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Effect of Core Strength Training in Addition to Conventional Training Program on Fitness in Adolescent Boys

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ABSTRACT

Objective: The aim of the study was to determine whether there was any effect of the core strength training along with the conventional training program (resistance and plyometrics) on fitness in adolescent boys

Design: Randomized pre-test, post-test different subject experimental design.

Participants: 30 subjects were recruited according to the inclusion and exclusion criteria (age =14.66± 0.48 years, height =172.66±4.36 cm and, weight = 57.80± 5.00 kg) and were randomly divided into two groups.

Intervention: Subjects participated in the training program for 6 weeks each for the two groups, ingroup 1 core strength training with resistance and plyometric exercises were given and in group 2 resistance and plyometric exercises were given. The exercises were given 2 times a week for the resistance training and plyometric training and 4 times a week for core stability training.

Outcomes: The participants were assessed according to the 5 variables- a) vertical jump, b) standing long jump, c) seated medicine ball toss, d) 9.1 m sprint and e) pro-agility shuttle run.

Results: A 6 weeks core strength training in addition to resistance and plyometric exercises showed significant improvement on the fitness performance variables as compared to resistance and plyometric exercises. There was significant improvement within both the groups on fitness parameters, though this improvement was more in the group where core stabilization exercises given in addition to resistance and plyometric exercise.

Conclusion: A combination of core stabilization exercises in addition to resistance training and plyometrics produces better gains on fitness of adolescent boys and core strength training must be incorporated in every fitness training.

Keywords: Core strength training, Plyometric exercises, Resistance training, Vertical jump, Standing long jump, Seated medicine ball toss, 9.1 m sprint, Pro-agility shuttle run

INTRODUCTION

Recently, there has been a significant increase in core strength training for both sports conditioning programs and the general population as a result of fitness professionals emphasizing training the core region of the body. Prior to this, core training exercises were reserved mainly for individuals with low back problems in physical therapy clinics [1]. The term core has been defined as the 29 pairs of muscles that support the lumbo-pelvic-hip complex [2]. Core muscles such as the Rectus Abdominis and Erector Spinae may stabilize the spine and pelvis and increase power transfer during functional movements [3]. Core strength and endurance are important both for athletic performance and overall general health, including prevention and treatment of low back pain [4]. Researchers suggest that strong and endurable core muscles stabilize the spine favorably by providing greater passive support with effective mechanical integrity and enhanced neurological recruitment patterns; including timely activation of these muscles when exposed to forces and loads [1,5]. Majority of the researches done on core is on the low back ache patients and on general population producing contradictory results and very few researches are done on adolescents.

In children and adolescents, it is well-established that during 1970's and 1980's resistance training was not often recommended because of the presumed high risk of injuries

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associated with the type of exercises. Current findings from the prospective resistance training studies indicate a low risk of injury in children and adolescents who follow age-appropriate training guidelines [6]. In fact, there are training-induced gains in strength and power is indeed possible following participation in a resistance training program [6-8].

All children need to participate regularly in physical activities that enhance and maintain cardiovascular and musculoskeletal health. Traditionally children have been encouraged to perform aerobic exercises such as bicycling and strength building activities such as push-ups. More recently, the potential benefits of plyometric training for youth have received increased attention. Previously thought of as a method of conditioning reserved for adult athlete, a growing number of trainers, teachers and youth coaches are now incorporating plyometric training into young athletes sports conditioning program [6]. More recent observations suggest that plyometric training may also be safe and effective for children and adolescents if age-appropriate training guidelines are followed [9-11].

As previously observed in adults, significantly greater gains in performance may be observed when plyometric training is combined with resistance training [12-17]. A Randomized, prospective studies have compared the effects of combined plyometric training and resistance training with resistance training and static stretching in children and adolescents [12]. It was observed that subjects who added plyometric exercises to their conditioning program (i.e., Resistance training) were able to achieve greater improvements in upper and lower body power as compared to the subjects who participated in conditioning program without plyometric exercises. Based on the frequency with which Core Stability exercises are used by Trainers, Instructors, and Therapists research confirms improvement in trunk muscle strength and improved joint stability [18,19]. With "Core" training programs the translation to performance is shaky. There is limited work done on the effect of core stabilization exercises with plyometric exercises and resistance training on fitness performance in youth.

Therefore, the purpose of the present study was to compare the effects of a 6-week training period of combined conventional exercises (plyometric, weight training) and core strength training with conventional training only on fitness in adolescent boys. Even though initial gains in strength and power due to training are mediated by neural factors in this study a six-week training program is used. Many strength and rehabilitation programs only give suggestions as to what exercises to use for the upper limb and lower limb. Despite the development of the many different training programs, few studies have been conducted to examine the effects of these training programs on the outcomes of fitness parameters. By developing a training program, fatigue and overuse injuries may be minimized. A full conditioning program consisting of resistance training, core stability, and plyometrics will help in improving the fitness levels in adolescent boys.

METHODOLOGY

Subjects

30 healthy boys of age 14 to 15 years of age were recruited. The participating subjects were engaged in some locally organized sports (cricket, football, tennis, basketball etc.). They were not engaged in any active weight training during the study and Participants were asked not to perform any vigorous physical activity the day before or the day of any study procedure. Subjects were excluded if there was Medical reported acute current disease or disorder of the hip, knee, thigh, lower back, upper extremity, ear (from last 6 months). Current episode of lower back pain past 6 weeks, Knee pain, pain in lower extremity or spine (which requires either self-medication or the physician intervention) in last 6 months **(Table 1)**.

Table 1. Baseline physical characteristics, data are mean (±S. D). None of the group difference were significant.

S. No.	Age	Height	Weight
1	14.66 (0.4)	172.66 (4.3)	57.80 (5)
2	14.66 (0.4)	172. 26 (7.9)	57.26 (7.68)

Study procedure

Subjects were recruited from those who voluntarily reported for the participation in Gulmohar Sports Complex. Subjects were randomly selected for the study and randomly assigned to 2 groups. Group 1 was given core strength training in addition to resistance and plyometric training and group 2 were given resistance and plyometric exercises. Core stabilization exercises were given 4 times a week and resistance and plyometric exercises were given 2 times a week. Prior to data collection all participants participated in one introductory session during which time proper form and technique on each fitness tests were reviewed and practiced. During this session researcher demonstrated proper testing procedures and participants practiced each test. Any questions participants had been answered during this time. Participants were asked not to perform any vigorous physical activity the day before or the day of any study procedure. The same researchers tested and trained the same participants and the fitness tests were performed in the same order with identical equipment, positioning, and technique. Pre-testing was performed the week before the training period and post-testing was performed the week after the training period. All the readings were taken at pre-test and at pro-test sessions.

Fitness testing procedures

Power, acceleration, speed and agility were evaluated using the vertical jump, long jump, seated medicine ball toss, 9.1 m (10 yd) sprint and pro agility shuttle run. These tests are often used to assess performance in athletes Standardized protocols for fitness testing were followed according to methods previously described [12]. Briefly, Subjects were instructed to jump as high as possible and touch the highest vane. The vertical jump was calculated by subtracting a subject's standing reach height from his maximal jump height. The standing long jump was measured on a mat which was fixed to the floor. Subjects were permitted to perform a countermovement (i.e., an active pre-stretch of the hip and knee extensors) prior to jumping vertically or horizontally. The seated medicine ball toss was performed with a 3.6 kg medicine ball (about the size of a shotput). The participants sat on the floor with their back against a wall and were instructed to toss the ball as far as they could with both hands at an approximate angle of 45° (similar to a chest pass). Prior to each toss the ball was coated with magnesium carbonate (e.g., weightlifting chalk) so that when the ball landed on the floor it left a distinctive mark that allowed for a precise measurement. The distance from the wall to the near edge of the mark on the floor made by the ball was measured. A stopwatch was used to time the 9.1 m sprint and pro agility shuttle run. The 9.1 m sprint test was used to assess acceleration. For the pro agility shuttle run, the subjects started on a center line facing the researcher. The subjects sprinted 4.55 m to the left, then 9.1 m to the right, and finally 4.55 m back to finish as they crossed the center line. Scores resulting from improper technique or incorrect body positioning during any fitness test were discarded.

Protocol of the training

Interventions were given to the participants according to their respective groups. Both groups participated in a 6-week regime. Group 1 received core strength training (for 6 weeks, four times a week), in addition to resistance and plyometric training (each for 6 weeks, twice a week) and group 2 receives resistance and plyometric training (for 6 weeks, twice a week).

Warm up procedure

A ten minutes jogging (warm up) at a self-selected pace followed by calisthenics. Static stretching for the muscles of upper limb and lower limb is given. Subjects held each stretch for 30 seconds at a point of mild discomfort, relax for 5 seconds and then repeat the same stretch for 30 seconds before progressing to the opposite side.

Core strength training protocol.

The CST group performed 5 exercises 4 times per week, 2 sets of 10-15 repetitions each. The exercises included:

a) Abdominal crunch on a stability ball to target abdominal muscles
b) Back extension on stability ball to target back extensor muscles
c) Supine opposite 1-arm/1-leg raise to target back/hip extensors muscles
d) Hip raise on stability ball to target back/hip extensors muscles
e) Russian twist on a stability ball to target abdominal muscles.

Each CST session took approximately 20 to 30 min. The group performed each exercise for two sets of ten repetitions during the first two weeks of the treatment period. Then, they performed each exercise for two sets of fifteen repetitions during the third and fourth week. Finally, they performed each exercise for three sets of twelve repetitions during the final two weeks of treatment period. Approximately 30 to 60 sec of rest periods were provided if desired. Total session volume should increase to challenge strength improvement rather than performing the same volume throughout the treatment. Therefore, this study was designed to increase the volume of exercise sessions every two weeks.

Resistance training protocol

All participants should participate in the progressive resistance training program. The first 10 min of each resistance training session included a weightlifting progression (e.g., modified cleans and snatches) with a light load (wooden dowel or unloaded aluminium bar [~7 kg]). Subjects performed one to three sets of four repetitions on each lift. Following the weightlifting progression, subjects performed additional resistance training exercises. On Tuesdays all subjects performed three sets of 10 to 12 repetitions on the following exercises: Squat, Bench Press, Overhead Press, Lateral Pull Down, Standing Calf Raise, and Biceps Curl. On Thursday's subjects performed three sets of 10 to 12 repetitions on the following exercises: Front Squat, Incline Press, Lateral Pull Down, Upright Row, Standing Calf Raise, and Triceps Extension. The last repetition of the third resistance training set on each exercise represented momentary muscular fatigue whereby participants were unable to perform additional repetitions. Following every resistance training session, subjects in both groups performed two sets of 12 to 25 repetitions of abdominal (e.g., abdominal curl), lower back (e.g., kneeling trunk extension) and rotator cuff (e.g., external rotation) strengthening exercises. The instructor reviewed the workout logs daily and made appropriate adjustments in training weight and repetitions throughout the study period [19].

Plyometric training protocol

Progressive plyometric training program is used the components of this program included preparatory movement training and plyometric training. Prior to the performance of the plyometric exercises, subjects performed one or two sets of six to ten repetitions on two or three preparatory exercises (e.g., push-up, body weight squat) which prepared them for the demands of more advanced training. Exercise is given twice per week for six weeks under carefully monitored and controlled conditions. The plyometric training program progressed from level one (weeks one and two; 1-2 sets of 10 repetitions) to level two (weeks three and four; 1-2 sets of 8 repetitions) and finally level three (weeks five and six; 1-2 sets of 6 repetitions). During weeks one, three and five, subjects performed only one set of each exercise because the plyometric training program stressed proper technique performance. During weeks two, four and six, subjects performed two sets of each exercise. Level one included low intensity exercises in order to safely introduce subjects to plyometric training. In addition, level one exercises provided the subjects with an opportunity to gain confidence in their abilities to perform basic plyometric movements before progressing to more advanced drills at levels two and level three exercise [19] **(Table 2)**.

Table 2. Plyometric exercises.

Weeks 1 and 2	Weeks 3 and 4	Weeks 5 and 6
1-2 sets / 10 reps	1-2 sets / 8 reps	1-2 sets / 6 reps
Double leg jumps forward	Ankle jumps	Dot drill
Double leg jumps backward	Hurdle hops	Single leg cone hops
Double leg “X” hop	Lateral cone hops	Long jump and sprint
MB ‘stuffer flutter”	Zigzag jump drill	Single leg zig-zag drill
Standing jump & reach	MB chest pass	MB lunge chest pass
Lateral taps on MB	Jump & turn 90°	Jump and turn 180°
MB overhead throw	High-5 drill	Tuck jump
MB single leg dip	MB backwards throw	MB partner push pass
Arrow cone drill	MB split squat	Split squat jump
Figure 8 drill	Power skipping	Alternate bounding
	Clock-drill	X-drill
	T-drill	Shuttle drill

DATA ANALYSIS

The data analysis was done by using SPSS (version 15) software system. Thirty subjects were recruited in the present study in the beginning, and four of them (three from group 1 and one from group 2) were excluded due to irregular attendance at the training sessions, these subjects were replaced by new subjects and only the data from those who completed all training sessions were used for final analysis. Physical characteristics data of subjects including age, height and weight were descriptively summarized. Performance tests were the outcomes of the study. Performance tests included Vertical Jump Test, Standing Long Jump Test, Seated Medicine Ball Toss, 9.1 m Sprint and Pro-Agility Shuttle Run.

To determine if there were any significant difference between groups at baseline (Pre-test scores), students t- test was applied. Same test was applied to the posttest readings to determine any significant difference between the groups. To determine the within group differences between scores of the two recording sessions (pre- and post-training), the paired sample t-test was used for the non-parametric dependent variables.

A 0.05 level of significance was used for the comparisons. P value > 0.05 was consider as non-significant difference while P values < 0.05 was considered to have represented a significant difference. Value of confidence interval was set at 95%.

RESULTS

Descriptive variables

Demographic details of all the groups are reported in **Table 3**. The mean ± S.D of age, height and weight of

the participants of group 1 are 14.66 ± 0.48, 172.66 ± 4.36 and 57.80 ± 5.00 respectively and of group 2 are 14.66 ±0.48, 172.26 ±7.9, 57.26 ±7.68.

Also, the t- testing showed that two groups were homogenous (statistically non-significant different) to each other (at significance level = 0.05) in the term of age (p=1.00), height (p=0.866) and weight (p=0.823) **(Table 3)**.

Between Group Comparison of Dependent Variables

T-test for between group comparison was applied to the difference between pre-test and post-test readings between the groups, to determine whether any significant difference existed among each variable among the two groups **(Table 4)**.

Between group comparison of the difference of pre-test and post- test reading of each variable, using T-test, at significant level of significance =0.05, statistically significant difference was found between the scores of all the variables among two groups (P= 0.0001).Vertical Jump Test. **Table 5** and **Figure 1** show that the post- test score was significantly different from the pre-test for vertical jump test in group 1(P = 0.0001) as well as in group 2 (P= 0.0001), however mean improvement of group 1 (mean difference = 7.824) was more than the mean improvement of group 2 (mean difference = 1.421). Standing Long Jump Test. **Table 6** and **Figure 2** show that the pre-test score was significant difference from the pre-test score in group 1 (P = 0.0001) as well as in group 2 (P= 0.0001), however mean improvement in group 1 (mean difference = 10.736) was more than that of group 2(mean difference = 1.888). Seated Medicine Ball Toss. The post- test score of seated medicine ball toss **(Table 7 and Figure 3)** was significantly different from the pre-test scores of groups 1 (P = 0.0001) as well as group 2 (P = 0.0001), however mean improvement in group 1 (mean difference = 20.579) was more than that of group 2 (mean difference = 2.734). 9.1 m Sprint. The post-test score of 9.1 m sprint **(Table 8 and Figure 4)** was significantly different from the pre-test score for group 1 (P = 0.0001) as well as for group 2 (P = 0.002), however mean improvement in group 1 (mean difference = 0.208) was more than the group 2 (mean difference = 0.013). Pro- Agility Shuttle Run. The post-test score of pro-agility shuttle run **(Table 9 and Figure 5)** was significantly different from the pre-test score for group 1 (P = 0.0001) as well as for group 2 (P = 0.002), however mean improvement in group 1 (mean difference = 0.265) was more than the group 2 (mean difference = 0.059).

Table 3. Descriptive Statistics of Physical Characteristics of Participants (individual group).

Groups	Age Mean ± S.D	Height Mean ± S.D	Weight Mean ± S.D
Group 1	14.66 ± 0.48	172.66 ± 4.36	57.80 ± 5.00
Group 2	14.66 ± 0.48	172.26 ± 7.9	57.26 ± 7.68
P-Value	1.000	0.866	0.823

Table 4. Between Group Comparison of the Difference of Pre-test, Post-test reading of Dependent Variables.

Variables	Group 1 Mean ± S.D	Group 2 Mean ± S.D	T-Value	P-Value
V.J	7.89 ± 2.28	1.42 ± 0.84	10.175	0.0001
S.L.J	10.73 ± 1.92	1.88 ± 1.01	15.778	0.0001
S.M.B.T	20.57 ± 5.86	2.73 ± 0.78	11.672	0.0001
M.S	0.20 ± 0.06	0.01 ± 0.01	11.881	0.0001
P.A.S.R	0.26 ± 0.07	0.05 ± 0.03	9.532	0.0001

Table 5. Within group comparison of Vertical Jump Test.

V.J	Pre-test reading Mean ± S.D	Post-test reading Mean ± S.D	Mean difference	T-Value	P-Value
Group 1	30.41 ± 8.24	38.24 ± 8.52	-7.824	-13.26	0.0001
Group 2	30.24 ± 3.31	31.66 ± 3.38	-1.421	-6.488	0.0001

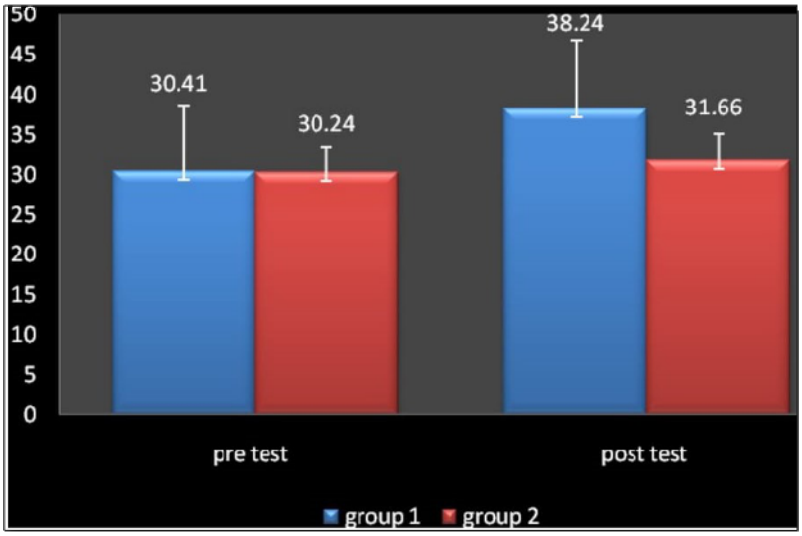

Figure 1. Comparison of Vertical Jump Test.

Table 6. Within group comparison of Standing Long Jump.

S.L.J	Pre-test reading Mean ± S.D	Post-test reading Mean ± S.D	Mean difference	T-Value	P-Value
Group 1	187.50 ±25.60	198.24 ± 25.35	-10.732	-21.64	0.0001
Group 2	187.48 ± 14.95	189.37 ± 15.24	-1.888	-7.225	0.0001

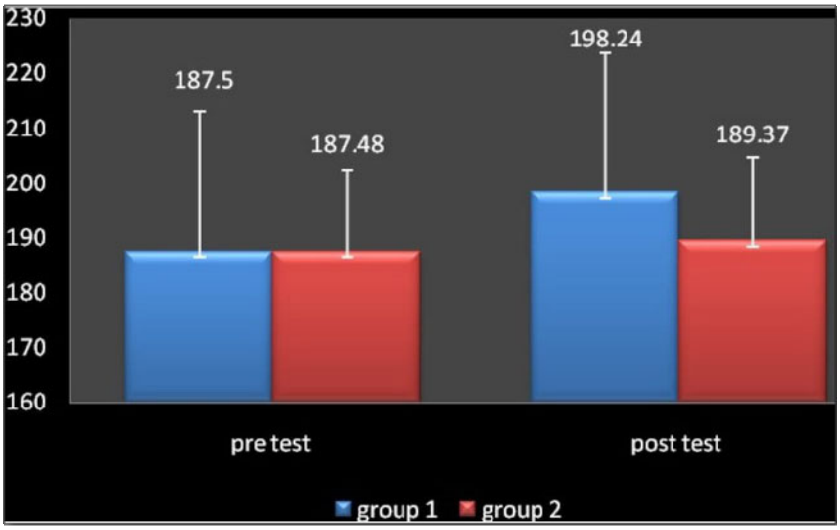

Figure 2. Comparison of Standing Long Jump.

Table 7. Within group comparison of Seated Medicine Ball Toss.

S.M.B.T	Pre-test reading Mean ± S.D	Post-test reading Mean ± S.D	Mean difference	T-Value	P-Value
Group 1	313.13 ± 44.57	334.30 ± 43055	-20.579	-13.582	0.0001
Group 2	313.57 ± 29.14	316.30 ± 29.07	-2.734	-13.451	0.0001

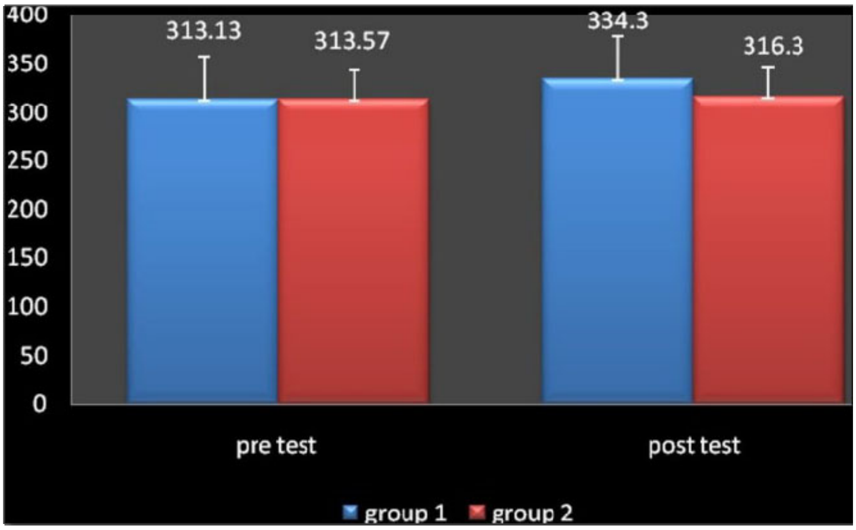

Figure 3. Comparison of Seated Medicine Ball Toss.

Table 8. Within group comparison of 9.1 m Sprint.

M.S	Pre-test reading Mean ± S.D	Post-test reading Mean ± S.D	Mean difference	T-Value	P-Value
Group 1	2.06 ± 0.14	1.85 ± 0.18	0.208	12.958	0.0001
Group 2	2.06 ± 0.12	2.05 ± 0.12	0.013	3.795	0.002

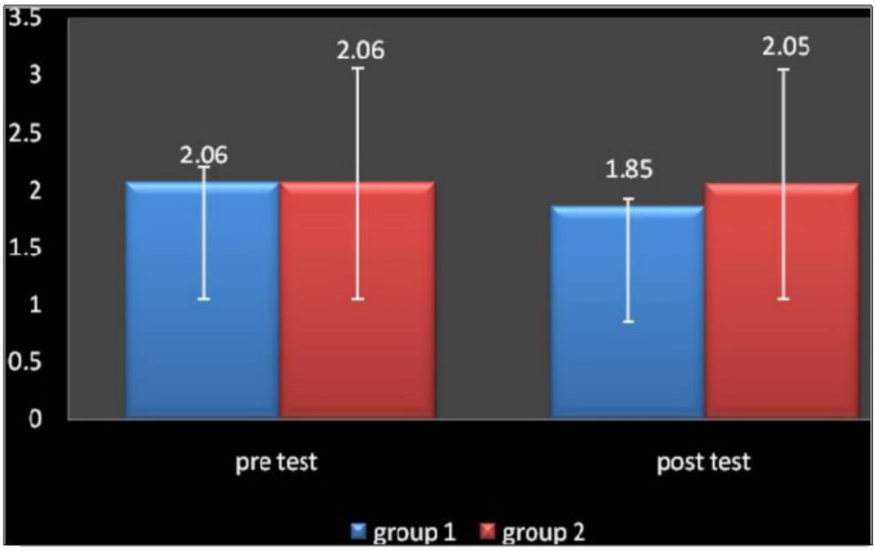

Figure 4. Comparison of 9.1 m Sprint.

Table 9. Within group comparison of Pro-Agility Shuttle Run.

P.A.S.R	Pre-test reading Mean ± S.D	Post-test reading Mean ± S.D	Mean difference	T-Value	P-Value
Group 1	5.74 ± 0.33	5.47 ±0.28	0.265	13.572	0.0001
Group 2	5.74 ± 0.17	5.68 ± 0.17	0.059	6.435	0.0001

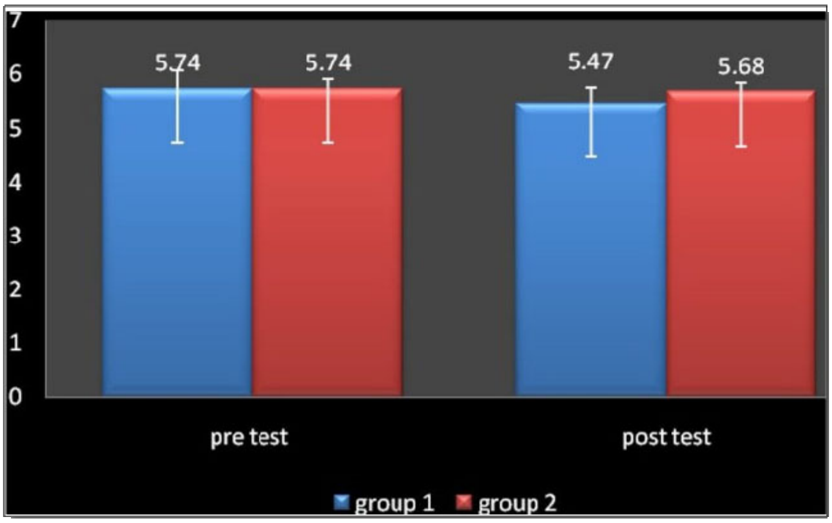

Figure 5. Comparison of Pro-Agility Shuttle Run.

DISCUSSION

The primary aim of the present study was to evaluate the effect of six weeks of core strength training in addition to combined resistance training and plyometric training would lead to greater improvements in fitness performance in healthy boys than resistance training and plyometrics It was observed that subjects who added core training to their conditioning program were able to achieve greater improvements in upper and lower body power, acceleration, speed and agility as compared with subjects who participated in a conditioning program without core strength training. Although the group without core training also improved significantly in fitness parameters but group with core training showed greater improvement.

To determine the efficacy of core strength training in addition to conventional training program in improving the fitness, the performance of the group 1 (core strength training with conventional training group) was compared with the group 2 (conventional training group on the same tests. Fitness tests were the outcomes of the study. Fitness tests further composed of Vertical Jump Test, Standing Long Jump Test, Seated Medicine Ball Toss, 9.1 m Sprint and Pro-Agility Shuttle Run.

All the variables were measured before training and after the finishing of training protocols. Results showed that both the training groups had statistically significant improvement in Vertical Jump, Standing Long jump, Seated Medicine Ball Toss and Pro-Agility Shuttle Run tests.

In this study there was better improvement in the lower extremity power (Vertical Jump Test and Standing Long Jump) in group 1 where core strength training is given with conventional training. It is possible that the explosive or high-intensity strength training methods employed in the previous studies preferentially stimulated the fast-twitch muscle fibers [16,17]. In contrast, Robert Stanton in his study showed that the Swiss ball training alone used, with its slow, controlled movements, may target predominately slow-twitch postural muscles. Therefore, Swiss ball training alone may not elicit the same performance advantage compared with explosive or high-intensity strength training. Therefore, in combination of core training with resistance and plyometric training there was an increase in the power performance as compared to the explosive training programs because of stimulating both the muscle groups simultaneously. Willardson [20,21] stated that power is the predominant component of many sports. Golf, tennis, baseball, football, and track and field events are only a few examples of power related sports where the combination of speed and strength make all the difference in performance outcomes. Whether changing direction, or accelerating one's body, limb, or implement, power can be the determining factor between movement success and failure. A strong and stable core allows power to be generated and transferred through the kinetic chain [20].

Most major muscles of the upper and lower body attach to the spine or pelvis. Strengthening this anchor helps to provide a stable platform, allowing more powerful and efficient movements of the limbs. Baseball players, tennis players, and other athletes who rely on a racket or other implement to impart power must have strong and stable core muscles in order to be successful [20].

Experts theorize that a weak core can lead to an overload on the extremities, causing injury in certain situations. Increasing one's ability to generate power while maintaining stability and balance leads to a reduced risk of injury. The muscles of the core when strong, stable, and efficient are better able to absorb and translate force, putting less stress on extremities [20].

The benefits of core strength and stability are interrelated. That is, without improved stability and balance, power cannot be generated at great rates, and movement efficiency suffers. Thus, strength, stability, and balance must be addressed when creating a core strength training program.

Seated Medicine Ball Toss has a significant improvement in group 1 as compared to group 2. McMullen [22] stated that kinetic chain rehabilitation approaches the shoulder as part of a kinetic link system and attempts to address shoulder function in a proximal-to-distal manner. The proximal trunk segment, rather than the more distal arm, acts as the "initiator" for appropriate shoulder motion. Based on this proximal-to-distal premise, quality arm elevation and shoulder function depend on trunk and scapular control. Trunk and scapular control exercises begin at the onset of therapeutic exercise in kinetic chain shoulder rehabilitation, since neither depends on arm motion. Based on proximal-to-distal sequencing, the arm ultimately depends on the segments proximal to it for movement. Full arm elevation requires full scapular retraction, which requires spinal extension, hip extension, and so on. The large muscles of the hips and trunk thereby help position the thoracic spine to accommodate appropriate scapular motion. In many athletic activities, these muscles must provide stability for effective function of the shoulder girdle.' Normal motor patterns of forward arm elevation demonstrate ipsi-lateral activation of hip extensors before deltoid activation [22].

Speed and Agility 9.1 m sprint and Pro-Agility Shuttle Run was compared between group 1 and group 2 and it was found that there was an improvement in group 1 (core strength training with conventional training group) as compared to group 2 (conventional training group). Gambetta [23] in 2006 stated the importance of the functional kinetic chain as “an integrated training program is a comprehensive approach that strives to improve all components necessary to achieve optimum performance. Since the core is where the human body’s centre of gravity is located and is where all movements begin.” Proper development of the core musculature will result in more efficient movement patterns and optimal performance [23].

The achievement of optimal muscular relationship’s result in the optimum force couple relationships in the lumbo-pelvic-hip complex. Gambetta [23] suggested that maintaining optimum length tension relationship and force couple relationships allow for the maintenance of optimum joint arthrokinematics in the lumbo-pelvic-hip complex during functional kinetic chain movements. The achievement of this allows for correct neuromuscular control of the entire kinetic chain and allows the muscles to contract with the correct balance of eccentric (braking), concentric (accelerating) and isometric (dynamic stabilization) contractions during functional movements throughout all planes of motion. Clark concluded that “the core operates as an integrated functional unit, enabling the entire kinetic chain to work synergistically to produce force, reduce force and dynamically stabilize against abnormal force.” It can be concluded that the core or lumbo-pelvic-hip complex must be trained in such a manner that allows the core to efficiently distribute the balance of weight, absorb the forces and transfer the ground reaction forces. The integrated interdependent system of the lumbopelvic- hip complex therefore needs to be trained in a fashion that allows for it to function efficiently during dynamic activities [23].

The development of neuromuscular efficiency is achieved by ensuring good postural control and stability strength are executed, as this will allow the body to decelerate forces of gravity, ground reaction forces and momentum which leads to improvement in agility. The importance of the neuromuscular efficiency is such that poor levels of neuromuscular efficiency will limit the ability of the kinetic chain to maintain optimum levels of forces resulting in loss of dynamic stabilization. This decrease in stabilization may lead to compensation factors such as synergistic dominance, reciprocal inhibition and arthrokinetic inhibition as well as poor posture during movement. This will lead to extra strain and stresses being placed upon contractile and non-contractile tissue. This in turn will progress to the start of the pain/injury cycle, as the muscles will develop repetitive micro trauma, abnormal biomechanics and injury [23].

This study’s design involved performing 4 training sessions per week, which was higher than in previous studies. Thus, the volume in the present study may have provided a strong enough stimulus to show significant effects in performance. According to the qualitative feedback from the subjects in the CST group, some were conscious of using their core muscles to stabilize their running form. Thus, the significant improvement in 5000-m run time for the CST group may be a true effect of CST [19].

In summary, this study shows a significant effect on performance from performing CST with conventional training program. Because previous studies using low training volumes (2 sessions per week for 6 weeks) did not show significant effects, this study might prove that a higher training volume is needed to show a significant effect [19].

There is a significant difference within group 2 pre- and post-test reading. It has been proved in the previous researches that the combined effect of plyometrics and resistance training produces more gains in fitness performance as compared to strength training or plyometric training alone. But no previous study has been conducted to test the effect of core in addition to conventional training program [12,16,17]. Faigenbaum [12] studied the effect of short term Plyometric and resistance training on fitness in adolescent boys, where he took two group, one of Plyometric and Resistance training group (PRT) and the other resistance training group (RT). He found that PRT made significant improvements on the vertical jump, long jump, pro agility shuttle run, medicine ball toss and flexibility whereas RT made significant improvements on the medicine ball toss and flexibility only, the effects of plyometric training and resistance training may actually be synergistic, with their combined effects being greater than each program performed alone. plyometric training may also 'prime' the neuromuscular system for the demands of resistance training by activating additional neural pathways and enhancing to a greater degree the readiness of the neuromuscular system. This potential advantage may be particularly beneficial during the first few weeks of training when young participants are learning how to perform 'loaded' exercises correctly [12].

Rahimi and Behpur [16] found that plyometric - weight training produces better results in both anaerobic power and muscular strength. During a plyometric movement, the muscles undergo a very rapid switch from the eccentric phase to the concentric phase. This stretch-shortening cycle decreases the time of the amortization phase that in turn allows for greater than normal power production, the muscles store elastic energy and stretch reflex responses are essentially exploited in this manner, permitting more work to be done by the muscle during the concentric phase of movement. This study clearly illustrates the close working relationship between neuromuscular efficiency (e.g., multiple fiber recruitment and facilitating the stretching reflex) and dynamic strength performance. With reasonable confidence, it can be said that WT programs are conducive to the development of hip and thigh strength, while the simultaneous application of plyometrics permits effective use of this strength to produce explosiveness in sports or events demanding speed and quickness [16,17].

While some evidence suggests that plyometric training and resistance training can increase speed in adults, data on the effects of resistance training or combined plyometric training and resistance training on speed enhancement in youth are limited [24]. Myer [25] demonstrated that a 6-week multi-component training program that included resistance training, plyometric training and speed training enhanced 9.1 m sprint performance in adolescent female athletes. Kotzamanidis [26] reported that running velocity improved in prepubertal boys following 10 weeks of plyometric training. However, Kotzamanidis [26] observed improvements in velocity for the running distances of 0 to 30 m, 10 to 20 m, and 20 to 30 m, but not for the distance of 0 to 10 m. Stone [27] studied the effect of plyometric on agility. The plyometric training improved times in the agility test measures because of either better motor recruitment or neural adaptations. This improvement was a result of enhanced motor unit recruitment patters. Neural adaptations usually occur when athletes respond or react as a result of improved coordination between the CNS signal and proprioceptive feedback.

CONCLUSION

Core strength training should receive some attention in the training programs of all athletes. The ability to strengthen the core region allows for efficient transfer of force between links in the kinetic chain [28]. Thus, from a scientific perspective, core strengthening in athletes should be addressed with varying methods in addition to resistance and plyometric training, depending on the phase of training and the health status of the athlete. Exercises performed on unstable equipment might be most effective for the development of core muscular endurance. These types of core exercises should be performed during off-season training cycles for the purpose of injury prevention and rehabilitation or to provide a break from the wear and tear associated with constant heavy training. Conversely, during pre-season and in-season training cycles the focus might shift to address performance needs.

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