EFFECT OF 8-WEEK CIRCUIT TRAINING ON THE DEVELOPMENT OF DIFFERENT FORMS OF MUSCLE STRENGTH IN PHYSICAL EDUCATION

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ABSTRACT

The aim of the research was to determine the effect of an 8-week circuit training program on explosive strength and strength endurance in physical education classes intended for high school students. The research included 60 students of two second-grade high school classes. Both classes attended regular physical education classes, where, within the main part of the class, one class had a special program for developing strength through circuit training (circuit group), while the other one had no modifications to the regular physical education program (control group). The classes were randomly marked as circuit group (n = 28) and control group (n = 32). Five strength tests were used in the study: squat jump, countermovement jump, squats, push-ups, and sit-ups. The results showed that the 8-week strength development program organized as circuit training contributed to a significant improvement in strength. The results of all tests showed a significant effect of training on students' strength. It has been determined that short-term circuit training in physical education classes is an effective way to develop students' physical performanc.

KEYWORDS

Explosive strength, strength endurance, students, physical activity, physical exercise

HOW TO CITE

Milenković D. (2022) 'Effect of 8-Week Circuit Training on the Development of Different Forms of Muscle Strength in Physical Education', *Journal on Efficiency and Responsibility in Education and Science*, vol. 15, no. 4, pp. 221-227. http://dx.doi.org/10.7160/eriesj.2022.150403

Article history
Received
May 20, 2022
Received in revised form
July 8, 2022
Accepted
November 30, 2022
Available on-line
December 20, 2022

Highlights

- *Changes in explosive strength and strength endurance after eight weeks of circuit training program in physical education classes.*
- *8-week strength development program contributed to a significant improvement.*
- *Short-term circuit training in physical education classes is an effective way of developing students' physical performance.*

INTRODUCTION

The global threat of a sedentary lifestyle arises the necessity for physical activity, which becomes a key factor in determining the proper physical, social, and mental development of children and adolescents (Görner and Reineke, 2020). Modern technological progress facilitates everyday life on one side, while on the other, it causes a radical reduction in physical activity in people, which further conditions a lower level of muscle strength and cardiovascular endurance (Kudryavtsev et al., 2018). Optimal levels of physical activity stimulate children's development and ensure motor needs (Gao and Wang, 2019), improve the functioning of the cardiovascular system and prevent risk factors (Andersen et al., 2011), build up muscle strength (Landry and Driscoll, 2012) and bones (Tan et al., 2014) and increase flexibility (Mikkelsson et al., 2006).

In children and adolescents, it is very important to maintain an optimal level of physical activity that is advised to be at least 60 minutes per day (Pate and O'Neill, 2008). However, there are also negative effects of decreasing physical activity that begins in childhood and culminates in adolescence (Caspersen, Pereira and Curran, 2000; Farooq et al., 2020; Harding et al., 2015; Kelder et al., 2003), which happens for a number of reasons, starting with obesity (Muhajarine et al., 2015), to a low level of motor competence and physical fitness (McIntyre et al., 2015).

The programs that promote the development of physical fitness significantly improve the complete motor status of children and adolescents (Brusseau et al., 2018). The most commonly used physical development programs for adolescents are strength development programs because of their popularity among students, as well as because of the speed due to which they give results (8–12 weeks) (Granacher et al., 2011). Raising the level of strength in

physical education teaching affects the development of internal organs, hormonal, and locomotor systems, which affects the optimal growth, development, and health of each student (Hollmann and Strüder, 2009). Therefore, a difference is spotted in relation to the aim of strength development in a sport in which the best possible results are achieved. Improvement of physical ability being one of the most important occupies a significant position in the annual curriculum of physical education (Milenković, 2021). Strength training has a positive effect on the development of children and adolescents. In addition to logically increasing strength levels (Faigenbaum and Myer, 2010; McKinlay et al., 2018), strength programs contribute to the prevention of sports-related injuries (Faigenbaum and Schram, 2004; Myers, Beam and Fakhoury, 2017), as well as the improvement of general health (Smith et al., 2020). The positive effects of strength training can also be seen in the improvement of self-confidence, self-esteem, and mental health (Faigenbaum, 2007). There is no evidence to support the view that it negatively affects growth or a higher risk of injury (dos Santos Duarte Junior et al., 2022).

Among others, explosive strength and strength endurance stand out as two components of strength that partially cover both the area of speed and endurance. Explosive strength is the ability to manifest maximum strength in the shortest possible time, while strength endurance refers to the ability to repeat an exercise that requires great muscle strength, thereby gaining muscle mass, while developing both strength and endurance (Milenković, 2021). It is known that improvements in general strength development in children and adolescents are possible after controlled short-term endurance strength training programs two to three times per week (Stenevi-Lundgren, Daly and Karlsson, 2010). Therefore, strength training in various forms is implemented in teaching physical education. The benefit of such programs can be seen in the development of explosive strength and strength endurance (Faigenbaum et al., 2015). In physical education classes, it is recommended to perform dynamic exercises of moderate to high intensity to improve core muscular endurance, as another element of general strength (Allen et al., 2014). Likewise, programs for developing muscle capacity through resistance training are used (Kennedy et al., 2018), as well as 15-minute circuit strength training (Martins et al., 2020).

It would be ideal to pay more attention to certain content of the teaching because it is known that the best way to successfully improve a certain physical component is that more time is spent on it (Camhi, Phillips and Young, 2011; Donnelly et al., 2009). However, as there are many other contents in the physical education program that have to be implemented, it is useful to find and use programs that will ensure faster progress. In order to achieve rapid effects on the motor status of adolescents, it is necessary to use short-term programs that will be effective in raising the level of physical fitness, including strength. Circuit training is one of the ways that effectively reduces the time required for practicing, and allows an optimal scope of training (Alcaraz, Sánchez-Lorente and Blazevich, 2008). Circuit training consists of a series of simple and well-known exercises united in a single whole in order to develop and improve basic physical fitness along with proper taking turns of loading and relieving not only between exercises but also between the exercise series (Milenković, 2021). This type of exercise allows a greater amount of time spent on motor engagement (Lozano et al., 2009) and has multilevel effects on physical fitness, especially in beginners (Dorgo et al., 2009; Wong et al., 2008). Therefore, circuit training used in this research was intended to confirm the allegations that indicate the effectiveness of this program and the speed of changes in the level of physical fitness in physical education classes.

The aim of the research was to determine the effect of an 8-week circuit training program on explosive strength and strength endurance in physical education classes intended for high school students. In that context, the research starts from the null hypothesis:

- H_0: *It is expected that after eight weeks, the effect of a circuit training on the development of explosive strength and strength endurance in physical education classes of second-grade high school students will be higher than that of regular physical education classes*.

MATERIAL AND METHODS

Participants

The research included 60 students of two high school second-grade classes. Both classes attended regular physical education program. One of those classes had a special program for the development of strength by using circuit training within the main part of the class (circuit group – CIR), while the other class did not have any modifications of a regular physical education program (control group – CON), but the strength of the control group of students was developed by the usual teaching contents. The classes were randomly marked as CIR group (n = 28) and CON group (n = 32). The classes were held by the same physical education teacher. There were no chronic diseases or major injuries in the students' health records. The parents' permission for the students to take part in the research was obtained, as well as the consent of the children themselves. Before the beginning of the program, the initial and after the end the final testing of both groups was carried out. The research was organized according to the recommendations for clinical research issued by the World Medical Association (2013).

Testing procedure

The testing was performed in the gym during the physical education classes with the students wearing adequate sports equipment. A week before the initial testing, the students went with their teacher through all the tests that were going to be used later to ensure the accuracy of the testing procedure. Furthermore, a trial test was organized to prepare the students for the entire procedure to which they were going to be subjected during the experimental testing. Two days later, the initial testing was done, and 8 weeks later the final one was carried out. 15-minute warm-up was performed before each testing. Each of the tests was repeated three times, so the best

value was taken for further analysis. After the completion of each test and before moving on to the next one, a rest of 5–8 minutes was allowed in order to avoid negative effects on testing caused by fatigue. The study used five tests for strength assessment. A closer look at the procedures and the scoring systems can be found on the Topend Sports website (Wood, 2008):

1. *Squat Jump* – a subject is in a starting position with his knees being bent at 90 degrees; hands are placed on the hips; the trunk is positioned as vertically as possible; feet are at hip width. From the starting position, the subject performs an explosive high jump, keeping the hands on the hips and extending the hips and knees.
2. *Countermovement Jump* – a subject is in an upright standing position; hands are placed on the hips; feet are at hip width. From the starting position, the subject squats down to 90-degree leg bent position and then performs an explosive high jump, keeping the hands on the hips and extending the hips and knees.

Both jumps (squat and countermovement) were performed using Optojump photocell system (Microgate, Bolzano, Italy) with force plate measurements for estimating vertical jump height which calculate jump height using the following formula: jump height = 9.81 x (flight time)^2 / 8 (Glatthorn et al., 2011). Both jump tests are reliable and valid for assessing explosive strength (Marković et al., 2004).

3. *Squats* – a subject is in a standing position with his feet apart at shoulder's width and hands on his hips. He squats until his knees are at right angles, then he returns to a standing position. The number of squats in 30 seconds is recorded.
4. *Push-ups* – a subject begins his push-up with the hands and toes touching the floor, the body, and legs in a straight line, feet slightly apart, the arms apart at shoulder-width, extended, and at a right angle to the body. Keeping the back and knees straight, the subject lowers the body to touch the ground or some other object, or until a 90° angle at the elbows, then returns back to the starting position with the arms extended. The number of push-ups in 30 seconds is recorded.
5. *Sit-ups* – a subject is lying on his back with his knees bent at a 90° angle. Fingers must be interlocked behind his head. The other person holds the subject's ankles with their hands only. From this position, the subject starts the sit-up by raising his upper body forward to the vertical position and then lowers his body until the bottom of his shoulder blades and the backs of his hands touch the ground. The number of sit-ups in 30 seconds is recorded.

All strength endurance tests are reliable and valid for assessing this fitness component (Blazevich, Gill and Newton, 2002; Ojeda, Maliqueo and Barahona-Fuentes, 2020).

Training procedure

Students of both groups (CIR and CON) had two classes of physical education per week, which is a total of 16 lessons in eight weeks. The teaching content of physical education included the regular program for the second grade of secondary school. They consisted of sport-specific skills (in that period of the school year basketball and gymnastics were taught) and exercises for the development of physical fitness in which, among other things, exercises for the development of strength were done.

However, in the CIR group, within the main part of each class, 15 minutes were used for the application of a specialized program of strength development organized as circuit training. This way, within the class itself, a modification was made which reinforced the development of strength by emphasizing the use of circuit training. The training program was focused on two dimensions of strength – explosive strength and strength endurance.

Two types of circuit training were used – training with a certain number of repetitions (characteristic for the development of strength endurance) and with limited training time (characteristic for the development of explosive strength).

Circuit training (number of repetitions) – before starting the circuit training, the students were tested using the maximum test to determine the initial number of repetitions for each student and the degree of load increase from cycle to cycle of the circuit training. Then, individual load assessment was performed at each exercise spot with an initial value of 50% of the maximum test for the first training cycle (Tmax/2). Later, from cycle to cycle (week after week), the number of repetitions was gradually increased depending on the progress of each individual student.

I week – Tmax/2	V week – Tmax/2+8
II week – Tmax/2+2	VI week – Tmax/2+10
III week – Tmax/2+4	VII week – Tmax/2+12
IV week – Tmax/2+6	VIII week – Tmax/2+14

Table 1: Load assessment of circuit training with number of repetitions

Circuit training (limited training time) – at scheduled training time (30 seconds – Tmax test) the exercise is repeated as many times as possible at maximum speed. The load assessment was done as shown in Table 2 (break time was extended up to 60 seconds).

I week – Tmax/2 (break – 45")	V week – Tmax test/2+13" (break – 32")
II week – Tmax test/2+3" (break – 42")	VI week – Tmax test/2+15" (break– 30")
III week – Tmax test/2+5" (break – 40")	VII week – Tmax test/2+18" (break – 27")
IV week – Tmax test/2+10" (break – 35")	VIII week – Tmax test/2+20" (break– 25")

Table 2: Load assessment of circuit training with limited training time

explosive strength	strength endurance
jumps in place	forward lunges
jumps on one leg in motion	squats with a medicine ball with arms raised
jumps on one leg forward/backward and left/right	stand up from a lying to a sitting position
jumps over hurdles	pull-ups
depth jumps	push-ups

Table 3: Exercises used in circuit training

Statistical analysis

Descriptive parameters (Mean ± St.Dev) were calculated for all variables. For differences in initial testing, a *t*-test for independent samples was used, while for changes within each group, a *t*-test for dependent samples was used. Covariance analysis (ANCOVA) was used to determine the effect. Statistical significance was established at the level of $p \leq .05$. The statistical package SPSS v. was used for data processing 20.0 (IBM SPSS Statistics).

RESULTS

The following chapter presents the obtained results in anthropometric measures and strength tests (Tables 4 and 5). The students successfully completed the experimental treatment without any injuries. Both groups of respondents had a high attendance rate (more than 95%). The testing carried out prior to experimental treatment, showed no significant differences between groups in any of the variables ($p > .05$).

Characteristics (total of 60)	CIR group (*N*=28)	CON group (*N*=32)
Age (*y*)	16.66 ± 0.7	16.54 ± 0.8
Body height (*cm*)	171.6 ± 6.6	172.3 ± 6.8
Body mass (*kg*)	58.8 ± 8.3	59.3 ± 8.5
BMI (kg/m^2)	21.9 ± 3.5	22.2 ± 3.7
CIR – circuit training; **CON** – control; **BMI** – Body mass index.		

Table 4: Group characteristics (Mean±St.Dev)

Strength tests	CIR group			CON group		
	Pre-test	Post-test	*p*	Pre-test	Post-test	*p*
Squat jump (*cm*)	27.93 (±3.88)	30.67 (±3.54)	< .001	28.48 (±4.45)	29.13 (±4.4)	< .001
Countermovement jump (*cm*)	30.91 (±4.18)	33.54 (±4.3)	< .001	31.67 (±4.98)	32.34 (±4.87)	< .001
Squats (*n*)	21.18 (±1.76)	24.79 (±2.42)	< .001	20.5 (±2.08)	22.28 (±2.08)	< .001
Push-ups (*n*)	9.82 (±2.5)	14.61 (±2.13)	< .001	10.44 (±2.7)	13.19 (±2.33)	< .001
Sit-ups (*n*)	16.36 (±1.73)	18.32 (±1.83)	< .001	15.81 (±1.99)	16.28 (±2.25)	< .001
Note: Significance level is $p \leq .05$						

Table 5: Pre- and post-test results for strength in Mean (±Std. Dev) for both groups

Changes in both groups (Table 5) show the statistical significance and obvious improvement in the results of all tests ($p \leq .05$): Squat jump ($p < .001$), Countermovement jump ($p < .001$), squats ($p < .001$), push-ups ($p < .001$) and sit-ups ($p < .001$).

Strength tests	*F*-test	*p*
Squat jump	64.88	< .001
Countermovement jump	65.94	< .001
Squats	34.63	< .001
Push-ups	50.57	< .001
Sit-ups	35.89	< .001
Note: Significance level is $p \leq .05$		

Table 6: Effects of exercise (analysis of covariance)

Considering that statistically significant changes were recorded in both groups of students, the effects of exercise on the development of strength (explosive strength and strength endurance) were calculated using the analysis of covariance (Table 6). It was found that a higher effect of exercise was recorded in the CIR group, where circuit training was applied within the traditional physical education class. The results of all tests contributed to the effects of exercise: Squat jump ($p < .001$), Countermovement jump ($p < .001$), squats ($p < .001$), push-ups ($p < .001$), and sit-ups ($p < .001$).

DISCUSSION

The results of the research showed an improvement in the strength development of both groups of students after 8 weeks of physical education classes ($p \leq .05$). However, when the effects of exercise were analyzed, it was found that the CIR group was more successful than the CON group and that a modification within the main part of the class that enhanced strength development by introducing the circuit training produced better results. The greatest improvement was recorded in the tests of the explosive strength of the lower limbs: Squat jump ($F = 64.88$; $p < .001$)

and Countermovement jump ($F = 65.94$; $p < .001$). This can be explained by the amount of content that was implemented in circuit training, which included various types of jumps (basketball contents were dominant). The effect of circuit training was also established in other tests: squats ($F = 34.63$; $p < .001$), push-ups ($F = 50.57$; $p < .001$), and sit-ups ($F = 35.89$; $p < .001$). This way, the 8-week program for developing strength by using circuit training contributed to a significant improvement in the level of this fitness component.

Similar conclusions were reached in previous studies when a kind of short-term strength development program (8–12 weeks) was used. Granacher et al. (2011) found a significant improvement in maximal isometric force during leg extension after eight weeks of ballistic strength training. Using fundamental integrative training (FIT), Faigenbaum et al. (2015) found that such exercise was helpful for children with low levels of muscle strength and the quality in the development of motor skills. Since lower percentage of such children participate in physical activities, it is believed that there is a greater possibility of physical development during such exercise development programs. Other authors also agree with this very statement (Fransen et al., 2014; The Hague, 2009; Hands, 2008). Since it is possible to develop and maintain the level of muscle strength and cardiovascular endurance during short-term programs in physical education (Mayorga-Vega, Viciana and Cocca, 2013), it is considered that such programs are necessary for physical fitness training to be effective and feasible within the school curriculum. So, such programs could guarantee the maintenance of previously achieved training effects.

Circuit training can make the best use of the time available to a physical education teacher, as one of the main goals is to make students active for as long as possible during classes (Whitehead, 2020). Using circuit training, students can easily achieve a minimum time of motor engagement, while performing numerous exercises (Lozano et al., 2009). Physical education classes last for 45 minutes, however, there is a lot of content that has to be implemented, so circuit training is a good organizational form that makes the most of the available time. In this regard, Dorgo et al. (2009) found a statistically significant improvement in muscle strength and cardiovascular endurance levels using circuit training. Besides, circuit training with individualized intensity that ensures maximum effort in a short period of time is very useful for improving overall strength (Chtara et al., 2008).

CONCLUSION

This research included the second-grade high school students in an 8-week strength development program in physical education classes. The strength development program was organized as a 15-minute circuit training (CIR) as part of the main part of the physical education class. The program, which was adapted to the age of adolescents, proved to be suitable, safe, and effective for working on the immediate development of strength (explosive strength and strength endurance) and the indirect development of other fitness components in which strength is significantly correlated with. Along with being fun, the program provided a sufficient amount of physical activity that led to improved physical performance.

The research indicates that strength development programs are effective and safe for children and adolescents as well as some previous studies (Behringer et al., 2011; Lesinski et al., 2020; Stricker, Faigenbaum and McCambridge, 2020). The study showed that eight weeks of a specialized program resulted in significant improvements in the level of explosive strength and strength endurance. It was also found that short-term circuit method training in teaching physical education, as one of the strength development programs, is an effective and safe way of developing the physical performance of students. Therefore, it can be stated that the null hypothesis (H_0: *It is expected that after eight weeks, the effect of a circuit training on the development of explosive strength and strength endurance in physical education classes of second-grade high school students will be higher than that of regular physical education classes.*) was not rejected because it was found that the effect of circuit training on the development of explosive strength and strength endurance in physical education classes of second-grade high school students was higher than that of regular physical education classes.

In accordance with previous research indicating the effectiveness of short-term circuit training, the results obtained in this study indicate that such a program is a sustainable model of work in physical education and that together with the professional guidance of physical education teachers it contributes to the improvement of the physical skills needed for proper development of children. This experimental treatment can also be used to design and implement other physical education programs with longer-term effects on students' physical and health status.

ACKNOWLEDGEMENT

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

The Author declares that there is no conflict of interest.

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