with previously published guidelines (Cook et al., 2006) using the FMS test kit (Functional Movement Systems, Chatham, VA). The players were familiarized with the movements required prior to testing. All movement patterns were scored on a 0-3 scale, and the maximal FMS score that could be achieved was 21. Each test was performed 3 times, and the best value of each attempt was recorded, while bilateral tests utilized lower score values. In the bilateral tests (hurdle step, in-line lunge, shoulder mobility, active straight leg raise, and rotary stability) the lesser of the two scores (right or left) was assigned to contribute to the FMS total score. To achieve a deeper understanding of where differences in the FMS total score existed between CTS and CTU, we separated the screen into 3 parts (Portas et al., 2016): FMS<sub>move</sub> (overhead deep squat, hurdle step, in-line lunge); FMS<sub>flex</sub> (shoulder mobility, active straight leg raise) and FMS<sub>stab</sub> (rotary stability, push-up). Players completed the FMS with guidance from a researcher trained in using the FMS. Other than the verbal instructions, no additional coaching points were used during the screening process. In order to increase the reliability of measurement, FMS tests were recorded on video and analyzed using video analysis software (Shultz et al., 2013). Three raters reviewed all videos and scored each test individually according to the scoring criteria.

*Vertical-Jump Performance.* The CMJ was performed on a mobile contact mat (Ergo Jump Bosco System, Globus, Treviso, Italy). Players were allowed 2 trials, with a 1 min recovery period between the attempts. The best trial was used for subsequent

analysis. From a standing position with the hands on the hips, the players were required to bend their knees to a freely chosen angle and perform a maximal vertical jump as high as possible. The hands were held on the hips during the jump to avoid any effect of the arm-swing. Participants were instructed to keep their body vertical throughout the jump, avoiding undue lateral and frontal movements, and to land with knees fully extended.

*Sprint test.* The 10 m sprint test was measured by means of a measuring system that consisted of two double infrared reflex photoelectric cells (DSD Laser System, León, Spain). The photoelectric cells were attached to tripods, raised to a height of 0.9 m and placed in pairs 1 m apart. Players began from a standing start, with the front foot 0.5 m from the first timing gate. Players were allowed 2 trials, with a 2 min recovery period in-between. The best trial was used for subsequent analysis.

*Repeated Sprint Ability test.* Photoelectric cells (DSD Laser System, León, Spain) were used to measure the futsal players' performance and to increase test reliability. The RSA protocol consisted of six maximal 25 m sprints. Following each sprint, there was a period of active recovery (25 s), while the athlete positioned themselves for a new start. Recovery was measured (stopwatch) to ensure that subjects returned to the initial point of course between the 23<sup>rd</sup> and 24<sup>th</sup> second. Verbal feedback was given at the 5<sup>th</sup>, 10<sup>th</sup>, 15<sup>th</sup>, and 20<sup>th</sup> s of recovery. The average time (AT), fastest time (FT), and total time (TT) were recorded during the RSA test according to previous studies (Wong et al., 2012). The percentage of the decrement score (%Dec) was then calculated using the following formula proposed by Fitzsimons et al. (1993), which has been demonstrated as the most valid and reliable method of quantifying fatigue in multiple sprint tests (Glaister et al., 2008):

$$(100 \times (TT \div \text{ideal sprint time})) - 100$$

where ideal sprint time = 6 × FT

### **Intervention programs**

After pre-testing, the subjects began one of the 6-week training protocols presented in Table 2 in addition to their usual futsal training. Players of the CTS and CTU groups performed the same four core-strengthening exercises. The only difference between the two interventions was that the CTU

group performed all exercises under unstable conditions (Togu® Dyn-Air). Each player of the CTU group was fully instructed to familiarize themselves with the stabilization exercises. The intervention program was carried out 3 times a week, on non-consecutive days (48 h rest). Training sessions lasted ~20 min and were conducted before field training. Training intensity and volume were increased progressively every two weeks (Table 1). The correct performance of the exercises was carefully supervised by an athletic coach and a sports physiotherapist. To improve the quality of supervision, a ratio of 1 athletic coach to 4 subjects was maintained during all the sessions.

### **Statistical Analysis**

All variables were normally distributed (Shapiro Wilks test). Data are presented as means with standard deviation (SD). A 2 (group: CTS and CTU) × 2 (time: pre, post) repeated measures analysis of variance (ANOVA) was calculated for each variable. Cohen's *d* effect sizes for identified statistical differences were determined. Effect sizes with values of >0.2, >0.5, and >1.2 were considered to represent small, moderate, and large differences, respectively (Batterham and Hopkins, 2006). In addition to this testing, for each variable percentage difference in the change scores between the CTS and CTU groups from the pre- to post-test were calculated. The chances that the differences in performance were better/greater (ie, greater than the smallest worthwhile change [0.2 multiplied by the between-subjects SD, based on the Cohen *d* principle]), similar, or worse/smaller were calculated. Quantitative chances of beneficial/better or detrimental/poorer effects were assessed qualitatively as follows: <1%, almost certainly not; 1 to 5%, very unlikely; 5 to 25%, unlikely; 25 to 75%, possibly; 75 to 95%, likely; 95 to 99%, very likely; and >99%, almost certainly (Cohen, 1988). A substantial effect was set at >75%. If the chances of having beneficial/ better and detrimental/poorer performances were both >5%, the true difference was assessed as unclear.

### **Results**

The CTS group completed 98.7 ± 2.9% of core strength training sessions throughout the 6-week training period, while the CTU group completed 99.3 ± 1.7% of training sessions. Absolute values for each variable at the pre- and post-test, together with the ANOVA results are displayed in Tables 2 and 3

**Table 1***Intensity and volume progression during the 6 week core strength training program.*

Exercise	Weeks 1 and 2	Weeks 3 and 4	Weeks 5 and 6
Shoulder Bridge	3 sets x 30 s	3 sets x 40 s With vertical arm reach	3 sets x 50 s With vertical arm reach and one leg reached out
Side Bridge	3 sets x 30 s	3 sets x 40 s With one arm reached out vertically	3 sets x 50 s With one arm reach and a lower leg lifted
Prone Plank	3 sets x 30 s	3 sets x 40 s With one arm reached out parallel to the floor	3 sets x 50 s With a contralateral arm and the ipsilateral leg reached out parallel to the floor
Crunch	3 sets x 30 s	3 sets x 40 s With a futsal ball in hands reached out over head	3 sets x 50 s With a futsal ball in hands reached out over head and one foot on the floor

**Table 2***Changes in CMJ, 10 m sprint, and RSA performance following 6 weeks of core strength training performed on stable (CTS) vs unstable surfaces (CTU) in female professional futsal players.*

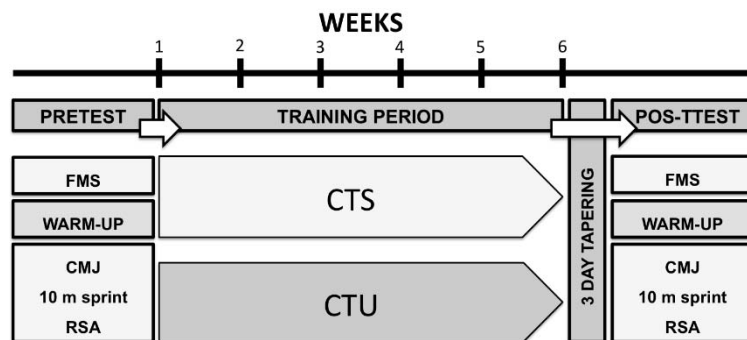
	CTS (n = 7)			CTU (n = 7)			ANOVA P values (d)		
	Pre	Post	$\Delta$ (%)	Pre	Post	$\Delta$ (%)	time	group	time $\times$ group
<b>CMJ (cm)</b>	25.24 $\pm$ 3.53	25.57 $\pm$ 3.49	1.40	25.89 $\pm$ 2.51	26.78 $\pm$ 2.77	3.44	.060 (1.457)	.584 (0.320)	.157 (0.869)
<b>10 m sprint (s)</b>	1.98 $\pm$ 0.05	1.88 $\pm$ 0.07	4.37	1.94 $\pm$ 0.08	1.85 $\pm$ 0.09	5.00	<.001 (3.175)	.330 (0.577)	.671 (0.246)
<b>RSA</b>									
<b>AT(s)</b>	4.30 $\pm$ 0.20	4.22 $\pm$ 0.18	1.63	4.20 $\pm$ 0.16	4.16 $\pm$ 0.17	0.82	.165 (0.859)	.395 (0.418)	.618 (0.285)
<b>FT(s)</b>	4.17 $\pm$ 0.22	4.05 $\pm$ 0.14	2.76	4.06 $\pm$ 0.16	4.06 $\pm$ 0.12	0.40	.259 (0.677)	.569 (0.339)	.158 (0.859)
<b>TT(s)</b>	25.80 $\pm$ 1.24	25.35 $\pm$ 1.10	1.63	25.22 $\pm$ 0.99	25.01 $\pm$ 0.77	0.82	.167 (0.856)	.388 (0.509)	.618 (0.285)
<b>%Dec</b>	2.97 $\pm$ 1.23	4.22 $\pm$ 1.37	- 75.31	3.53 $\pm$ 1.69	2.26 $\pm$ 1.35*+	30.8 5	.987 (0.063)	.281 (0.648)	.014 (1.656)

D = effect size (i.e., Cohen's d). \*Significantly different from the pre-test ( $p < .05$ ).+ Significantly different from CTS ( $p < .05$ ).

**Table 3**  
*Changes in individual and total scores of the Functional Movement Screen (FMS™) following 6 weeks of core strength training performed on stable (CTS) vs unstable surfaces (CTU) in female professional futsal players.*

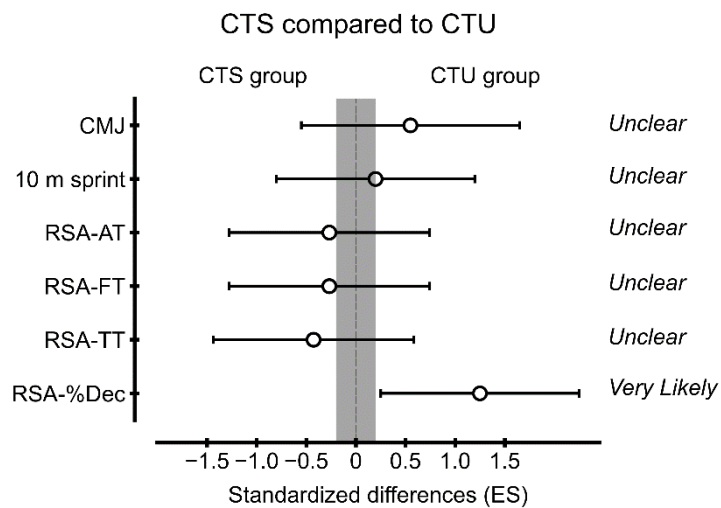
	CTS (n = 7)			CTU (n = 7)			ANOVA P values (d)		
	Pre	Post	Δ (%)	Pre	Post	Δ (%)	time	group	time × group
<b>Total FMS score</b>	15.85 ± 2.11	17.42 ± 2.14	10.39	16.00 ± 1.15	17.7 ± 1.11	11.10	<.001 (2.549)	.802 (0.126)	.851 (0.089)
<b>FMS<sub>move</sub></b>	7.00 ± 1.15	8.00 ± 1.15	15.40	7.00 ± 1.29	8.14 ± 0.69	19.40	.002 (2.229)	.892 (0.063)	.801 (0.141)
Deep Squat	1.71 ± 0.48	2.28 ± 0.75	35.71	1.85 ± 0.37	2.28 ± 0.48	28.57	.004 (2.020)	.784 (0.155)	.626 (0.278)
Hurdle Step									
Right	2.44 ± 0.53	2.71 ± 0.48	9.52	2.57 ± 0.53	2.85 ± 0.37	9.52	.049 (1.259)	.539 (0.357)	.989 (0.063)
Left	2.14 ± 0.37	2.71 ± 0.48	19.04	2.14 ± 0.69	2.72 ± 0.49	21.42	.002 (2.298)	.999 (0.033)	.999 (0.033)
In-line Lunge									
Right	2.85 ± 0.37	3.00 ± 0	4.76	2.57 ± 0.53	3.00 ± 0	14.28	.040 (1.328)	.271 (0.659)	.271 (0.659)
Left	2.85 ± 0.37	3.00 ± 0	7.14	2.42 ± 0.53	3.00 ± 0	28.56	.014 (1.438)	.109 (1.000)	.109 (1.000)
<b>FMS<sub>flex</sub></b>	5.75 ± 1.13	5.75 ± 1.13	0	5.85 ± 0.37	5.71 ± 0.48	-2.38	.337 (0.569)	.645 (0.263)	.337 (0.569)
Shoulder Mobility									
Right	2.71 ± 0.75	2.71 ± 0.75	0	2.85 ± 0.37	2.71 ± 0.48	-4.76	.337 (0.536)	.828 (0.126)	.337 (0.536)
Left	2.71 ± 0.75	2.85 ± 0.37	14.28	2.71 ± 0.48	2.57 ± 0.53	-4.76	.889 (0.109)	.619 (0.285)	.183 (0.826)
Straight Leg Raise									
Right	2.85 ± 0.37	2.85 ± 0.37	0	3.00 ± 0	3.00 ± 0	0	---	---	---
Left	2.85 ± 0.37	2.85 ± 0.37	0	3.00 ± 0	3.00 ± 0	0	---	---	---
<b>FMS<sub>stab</sub></b>	3.42 ± 0.78	4.00 ± 1.00	14.76	3.71 ± 0.48	4.14 ± 0.37	12.13	.035 (1.368)	.508 (0.386)	.740 (0.190)
Rotary Stability									
Right	1.85 ± 0.37	2.14 ± 0.37	21.42	2.00 ± 0	2.14 ± 0.37	7.14	.091 (1.059)	.594 (0.306)	.552 (0.345)
Left	1.85 ± 0.37	2.00 ± 0	14.28	1.85 ± 0.37	2.14 ± 0.37	21.42	.091 (1.059)	.594 (0.306)	.552 (0.345)
Push-up	1.57 ± 0.53	1.85 ± 0.69	21.42	1.71 ± 0.48	2.00 ± 0.57	21.42	.049 (1.259)	.619 (0.285)	.991 (0.063)

*D* = effect size (i.e., Cohen's *d*).



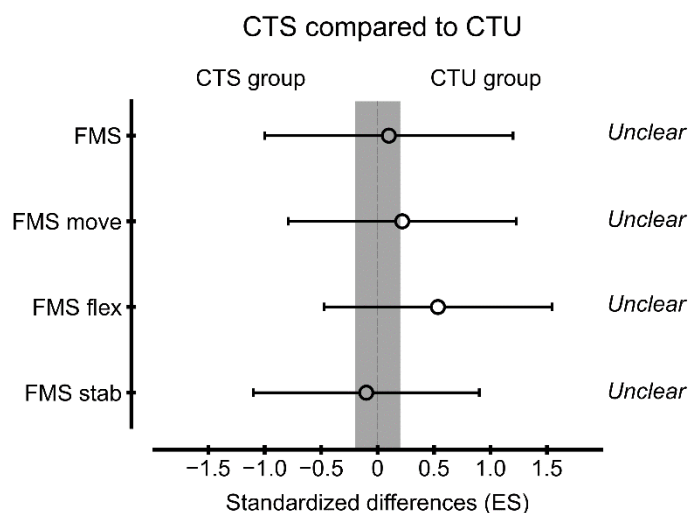
**Figure 1**

Schematic representation of the experimental protocol. FMS= Functional Movement Screen; CMJ= countermovement jump; RSA= repeated sprint ability; CTS= core strength training under stable surfaces; CTU= core strength training under unstable surfaces.



**Figure 2**

Effectiveness of CTS in comparison to CTU in improving countermovement jump (CMJ) and 10 m sprint performance and repeated sprint ability (RSA) average time (AT), fastest time (FT), total time (TT), and percentage of decrement (%Dec) (bars indicate uncertainty in the true mean changes with 90% confidence limits). Trivial areas were calculated from the smallest worthwhile change (see methods).



**Figure 3**

*Effectiveness of CTS in comparison to CTU in improving the Functional Movement Screen total score (FMS),  $FMS_{move}$ ,  $FMS_{flex}$ , and  $FMS_{stab}$  (bars indicate uncertainty in the true mean changes with 90% confidence limits). Trivial areas were calculated from the smallest worthwhile change (see methods).*

In the within-group analysis, significant improvements in the 10 m sprint were found in CTS (+4.37%;  $d = 1.64$ ) and CTU (+5%;  $d = 1.05$ ) groups from the pre- to post-test. Players in both CTS and CTU groups also showed significant enhancements in the FMS total score (+10.39%;  $d = 0.73$  and +11.10%;  $d = 1.50$ , for the CTS and CTU group, respectively),  $FMS_{move}$  (+15.40%;  $d = 0.86$  and +19.49%;  $d = 1.12$ , for the CTS and CTU group, respectively), and  $FMS_{stab}$  (+14.76;  $d = 0.64$  and +12.13;  $d = 1.00$ , for the CTS and CTU group, respectively) from the pre- to post-test. In addition, a significant time effect ( $d = 0.84$ ) was also observed for CTU in %Dec decreasing from the pre- to post-test (-30.85%). Results from between-group analyses are illustrated in Figures 2 and 3. There were no differences between the core strength training groups (CTS vs CTU) in any variable except for %Dec (Figure 2).

## Discussion

This is the first study that investigated the effects of in-season CTS compared with CTU in

combination with regular futsal training on physical fitness and FMS scores in professional female futsal players. The main findings of our study were that: a) performance in the 10 m sprint significantly improved in both intervention groups over the 6-week training period; b) total FMS scores,  $FMS_{move}$  (DS, HS, and IL), and  $FMS_{stab}$  significantly improved following 6 weeks in both the CTS and CTU group; c) a larger performance enhancement in %Dec for the CTU group compared to the CTS group was observed.

Sprinting speed is an essential fitness component in futsal (Castagna et al., 2009). Our findings showed significant improvements in 10 m sprint time in professional female futsal players after 6 weeks of CTS and CTU interventions. This positive effect of core strength training on sprint performance can, most likely, be explained by the specific role of the trunk as a linkage between upper and lower extremities that facilitates the torque transfer and angular momentum during the execution of whole body movements such as a sprint (Behm et al., 2010; Granacher et al., 2014). These results are consistent with those of Prieske et



al. (2016b), who found significant improvements in 10-20 m sprint time after 8 weeks of CTS and CTU in elite young soccer players during the competitive season. Additionally, the present results are partly in line with the literature investigating the effects of core strength training using stable conditions on sport-specific skills in young soccer players (Hoshikawa et al., 2013), who reported significant improvements in 15-m sprint performance ( $ES = 1.12$ ) after 6 months (4 sessions/week) of combined CTS and soccer training. In contrast to our findings, Granacher et al. (2014) found improvements in trunk muscle strength, jumping and balance tests, but not in sprint performance after 6 weeks of CTS and CTU in healthy subjects. Taking into account these inconsistent findings between our study and the aforementioned investigation, it can be speculated that training status of our subjects (professional female futsal players vs. young healthy subjects) or differences in training frequency (3 sessions/week vs. 2 sessions/week) may have contributed to the findings of additional enhancements following CTU and CTS in 10-m sprint time in the present study (Granacher et al., 2014).

During the most intense periods of a futsal game, the occurrence of short sprint sequences with brief recovery periods suggests that RSA may be considered as a futsal-specific capacity (Castagna et al., 2009). Therefore, training interventions aimed at improving RSA may be priority for futsal coaches. Different training approaches have shown positive effects on team sports players' RSA (Rey et al., 2017; Viaño-Santamarinas et al., 2017). However, the influence of periodized core strength training on RSA has not been studied yet. In the present study, a larger performance enhancement in %Dec was observed following CTU as compared to CTS. However, no significant within-group differences were found after any of the two core strength training programs in AT, FT, and TT. These results suggest that CTU may contribute to improving the ability to recover between sprints, but not the ability to increase the overall sprint performance. It is hard for this finding to be put into perspective with the literature, as no other study has investigated the effect of core strength training on RSA. However, the results of the present study are partially in agreement with those obtained in a recent meta-analysis that

concluded that strength training using unstable surfaces had limited additional effects on physical performance compared with strength training on stable surfaces (Behm et al., 2015). Functionally, the rationale for incorporating unstable surfaces in strength-training exercises is that high levels of muscle activity occur during training (Behm et al., 2015; Vera-García et al., 2000). Thus, the integration of unstable surfaces in core strength training could generate superior neuromuscular adaptations and help transmit energy in a more efficient form to upper and lower extremities compared with training under stable surfaces. Given the importance of RSA in futsal and the fact that %Dec was improved by CTU, coaches may consider conducting core strength training on unstable surfaces to improve this quality in addition to standard training. However, the present data also suggest that more specific training strategies than those employed in this study may be required to improve sprint capacities of RSA.

Movement screening is a type of assessment frequently used within professional players that aims to measure the quality of a movement pattern in order to identify injury risk factors (Bonazza et al., 2016). FMS is a screening tool that is widely used with the goal of identifying deficits in movements that may predispose to future injury. Moreover, core strength training is frequently used as a prophylactic strategy in an attempt to improve neuromuscular control and ineffective movement patterns (Huxel Bliven and Anderson, 2013). However, there is currently no evidence of the ability to change scores on the FMS based on an in-season core strength-training program using stable and unstable surfaces. The results of this study support that both CTS and CTU can significantly improve scores on the FMS. The data also indicated that both intervention programs significantly increased the score for FMSmove and FMSstab. It is difficult to directly compare our results to other research as we are unaware of any other study published to date, which has tested FMS changes after core strength training programs.

based on FMS corrective exercises can improve scores of FMS in male semi-professional mixed martial arts athletes and professional American

football players, respectively. Exercises improving both strength and stability of the core muscles may affect player's ability to activate the muscles in a more coordinated way or generate more force (Willardson, 2007). Changes in coordination, increased force generation or in both of them might improve proprioception and motor control in athletic movements. This may explain the significant enhancement in FMS scores, especially in FMS<sub>mov</sub> and FMS<sub>stab</sub>, after the training period. Based on the present results the implementation of training programs aiming to increase FMS score via enhanced core strength and stability may prove valuable in such an athlete's cohort. The results of this study suggest that CTU and CTS may contribute to increasing movement proficiency in elite female futsal players.

While the study had many unique aspects (professional level players), it is important to point out the limitations of the present study. The lack of a control group, even taking into account coaches are reluctant to create a control condition looking to improve the functionality as fast as possible, is a major issue to bear in mind. While participant numbers in this experiment were similar to other studies that have assessed strength methods in team sports, our sample size was relatively small. Finally, even being the duration similar to the one applied in other

studies, the 6 week core training program could be too short to induce significant changes in elite female futsal athletes. Future studies using larger sample sizes and longer intervention time may provide more conclusive results.

## Conclusions

Data from the current study suggest that 6 weeks of CTS and CTU combined with futsal training appears to be effective in improving sprint performance and quality of movement based on FMS scores. Training exercises have to resemble the sport-specific demands and core strength training using unstable surfaces should also be beneficial for reducing %Dec of RSA. The integration of these feasible exercises can be a potential preventive training modality based on the improvements observed in FMS scores. However, to date, the question regarding the contribution of core strength training on stable and unstable surfaces to reducing the injury incidence remains unanswered and future studies should investigate the manipulation of program variables and exercise selection. From a practical point of view, the advantage of the intervention programs is that they integrate exercises which are commonly used for injury prevention and performance enhancement: those exercises are oriented towards core strengthening in an ecological and real futsal team context.

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