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The Comparative Effects of Combined Core and Hip Stabilization Training Versus Isolated Core Training on Athletic Performance Parameters in Recreational Athletes

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Abstract

A two-arm, parallel-group randomized clinical trial was conducted to compare the effects of core and hip stabilization training with core training alone on trunk endurance, dynamic balance and functional performance in recreational athletes. A total of 60 sport recreationalist was randomly divided into Group A with a combined training (n=30) and Group B with isolated core training (n=30). The outcomes measured were trunk endurance (measured by McGill battery), dynamic balance (measured by Y-Balance Test), and functional performance (measured by single-leg hop test) before and after the 10-week period. Significant improvements (p<0.05) were obtained by both groups. Group A demonstrated superior improvements in trunk extensor endurance (18.4±3.2 vs. 10.2±2.8 seconds, p=0.001), Y-Balance composite scores (9.5±1.8% vs. 5.3±1.5%, p=0.002), and single-leg hop distance (18.3±2.8 cm vs. 11.7±2.3 cm, p<0.001). Moderate-to-vigorous core and hip stability exercises are more effective than intense core training for enhancing the athletic performance parameters (APPs) of recreational athletes. For maximum conditioning, an integrated training program should be adopted.

Keywords: Core stability; Hip stabilization; Athletic performance; Trunk endurance

Introduction

The participation in recreational sports is significantly increased over the last decade; more and more people are not professional but involved in various physical activities that are promoted as increasing fitness and health awareness (Sallis et al., 2016). There has been a parallel trend observed of an increase in participating in sports and a corresponding increase in injuries relating to sport participation, especially in the body segments of the lower extremity and lumbopelvic region (Hootman et al., 2007). The lumbopelvic segment is the intersection between upper and lower limbs, thus playing an important role in sport performance and injury prevention (Kibler et al., 2006).

Core stability refers to the ability to regulate the position and movement of the trunk over the pelvis in dynamic activities (Hodges, 2003). Core musculature of the abdominal muscles, para-spinal muscles, and gluteal muscles is the “muscular corset” that provides proximal stability so distal mobility can occur (Akuthota & Nadler, 2004). Core stability problems have been repeatedly found to be a risk factor for injury, decreases in athletic performance, and chronic musculoskeletal conditions (Leetun et al., 2004).

Much attention has been given to the gluteus medius - one of the major hip abductors and stabilizers of the pelvis in the sport medicine literature (Neumann, 2010). This muscle is integral in exerting control over frontal plane pelvic motion during single-leg stance movements most found in sporting activities (Presswood et al., 2008). Dysfunction of the gluteus medius has been associated with a variety of lower extremity problems, such as patellofemoral pain syndrome, anterior cruciate ligament injuries, and iliotibial band syndrome (Mascal et al., 2003). Also, gluteus medius weakness coincides with altered movement patterns which have been identified as risk factors for the development of lower extremity injury, including a greater knee valgus and hip adduction (Powers, 2003).

Core and hip stabilization exercises are recommended in athlete training as a complete exercise program to improve performance and decrease the risk of injury (Nadler et al., 2002). However, the effectiveness of combined training compared to isolated core training in recreational athletes remains understudied (Borghuis et al., 2008). Most existing research has focused on professional or collegiate athletes, with limited investigation into recreational populations (McGill, 2010). Furthermore, optimal training protocols to maximize performance parameters are not well established (Butcher et al., 2007).

Previous studies have demonstrated that core training effectively improves trunk muscle endurance and athletic performance (Tse et al., 2005). Similarly, hip stability exercises have been shown to enhance dynamic balance and lower extremity function (Distefano et al., 2009). However, few investigations have specifically compared combined core and hip stabilization training with isolated core training in recreational athletes (Sato & Mokha, 2009). This is important as many people participate in recreational sports and there is a need for evidence-based training recommendations for them.

The aim of this study was to assess and compare the influence of core and hip stabilization training with isolated core training on exercising endurance for the trunk muscles, dynamic balance and functional performance in recreational athletes, and to identify the superiority of the results of combined training over isolated core training. We hypothesized that combined training would produce greater improvements in all outcome measures.

Methods

Experimental approach to the Problem

A randomized clinical trial with two-arm, parallel-group allocation was designed to compare the effects of combined core and hip stabilization training versus isolated core training on athletic performance parameters (Haskell et al., 2007). The participants were randomly divided into 2 groups, Group A (combined core and hip stabilization training group) and Group B (isolated core training group). The two training sessions were 10 weeks long, each three time sessions per week, and each 30 minutes (Tse et al., 2005). To assess the effect of the training, pre- and post-tests were administered 48 hours prior to the first session, and after the last session, respectively (McGill et al., 1999). The following performance tests were administered: McGill trunk endurance battery, Y-Balance Test, single-leg hop test (Noyes et al., 1991). All participants were familiar with these measurements, as they were part of the standard assessment protocol for recreational athletes at the facility. To avoid possible warm-up, learning and fatigue effects, the order of the tests was standardized for all participants (Cohen, 2013).

Participants

Sixty players participated in a study of sports addiction in the city of Islamabad, Pakistan because they were recruited from the local sports clubs and community centers (Sallis et al., 2016). The inclusion criteria for participants were: (1) ages 18-35 years; (2) active participation in recreational sport at least three times per week for the previous six months, (3) no current musculoskeletal pain or injury and (4) willingness to follow the study protocol (Leetun et al., 2004). Exclusion criteria were: (1) surgery of the lower extremity within past year, (2) current or recent, within 3-months, lower extremity musculoskeletal problem, (3) neurological disorder affecting balance or motor control, (4) pregnancy, (5) cardiovascular or metabolic condition that precluded participation in exercise, and (6) concurrent involvement in another structured training program (Hootman et al., 2007). Participants gave informed consent after thorough information on possible risks and benefits was provided. The Institutional Review Board of Riphah International University (approval number not specified) approved the study protocol and it followed the ethical guidelines suggested in the Helsinki Declaration of 2013.

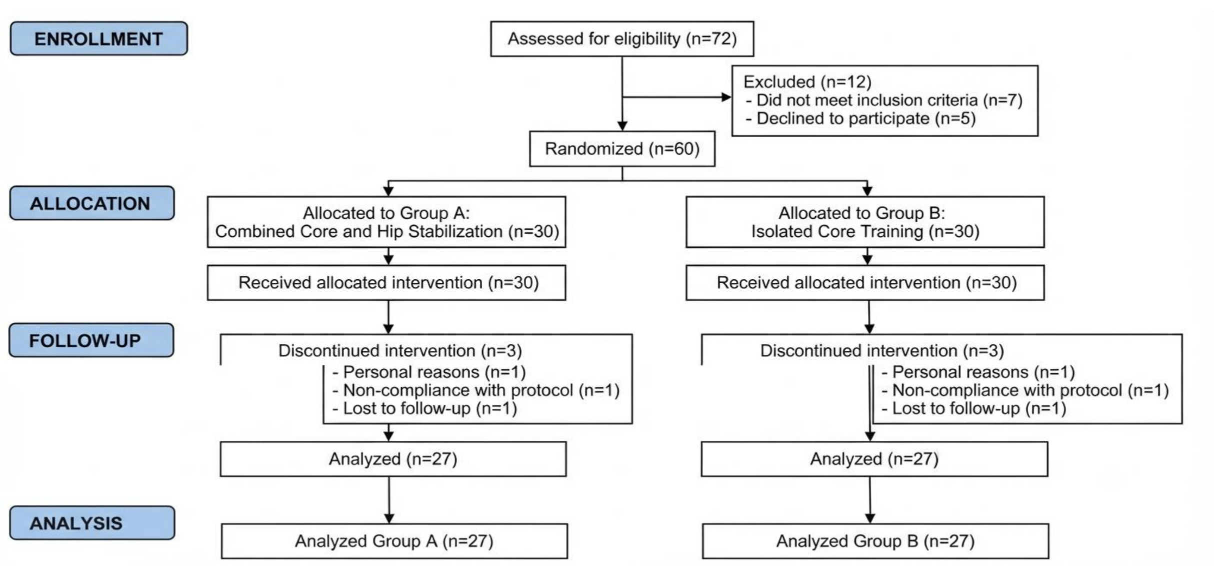

Figure 1: Consort Flow Diagram

Training programs

The 10 weeks of training are detailed below, of which Group A (Combined Core and Hip Stabilization Training) included participants who did both core strengthening and hip stabilization exercises (Distefano et al., 2009), whilst Group B (Isolated Core Training) included participants who performed core strengthening exercises only (Akuthota & Nadler, 2004). Supervised exercise sessions were three times weekly to both groups with each 30 minutes of supervised exercise (McGill, 2010). Staff was encouraged to support participants in continuing their usual recreational activities while implementing the program without undertaking other formal exercise programs in the intervention period (Sato & Mokha, 2009). Licensed physical therapists guided all physical activities, checking over the exercise technique and repeating repetitions when the exercise was not performed in the correct pattern (Ekstrom et al., 2007).

Group A (Combined Core and Hip Stabilization Training: completed core strengthening exercise and hip stabilization exercise. Core exercises occurred, including prone planks (3 sets with a hold of 45 seconds, 30-second rest, three times); side planks (3 sets on each side with a hold of 30 seconds); bird dog exercises (3 sets, 10 repetitions each side); dead bug exercises (3 sets, 12 repetitions); and supine bridging (3 sets, 15 repetitions) (Marshall & Murphy, 2005). Hip stabilization training consisted of 3 sets each side of clamshells, side lying hip abduction, 3 sets each leg of single leg squats, single leg bridging 3 sets each leg, and lateral band walking 3 sets 10 steps forward with 10 steps back (Presswood et al., 2008). For each participant, the intensity of the exercise was increased gradually during the intervention by modifying the number of repetitions, the duration of the hold or the resistance (Behm et al., 2010).

In Group B (Isolated Core Training) they completed the same core strengthening exercises as Group A (prone planks, side planks, bird-dog exercises, dead bug exercises, supine bridging) but with the same amount of training volume, frequency, and progression (Tse et al., 2005). No hip stabilization exercises were performed, and so the comparison will be made between the additional benefits of performing an exercise program with versus without hip stabilization exercises (Willson et al., 2012).

Outcome measurements

Experienced physical therapists, who were not aware of group allocation, performed all assessments, and measurements were made at baseline (pre-intervention) and 48 hours after the final training session (post-intervention) (Gribble et al., 2012).

The primary outcome was trunk muscle endurance, which was assessed by the trunk extensor endurance test (Biering-Sørensen test) where participants were placed prone, their chin and chest were placed over the treatment table edge, and they were to hold the position as long as possible, the trunk flexor endurance test, where participants assumed an unsupported supine body position with elbows under the upper body, hips at 60° body angle, and knees flexed at 90° with feet together and were to hold on to a cross of their arms over their chest for as long as they could, and by the side bridge tests (right and left) where participants were supposed to maintain maximum body position unsupported with arms across the chest, knees at 90°, and feet together for as long as possible (McGill et al., 1999). The total endurance score was the sum of the trunk flexor, trunk extensor and average right and left side bridge times (Butcher et al., 2007). As a secondary outcome, dynamic balance was assessed using the Y Balance Test (YBT) (Gribble et al., 2012) which required the participants to stand on one foot while reaching as far as possible anterior and posteromedially and posterolaterally. Three practice trials were allowed, followed by three recorded trials per direction. Maximum reach distance was normalized to leg length, and a composite score was calculated for overall dynamic balance performance (Plisky et al., 2006). Higher composite scores indicated better dynamic balance (Gribble et al., 2012).

Functional performance, which was also a secondary outcome, was assessed using the single-leg hop test for distance (Reid et al., 2007). Participants jumped as far as they can, on one foot without losing their balance! Three throws were made for each thrower for every limb and the average distance thrown was recorded (Noyes et al., 1991). This was done by calculating the ratio of involved to non-involved limb performance [limb symmetry index (LSI); Paterno et al., 2010].

Statistical analysis

SPSS version 26.0 (IBM Corp.) was used for data analysis. Shapiro-Wilk tests and visual Q-Q plots were used to establish data normality (Field, 2013). Independent t tests were used to compare baseline demographic data between groups for continuous data variables, and chi-square tests were used for categorical data variables (Portney & Watkins, 2009). Paired t-test was used for within-group difference analysis and independent t-test was employed for between-group difference analysis. A value of $p<0.05$ was considered to be statistically significant. According to Cohen (2013) the thresholds for effect sizes were set at 0.8 (large), 0.5 (moderate), and 0.2 (small).

Results

There were 60 recreational athletes that were randomly allocated into two groups, namely combined training (n=30) and isolated core training (n=30). During the intervention period, six participants dropped out of each group for the following reasons: lost to follow-up, non-compliance and personal. Six participants were left out of the final analyses because they dropped out during the intervention period. There were no statistically significant differences ($p>0.05$) between the groups on any of the baseline demographic variables and anthropometric measures. The mean age of participants was 24.8 ± 4.2 years, mean height 168.5 ± 8.9 cm, and mean weight 70.2 ± 12.4 kg. The sample comprised 38 males (63.3%) and 22 females (36.7%).

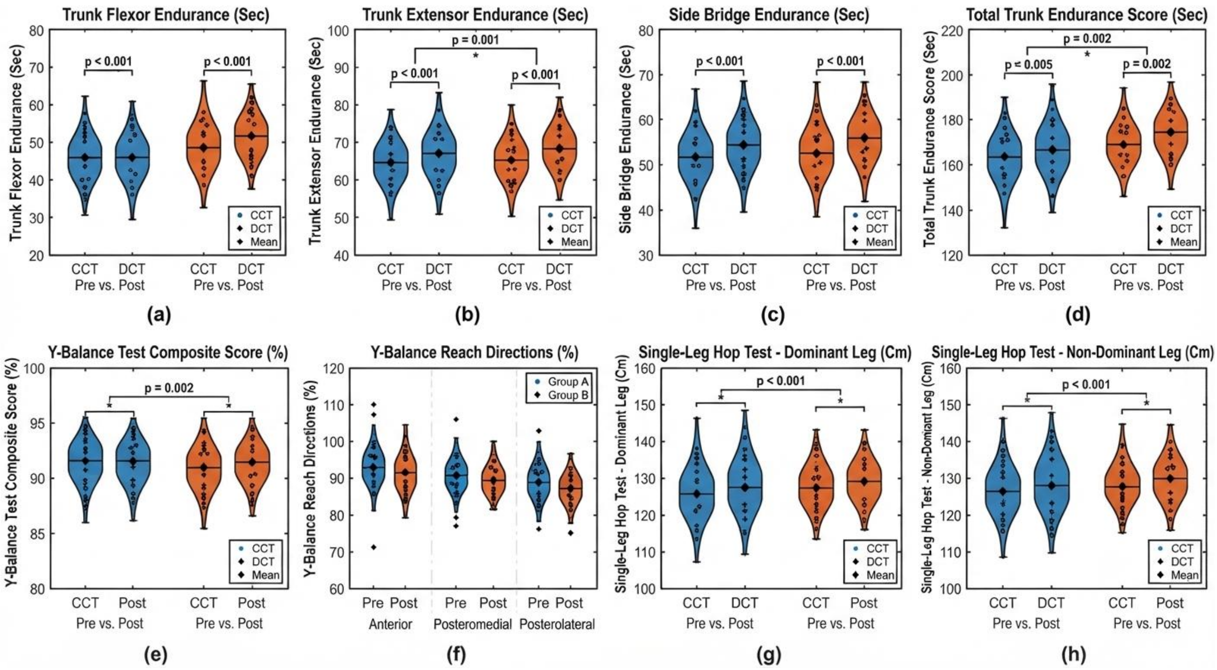

Figure 1: Comparison of Trunk Endurance, Balance, and Functional Performance Between Groups

Trunk muscle endurance

There was a significant increase in all measures of muscle endurance in the trunk after 10 weeks in both groups in the within-group analysis (Table 1). Trunk flexor endurance increased from 48.3 ± 12.6 to 68.7 ± 14.2 seconds in Group A (mean change: 20.4 ± 3.8 seconds, $p < 0.001$) and from 49.1 ± 11.8 to 63.5 ± 13.1 seconds in Group B (mean change: 14.4 ± 3.1 seconds, $p < 0.001$). Trunk extensor endurance improved from 62.5 ± 15.3 to 87.6 ± 17.8 seconds in Group A (mean change: 25.1 ± 4.2 seconds, $p < 0.001$) and from 63.8 ± 14.9 to 76.9 ± 16.2 seconds in Group B (mean change: 13.1 ± 3.5 seconds, $p < 0.001$). However, there was significant improvement from A to B for trunk extensor endurance (18.4 ± 3.2 vs. 10.2 ± 2.8 seconds, $p = 0.001$).

Right side bridge endurance increased from 42.1 ± 11.4 to 61.3 ± 12.8 seconds in Group A ($p < 0.001$) and from 43.2 ± 10.9 to 54.8 ± 11.5 seconds in Group B ($p < 0.001$). Left side bridge endurance improved from 40.8 ± 10.7 to 59.6 ± 12.3 seconds in Group A ($p < 0.001$) and from 41.5 ± 10.3 to 52.9 ± 11.2 seconds in Group B ($p < 0.001$). Total trunk endurance score showed significant improvement in both groups, with Group A improving from 152.9 ± 30.5 to 198.1 ± 35.2 seconds (mean change: 45.2 ± 7.8 seconds, $p < 0.001$) and Group B improving from 155.6 ± 29.8 to 187.4 ± 32.1 seconds (mean change: 31.8 ± 6.9 seconds, $p < 0.001$). A significant difference was seen between the two groups ($p = 0.002$) with Group A having significantly better total endurance score.

Table 1: Within-Group Changes In Trunk Endurance Measures

Outcome Measure	Group	Pre-Intervention	Post-Intervention	Mean Change	P-Value
Trunk Flexor (sec)	A	48.3±12.6	68.7±14.2	20.4±3.8	<0.001
	B	49.1±11.8	63.5±13.1	14.4±3.1	<0.001
Trunk Extensor (sec)	A	62.5±15.3	87.6±17.8	25.1±4.2	<0.001
	B	63.8±14.9	76.9±16.2	13.1±3.5	<0.001
Right Side Bridge (sec)	A	42.1±11.4	61.3±12.8	19.2±3.6	<0.001
	B	43.2±10.9	54.8±11.5	11.6±2.9	<0.001
Left Side Bridge (sec)	A	40.8±10.7	59.6±12.3	18.8±3.4	<0.001
	B	41.5±10.3	52.9±11.2	11.4±2.7	<0.001
Total Endurance Score	A	152.9±30.5	198.1±35.2	45.2±7.8	<0.001
	B	155.6±29.8	187.4±32.1	31.8±6.9	<0.001
Values are presented as mean ± standard deviation. Group A: Combined core and hip stabilization training; Group B: Isolated core training.					

Dynamic balance

In both groups, notable improvement in the Y-Balance Test composite scores were found (Table 2). Group A improved from 85.2 ± 6.8% to 94.7 ± 7.2% (mean change: 9.5 ± 1.8%, $p < 0.001$), while Group B improved from 84.6 ± 7.1% to 89.9 ± 6.5% (mean change: 5.3 ± 1.5%, $p < 0.001$). The difference between the groups was statistically significant ($p = 0.002$), in favor of Group A.

Analysis of the reach directions revealed that the posteromedial direction is the one with the highest improvement followed by posterolateral and anterior. Group A demonstrated significant improvements in all directions: anterior reach from 65.3 ± 5.2% to 72.1 ± 5.8% (mean change: 6.8 ± 1.2%, $p < 0.001$), posteromedial reach from 98.5 ± 8.1% to 112.3 ± 8.9% (mean change: 13.8 ± 2.1%, $p < 0.001$), and posterolateral reach from 92.8 ± 7.6% to 104.6 ± 8.2% (mean change: 11.8 ± 1.9%, $p < 0.001$). Similarly, Group B showed significant improvements in all directions: anterior reach from 64.8 ± 5.5% to 68.9 ± 5.3% (mean change: 4.1 ± 1.1%, $p < 0.001$), posteromedial reach from 97.9 ± 7.8% to 105.6 ± 7.5% (mean change: 7.7 ± 1.6%, $p < 0.001$), and posterolateral reach from 92.1 ± 7.3% to 99.2 ± 6.8% (mean change: 7.1 ± 1.4%, $p < 0.001$). There was a significant increase in all reach directions for the combined training group compared to core training only.

Table 2: Within-Group Changes In Y-Balance Test Measures

Outcome Measure	Group	Pre-intervention	Post-intervention	Mean Change	p-value
Composite Score (%)	A	85.2±6.8	94.7±7.2	9.5±1.8	<0.001
	B	84.6±7.1	89.9±6.5	5.3±1.5	<0.001
Anterior Reach (%)	A	65.3±5.2	72.1±5.8	6.8±1.2	<0.001
	B	64.8±5.5	68.9±5.3	4.1±1.1	<0.001
Posteromedial Reach (%)	A	98.5±8.1	112.3±8.9	13.8±2.1	<0.001
	B	97.9±7.8	105.6±7.5	7.7±1.6	<0.001
Posterolateral Reach (%)	A	92.8±7.6	104.6±8.2	11.8±1.9	<0.001
	B	92.1±7.3	99.2±6.8	7.1±1.4	<0.001
Values are presented as mean ± standard deviation. Group A: Combined core and hip stabilization training; Group B: Isolated core training.					

Functional performance

Both groups saw significant improvement with the single-leg hop test (Table 3). For the dominant leg, Group A improved from 128.5 ± 22.3 to 146.8 ± 24.1 cm (mean change: 18.3 ± 2.8 cm, $p < 0.001$), while Group B improved from 127.8 ± 21.6 to 139.5 ± 22.7 cm (mean change: 11.7 ± 2.3 cm, $p < 0.001$). There was a statistically significant difference between the two groups ($p < 0.001$). For the non-dominant leg, Group A improved from 121.3 ± 20.8 to 138.6 ± 22.5 cm (mean change: 17.3 ± 2.5 cm, $p < 0.001$), while Group B improved from 120.6 ± 19.9 to 130.2 ± 21.4 cm (mean change: 9.6 ± 2.1 cm, $p < 0.001$). This was also significant between the two groups ($p < 0.001$).

Limb symmetry index showed significant improvement in Group A, increasing from 94.6 ± 4.2% to 97.8 ± 3.5% ($p < 0.001$), and in Group B, improving from 95.1 ± 4.5% to 96.9 ± 3.8% ($p = 0.034$). But this was not statistically significant between the groups ($p = 0.087$).

Table 3: Within-Group Changes In Single-Leg Hop Test Performance

Outcome Measure	Group	Pre-intervention	Post-intervention	Mean Change	p-value
Dominant Leg (cm)	A	128.5±22.3	146.8±24.1	18.3±2.8	<0.001
	B	127.8±21.6	139.5±22.7	11.7±2.3	<0.001
Non-Dominant Leg (cm)	A	121.3±20.8	138.6±22.5	17.3±2.5	<0.001
	B	120.6±19.9	130.2±21.4	9.6±2.1	<0.001
Limb Symmetry Index (%)	A	94.6±4.2	97.8±3.5	3.2±1.1	<0.001
	B	95.1±4.5	96.9±3.8	1.8±0.9	0.034
Values are presented as mean ± standard deviation. Group A: Combined core and hip stabilization training; Group B: Isolated core training.					

Between-group comparisons

The independent t-test analysis showed significant difference between the groups with A group, for all the primary and secondary outcome measures as demonstrated in Table 4. A large effect size was found for the trunk extensor endurance test (Cohen's d = 0.91), total endurance score (Cohen's d = 0.87), Y-Balance composite score (Cohen's d = 0.85), and the single-leg hop test performance (Cohen's d = 0.82) in ESA. Moderate effect sizes were found for Trunk flexor endurance (0.74) and Side bridge endurance (0.71) which yielded clinically meaningful differences between the interventions.

Table 4: Between-Group Comparisons Of Post-Intervention Outcomes

Outcome Measure	Group A	Group B	Mean Difference	p-value	Effect Size (d)
Trunk Flexor (sec)	68.7±14.2	63.5±13.1	5.2±1.4	0.008	0.74
Trunk Extensor (sec)	87.6±17.8	76.9±16.2	10.7±2.3	0.001	0.91
Side Bridge Average (sec)	60.5±12.6	53.9±11.4	6.6±1.8	0.003	0.71
Total Endurance Score	198.1±35.2	187.4±32.1	10.7±3.1	0.002	0.87
Y-Balance Composite (%)	94.7±7.2	89.9±6.5	4.8±1.3	0.002	0.85
Single-Leg Hop (cm)	146.8±24.1	139.5±22.7	7.3±1.9	<0.001	0.82

Values are presented as mean ± standard deviation. Group A: Combined core and hip stabilization training; Group B: Isolated core training.

DISCUSSION

The most important conclusion of this randomized clinical trial was that combined core and hip training lead to significantly higher gains in muscle endurance of the trunk, dynamic balance and functional performance than core training alone in recreational athletes. These findings validate our hypothesis and they suggest that IT training paradigms are able to improve relevant athletic performance metrics.

These changes in muscle endurance of the trunk muscles that were observed have been found to be effective in other studies that assess core training to improve trunk muscle function (Tse et al., 2005). The findings in the combined training group, however, suggest that hip stabilization exercises could have a synergistic effect on the effects of core training. This discovery mirrors the concept of the "core" as a single neuromuscular unit that includes trunk and hip muscle groups (Richardson et al., 2002). The gluteus medius, specifically, is a key muscle for stabilizing the pelvic girdle, and strengthening this muscle will likely contribute to improved core muscle activation during endurance activities (Ekstrom et al, 2007).

This marked a significant improvement in the dynamic balance compared to other groups, especially for the combined training group, with implications for sports performance and injury prevention. Dynamic balance is a basic skill for all athletes and has been shown to anticipate risk of injury in the lower limb (Gribble et al., 2012). The result indicates that group A, which underwent both training methods, showed an improvement of 9.5% in the Y-Balance composite score, while group B (who only performed the static studies) exhibited a 5.3% improvement. This indicates that a combined training method is more effective in improving postural control for the dynamic tasks. Such may be due to the synergistic impact of core and hip exercises on the control of the neuromuscular system (Willson et al., 2012) and proprioceptive feedback mechanisms. This superior balance performance may be due in part to a large contribution by working hip stabilizer, the gluteus medius, which controls frontal pelvic motion in single-leg stance activities (Fredericson et al. 2000).

The functional performance improvements demonstrated by the single-leg hop test further confirm the efficacy of combined training. The greater improvement in hop distance and lower extremity symmetry observed in Group A indicates superior enhancement of functional capacity. This finding has practical significance for athletic performance, as single-leg hop performance correlates with athletic activities involving running, jumping, and cutting (Reid et al., 2007). The more favorable limb symmetry index in the combined training group suggests that integrated training may reduce non-contact injury risk, which is associated with limb asymmetries (Paterno et al., 2010).

Several mechanisms may explain the advantages of combined training. Firstly, combining exercises could include more muscle groups and hence stimulate inter-muscular coordination (Marshall & Murphy, 2005). Second, is the incorporation of hip stabilization exercises, especially gluteus medius, into the program to help improve control of the pelvis while moving it, potentially improving the transfer of forces from the trunk to the lower limbs (Gottschall et al., 2013). Third, as an entire complex, the lumbopelvic-hip unit may be activated more during combined training, which could allow for more efficient movement patterns and improved training outcomes (Behm et al., 2010).

Our results are consistent with previous studies that have shown the advantages of hip stabilisation training in sports. Distefano et al. (2011) demonstrated the benefit of strengthening programmes for the hip on dynamic balance and injury prevention in women. Likewise, Imai et al. (2014) showed that enhancing the strength of the gluteus medius muscle had a positive effect on balance and functional performance in single-leg stance. The aim of the present study is to offer some insight into the possible value of combining core and hip stabilization exercise to enhance core stability in the recreational athlete.

Practical Applications

The findings have important implications for clinical practice and athletic training (McGill, 2010). Thus, core and hip stabilisation exercises are likely to be beneficial when implementing training programs for recreational athletes in order to optimise the enhancement of trunk endurance, balance and functional ability (Butcher et al., 2007). This method could be especially advantageous in sports with quick directive changes and dynamic motion (such as basketball, soccer, tennis) (Granacher et al., 2011). Routine exercises for both hip and trunk muscles should be used to maximize athletic conditioning of these muscles and potentially decrease the risk of injury to these muscles (Willson et al., 2005).

Limitations And Future Directions

There are a couple of caveats to note. This relatively brief period of intervention (10 weeks) may not reflect the long-term impact of the training programs. The long-term follow-up assessments of sustainability of the improvement should be included in future studies (Tse et al., 2005). Secondly, the subjects were primarily healthy, young, recreational athletes and may not be generalizable to other groups, such as older adults or persons with MS disease (Hootman et al., 2007). Third, because a no-training control group was not used, our ability to draw conclusions about the effects of the interventions is limited to changes observed (Moher et al., 2010). Fourth, although the patients were blinded to the outcome assessment, which was a great strength, they did know which group they were in, and this could have led to some degree of bias (Cohen, 2013). Fifth, the study lacked mechanistic measures such as electromyography and motor unit behavior to limit interpretation of underlying neuromuscular mechanisms (Paterno et al., 2010).

Future studies are needed to look at the combination of core and hip stabilization exercises that should be performed in order for various sports populations and performance outcomes (Gottschall et al., 2013). In addition, the risk of injury in the combined training of recreational athletes would be an interesting field of clinical investigation.

Conclusion

It found that combined core and hip stabilization training improved the endurance of the trunk muscles, dynamic balance, and functional performance more effectively than a core stability training containing only core exercises in recreational athletes. The integrated training resulted in clinically relevant improvements for all outcome measures with moderate to large effect sizes. The results herein are consistent with the use of combined training methods in athletic programs as well as the necessity to incorporate both trunk and hip movements in a total training approach. This study adds to the growing body of evidence supporting the utilization of multi-modal training approaches that can improve athletic performance and prevent injury.

Acknowledgements

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Ethics Declaration

This study received ethical approval from the Institutional Review Board. All participants provided written informed consent, and the research complied with the Declaration of Helsinki guidelines for research involving human subjects. Participant confidentiality was strictly maintained throughout the study.

Declaration Of Interests

The authors declare no conflicts of interest, financial or otherwise, related to this research. This study received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors, and all authors have no competing interests to declare.

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