Effect of Calisthenics Training on Core Stability, Muscle Strength, Static Balance and Trunk Proprioception in Adolescent Boys

Abstract

Background: Physical activity decreases at the beginning of adolescence, so organized physical activity at school plays an essential role in promoting the health and proper physical development of students. The purpose of this study was to investigate the effect of eight weeks of calisthenics training on core stability, muscle strength, static balance and trunk proprioception of male teenagers.

Methods: In this semi-experimental study with a pre-test-post-test design, 40 male high school students aged 15 to 18 in Zavareh city were selected as a sample and randomly divided into two groups: calisthenics training (n=20) and control (n=20). The experimental group received calisthenics training for eight weeks, three times per week, for 60 minutes each session. Before and after the eight-weeks training, static balance, core stability, muscle strength and trunk proprioception were measured using the Stroke balance test, McGill test, chest press, leg press, rowing and repositioning error (RE) of trunk flexion at a 45° angle respectively.

Results: The results of the independent t- test showed that eight weeks of calisthenics training increased the amount of static balance ($P < 0.0001$), trunk proprioception ($P < 0.0001$), core stability in trunk flexion ($P < 0.0001$), and muscle strength in the rowing and leg press test ($P < 0.05$) significantly.

Conclusion: Overall, the findings from the present study suggest that following an 8-weeks participation in calisthenics training improvement in, trunk proprioception, core stability in flexion, muscle strength and static balance is seen in teenagers. Therefore, this type of exercises can be used along with other exercises or as a suitable alternative in schools.

Keywords: Core stability, Muscle strength, Proprioception, Exercise training, Calisthenics

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Introduction

Adolescence is a transitional period between childhood and adulthood, considered one of the most crucial phases of human growth and development. According to the World Health Organization's statistics, over 80 percent of the global adolescent population lacks sufficient physical activity [(1)]. Organized physical activity in schools plays a fundamental role in promoting good health and physical growth, especially during early adolescence when students tend to show less interest in physical activities [(2)]. Posture control and stability are fundamental motor skills and serve as the foundation for daily tasks and sports activities [(3)]. This index of neuromuscular control can be accessed through both static and dynamic balance [(4)]. Preserving and enhancing balance play crucial role in preventing movement disorders and establishing a developed postural control system necessary for successful daily and sports-related activities. Improvement in postural control can be achieved through physical exercise at all ages [(5, 6)].

Postural control and balance are a result of the interaction between the nervous and musculoskeletal systems. Components of the nervous system involved in postural control include motor processes such as neuromuscular synergy and sensory processes like vestibular, visual, and proprioceptive systems. In other words, postural control is achieved through close and complex interaction between sensory inputs and appropriate motor responses, including control of the motor system and efficient muscle strength [(7)].

The proprioceptive system comprises a combination of joint position sense, movement sense, and the ability to sense force changes within the body [(8)], providing feedback regarding both core and peripheral limbs.

On the other hand, muscle strength is one of the determinants of sports performance, and increased muscle strength has positive effects on rate of force development (RFD), power, jump and sprint performance, and improved running economy [(9)].

Core muscle strength and stability are considered essential and vital for many sports and daily activities. Anatomically, the core can be described as a muscular box, with abdominal muscles in the front, paraspinal and sacral muscles in the back, the diaphragm as the ceiling, and the muscles of the pelvic floor and hip girdle as the bottom [(10)]. Functionally, the body's core can be viewed as a kinetic chain facilitating the transfer of torques and angular momentum between the upper and lower limbs, which holds critical importance for specific sports and daily activities across different age groups [(11)].

Strength training can be an engaging method for adolescent students to actively participate in physical education classes and adhere to exercise programs. One low-cost and practical form of strength training that can potentially improve neuromuscular systems in children and adolescents is calisthenics exercises [(12)].

Calisthenics training is rhythmic movement exercises performed based on one's body weight and minimal equipment, utilized to enhance various muscle groups and improve coordination and proprioception in rehabilitation and exercise [(13, 14)]. It seems that calisthenics exercises could be a useful and safe tool for improving and maintaining functional strength, muscle endurance, coordination, and flexibility [(15)].

Despite the benefits mentioned for this type of exercise and the review of previous research, there's limited internal research, and most foreign studies have focused more on the body composition following this type of training.

For instance, studies conducted by Jain et al. (2020) and Panjihar and Rani (2022) showed significant improvements in balance due to calisthenics training [(16, 17)]. Conversely, Aslan and Lyavanluoglu (2003) found no significant impact on balance following calisthenics training [(18)]. Regarding the effect of calisthenics training on muscle strength, some studies indicated improvements in isokinetic leg muscle strength [(19)] and Swedish swim and barfix [(20)]. However, Guvara et al. (2019) observed substantial changes in performance in medicine ball throws and horizontal jumps [(12)], while Thomas et al. (2017) did not demonstrate improvements in grip strength [(20)].

No research has been conducted on the effects of calisthenics exercises on central stability, and regarding proprioception, only one study has been carried out on women aged 25 to 50 comparing proprioception between three groups: calisthenics training, Pilates, and a control group, showing no difference in proprioception among the groups during exercise [(21)]. There is, therefore, a need for further investigation and examination regarding the impact of calisthenics exercises on the mentioned variables within the adolescent age group.

Hence, this current study aimed to answer the question: "Does eight weeks of calisthenics exercises have a significant impact on the central stability, muscle strength, balance, and proprioception of male high school students in the second cycle in the Zavareh city?"

Methods

The present research was a semi-experimental study conducted in a pre-test/post-test design format, following ethical approval from the Research Ethics Committee of Payame Noor University (IR.PNU.REC.1401.470).

Participants

The study population consisted of male high school students in Zavareh, aged between 15 to 18 years old. The sample size, based on similar previous studies, considering a type I error rate of 0.05 and power of 0.80, using NCSS (PASS) software, determined 16 individuals in each group. Anticipating possible dropouts during the research stages, 40 participants were selected randomly out of 72 volunteers to form two groups: control (20 participants) and calisthenics exercise (20 participants). The inclusion criteria comprised age, gender, having overall physical and mental health, and informed consent to participate. Exclusion criteria involved prior experience with strength exercises within six months before the study, dietary supplement intake three months before the exercise, history of lower limb injuries such as fractures, tears, ligament damages, neurological disorders like diabetes, neuropathy, myopathy, multiple sclerosis, etc. Participants were fully informed about the exercise procedures and provided written consent, along with parental consent, before entering the study.

Data Collection Method

The participants in the calisthenics exercise group underwent an eight-week training regimen consisting of three sessions per week, each lasting for one hour. Before commencing the exercises, proper guidelines regarding the execution of each exercise were explained to the participants. According to the exercise protocol, each training session started with a 10-minute general warm-up (walking and jogging), followed by a 40-minute exercise regimen comprised of calisthenics exercises. At the conclusion of each session, a 10-minute cool-down (walking, jogging, and stretching movements) was performed. The exercises consisted of 11 movements (Figure 1) with gradually increasing sets and repetitions, and new exercises were added in certain weeks [23, 22]. Rest periods between sets were 30 to 90 seconds, and rest between movements was up to 120 seconds (Table 1) [22]. Muscle strength, static balance, core stability, and proprioception were assessed before and eight weeks after the completion of the strength training program using the relevant tests.

Muscle Strength

To assess the muscle strength, the leg press test (evaluating the strength of quadriceps, hamstrings, and lower back), bench press test (assessing chest muscles' strength), and rowing test (evaluating the strength of the major back muscles) were conducted using locally manufactured bodybuilding equipment "InPars" models. The maximum strength of the participants was determined one week before the start of the resistance training program. This determination involved familiarizing the participants with the resistance exercises' execution method and using the one-repetition maximum (1RM) test formula devised by Brzycki [23, 24].

Brzycki Formula: One Repetition Maximum = load ÷ (1.0278 - (0.0278 × Number of repetitions).

Table 1: 8-Week Calisthenics Exercise Protocol

Movement	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Sit-ups	2×10	2×15	2×20	2×25	3×25	3×30	3×30	3×35
Squats	2×10	3×15	4×15	4×20	5×20	5×25	6×25	6×25
Bridge	2×10	2×15	3×15	3×20	3×25	3×25	3×30	3×30
Pike push up	2×10	2×10	3×10	3×10	4×8	4×8	5×8	5×8
Plank (second)	2×15	2×15	3×20	3×20	3×30	3×30	4×40	4×45
Mountain Climbers	-	-	2×12	2×15	3×20	3×25	3×25	3×30
Side Plank (seconds)	-	-	2×15	2×15	3×20	3×20	3×30	3×30
Push up	-	-	2×10	2×10	3×12	4×10	5×10	6×10
Plyo Jacks	-	-	2×10	2×10	2×12	3×12	3×15	3×20
Dip Box	-	-	-	-	3×12	4×12	5×15	6×15
Wall-Walk	-	-	-	-	-	2×10	3×12	3×15

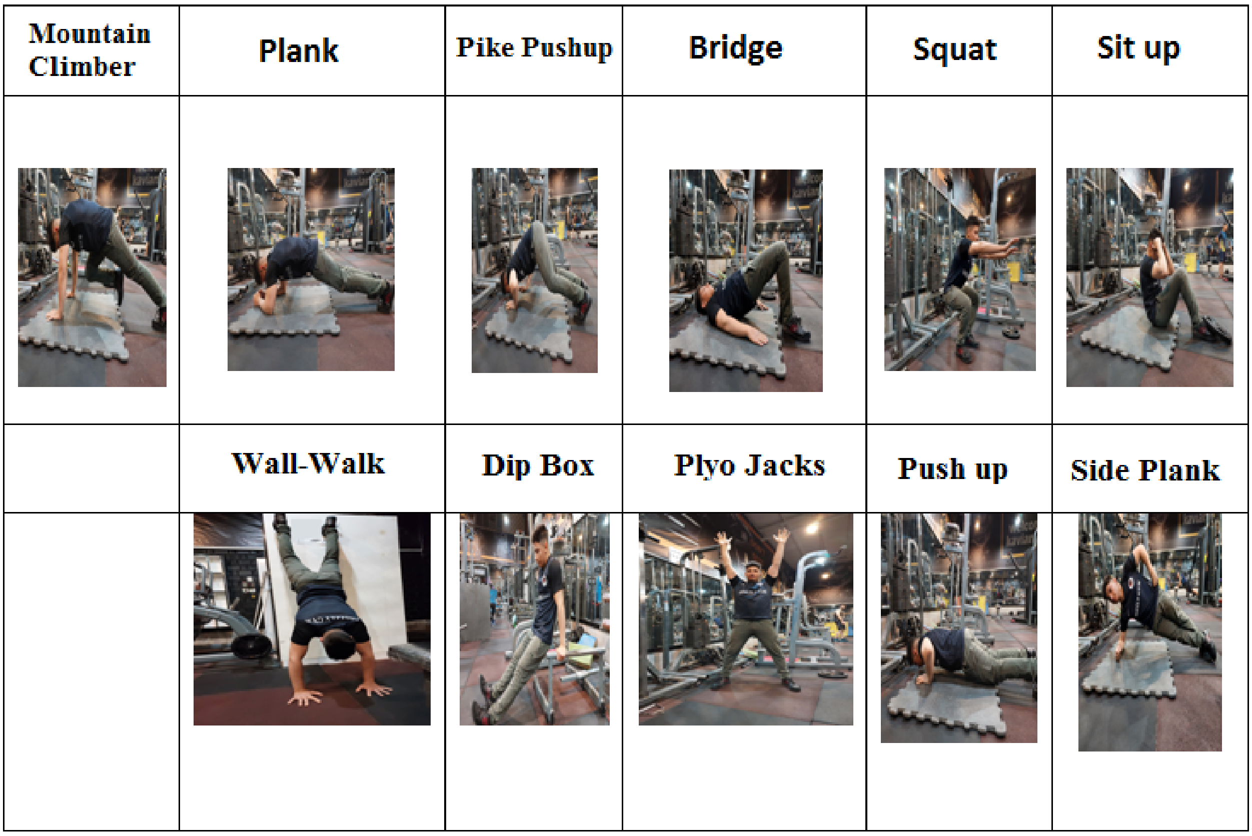

Figure 1: The exercises consisted of 11 movements

Static Balance

Static balance was measured using the Stork Balance Stand Test with eyes open. This test is a valid measure of static balance, where abnormal time duration of standing on one leg with eyes open indicates peripheral neuropathy and intermittent claudication [25].

In this test, the participant stood barefoot on a flat surface, placed their hands on their hip joints, and then positioned the non-supporting foot adjacent to the knee of the supporting leg or the higher leg. Subsequently, the participant raised the heel of the non-supporting foot to balance on the toes (forefoot). The stopwatch started timing from the moment the participant raised the heel from the ground. The duration the participant could maintain this position was recorded as their score, and any errors resulted in stopping the stopwatch. Errors in this test included opening hands to maintain balance, swaying of the supporting leg in any direction, separation of the non-supporting foot from the knee, and the heel of the supporting foot touching the ground. Before performing the balance test, each participant practiced this position two to three times. The balance test was repeated twice for each participant, and the best time was recorded as their balance score [26].

Proprioception of the Trunk

To measure the level of trunk depth sensation, the 45-degree flexion reproduction error test was used. The trunk's Proprioception was measured using a spine goniometer. The test was performed by repositioning the trunk's 45-degree flexion from an upright position (Newcomer method). All evaluations were conducted by one examiner in both the pretest and posttest. The test was administered by initially positioning the participant's arms crossed in front of the chest. To eliminate lower limb movements, individuals' feet were immobilized using specially designed straps placed close to the thighs. Then, a spine goniometer (EA8161 model, MSD Company, Belgium) specifically for the vertebral column was aligned parallel to the first lumbar vertebra. The goniometer's center was positioned at the iliac crest. To begin the test, the participant was instructed to bend the trunk at a relatively constant speed, maintaining an upright posture, and, upon reaching a 45-degree angle, hold this position for five seconds. They would then return to the upright position and, after 15 seconds, repositioning the 45-degree angle with eyes closed. This reconstruction of the 45-degree angle was repeated three times, and the average error value in relation to the 45-degree angle was recorded as the reproduction error value [27].

Core Stability
The McGill test was employed to evaluate core stability. The reported reliability coefficient for this test is approximately 0.97 and includes four components: trunk flexion, trunk extension, right and left lateral flexions (lateral muscle test). In this test, the core area of the body is divided into four sections: front, back, left, and right, and the capabilities of these sections are assessed separately. In the present study, a chronometer was used to record the duration of stable position maintenance by the participants in three positions: trunk flexion, trunk extension, and right lateral bridge (dominant side). A minimum of five minutes of rest was determined between each test [28].

Statistical Analysis Method
Data analysis was performed using SPSS software (Version 19) in two sections: descriptive and inferential. After assessing the normality of the data using the Shapiro-Wilk test, an independent t-test was utilized to compare the pretest and posttest between the two groups to investigate the research hypotheses. A significance level of 0.05 was considered for the relevant hypothesis tests.

Results

Demographic characteristics of the participants are presented in Table 2. Before determining the type of test used for data analysis, the normality of variable distributions in the two examined groups was evaluated using the Shapiro-Wilk test at a significance level (p-value) of 0.05. Both groups exhibited normally distributed variables. Therefore, an independent parametric t-test was employed to determine changes in variables before and after the training period.
The results of the independent t-test comparing the level of trunk core stability after eight weeks of calisthenics exercises showed that there was no significant difference between the two groups - the calisthenics training group and the control group - in terms of trunk core stability in lateral and trunk extension positions
($p > 0.05$). However, there was a significant difference in trunk flexion stability ($p < 0.05$). Thus, calisthenics exercises had a statistically significant effect (31% improvement) on enhancing and increasing trunk flexion stability in male adolescents aged 15 to 18 (Table 3).

Table 2. Demographic Characteristics of Participants

Group	Number	Index	Demographic Characteristics of Participants (Mean ± Standard Deviation)			
			Age (years)	Height (cm)	Weight (kg)	Body Mass Index (kg/m²)
Control	20		17±0.88	172.10 ± 3.21	64.42 ±6.54	21.73±1.97
Calisthenics Exercises	20		17.24±1.03	173.55 ± 2.28	67.45±6.32	22.37±1.79
Mean Comparison	t		-0.785	-1.64	-1.48	-1.6
	P		0.437	0.108	0.146	0.292

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The results of the independent t-test comparing the upper and lower trunk muscle strength after 8 weeks of calisthenics exercises indicated that between the two groups - the calisthenics training group and the control group - there was no significant difference in terms of upper trunk strength in the bench press test ($p > 0.05$).

However, in the back extension test ($p < 0.05$) and lower trunk strength test (leg press), there was a significant difference, with improvements of 24% and 21.83%, respectively, observed in the calisthenics group (Table 4).

The results of the independent t-test comparing static balance after 8 weeks of calisthenics exercises revealed a significant difference between the two groups - the calisthenics exercise group and the control group - in terms of static balance ($p = 0.007$). The exercise group showed an improvement of 11.36% in static balance (Table 5).

Based on the results of the independent t-test, there was a significant difference in the level of trunk proprioception after 8 weeks of calisthenics exercises between the calisthenics training and the control group ($p = 0.016$). Therefore, engaging in 8 weeks of calisthenics exercises had a significant effect on reducing repositioning error and consequently led to improvement (4.26%) and increased trunk proprioception in boys aged 15 to 18 years (Table 6).

The effect size was calculated using Cohen's d formula and documented in the tables. A value of 0.2 was categorized as a small effect size, 0.5 as a medium effect size, and 0.8 as a large effect size [17].

Table 3: Independent t-test results of central stability among the participants before and 8 weeks after calisthenics training in the two groups of control and exercise

Variable	Time	95% Confidence Interval		t-value	Significance	Mean Difference	Cohen's d Effect Size
		Upper Bound	Lower Bound				
Core Stability-Lateral	Pre-test	13.81	-2.11	1.487	0.145	5.85	0.47
	Post-test	5.11	-10.01	-0.656	0.516	-2.45	0.23
Core Stability-Flexion	Pre-test	22.33	-8.13	0.944	0.351	7.10	0.29
	Post-test	-5.18	-33.21	-2.774	0.009	-19.2	0.87
Core Stability-Extension	Pre-test	21.18	-6.88	1.032	0.309	7.15	0.32
	Post-test	13.61	-10.61	0.251	0.804	1.5	0.07

Table 4: Results of Independent t-test on Upper and Lower Body Strength of Participants Before and 8 Weeks After calisthenics training

Variable	Time	95% Confidence Interval		t-value	Significance	Mean Difference	Cohen's d Effect Size
		Upper Bound	Lower Bound				
Upper Body Strength (Rowing Test)	Pre-test	13.40	-13.74	-0.030	0.976	-0.2	0.009
	Post-test	-4.1	-30.79	-2.62	0.012	-17.45	0.83
Upper Body Strength (Chest Press)	Pre-test	20.9	-9.97	0.717	0.478	5.46	0.22
	Post-test	12.59	-16.39	-0.265	0.792	-1.9	0.083
Lower Body Strength (Leg Press)	Pre-test	25.57	-36.34	-0.352	0.727	-5.38	0.11
	Post-test	-8.34	-66.65	-2.60	0.013	-37.5	0.82

Discussion

This study aimed to determine the impact of eight weeks of calisthenics training on the core stability, muscular strength, static balance, and trunk proprioception of male adolescents aged 15 to 18 in the city of Zavareh.

The findings of this research revealed that conducting eight weeks of calisthenics training enhances core stability in adolescents during trunk flexion. Calisthenics exercises generally comprise rhythmic simple movements and short-term muscular contractions, increasing muscular strength and flexibility through body-weight exercises such as bending, rotating, jumping, and other similar movements engaging various muscle groups throughout the body [17].

Core muscles, including the transverse abdominal muscles, multifidus, diaphragm, and pelvic floor muscles, play a role in spinal stability. It has been demonstrated that performing strength exercises for abdominal muscles increases stability in the lumbar region. Therefore, based on these findings, it can be argued that the calisthenics training conducted in this study, including sit ups, bridges, mountain climber, side plank, push up and dip box, bridges, mountaineer steps, plank variations, as well as dynamic swimming and dips, have significantly impacted the endurance and strength of core muscles, leading to enhanced core stability resulting from improved strength, endurance, and better neuromuscular performance in the muscles involved in the core region.

Additionally, the research findings indicated that eight weeks of calisthenics training could increase muscle strength in leg press and rowing tests. This research outcome aligns with several other studies highlighting an increase in strength following calisthenics training [12, 19, 20, 29]. Although, different muscle groups and tests were employed in these studies. Given that calisthenics training involves multi-joint movements, the improvement in strength may be due to enhanced coordination and reflex-driven or voluntary changes in neuromuscular activation [12, 15]. As hypertrophy plays a lesser role in strength gain after eight weeks of physical activity, the strength increase in present training is achieved through neuromuscular adaptation. Neuromuscular activation changes involve alterations in both intramuscular coordination and intermuscular coordination [30]. Such adaptations may include reduced antagonist muscle activation, improved synergy among muscles, and increased neural drive to agonist muscles, leading to recruiting additional motor units and enhancing motor unit firing rate [30].

Table 5: Results of Independent t-test for Static Balance of Participants Before and 8 Weeks After calisthenics training in Two Control and Exercise Groups

Variable	Time	95% Confidence Interval		t-value	Significance	Mean Difference	Cohen's d Effect Size
		Upper Bound	Lower Bound				
Static Balance	Pre-test	2.49	-1.69	0.386	0.702	0.40	0.12
	Post-test	-1.008	-5.89	-2.86	0.007	-3.45	0.90

Table 6: Results of Independent t-test for Trunk Proprioception of Participants Before and 8 Weeks After calisthenics training in Two Control and Exercise Groups

Variable	Time	95% Confidence Interval		t-value	Significance	Mean Difference	Cohen's d Effect Size
		Upper Bound	Lower Bound				
Trunk Proprioception	Pre-test	1.05	-0.59	0.572	0.570	0.233	0.17
	Post-test	1.97	0.21	2.53	0.016	0.091	0.79

Regarding the impact of calisthenics training on improving static balance, the results demonstrated an enhancement in static balance following this type of exercise. However, this finding contrasts with the research of Isler and Lévanoğlu [18]. The disparity could be attributed to differences in age, gender of participants, training duration, exercise protocol, and the test used for balance assessment. Nevertheless, the current research findings were consistent with the studies by Jennings [19] and Aydın et al. [31]; suggesting that calisthenics training, involving movements activating various muscle groups, contribute to the development of proprioception and coordination.

As gravity affects body equilibrium, various mechanisms exist to maintain balance [32]. These mechanisms activate when the body is at risk of falling, working to preserve balance. They include muscle contractions, inhibiting deep receptors, and self-motion patterns, controlled by specific patterns in the brain's membrane [32]. These mechanisms correspond to autonomic reactions and entail predictable changes in muscle strength concerning the head and trunk positions. They involve an increase in flexor and extensor muscle activity to restore balance [32]. Considering that the body's core comprises abdominal muscles at the front, back muscles in the posterior area, the diaphragm above, and pelvic floor muscles below, protecting the central force from the spine and ensuring neutral pelvic stability, this aspect may significantly contribute to improving body control and balance. Thus, given the improvement in strength and core stability in this study, part of the enhanced balance might result from improved strength and core stability, as the central body part acts as a foundation for distal movements or "proximal stability for distal mobility". The major muscles in the central body part create a firm cylinder against body movements. Abdominal muscles, including the transverse abdominis, internal and external obliques, and rectus abdominis, all contract to provide spinal column stability, establishing a firm base for lower limb movement. When the transverse abdominal muscle contracts, intra-abdominal pressure increases, contracting the thoracolumbar fascia. These contractions occur before movement initiation, allowing stability for movement and muscle activation. The rectus abdominis and oblique muscles also support the position [33].

Regarding the impact of calisthenics training on improving trunk proprioception in male adolescents, the study's outcome contrasted with the research of Özer Kaya et al. [21]. The participants in Özer Kaya's research were women aged 25 to 50, and the training duration and protocol differed. Since there is limited research on calisthenics training, neither in Iran nor internationally, regarding their effect on proprioception, it was challenging to find relevant studies. However, it can be stated that sports exercises involving repetitive movements increase an individual's ability to control joint movements in all positions and contribute dynamic stability to control unnatural joint movements. It seems that motor control is improved through a reflex pathway [34]. There is a close interaction between strength and proprioception [35]. Therefore, considering that calisthenics training incorporate body-weight movements involving various exercises (bending, jumping, bouncing, and rotating) and engage nearly all muscle groups, it's not unexpected that they might also affect individuals' proprioception.

Conclusion

Overall, the findings of the current research indicate that engaging in eight weeks of calisthenics training leads to improvements in core stability, muscular strength, balance, and trunk proprioception in male adolescents. Considering that individuals, from the most basic levels of physical readiness to the most professional athletes, can engage and experience high training pressure without the need for specific weights or machines, the use of these training is recommended in schools, fitness clubs, and even at home. Moreover, calisthenics training can be used as a separate program or combined with weight loss, bodybuilding, or fitness programs.

Generally, every research study has certain limitations. The limitations of the current study include the number of participants, limited training duration, and the absence of post-exercise variable examination after a detraining period to assess the sustainability effect, and the lack of more precise laboratory facilities to use non-field tests.

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