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Research Article

Effects of a Training Program on Physical Fitness and Specific Motor Skills in the Elementary School

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Abstract

This study aimed to identify the effects of applying a multivariate training program for low and moderate loads with a reduced volume on physical fitness and throw ability in basketball in an elementary school context. Thirty-two students participated in the study. A training program composed of countermovement jumps, 20m sprints, throws with a basketball ball, chest passes with a basketball ball, and aerobic running was applied for 6 weeks during the physical education class. The students were assessed before and after the training program. The applied tests were stationary two-point shooting test, dynamic 60-second two-point shooting test, shuttle test, sprint, push-ups, and vertical impulse test. A comparison between the pre- and post-training tests was evaluated using standardized mean differences calculated with combined variance and respective 90% confidence intervals. The limits for the statistics were 0.2 (trivial), 0.6 (small), 1.2 (moderate), 2.0 (large), and >2.0 (very large). The results showed positive changes in all tests performed except for throwing ability, for which no significant differences were found between the two analyzed moments. These results demonstrate that the application of a multivariate training program induces improvements in physical fitness but not in throw ability.

Introduction

Physical education plays a fundamental role in the integral development of the student as it enables cognitive, psychomotor, and affective learning while also stimulating healthy lifestyles, socialization, team spirit, and sports practice [1]. Thus, to improve physical fitness and promote healthy lifestyle habits, it is imperative to train motor skills [2], ideally at certain stages of the child's growth [3] given the existence of critical periods when individuals are more susceptible to external influences [4]. Motor capacities can be divided into coordinating capacities, through nerve conduction processes and aspects of a sensorimotor nature, and conditional capacities with aspects of an energetic-functional nature where metabolic processes in muscles and organic systems predominate [5]. Although presented separately, motor skills act in a coordinated way through combinations in which, depending on the situation, one or the other assumes a decisive influence [6].

Particularly concerning conditional capabilities, and specifically the development of strength capacity, it has been suggested that this should happen with monitoring and analysis [7] since strength training requires additional care with the load applied to children and young people. This is because intensive strength training constitutes a risk factor for the child's locomotor system due to the height of growth spurts, which may result in malformations in the skeletal system and delays and imbalances in the training process [8]. However, recent studies highlighted the beneficial impact of an adequate and supervised strength training program for children and young populations [9-11]. These types of programs provide an increase in muscle strength and a capacity for localized muscular endurance when participating in sports and other recreational activities as well as a decrease in the risk of injuries during physical activity [12].

As mentioned above, the optimal development of strength is directly influenced by the different sensitive phases, and this has been demonstrated through the effectiveness of strength training programs in children ages 6 to 13 years in different sports, as previously reported in the literature [13-16]. Therefore, the assessment of motor performance can be beneficial as it allows the collection of important information for the development of motor skills requested during the practice of physical activity [17] and particularly during physical education classes [18]. Furthermore, tests involving fundamental motor skills are recommended across all age groups and learning levels because they require specific skills, such as strength, speed, and resistance, which are attributes manifested in all specific tasks of movement [19]. According to *Malina et al.* [3], specific motor skills constitute a central component of the development of athletes of different modalities, including basketball.

Basketball is characterized as a sport of opposition and cooperation that involves simultaneous actions of attack and defense between two teams that occupy a common space, providing direct contact between athletes [21]. The functional structure of basketball is directly related to the main physical capabilities that determine performance [22], which depend on the specific techniques of the game, enhanced by the factors of strength, speed, and the capacity to continue intermittent effort over time [23]. Based on the assumed importance of strength for game actions, strength training in young players has been suggested as beneficial for improving physical performance [15]. Strength training is also considered decisive for the correct development of technique and coordination since difficulties associated with improving the technique are often based on strength deficits [15].

Additionally, considering the main objective of basketball is to score a basket, throw ability assumes special preponderance because it is the culmination of all individual and collective actions performed by the attacking team [24]. Therefore, throw ability emerges as a specific skill that allows a quick and objective assessment of performance and differentiation in the athlete's value [25].

However, despite the existence of some studies based on the importance of physical fitness and assessment and control tests [9,26-28] and on the contribution of motor skills in the specific domain of learning modalities in the school context [29], a gap exists in the literature regarding methodological guidelines related to the application of training programs during physical education classes, particularly in basketball. Therefore, based on the importance attributed to physical fitness and its relationship with motor skills in basketball, our study aimed to analyze the effects of applying a multivariate training program for low and moderate loads with a reduced volume on physical fitness and throw ability in basketball in a school context. It was hypothesized that the application of a multivariate training program of low and moderate loads with reduced volume would have positive effects on physical fitness and specifically on throw ability in basketball.

Material and Methods

1.1. Participants

A group of 32 students from a Portuguese school (18 males and 14 females; mean age = 10.13 ± 0.91 years; height = 1.43 ± 0.07m) participated in the study. The sample was divided into a control group and an experimental group. The control group consisted of 17 students (9 females and 8 males; age = 9.82 ± 0.53 years; weight = 34.6 ± 6.06 kg; height = 1.41 ± 0.06m; body mass index [BMI] = 17.2 ± 2.25%). The experimental group consisted of 15 students (5 females and 10 males; age = 10.47 ± 1.13 years; weight = 38.4 ± 8.12 kg; height = 1.44 ± 0.07m; BMI = 18.1 ± 2.54%).

All participants and the teacher were fully informed verbally and in writing regarding the nature and demands of the study as well as the known health risks. They completed a health history questionnaire and were informed that they could withdraw from the study at any time, even after giving their written consent. All parents provided their informed consent allowing the voluntary participation of their children in the study, which had the approval of the Academy's Ethical Advisory Commission and was conducted in accordance with the Declaration of Helsinki.

1.2. Experimental design

This study aimed to analyze the effects of applying a multivariate training program for low and moderate loads with a reduced volume on physical fitness and throw ability in basketball. The training program was applied to the control group and took place over 6 weeks during the physical education class. Both groups had classes on the same days with a workload of 135 weeks spread over two blocks: one 90m and the other 45m. All experimental procedures were carried out in coordination with the teacher and did not cause any change in the routine of the students. Before the pretest stage, all participants were familiarized with the different tests during a practice session to minimize learning effects. Pre- and posttests were performed with maximal intensity. All tests were conducted in an indoor space to eliminate the effect of weather conditions on results. The students were evaluated before (pre-training test) and after (post-training test) the application of the training program. The tests conducted during the current study were a stationary two-point shooting test and dynamic 60-second two-point shooting test, according to an adaptation to the protocol used by *Pojskić et al.* [30]. In both tests, 3 series of 10 throws were performed with a 3 min rest period between each. The evaluation of physical fitness was performed based on the Fit Escola test battery [31], namely the shuttle test, sprint, and push-ups, as well as the collected anthropometric measurements (weight, height, and BMI).

1.3. Procedure

The anthropometric variables of height and body mass were measured for each subject on a leveled platform scale (Año Sayol, Barcelona, Spain) with an accuracy of 0.001m and 0.01kg, respectively.

1.4. Warm-up

Before the beginning of the tests, the students performed a warm-up based on the protocol described [32] for physical education classes. The warm-up routine did not require equipment or much space. Students performed dynamic movements (i.e., low jacks, high-knee march, standing flutter, standing toe touches, stepping trunk turns, crunches, side shuffle marching, high-knee skips, and partial push-ups) over approximately 10 min with a few seconds of rest between repetitions. Later, they repeated the movement and returned to the starting position. Students performed six to eight different exercises that progressed from simple movements to more challenging and complex exercises. This protocol was used because it is specific for physical education classes.

1.5. Stationary two-point shooting test

Five different points were marked on the ground, 2.5m away from the basket and 45° apart. Each participant, in each of the three series, completed 2 launches for a total of 10, without a time limit [30]. The performance of this test required the help of two people, one to catch the rebounds and the other to pass the ball to the player. This test was an adaptation: in the aforementioned protocol [30], the distance from the basket to the points was 5m.

1.6. Dynamic 60-second two-point shooting test

The participant started in a position under the basket next to first cone and moved to second cone [30]. After the throw, the player went around the cone under the basket and moved to next cone, and so on. The test lasted 45 s, as it was adapted according to the characteristics of the sample. Participants needed to launch and run as fast as possible to be able to execute the largest number of launches. Three helpers were needed, one to collect the ball on the bounce and two to pass it back to the player.

1.7. Shuttle test

The shuttle test consisted of executing the maximum number of courses performed over a distance of 20m at a predetermined cadence, an adaptation to the protocol used by *Liu et al.* [33]. The evaluation was carried out in a wide space with two signposted lines 20m apart. Students formed groups of two with one student taking the test while the ot\her counted the courses, and vice versa. The test was monitored using an audio file played over a sound system. The teacher defined the cadence and ended the test when the student could not complete the course, gave up, or was unable to complete a course for the second time (2nd1 foul). The student being evaluated ran along the 20m course at the distance marked by two lines and was required to step on the line with at least one foot upon hearing the beep. At the audible signal, the student was required to invert the running direction and run to the other end. If the student reached the line before the beep, they had to wait for the new beep to run in the opposite direction. Initially, the speed was reduced (8.5km/h) and increased progressively (0.5km/h every minute; 1 min was equal to one stage) up to a maximum of 120 courses. A beep indicated the end of a 20m course, and a triple beep indicated the end of each level. The test was completed when the student could not reach the line before the audio signal on two occasions, not necessarily consecutive.

1.8. Sprint

The 20m sprint was carried out in an indoor physical education school with a polypropylene-copolymer floor and participants wearing shoes for indoor use [30]. The time required to run 20m was obtained using a Casio HS 5M chronometer. All subjects were encouraged to run as fast as possible and to slow down only after crossing the finish line. Each player repeated the same procedure for two attempts, using only the best time to cover the 20m distance in the sprint test in the data analysis.

1.9. Push-ups

The push-up test was scored as the greatest number of push-ups (flexion movement of the arms and elbow extension) performed with a predefined cadence. This test aimed to assess the resistance strength of the upper limbs. In our study, we used an adaptation based on the protocol described by *Baumgartner et al.* [34]. The evaluation was carried out with students in groups of two; one student performed the test on a mattress while the other counted the number of executions. The test was monitored using an audio file played over a sound system, which defined the execution rate. The student started the test with their body on a plank, elbows extended, and feet slightly apart, resting on the tip of their feet. Their hands were to be placed under, or slightly beside, their shoulders with their fingers oriented forward (starting position). The student was required to maintain the plank position and flex their elbows in a slow and controlled manner (respecting the cadence) until their shoulders reached the level of their elbows and their arms were parallel to the ground, forming approximately a 90° angle between their arms and forearms (final position). The student needed to return to the initial position slowly (respecting the cadence) and in control until their elbows were completely extended. In each minute, the student performed 20 push-ups, which corresponded to one push-up for 3 s. The student continued the test until they could not perform more repetitions within the cadence or until they reached the maximum number of push-ups. The test was interrupted at the second incorrect execution considering the following errors: the student did not respect the sound cadence, reach 90º when descending the trunk, maintain the plank position, or perform the full elbow extension when returning to the starting position.

1.10. Vertical impulse test

The vertical impulse test [30] consisted of reaching the maximum distance in a vertical jump while moving both feet simultaneously. This test aimed to assess the explosive strength of the lower limbs. A horizontal line was drawn on the floor (perpendicular to the wall) to indicate the starting point and a tape measure was glued to the wall. To facilitate the measurement of the distance reached, reference lines were glued every 10cm (up to 1.5m in height). The student was required to stand upright, perpendicular to the wall, and on the line that marked the jump, positioned with feet shoulder-width apart. The student then extended their arm closest to the wall so that the teacher/evaluator could record the initial height as a reference for calculating the maximum distance (this point was marked with chalk). The student then bent their knees, pulled their arms back, and jumped as high as possible. The teacher/evaluator faced the jump zone and recorded the height achieved. The result of the jump was the distance between the initial height and the maximum height reached (calculated using the difference between the final height and the initial height); two jumps were made for each student. The recorded value was the best result of the two evaluations in centimeters.

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1.11. Training program

The program was performed twice per week immediately following the warm-up to ensure that the students were in a rested state and gained optimal benefits from the specific program, according to the training principle of priority. The training program was applied for 6 weeks and consisted of Counter Movement Jumping (CMJ), throws with a basketball (TB), chest passes with a basketball (CB), a 20m sprint, and Aerobic Running (AR) as shown in Table 1.

Table 1: Training Program.

		CMJ	Sprint	TB	CB	AR
Week 1	Session 1¥	2X4	2X20m	2x1’	2x1’	2x440m
	Session 2¥	2X4	2X20m	2x1’	2x1’	2x440m
Week 2	Session 3¥	2X4	2X20m	2x1’	2x1,5’	2x440m
	Session 4¥	3X4	3X20m	3x1’	3,1’	2x540m
Week 3	Session 5¥	3X4	2X20m	3x1’	2x1,5’	2x540m
	Session 6¥	3X4	3X20m	2x1,5’	2x1,5’	2x540m
Week 4	Session 7*	3X5	4x20m	2x1,5’	2x1,5’	2x440m
	Session 8*	3X5	4x20m	2x1,5’	3x1,5’	2x540m
Week 5	Session 9*	3X5	4x20m	3x1’	3x1’	2x540m
	Session 10*	3X4	4x20m	3x1’	3x1’	3x440m
Week 6	Session 11*	2X5	3x20m	3x1’	2x1,5’	3x440m
	Session 12*	4X4	3x20m	2x1,5’	2x1,5’	3x440m

Legend: ¥ = 2 minutes recovery between series and 3 minutes between exercises; * = 1 minute recovery between series and 2 minutes between exercises; CMJ = Countermovement Jump; Sprint = Sprint 20m; TB = Basketball Ball Launch; CB = Basketball Chest Pass; AR = Aerobic running

1.12. Statistical analysis

A descriptive analysis was performed using means and standard deviations. Differences in means for pre- and post-training tests were expressed in percept units with 90% confidence limits [35]. The smallest worthwhile differences were estimated from the standardized units multiplied by 0.2. Thresholds for effect size statistics were 0.2 (trivial), 0.6 (small), 1.2 (moderate), 2.0 (large), and >2.0 (very large) [36-38].

Results

Table 2 and Figure 1 show the effects when comparing the moment of analysis (pre-training vs post-training) between the control and experimental groups. Comparing the pre- and post-training, the positive effect of the training program on four of the six variables analyzed (i.e., 20m sprint, shuttle test, push-ups, and vertical impulse) showed a possible increase in the push-ups (difference in the averages = 3.0 ± 3.4; 90% confidence limit), a likely increase in the 20 m sprint and shuttle test (0.13 ± 0.10; 6.8 ± 4.5, respectively), and a very likely increase (3.8 ± 2.1) in the vertical impulse, with a small effect on any of the variables mentioned. Comparing the pre- and post-training moments concerning the performance of the variables during dynamic 60-second two-point shooting and stationary two-point shooting tests, the results appeared to be similar, presenting an unclear effect (0.01 ± 0.62; -0.3 ± 0.7, respectively).

Table 2: Descriptive statistics when comparing the different conditions (Pre-Training; Post-Training) and the different groups (control and experimental).

	Control Group		Experimental Group		Difference in means (±90% CL). Pré-Training vs Post-Training
Variables	Pré-Training	Post-Training	Pré-Training	Post-Training	
Dynamic 60-second two-point shooting	1.59±1.01	1.47±0.83	1.02±0.91	0.91±0.73	0.01; ±0.62 unclear
Stationary two-point shooting	2.08±1.22	2.53±1.13	1.38±0.89	1.53±0.95	-0.3; ±0.7 unclear
Sprint 20m	4.25±0.22	4.32±0.17	4.30±0.29	4.50±0.26	0.13; ±0.10 likely +ive
Shuttle Test	30.0±14.16	34.65±14.08	23.33±10.30	34.80±11.47	6.8; ±4.5 likely +ive
Push-ups	14.18±8.23	16.06±9.13	6.07±6.69	10.93±11.04	3.0; ±3.4 possible +ive
Vertical impulse	26.00±4.92	24.59±6.51	22.73±5.56	25.13±5.29	3.8; ±2.1 very likely +ive

Legend: +ive = positive; CL = confidence limits.

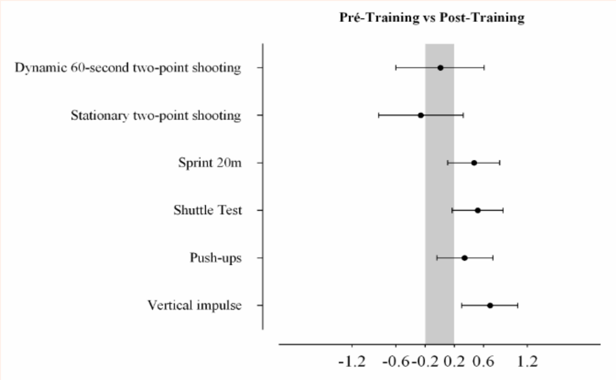

Figure 1: Standardized cohen's *d* differences for comparative results of the Pre-Training vs Post-Training in the different variables.

Discussion and Conclusion

Our study aimed to analyze the effects of the application of a multivariate training program of low and moderate loads with a reduced volume on physical fitness and particularly on the launch in basketball in young students in a school context. In general, the results showed that the training program had a positive effect on all tests performed, namely speed test (20m), shuttle test, push-ups, and vertical impulse. However, regarding the results of the two tests performed, the dynamic 60-second two-point shooting and stationary two-point shooting tests, the program did not seem to have induced significant changes in either case. Therefore, these results demonstrate that although a training program of low and moderate loads with a reduced volume optimizes the physical fitness of children, it is not enough to induce significant improvements in the ability to throw in basketball.

As a result of the application of the multivariate training program, the shuttle test, speed test (20 m), push-ups, and vertical impulse variables were positively affected. These data reiterate the benefits of using strength training in young populations, which goes against what was previously reported in the literature [9, 15, 39-41]. The increase in strength in children and young people has gained greater notoriety, with the awareness that effective improvements can be achieved with the application of these types of programs. However, practitioners must apply such training in sufficient quantities with functional and adequate loads that exceed the usual muscular activities and ensure that the methodological recommendations for the development of strength in children and young people are followed [41]. Notably, the effectiveness of strength programs occurs between 6 to 13 years of age [7], which makes physical education classes the ideal environment for their successful application.

Many physical education teachers, coaches, and physiologists remain reticent to strength training in children and young adolescents [42]. Most of the time, these opinions result from a wrong understanding of strength given that strength is almost always associated with muscle mass and training with external loads of great magnitude [43]. It was commonly reported that children did not have the same muscle support as adults and, therefore, the absence of androgens, especially testosterone, was a limiting factor in strength work [7]. However, hormones, such as the growth hormone and insulin, combined with neuromuscular coordination are fundamental factors for developing strength in children [44]. One recent study [10] indicated that prepubertal children submitted to strength training showed an increase in overall strength, mainly due to neural adaptations. Moreover, these changes did not seem to have a significant relationship with testosterone synthesis; that is, the increase in muscle strength was also related to the adaptations of the neuromuscular system that must be considered, especially in prepubertal children.

In terms of physical capacity, resistance assessed through the shuttle test, we also found significant gains, which is in line with previous studies [45, 46]. Further, it should be noted from the battery of tests used and their theoretical references that the experimental group presented values within the healthy zone of the benchmark of the Fitescolas [31] in the post-training, which did not happen in full in all the variables considered in the pre-training moment, namely, in the 20 m speed and push-up tests, which reinforces the evidenced data.

The multivariate training program increased resistance to fatigue; that is, it increased the muscle's ability to recover during intermittent high-intensity exercise, and these phenomena in children have been associated with biological maturation [47]. It is known that the physiological response of children to stimulation is different from that of adults [48]. Effectively, children appeal more to oxidative metabolism and need less anaerobic contribution relative to high intensity compared with adults [49-51]. During exercise, children recruit a higher percentage of type I fibers, a lower percentage of type II, and have higher enzyme activity [52, 53] and these indicators may be important to help explain the improvements found in our results.

Regarding the 20 m sprint capacity, significant gains were verified in the experimental group with the weighted and regulated application of the training program, which is in line with several previous studies [54-56]. We must consider the fact that the studies are similar, but not identical, as the school context, age group, and even typology of the training plan differ. However, our results may be because the stimulus induced during the training program is of a vertical and horizontal nature, which may have increased the adaptation of students considering the importance of the production of horizontal strength for performance in running [57] and the principle of training specificity [58]. The improvements in sprint performance reflect neural adaptations, namely increased nerve conduction speed, maximized electromyogram, improved intermuscular coordination, improved motor unit recruitment strategy, and increased reflex excitability (Hoffmann's reflex) [59]. Thus, it is well known that the multivariate training program carried out during the present study may be important for adaptations in sprint capacity in the school context.

Particularly concerning the improvements that have occurred in the vertical impulse, several studies reinforce the results found, also pointing to quite significant improvements after the application of a training program [13, 40, 54, 60]. Improvements in muscle power and, consequently, in height of the vertical impulse after application of strength training programs have been described previously [59], and our results are consistent with these findings. The adaptation that occurred in response to the type of training applied is probably neural because it predominates in the initial stages of strength and strength training and is the main adaptation to this type of program [9]. There is some consensus that neural adaptations seem to be the predominant mechanism responsible for the increase in strength induced by exercise in children [61, 62]. Also, this phenomenon may occur because the vertical impulse involves a stretching-shortening cycle and, therefore, is very similar to the training exercise used in our study. The ability to jump, when properly developed, can be a determining factor in success during a basketball game given its importance in disputing the ball in offensive and defensive actions during a game as well as in the launch.

As a result of applying the training program to the throw variables considered, the results may be due to the fact that students do not yet have an established action scheme [63, 64]. According to a recent study [64], action schemes only form when an action is practiced repeatedly, which occurs in all sports movements; thus, the development and use of preperformance routines are fundamental to basketball performance and throw ability. This same scheme is kept in memory and can be evoked later. All study participants had their first approach to the modality during the teaching of the didactic unit and, therefore, the time of practice appeared insufficient to consolidate the behavioral patterns (action scheme) mentioned above.

Another possible justification is that the students' learning was carried out using constant feedback from the teacher, and the assessment of the throwing skill was carried out independently. This is because individuals in the early stages of learning can exponentially benefit from feedback given by the teacher or coach to improve their performance [65]. Learning motor skills is a complex and multifaceted process where the integration of motor, cognitive, and emotional dimensions is essential [66].

Still, in this sense, Lees [67] stated that sports techniques are organized based on basic movements. The transformation of fundamental movements into specific techniques is an ongoing process, with no ideal moment from which basic movements are consolidated and the training of specific techniques can begin. Balyi and Hamilton [68] reinforced these ideas when considering that the technical models are developed in three fundamental phases, that of learning, adjustment, and domain stabilization. On the other hand, these results can also be related to the end of the training program because a decrease or stagnation of the technical performance of the players is possible [69].

Conclusion

In conclusion, this study aimed to analyze the effects of the application of a training program with low and moderate loads and a reduced volume on physical fitness and throw in basketball in young students in a school context. After its application, improvements occurred in the physical capacities in question, namely lower and upper strength, speed, and aerobic endurance, showing that in terms of physical fitness, the training program had a positive effect and was efficient for the characteristics of these students, even if applied in a short time.

Regarding specific motor skills, namely the throw in basketball, the effect of the training program was irrelevant probably because it was the first school with the sport and these young people were still in a potential phase of acquisition of basic movements without a consolidated action plan. It will be interesting, in the future, to carry out more studies in the scope of this theme, such as the application of the training program to other didactic units, a different sample of students (with more practical experiences in the modality and with the gesture technique developed), and in a different academic year or subsequent cycle, so that comparison/evolution is possible.

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