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The Effect of 12-Week Core Strengthening and Weight Training on Muscle Strength, Endurance and Flexibility in School-Aged Athletes

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Abstract: This study investigates the effect of 12-week core strengthening and weight training on muscle strength, endurance and flexibility in school-aged athletes. Ninety male athletes at the age of 12 were randomly divided into three equal groups (30 in each). Group 1 underwent core strengthening training, group 2 underwent weight training, and group 3 was the control. The training was for 12 weeks, with three sessions per week (one hour per session). Prior to and after the training, abdominal strength, endurance, and flexibility were evaluated using the sit-ups test, the Cooper 12 min run test and the sit and reach test. The analysis of variance was used to analyze pre- and post-intervention data. The results showed that both the core strength training group and the weight training group significantly (p = 0.00) improved in abdominal strength, represented by the number of sit-ups (from 18.70 ± 3.20 to 22.21 ± 3.50 and from 17.60 ± 3.29 to 21.60 ± 3.63, respectively); endurance, represented by distance covered in 12 min (from 1817 ± 185.78 m to 2008.97 ± 214.79 m and from 1806 ± 237.25 m to 2002.59 ± 83.32 m, respectively); and flexibility, represented by the sit and reach distance (from 23.48 ± 2.75 cm to 25.96 ± 2.38 cm and from 23.66 ± 2.92 cm to 25.86 ± 2.55 cm, respectively) when compared to the control group (from 17.20 ± 3.20 to 16.39 ± 2.69; from 1813 ± 224.69 m to 1778.15 ± 05.28 m; from 23.46 ± 3.06 cm to 21.76 ± 2.56 cm). More specifically, abdominal strength and endurance improved slightly more in the weight training group than in the core strength training group, whilst flexibility increased slightly more in the core strength training group than in the weight training group. These findings indicate that both core strengthening training and weight training are effective in improving physical fitness in school-aged athletes; however, the improvement is to differing extents regarding their endurance, flexibility, and abdominal strength.

Keywords: Cooper 12 min run test; core strengthening exercises; resistance exercises; sit and reach test; sit-up test

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1. Introduction

Resistance training represents a main part of performance and health-oriented exercise programs [1]. It increases muscle strength, power, endurance, and hypertrophy, which are beneficial to improving motor performance [1]. Among potential health benefits may be included "reduced body fat, increased basal metabolic rate, decreased blood pressure and the cardiovascular demands to exercise, improved blood lipid profiles, glucose tolerance, and insulin sensitivity, increased muscle and connective tissue cross-sectional area, improved functional capacity, and relieved low back pain" [1].

Recently, exercises that strengthen and stabilize core musculature have become a part of conditioning programs for competitive athletes as well as recreationally physically active individuals [2]. These exercises are usually performed alone [3–7] or in combination with plyometric and body strengthening exercises [8] under stable and unstable conditions [3,5,6,8]. The intervention usually takes from 4 to 8 weeks [3–8], twice per week in durations of 25–45 min when it is a part of warm-up [3,5,6,8] and 60–75 min when it is performed as part of the standard training program [4,7].

Training programs focused on the development of core muscle strength, muscular endurance, and postural and core stability [3,6–8] have been found to improve functional movements [3,5,7,8] and consequently also athletic performance [4,6]. While core strengthening exercises increase activation of local stabilizers and global mobilizers and facilitate the transfer of muscle power, core stabilization exercises improve control of the lumbar spine [4,5,9]. A recent systematic review by Luo et al. [10] showed that overall control of motion and the transfer of force to the terminal segment during athletic tasks can be optimized by core strength exercises; thus, they should be included in daily training routines. Furthermore, these exercises may be beneficial for prevention of back problems in young athletes. As core musculature provides stability for effective control of body motions and force production in the lower extremities, its deficiency or imbalance can increase fatigue and decrease muscular endurance, leading to greater susceptibility to injuries [11].

Therefore, most current conditioning programs in schools also include exercises strengthening core musculature, in addition to traditional resistance exercises. Research so far has been aimed at investigations of the relationship between core stability and athletic performance, as well as the assessment of the effectiveness of core strengthening and stabilization exercises in children and adolescents [3–5,7–9,12–18]. Nevertheless, there are only a few studies dealing with young athletes. For instance, a 6-week core conditioning intervention enhanced endurance of the core muscles (lateral and prone plank, parallel dynamic back extension on a roman chair, static and dynamic curl-ups) in school-aged children [19]. Similarly, a 10-week Quad-Core training improved strength and endurance of the core muscles in school football players [20]. Furthermore, an 8-week core training using body weights along with handball training improved vertical vault, flexibility, 20 m speed, balance, right hand clutch power, agility, back-leg strength, dribbling, quick passes, and point shooting in 9–10-year-old male handball players [21]. The trunk muscle strength and dynamic balance was also improved after one year of simple core muscle training in pediatric male soccer players [22]. Moreover, one-leg, but not bipedal, vertical jump height was increased after a 4-week integrated program focused on core stabilization in prepubertal athletes [4]. Postural balance control, but not jump ability, was improved after an 8-week integrated neuromuscular training aimed at dynamic balance, core stability, and plyometrics in junior alpine skiers [8]. Throwing velocity was increased after progressive isolated unstable core stability training in young handball players [6]. Similarly, maximal throwing velocity was increased after a 6-week sling training based on core stability in young female handball players, indicating that rotational velocity in multisegmental movements can be improved following core stability training including unstable, closed kinetic chain motions due to a more stable and stronger lumbopelvic-hip complex [4]. Ball-exit velocity, but not throwing velocity, was increased after a 6-week isolated resistance training program in young baseball players [7]. Core muscle stability was improved after a 6-week Swiss ball training, whereas there were no significant changes in myoelectric activity of the back and abdominal muscles, running posture, running economy, and treadmill VO_{2max} in young male athletes [3].

However, in comparison with a predominant number of studies that conducted research on competitive athletes, a scarce amount of research deals with core strengthening exercises and their efficiency in improving overall fitness in school-age athletes. In order to partly fill this gap in the literature, we have investigated the effect of 12-week core strengthening training and weight training on physical fitness among school-age athletes. Both training programs have been assumed to be effective in improvement of their physical performance; however, their effectiveness is assumed be to different extents regarding the endurance, flexibility, and abdominal strength.

2. Materials and Methods

2.1. Participants

Ninety male school-age athletes were randomly divided into three equal groups (Table 1). Experimental group 1 underwent core strengthening training, experimental group 2 underwent weight training, and group 3 was the control. Participants were informed about the main purpose of this study and related procedures. They were examined by a qualified physician and all of them were fit for participating in this study. Participants were free to withdraw their consent if they felt any discomfort during training programs. There were no dropouts in this study. The procedures followed were in accordance with the ethical standards on human experimentation stated in compliance with the 1964 Helsinki Declaration and its later amendments.

Table 1. Characteristics of participants (mean ± SD).

Groups of Athletes	n (1)	Age (Years)	Height (cm)	Body Mass (kg)
Core strength training group (G1)	30	12.3 ± 0.3	142.4 ± 6.1	33.0 ± 6.1
Weight training group (G2)	30	12.2 ± 0.3	141.8 ± 5.9	33.3 ± 6.2
Control group (G3)	30	12.2 ± 0.3	142.0 ± 6.0	33.1 ± 6.1

2.2. Experimental Protocol

Group 1 underwent core strengthening training that included exercises such as side planks, bridges, leg-raises, flutter kicks, buttefly sit-ups, dead bugs, and rolling like a ball (3–4 sets). Group 2 underwent weight training that included exercises such as military presses, back presses, biceps curls, bench presses, heel raises, half squats, and lunges (2–3 sets, 8–12 reps). The increase in training load reflected individual capacity to respond and adapt to particular exercise. Interventions were administrated for a duration of 12 weeks. The number of sessions per week was confined to three alternative days and each session lasted an hour. Both experimental groups underwent their respective training program simultaneously under the supervision of the research scholar. Control group 3 was not exposed to any conditioning program.

Abdominal strength, flexibility, and endurance were evaluated before and after training programs using the sit-ups test, the sit and reach test, and the Cooper 12 min run test. The items selected to measure these abilities were the number of sit-ups, the sit and reach distance, and the distance covered in 12 min.

2.2.1. Sit-Ups Test

To evaluate the strength of abdominal muscles, participants performed repeated sit-ups [23]. An ICC of 0.96 (0.94–0.97) and CV of 2.02% (−1.12–3.42%) signifies good reliability of this test [24]. Participants were instructed to lie on their backs with knees flexed, feet on floor, and heels between 12 and 18 inches from the buttocks. Their arms were crossed over chest with hands on opposite shoulders. Feet were held to the mat by a partner. On "Ready" and "Go" the participants were asked to curl to a sitting position with arms contacting the chest. When their elbows touched their thighs, the sit-up was completed. Participant were then instructed to uncurl to a position where the mid-back contacts the mat. They were asked to complete as many sit-ups in this manner as possible in one minute. Only correctly performed sit-ups were counted.

2.2.2. Cooper 12 Min Run Test

To evaluate their endurance, participants performed the Cooper 12 min run test [25]. Cooper [25] reported a correlation of 0.90 between VO_{2max} and the distance covered in a 12 min walk/run. The reported ICC (95% CI) for distance was 0.99 (0.96–0.99), for maximum heart rate it was 0.93 (0.80–0.98), and for rate of perceived exertion it was 0.68 (0.05–0.89) [26]. The reported CV for distance was 1.7%, for maximum heart rate it was 1.3%, and for rate of perceived exertion it was 7.5% [26]. Participants were asked to stand behind the start line of a 400 m track after a warm-up session. They were instructed to start running on the starter's gun. They were asked to run for 12 min as fast as possible. The distance covered in 12 min was recorded.

2.2.3. Sit and Reach Test

To evaluate the lower back and hamstring flexibility, participants performed the sit and reach test [27]. High values of ICC indicate that both versions, the chair sit and reach (0.92–0.96) [28] and the back saver sit and reach (0.99) [29], are reliable. An apparatus which had 25 cm mark equivalent to the point where the feet touch the box was used. Participants were asked to warm-up by performing slow stretching exercises. They were asked to "sit barefoot with the legs fully extended with the soles of the feet placed flat against the horizontal cross board of the apparatus, with the inner edge of the sole placed 2 cm from the scale, keeping the knees fully extended, arms evenly stretched, and palms down". Participants were then asked to bend and reach forward (without jerking) while pushing the sliding marker along the scale with the fingertips as far forward as possible. They held maximum flexion position for approx. two seconds. The test was performed twice. The trial was not recorded if the knees flexed. The record taken was the max. distance reached to the nearest 0.5 cm.

2.3. Statistical Analysis

Data analysis was performed using the statistical program SPSS for Windows (SPSS, Inc., Chicago, IL, USA). The pre- and post-random group design was used as an experimental design, in which ninety school-age athletes were divided into three groups. One-way analysis of variance (ANOVA) was used to estimate differences among G1, G2, and G3 prior to and after a 12-week period. Furthermore, pre- and post-intervention data was statistically analyzed by means of ANOVA to assess the discrepancies if any of the groups were to be assessed separately on a selected dependent variable. Whenever the 'F' ratio for post-interventions was found to be relevant, the post hoc Scheffé test was used to assess the paired mean differences, if any. The confidence level of 0.05 was set for significance to test the 'F' ratio obtained. Data are presented as mean $\pm$ standard deviation (SD). Between-group effect sizes (Cohen's d) were calculated by using a pooled standard deviation. An effect size of 0.80 and higher was considered as large, 0.50–0.79 as medium, 0.20–0.49 as small, and 0–0.19 as trivial [30].

3. Results

Table 2 shows the 12-week pre- and post-intervention/no-intervention changes in physical fitness variables among school-aged athletes.

Abdominal strength. The analysis of pre-intervention data showed that the obtained F value of 2.03 was less than the 0.95 p-value needed. As a result, the pre-test importance of the core strength training group, the weight training group, and the control group on abdominal strength prior to respective interventions was found to be insignificant, at the 0.05 level. This therefore confirms that the random allocation of subjects into three groups has been successful.

The analysis of post-intervention data showed that the obtained F value of 28.01 was greater than the 0.00 p-value. Thus, the post-test mean value of abdominal strength revealed significant confidence at 0.05. Accordingly, these results showed that both core strengthening training and weight training programs led to significant improvements in abdominal strength among intervention groups.

Table 2. Pre- and post-12-week changes in physical fitness variables among school-aged athletes.

Test	Pre-Post	Group	Mean ± SD	*p* Values
Number of sit-ups (#)	Pre	G1	18.70 ± 3.20	0.13
		G2	17.60 ± 3.29	
		G3	17.20 ± 3.20	
Number of sit-ups (#)	Post	G1	22.21 ± 3.50	0.00
		G2	21.60 ± 3.63	
		G3	16.39 ± 2.69	
Distance covered in 12 min run test (m)	Pre	G1	1817 ± 185.78	0.97
		G2	1806 ± 237.25	
		G3	1813 ± 224.69	
Distance covered in 12 min run test (m)	Post	G1	2008.97 ± 214.79	0.00
		G2	2002.59 ± 283.32	
		G3	1778.15 ± 205.28	
Sit and reach distance (cm)	Pre	G1	23.48 ± 2.75	0.96
		G2	23.66 ± 2.92	
		G3	23.46 ± 3.06	
Sit and reach distance (cm)	Post	G1	25.96 ± 2.38	0.00
		G2	25.86 ± 2.55	
		G3	21.76 ± 2.56	

Endurance. The analysis of pre-intervention data showed that the obtained F value of 0.02 was less than the 0.98 *p*-value needed. As a result, the pre-test importance of the core strength training group, weight training group, and the control group on endurance prior to the respective interventions was found to be insignificant, at the 0.05 level. This therefore confirms that the random allocation of subjects into three groups has been successful.

The analysis of post-intervention data showed that the obtained F value of 9.29 was greater than the 0.00 *p*-value. Thus, the post-test mean value of endurance showed significant confidence at 0.05. Accordingly, these results showed that both the core strengthening training and weight training programs led to significant improvements in endurance among intervention groups.

Flexibility. The analysis of pre-intervention data showed that the obtained F value of 0.04 was less than the 0.96 *p*-value needed. As a result, the pre-test importance of the core strength training group, the weight training group, and the control group on flexibility prior to respective interventions was found to be insignificant, at the 0.05 level. This therefore confirms that the random allocation of subjects into three groups has been successful.

The analysis of post-intervention data showed that the obtained F value of 27.12 was greater than the 0.00 *p*-value. Thus, the post-test mean value of flexibility showed significant confidence at 0.05. Accordingly, these results showed that both core strengthening training and weight training programs led to significant improvements in flexibility among intervention groups.

However, there were no significant differences in gains obtained after intervention programs in G1 and G2 in the number of sit-ups (3.51 and 4.0, respectively), distance covered in 12 min run test (191.97 m and 196.59 m, respectively), and the sit and reach distance (2.48 cm and 2.2 cm, respectively). This may be also corroborated by trivial Cohen's d when compared post-intervention differences between G1 and G2 in abdominal strength (0.171), endurance (0.025), and flexibility (0.042).

4. Discussion

Findings revealed significant improvements in abdominal strength, endurance, and flexibility in school-aged athletes following a 12-week core strengthening training as well as weight training. However, abdominal strength and endurance improved slightly more in the weight training group than in the core strength training group, whilst flexibility increased slightly more in the core strength training group than in the weight training group. This may be ascribed to adaptations to exercises used. While the core strengthening training included exercises such as side planks, bridges, leg-raises, flutter kicks, butterfly sit-ups, dead bugs, and rolling like a ball, the weight training included exercises such as military presses, back presses, biceps curls, bench presses, heel raises, half squats, and lunges.

These findings are in line with those of previous studies, which demonstrated a significant increase in muscle power and strength following weight training. For instance, maximal lifting power and isometric hip and trunk extension strength increased after an 8-week training, including maximal voluntary co-contraction of abdominal muscles, in young adult men [31]. Core/torso stiffness improved more after a 6-week isometric compared to a dynamic core training [32]. However, core strength training can also be effective in improving various physical fitness variables. Similar to our study, the endurance and strength of the core muscles improved after a 10-week Quad-Core training in school football players [20]. Regarding the flexibility, spine range of motion, lateral flexibility, dynamic balance, and endurance and/or strength of the back, abdominal and leg muscles improved after an 8-week core muscle training program using BOSU and a Swiss ball in male university students [33]. The range of motion in the stand and reach test also improved after an 8-week training program using a foam roll, without a decrease in muscle performance, strength endurance of the core muscles, or balance [34]. Strength of the core muscles increased following core stability exercises with a Swiss ball in junior swimmers [35]. Thus, a Swiss-ball core strength training program can be used for improvements in muscle strength of the lower limb flexors (hamstrings), lower limb extensors (quadriceps), trunk flexor (abdominal), trunk extensor (lower back), endurance of the lower limb, lower back and abdominal muscles, flexibility of the lower back, and dynamic balance [36]. A 6-week program of Swiss ball training can be a suitable alternative to traditional floor exercises for improvements in core strength in collegiate athletes [37]. Balance, strength of the legs, and abdominal muscles were enhanced after both core stability dynamic and medicine ball training in male students of recreation health and physical education [38]. Furthermore, neuromuscular control of lower limbs and the trunk during single-legged squatting and jump landing improved after an 8-week core muscle training in female collegiate basketball players [39]. Speed, agility, upper body strength, and leg explosive power improved after an 8-week core strength training in male handball players [40]. Performance in runners in terms of faster times in the 5000-m run improved after a 6-week core muscle strength training [41]. Running economy and endurance were enhanced by adding inspiratory loaded core conditioning exercises to a 6-week high-intensity interval training [42]. Running economy, core endurance, and static balance also improved after an 8-week core muscle training program in male college athletes, such as long-distance runners, basketball, football, and rugby players [43]. Additionally, long jump explosive force and agility skills, but not double right/left foot balance, increased after an 8-week core strength training in runners [44]. In addition, core muscle strength improved after an 8-week core strength training program in male young cyclists [45]. Similarly, core stability training improved core muscle strength in professional football players [46]. Flexibility and body balance improved after a 12-week static stretching and core specific training in Tripura cricketers [47]. A 12-week program of core muscle training enhanced isometric strength of the trunk and the prone bridge core endurance in rhythmic gymnasts [48]. A shorter, 6-week training program including core stability exercises enhanced core endurance and strength, which contributed to better static and dynamic balance by reducing postural fluctuations in female students with trunk control defects [49]. A 6-week core muscle strength and proprioceptive training program increased single leg hop and Y-balance test scores in taekwondo athletes [50]. Furthermore, a 10-week core strength training program improved core strength, power, balance, the spinning wheel kick, and reaction speed in female young karate athletes [51]. Maximal throwing velocity increased following a 6-week core stability training program including unstable, closed kinetic chain motions in female, high school handball players, indicating that a more stable and stronger lumbopelvic-hip complex contributes to greater rotational velocity in multi-segmental movements [4]. A review of 12 studies revealed that smash stroke performance and dynamic balance are improved by core stability training in badminton players; thus, the training can be implemented in various racquet sports for enhancement of athletic skill performance [52]. Moreover, rotational power and force, peak arm speed and acceleration, ball speed, and carry distance improved more after a 9-week isokinetic training program compared to an isotonic training program in pre-elite golfers [53]. An 8-week core strength training program also improved core strength, rotational power, estimated peak power, time to peak acceleration, rotational flexibility, and maximal countermovement jump in junior competitive surf athletes [54]. There was an increase in trunk rotational power after both preparatory and competitive periods in tennis players, whereas this only occurred after the preparatory period in ice-hockey players and canoeists, which reflected the specificity of their training programs [55].

In addition to the enhancement in athletic performance [11,56–58], exercises that strengthen and stabilize core musculature have been recommended for prevention and rehabilitation of musculoskeletal disorders [56]. A recent review by Zemková and Zapletalová [59] revealed that these exercises, performed alone or combined with athletic training, contribute to a decrease in back problems in athletes. Thus, a better understanding of the role which core strength and stability plays in physical activities has applications for enhancement of athlete performance as well as for a reduction in their risk of back problems. However, more research is needed to investigate whether these exercises contribute to back health in school-aged athletes. This may be helpful for designing core exercise programs for physically active as well as sedentary young individuals, and avoid future back-related problems [60–62]. Improving core muscular endurance by including moderate-to-high intensity dynamic core exercises in physical education classes may be beneficial for children and adolescents because risk factors for low back pain start to increase during childhood [19].

The strength of this study is in its high number of participants that underwent interventions in the form of 12-week core strengthening training and weight training (three sessions per week, one hour per session). An additional benefit of the study is that the sample consisted of school-aged athletes which has partially filled the gap in studies investigated so far, as most of them have conducted research on competitive athletes. However, a limitation is that only abdominal strength, endurance, and flexibility were evaluated using the sit-ups test, the Cooper 12 min run test and the sit and reach test prior to and after the 12-week period in both experimental groups and the control group. Therefore, further research should also include core strength or core stability tests applicable in the school environment, which could provide us with more valuable information on the efficiency of such training programs.

5. Conclusions

Both 12-week core strengthening training and weight training programs significantly improved abdominal strength, endurance, and flexibility in school-aged athletes when compared to the control group. More specifically, abdominal strength and endurance improved slightly more in the weight training group than in the core strength training group, whilst flexibility increased slightly more in the core strength training group than in the weight training group. These findings indicate that both core strengthening training and weight training are effective in improving physical fitness of school-aged athletes; however, this improvement is to differing extents regarding their endurance, flexibility, and abdominal strength.

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