



## The Effects of Concurrent Resistance and Endurance Training Follow a Specific Detraining Cycle in Young School Girls

by

Albano Santos<sup>1,2</sup>, Daniel A. Marinho<sup>1,2</sup>, Aldo M. Costa<sup>1,2</sup>, Mikel Izquierdo<sup>3</sup>,  
Mário C. Marques<sup>1,2</sup>

*The purpose of this study was to compare the effects of an 8-week training period of strength training alone (GR), or combined strength and endurance training (GCOM), followed by 12-weeks of de-training (DT) on body composition, power strength and VO<sub>2</sub>max adaptations in a schooled group of adolescent girls. Methods: Sixty-seven healthy girls recruited from a Portuguese public high school (age: 13.5±1.03 years, from 7<sup>th</sup> and 9<sup>th</sup> grade) were divided into three experimental groups to train twice a week for 8 wks: GR (n=21), GCOM (n=25) and a control group (GC: n=21; no training program). Anthropometric parameters variables as well as performance variables (strength and aerobic fitness) were assessed. Results: No significant training-induced differences were observed in 1kg and 3kg medicine ball throw gains (2.7 to 10.8%) between GR and GCOM groups, whereas no significant changes were observed after a DT period in any of the experimental groups. Significant training-induced gains in CMVJ (8 to 12%) and CMSLJ (0.8 to 5.4%) were observed in the experimental groups. Time of 20m significantly decreased (GR: -11.5% and GCOM: -10%) after both treatment periods, whereas only the GR group kept the running speed after a DT period of 12 weeks. After training VO<sub>2</sub>max increased only slightly for GCOM (4.0%). No significant changes were observed after the DT period in all groups, except to GCOM in CMVJ and CMSLJ. Conclusion: Performing simultaneous strength and endurance training in the same workout does not appear to negatively influence power strength and aerobic fitness development in adolescent girls. Indeed, concurrent strength and endurance training seems to be an effective, well-rounded exercise program that can be prescribed as a means to improve initial or general strength in healthy school girls. De-training period was not sufficient to reduce the overall training effects.*

**Key words:** Youth, Strength, Endurance, School, Experimental, weight training, detraining

### Introduction

Strength training is defined as a specialized method of conditioning that involves the progressive use of a wide range of resistive loads and a variety of training modes (e.g., free weights, weight machines, elastic cords, medicine balls, and body weight) designed to enhance health, fitness and sports performance (0). Scientific evidence indicates that strength training should be part of a comprehensive health maintenance (Faigenbaum, 2007) and physical performance (Anderson and

Haraldsdottir, 1995) effective strategy for youth, as long as it is carefully prescribed and monitored (Simons-Morton et al., 1993; Sharma, 2006; Izquierdo et al., 2010). Further, female participation in sport has increased dramatically over the previous 20 years in a variety of events. However, despite the increase in female physical activity (PA) regular programs, there is a paucity of research on performance characteristics of female adolescents and to the authors' knowledge few data are available for young school girls

<sup>1</sup> - Department of Sport Sciences, University of Beira Interior (UBI), Covilhã, Portugal

<sup>2</sup> - Research Centre for Sport Sciences, Health and Human Development, Vila Real, Portugal

<sup>3</sup> - Department of Health Sciences, Public University of Navarre, Navarre, Spain

(Sweeting, 2007; Faigenbaum et al., 2009).

School girls have been described as less active than their male age-peers (Nielsen and Andersen, 2003; Faigenbaum, 2007) and become even less physically active as they are going through adolescence (Twisk et al., 2000; Sweeting, 2007). Nevertheless, it was reported by several studies that physical activity levels of children aged 13 to 15 years old are positively related with physical fitness (Malina, 2001). Moreover, there is strong evidence that school-based interventions are effective to promote PA levels (Faigenbaum et al., 1996; Strong et al., 2005; Sweeting, 2007) and, therefore, school seems to provide an excellent setting to enhance its levels by implementing physical fitness programs.

Both strength and endurance training are often performed concurrently in most exercise programs in wellness, fitness and rehabilitative settings, in an attempt to reach different physical fitness goals (Anderson and Haraldsdottir, 1995). Several studies using young adult sample, have shown that simultaneously performing strength and cardiovascular training, the strength gains achieved by strength training alone may be impaired (Kraemer et al., 1995). Unfortunately, few authors have examined the effects of concurrent strength and endurance training on different days (Sale et al., 1990), on the same day (Abernethy and Quigley, 1993; Volpe et al., 1993) or a compound of both methods (Hunter et al., 1987). Researches in a school environment, concerning this issue, are even scarcer (Izquierdo et al., 2010). Moreover, to our best knowledge, no study prior to ours had studied the effects of power training with concurrent power and endurance training on muscular strength development in a large sample of non-athlete adolescent girls.

Physical activity interruption because of illness, injury, holidays, or post-season break occurring through life or other factors are normal situations in any kind of sport (0; Garrido et al., 2010). The magnitude of this reduction may depend upon the length of the detraining period in addition to training levels attained by the subject (0). However, the detraining period and its consequences are not well reported in sports literature during puberty. Additionally, a period of strength training cessation can also produce a positive delay transformation to enhanced sports

specific performance (0). In fact, it has been shown that physical fitness improves during the school year (yr), with little or no changes during the summer holidays (0). Another study (0) could observe that girls can significantly reduce cardiorespiratory fitness after the holiday period. However, the detraining period and its consequences are not well reported in the scientific community, or within a group of school girls (0; 0). Furthermore, the effects of training may not manifest soon after the training but may appear later.

According to the above mentioned, we hypothesized that concurrent strength and endurance training would have a bigger positive effect on muscular strength development of untrained school girls compared with the results found when strength was trained alone. We also hypothesized that both strength training and concurrent strength and endurance training groups would keep some strength gains after a training break. Therefore, the main purpose of the current study was twofold: (i) to analyze the effects of strength training alone, or combined strength and endurance training on body composition, strength and cardiovascular markers on a sample of healthy schoolgirls and, (ii) to assess the effects of a de-training period on strength and endurance performance.

## Methods

### *Experimental design*

Sixty-seven healthy girls (13.5±1.03 years old) recruited from a Portuguese public high school were divided into two experimental groups (to train 2 times per week for 8 weeks) and one control group as follows: one group performing strength training only (GR: n=21); another group performing combined strength and endurance training (GCOM: n=25); an additional group as control (GC: n=21; without training program). All subjects attended physical education classes twice a week, with a duration of 45 min and 90 min each class respectively. In these classes, students took part in various sports (gymnastics drills, soccer, basketball and volleyball) with a clear pedagogical focus. As such, according to other researchers (Simons-Morton et al., 1993; Silva et al., 2010) the physical activity intensity is considered low to moderate.

Participants in all groups were asked to maintain normal eating and physical activity patterns over

the duration of the study. This procedure was the same as Lubans et al. (2010).

**Table 1**

*Design of the training program performed*

Exercises	Session 1	Session 2	Session 3	Session 4	Session 5	Session 6
Chest 1 kg Medicine Ball Throw <sup>1,2</sup>	2x8	2x8	2x8	2x8	6x8	6x8
Chest 3 kg Medicine Ball Throw <sup>1,2</sup>	2x8	2x8	2x8	2x8		
Overhead 1kg Medicine Ball Throw <sup>1,2</sup>	2x8	2x8	2x8	2x8	6x8	6x8
Overhead 3kg Medicine Ball Throw <sup>1,2</sup>	2x8	2x8	2x8	2x8		
CMJ onto a box <sup>1,2</sup>	1x5	1x5	3x5	3x5	3x5	4x5
Plyometric Jumps above 3 hurdling <sup>1,2</sup>	5x4	5x4	5x4	5x4	2x3	2x3
Sprint Running (m) <sup>1,2</sup>	4x20m	4x20m	3x20m	3x20m	3x20m	3x20m
20m Shuttle Run (MAV) <sup>2</sup>	75%	75%	75%	75%	75%	75%
Exercises	Session 7	Session 8	Session 9	Session 10	Session 11	Session 12
Chest 1 kg Medicine Ball Throw <sup>1,2</sup>						
Chest 3 kg Medicine Ball Throw <sup>1,2</sup>	2x5	2x5	3x5	3x5	3x5	2x5
Overhead 1kg Medicine Ball Throw <sup>1,2</sup>						
Overhead 3kg Medicine Ball Throw <sup>1,2</sup>	2x8	2x8	3x8	3x8	3x8	
CMJ onto a box <sup>1,2</sup>	4x5	5x5	5x5	5x5	5x5	4x5
Plyometric Jumps above 3 hurdling <sup>1,2</sup>	3x3	4x3	4x3	4x3	4x3	
Sprint Running (m) <sup>1,2</sup>	4x30m	4x30m	4x30m	4x30m	4x30m	3x40m
20m Shuttle Run (MAV) <sup>2</sup>	75%	TestM	75%	75%	75%	75%
Exercises	Session 13	Session 14	Session 15	Session 16		
Chest 1 kg Medicine Ball Throw <sup>1,2</sup>						
Chest 3 kg Medicine Ball Throw <sup>1,2</sup>	2x5	1x5				
Overhead 1kg Medicine Ball Throw <sup>1,2</sup>		3x8	2x8	2x8		
Overhead 3kg Medicine Ball Throw <sup>1,2</sup>	3x8					
CMJ onto a box <sup>1,2</sup>	4x5	2x5	2x4	2x4		
Plyometric Jumps above 3 hurdling <sup>1,2</sup>	4x3	3x3				
Sprint Running (m) <sup>1,2</sup>	3x40m	4x40m	2x30m	2x30m		
20m Shuttle Run (MAV) <sup>2</sup>	75%	75%	75%	75%		

*For the Medicine Ball Throwing and Jump onto box the 1<sup>st</sup> no. corresponds to sets and 2<sup>nd</sup> corresponds to repetitions.*

*For Sprint Running 1<sup>st</sup> number corresponds to sets and 2<sup>nd</sup> corresponds to the distance to run.*

*For 20m Shuttle Run training each girl ran each session (until testM) 75% of maximum individual aerobic volume performed on pre-test and after this testM moment until program end, ran 75% of maximum individual aerobic volume performed on testM. CMJ – Counter movement jump.*

*MAV - maximum individual aerobic volume 1=power strength training protocol (GR).*

*2=concurrent resistance and endurance training (GCOM).*

Beyond to physical education classes, and after a 10 min warm up period (7 min running with an intensity sufficient to raise breath rate, 3 min stretching and joint specific warm up), both experimental groups were submitted to a strength training program composed by: 1 and 3 kg medicine ball throws; jumps onto a box (from 0.4 m to 0.6 m); plyometric jumps above 0.4-0.6 m of height hurdle and; sets of 30 to 40m speed running. The GCOM group was further subjected to a 20m shuttle run exercise (0).

This endurance task, which occurred immediately after the strength training session, was developed based on an individual training volume - set to about 75% of the established maximum aerobic volume achieved on a previous test.

After 4 weeks of training, GCOM subjects were reassessed using 20m shuttle run tests in order to readjust the volume and intensity of the 20m shuttle run exercise. All participants were familiarised with power training tests (sprints, jumps and ball throws) as well as with the 20m shuttle run test. A more detailed analysis of the program can be found in table 1.

All sample groups were assessed for upper and lower body power strength (overhead medicine ball throwing and counter movement vertical jump, respectively), running speed (20 m sprint run) and  $\text{VO}_2\text{max}$  estimate (20 meters shuttle run test) before and after 8-weeks of training.

In order to evaluate the DT effects, all individuals were reassessed 12 weeks after training has ceased. The DT period was coincidental with summer holidays. Throughout this period, the subjects reported their non-involvement in regular exercise programs for developing or maintaining strength and endurance performance. The testing assessment procedures were always conducted in the same indoor facility, at the same hour and on the same weekday (from March to September of 2010). Data collection was performed by the same investigator and after a general warm-up of 10 minutes.

### **Subjects**

A sample of 67 healthy girls recruited from a Portuguese public high school (from 7<sup>th</sup> and 9<sup>th</sup> grades) was used in this study. To fulfill the ethical procedures of the Helsinki statement (WMA Declaration of Helsinki, 2008), a consent

form was obtained prior to all the testing from parents or a legal guardian of the adolescents. Efforts were made to pick subjects for making comparable groups. Maturity level based on Tanner stages (Duke et al., 1980) was self-assessed. Students were asked to answer to an image with corresponding legend questionnaire. Students answered the questionnaire in an individual booth without interference from their teachers or school friends. There were no significant differences ( $p>0.05$ ) between groups for age or Tanner stages, neither in strength or endurance fitness performances at the beginning of the protocol. No subject had regularly participated in any form of strength training program prior to this experiment. The following exclusion criteria were used: subjects with a chronic paediatric disease or with an orthopaedic limitation.

### **Anthropometrical Variables**

Total height (m) was assessed according to international standards for anthropometric assessment (0), with a Seca 264 Stadiometer (Hamburg, Deutschland). Weight and body fat were assessed using a Tanita body composition analyser; model TBF-300 (Tanita Corporation of America, Inc, Arlington Heights, IL) with a range of ratio 1%-75%. These two parameters were assessed prior to any physical performance test. Subjects were measured wearing shorts and t-shirts (shoes and socks were asked to be removed).

### **Overhead Medicine Ball Throwing**

An overhead medicine ball throw was used to evaluate the upper body ability to generate muscular actions at a high rate of speed. Prior to baseline tests, each subject underwent one familiarization session and was counselled on proper overhead throwing with different weighted balls. Pre-tests, post-tests and de-training measurements were taken on maximal throwing velocity using medicine balls weighing 1kg (perimeter 0.72m) and 3kg (perimeter 0.78m). A general warm-up period of 10 minutes, which included throwing the different weighted balls, was allowed. While standing, subjects held medicine balls with 1 and 3kg in both hands in front of the body with arms relaxed. The students were instructed to throw the ball over their heads as far as possible. A counter movement was

allowed during the action. Five trials were performed with a one-minute rest between each trial. Only the best throw was used for analysis. The ball throwing distance (BTd) was recorded to the closest cm as proposed by van Den Tillaar & Marques (2009). This was possible as polyvinyl chloride medicine balls were used and when they fall on the Copolymer Polypropylene floor they make a visible mark. The ICC of data for 1kg and 3 kg medicine ball throwing was 0.94 and 0.93, respectively.

#### ***Counter Movement Vertical Jump (CMVJ)***

The standing vertical jump is a popular test of leg power and is routinely used to monitor the effectiveness of an athlete's conditioning program. The students were asked to perform a counter movement jump (with hands on pelvic girth) for maximum height. The jumper starts from an upright standing position, making a preliminary downward movement by flexing at the knees and hips; then immediately extends the knees and hips again to jump vertically up off the ground. Such movement makes use of the stretch-shorten cycle, where the muscles are pre-stretched before shortening in the desired direction (0). It was considered only the best performance from the three jump attempts allowed. The counter movement vertical jump has shown an ICC of 0.89.

#### ***Counter Movement Standing Long Jump (CMSLJ)***

Each participant completed three trials with a 1-min recovery between trials using a standardised jumping protocol to reduce inter-individual variability. From a standing position, with the feet shoulder-width apart and the hands placed on the pelvic girth, the girls produced a counter movement with the legs before jumping horizontally as far as possible. The greatest distance (meters) of the two jumps was taken as the test score, measured from the heel of the rear foot. A fiber-glass tape measure (Vinex, MST-50M, Meerut, India) was extended across the floor and used to measure the horizontal distance. The counter movement standing long jump has shown an ICC of 0.96.

#### ***Sprint Running***

The time to run 20m was obtained using a Brower Timing System (Utah, USA). At the start each subject trod the cell pad. The time to run the distance was recorded using a digital and

automatic chronometer commanded by the cell pad and a pair of photocells positioned above the 20m line. All subjects were encouraged to run as fast as possible and to decelerate only after listening to the beep emitted by the last photocells pair. Each student repeated the same procedure for 3 attempts and only the best time reached was recorded. The sprint running (time) has shown an ICC of 0.85.

#### ***20 Meter Shuttle Run ( $VO_{2max}$ )***

This test involves continuous running between two lines (20m apart in time) to recorded beeps. The time between recorded beeps decreases each minute (level). We chose to use the common version that has an initial running velocity of 8.5 km/h, which increases by 0.5 km/h each minute (0). The final students score was based on the level and number of shuttles reached before they were unable to keep up with the audio recording. Estimated  $VO_{2max}$  ( $ml.kg^{-1}.min^{-1}$ ) was calculated by the Léger's equation (0). The 20m Shuttle Run test has shown an ICC of 0.91.

#### ***Statistical analyses***

Standard statistical methods were used for the calculation of the means and standard deviations (SD). One-way analysis of variance (ANOVA) was used to determine any differences among the three groups' initial strength, endurance, running speed and anthropometry. The training related effects were assessed using a two-way ANOVA with repeated measures (groups x moment). Selected absolute changes were analyzed via one-way ANOVA. The  $p \leq 0.05$  criterion was used for establishing statistical significance.

#### ***Results***

At baseline, no significant differences were observed between groups for any of the pre-training anthropometrics and performance variables ( $p > 0.05$ ). Body fat (BF) significantly decreased ( $p < 0.01$ ) from the pre-training to the post-training period in all groups (Table 2). No significant changes were observed for height, body weight and body mass index (BMI) in any of the groups. Only GCOM increased significantly 1kg and 3kg ball throw distance ( $p < 0.05$ ). GR increased significantly 3kg ball throw distance ( $p < 0.05$ ) (Table 3). The CMVJ height remained stable after the training program for group GR

(0%; ns) whereas GR (+8%; 0.01) and GCOM (+12%; 0.00) significantly increased CMVJ height after the training program. Both experimental groups also increased their performance in CMSLJ after the training program: GR (+0.8%; 0.04) and GCOM (+5.4%; 0.01). GC (-2.3%; ns) didn't change significantly CMSLJ height in the same period. The time to run 20m significantly decreased in GR (-11.5%,  $p=0.00$ ) and GCOM (-10%,  $p=0.00$ ), whereas remained constant in GC. The amount of changes was similar in both GR and GCOM groups. Finally, the  $VO_{2max}$  increased significantly in both GC (+3.2%,  $p<0.05$ ) and GCOM (+4.0%,  $p<0.01$ ), whereas it remained unchanged in GR group.

The detraining period resulted in an increase in body weight (+1.6%,  $p<0.04$ ) for GCOM (Table 3), whereas remained constant for the GR and GC groups. Body height increased significantly for GR (+0.2%,  $p<0.03$ ).

This endurance task, which occurred immediately after the strength training session, was developed based on an individual training

volume - set to about 75% of the established maximum aerobic volume achieved on a previous test.

No significant changes were observed in the 1kg and 3kg medicine ball throw gains after the DT period in any of the experimental groups (Table 3). Additionally, table 3 shows that all groups had significantly lower scores in the vertical jump height after DT period: less 23.1% for GC ( $p=0.00$ ), less 3.7% for GR ( $p=0.02$ ) and less 14.3% for GCOM ( $p=0.00$ ). Significant differences were found between GC and GR as well as between GR and GCOM groups. Both GC (+1.6%; ns) and GR (-3.8%; ns) didn't change their CMSLJ performance after the de-training period. However, GCOM (-4.4%; 0.00) has reduced CMSLJ height in the same period. The time to run 20m decreased in GC and GCOM (1.2% and 1.9%, respectively), yet no significant differences between groups were observed after DT. Estimated  $VO_{2max}$  remained unchanged after DT period in all groups.

**Table 2**  
Descriptive (mean  $\pm$  standard deviation) characteristics of the participants during three testing trials (M1, M2 and M3) for all groups

Variable	Group	M1	M2	M3	(M1-M2)	(M2-M3)
		$\bar{x} \pm \sigma$	$\bar{x} \pm \sigma$	$\bar{x} \pm \sigma$		
Body Weight (kg)	GC	51,5 $\pm$ 11,1	53,9 $\pm$ 12,7	51,9 $\pm$ 12,2	0,39	0,99
	GR	58,9 $\pm$ 13,5	59,0 $\pm$ 14,1	60,4 $\pm$ 15,4	0,95	0,56
	GCOM	54,8 $\pm$ 17,1	54,5 $\pm$ 18,0	55,2 $\pm$ 18,3	0,64	<b>0,04</b>
Total Standing Height (cm)	GC	156,8 $\pm$ 6,5	158,3 $\pm$ 6,9	158,9 $\pm$ 6,9	0,06	0,34
	GR	159,4 $\pm$ 6,1	159,4 $\pm$ 6,0	160,2 $\pm$ 6,3	0,14	<b>0,03</b>
	GCOM	157,9 $\pm$ 8,2	158,0 $\pm$ 7,8	158,2 $\pm$ 7,9	0,79	0,07
BMI (kg.m <sup>-2</sup> )	GC	20,9 $\pm$ 4,0	21,6 $\pm$ 4,7	20,9 $\pm$ 4,9	0,68	0,65
	GR	23,0 $\pm$ 4,1	23,0 $\pm$ 4,5	23,2 $\pm$ 5,4	0,35	0,62
	GCOM	21,6 $\pm$ 5,3	21,6 $\pm$ 5,4	21,8 $\pm$ 5,6	0,24	0,12
Body Fat (%)	GC	24,34 $\pm$ 6,5	24,29 $\pm$ 7,8 <sup>‡</sup>	22,42 $\pm$ 8,8	<b>0,01</b>	0,79
	GR	32,14 $\pm$ 7,7	30,16 $\pm$ 8,2	31,53 $\pm$ 8,6 <sup>‡</sup>	<b>0,00</b>	0,3
	GCOM	26,79 $\pm$ 9,9	24,23 $\pm$ 10,4 <sup>‡</sup>	25,34 $\pm$ 11,1	<b>0,00</b>	0,3

$\bar{x}$  - mean;  $\sigma$  - standard deviation; M1 - before training program; M2 - After training program; M3 - After detraining period;  $p(M1-M2)$  -  $p$  value for comparison between 2<sup>nd</sup> and 1<sup>st</sup> moment,  $p(M2-M3)$  -  $p$  value for comparison between 3<sup>th</sup> and 2<sup>nd</sup> moment; GC - Control Group, GR - resistance training group, GCOM - concurrent resistance and endurance training, † - Significant changes between GC and GR; ‡ - Significant changes between GC and GCOM; § - Significant changes between GR and GCOM.

## Discussion

### Training period

The primary findings of the study showed that concurrent strength and cardiovascular training may be a positive training stimulus to induce power strength and aerobic fitness development and also showed an extremely positive effect on body fat loss in adolescent school girls. Therefore, the present results may suggest that concurrent strength and endurance training seems to be an effective, well-rounded exercise program that can be used as a means to improve initial or general strength in healthy school girls.

In GCOM, the magnitude of decrease observed in BF was significantly greater (-11.4%,  $p=0.01$ ) than that observed in GR (-6.2%;  $p=0.03$ ). However, we did not find any change in body weight and BMI for any group. These results suggest a major positive effect of concurrent strength and endurance training over body fat loss occurs. This could be related to the fact that aerobic exercise can contribute an increase on fat metabolism. In fact, it is known that insulin sensitivity increases with aerobic training and also has an effect on glucose transportation; insulin has an anabolic effect on fat storage in the fat cells (Nielsen and Andersen, 2003).

**Table 3**

*Mean  $\pm$  standard deviation of CMVJ, CMSLJ, 1 and 3kg Medicine Ball Throwing, Running Speed and VO<sub>2</sub>Max at all three testing trials (M1, M2 and M3) for each group*

Variable	Group	M1	M2	M3	(M1-M2)	(M2-M3)
		$\bar{x} \pm \sigma$	$\bar{x} \pm \sigma$	$\bar{x} \pm \sigma$		
1Kg Medicine ball throwing (m)	GC	5,91 $\pm$ 0,83	5,76 $\pm$ 0,57	5,57 $\pm$ 0,52	0,29	0,23
	GR	6,43 $\pm$ 1,26	6,80 $\pm$ 1,34 <sup>F</sup>	6,73 $\pm$ 1,18 <sup>F</sup>	0,08	0,06
	GCOM	6,14 $\pm$ 1,00	6,67 $\pm$ 1,16 <sup>‡</sup>	6,69 $\pm$ 1,18 <sup>‡</sup>	<b>0,00</b>	0,78
3Kg Medicine ball throwing (m)	GC	3,79 $\pm$ 0,50	3,76 $\pm$ 0,43	3,59 $\pm$ 0,50	0,37	<b>0,03</b>
	GR	3,93 $\pm$ 0,73	4,29 $\pm$ 0,74 <sup>F</sup>	4,67 $\pm$ 1,34 <sup>F</sup>	<b>0,01</b>	0,23
	GCOM	3,89 $\pm$ 0,64	4,25 $\pm$ 0,73 <sup>‡</sup>	4,25 $\pm$ 0,74 <sup>‡</sup>	<b>0,00</b>	0,49
CM Vertical Jump (cm)	GC	0,26 $\pm$ 0,07	0,26 $\pm$ 0,06	0,20 $\pm$ 0,04	0,13	<b>0,02</b>
	GR	0,25 $\pm$ 0,06	0,27 $\pm$ 0,07	0,26 $\pm$ 0,06 <sup>F</sup>	<b>0,01</b>	<b>0,02</b>
	GCOM	0,25 $\pm$ 0,06	0,28 $\pm$ 0,08	0,24 $\pm$ 0,06 <sup>‡</sup>	<b>0,00</b>	<b>0,00</b>
CM Standing Long Jump (m)	GC	1,32 $\pm$ 0,23	1,29 $\pm$ 0,20	1,31 $\pm$ 0,31	0,17	0,50
	GR	1,31 $\pm$ 0,24	1,32 $\pm$ 0,26	1,27 $\pm$ 0,29	<b>0,04</b>	0,23
	GCOM	1,30 $\pm$ 0,26	1,37 $\pm$ 0,22	1,31 $\pm$ 0,30	<b>0,01</b>	<b>0,05</b>
Running Speed 20m (s)	GC	4,42 $\pm$ 0,44	4,20 $\pm$ 0,36	4,25 $\pm$ 0,36	0,10	<b>0,03</b>
	GR	4,91 $\pm$ 0,57	4,28 $\pm$ 0,38	4,32 $\pm$ 0,40	<b>0,00</b>	0,86
	GCOM	4,80 $\pm$ 0,53	4,25 $\pm$ 0,34	4,33 $\pm$ 0,39	<b>0,00</b>	<b>0,00</b>
VO <sub>2</sub> Max (mL.kg <sup>-1</sup> .min <sup>-1</sup> )	GC	40,8 $\pm$ 4,05	41,0 $\pm$ 4,27	45,0 $\pm$ 8,20	<b>0,05</b>	0,21
	GR	39,2 $\pm$ 4,29	40,7 $\pm$ 3,98	42,0 $\pm$ 6,84	0,13	0,58
	GCOM	42,5 $\pm$ 4,37	43,7 $\pm$ 4,09 <sup>‡Y</sup>	41,9 $\pm$ 5,80	<b>0,01</b>	0,43

*x* – mean;  $\sigma$  – standard deviation; CM – counter movement; M1 – before training program;

M2 – After training program; M3 – After detraining period;

*p* (M1-M2) - *p* value for comparison between 2<sup>nd</sup> and 1<sup>st</sup> moment;

*p* (M2-M3) - *p* value for comparison between 3<sup>th</sup> and 2<sup>nd</sup> moment;

GC – Control Group, GR – resistance training group,

GCOM - concurrent resistance and endurance training,

<sup>F</sup> - Significant changes between GC and GR;

<sup>‡</sup> - Significant changes between GC and GCOM;

<sup>Y</sup> - Significant changes between GR and GCOM.

Insulin affects appetite regulation through the change in substrates in the blood. Insulin sensitivity may therefore be one of the key mechanisms behind the association found between body composition and fitness (Nielsen and Andersen, 2003). Furthermore, although the design of the training intervention of this study is different from research conducted by Watts et al. (2004), the current results are in agreement with their study results. Watts et al. (2004) examined 19 obese adolescents aged 12–16 years independent influence of 8 weeks of combined strength and aerobic training. Here, although bodyweight and BMI has not changed with exercise, significant improvements in central adiposity were observed following the 8-week circuit-training programme.

Moreover, the total body fat decreased but the majority of fat tissue mass was lost from the abdominal and trunk areas. Interestingly, subcutaneous (skinfold) fat measures did not change, even in these areas, suggesting that exercise training may beneficially modify body composition, with initial decreases in fat predominantly occurring from the viscera.

Upper power strength (e.g. the medicine ball throw with 1kg and 3kg), has significantly increased in both GCOM and GR group. This data may suggest a positive influence of strength training on power strength performance results, no matter with or without concurrent strength and endurance training. Concordantly to the upper body strength results, the power of lower limbs revealed by the CMVJ and CMSLJ performance has changed for both experimental groups. To our best knowledge, very few studies have compared the effects of different methods of organising training workouts. For example, Sale et al. (1990) observed that concurrent strength and endurance training applied on separate days produced gains superior to those produced by concurrent training on the same day. Although the training programs were held otherwise constant, alternate-day training was more effective in producing maximal leg press strength gains than same-day training. This suggests that the interference effect may also be true when the overall frequency and/or volume of training are higher than in this particular study. Briefly, the results do not demonstrate the universality of the interference effect in strength development when strength training is performed concurrently with

endurance training in school girls. It is difficult to compare the results in scientific literature when studies differ markedly in their design factors including mode, frequency, intensity, volume of training, and training history of subjects (Izquierdo et al., 2010). Therefore, further research is required to investigate these causes and identify other possible mechanisms responsible for the observed inhibition in strength development after concurrent training (Watts et al., 2004).

Running speed increased significantly in all experimental groups. These results seem to indicate that additional endurance training does not have an additional effect over strength training to enhance running speed in young girls. On the other hand, all students approached various sports during Physical Education classes. Although physical activity intensity can be considered low to moderate, some sports (for instance, soccer and basketball) elicit high intensity performances (sprints) and low-intensity periods, which could have enhanced running speed performance.

Many people rationalise that concurrent training will give them the benefits of both strength and endurance training (Abernethy and Quigley, 1993). The fact that an inhibition in strength or endurance adaptation as a consequence of concurrent training has been reported (Volpe et al., 1993). The present study, however, could observe a significant enhancement in  $\text{VO}_2\text{max}$  ( $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ) for both GC and GCOM, suggesting that the endurance training program component was effective to a rising in aerobic fitness independently of the treatment group. Our data suggest that dependent variable selection can influence conclusions made with respect to changes in strength and endurance as a result of concurrent training. However, differences in the design of concurrent training interventions, such as mode, duration, and intensity of training, may influence whether any interference in strength or endurance development is observed. Clearly, the interaction between strength and endurance training is a complex issue, and it may still be possible to design specific concurrent training regimens that can minimize or possibly avoid any interference effects.

#### *Detraining period*

To our best knowledge, no other study

has established the effect of an 8-week school based endurance and strength training program and de-training on dynamic muscular strength and body composition in adolescent girls, performed additionally to the physical education lessons. Thus, it is difficult to compare the present results with other studies that have investigated physical training cessation because they differ markedly in a number of factors, including the sample and the method of measurement.

The detraining period was coincided with the summer holidays: 12 consecutive weeks. Thus, sample subjects had no formal physical activity (Physical Education lessons or institutional training programs) during this period. Despite that physical activity had decreased in an overall view, all groups kept body composition. Only the GCOM increased significantly in body weight (+1.6%) but not BF. Additionally, the biggest BF percentage loss was noticed in GCOM during the intervention period. Therefore, we can assume that the sustainment of BF obtained within the training programs participation is visible for several weeks after the programme has finished. Regarding to CMVJ, all groups had shown a significant loss of performance trend ( $p < 0.02$ ). However, in CMSLJ only GCOM had significantly reduced ( $p = 0.00$ ) performance during the de-training recess. This decrement is not surprising since GCOM had a higher increase (however not significantly different from GR) during the training period. In speed running a significant loss of performance was found in GC and GCOM, but not in GR. This loss was expected as speed running is strongly affected by the nervous system adaptation and phosphocreatine reserves. In the 1 and 3kg medicine ball throw distance test, no significant changes were observed for the experimental groups, despite an overall increase in performance, which means a more sustained effect of training in this power task. The control group had the worst performance marks for both

the 1 and 3kg medicine ball throw distance test. Yet, only the 3kg medicine ball throw distance test, change was significant. For both variables, differences were found between GC and GR as well as between GC and GCOM. Thus, power strength gains from both training programs were kept after a DT period of 12 weeks, as strength is determined, among other factors, by muscular mass. Faigenbaum et al. (1996) results show that the 8 weeks of de-training led to significant losses of leg extension (-28.1 %) and chest press (-19.3%) strength whereas the control group strength scores remained relatively similar. Finally, the  $VO_{2max}$  ( $ml \cdot kg^{-1} \cdot min^{-1}$ ) remained stable for all groups, except for GCOM where a significant loss (-4.3%) was observed. Mujika and Padilla (2001) found that changes are more controlled in recently trained subjects (compared with highly trained subjects) in the short-term, but recently acquired  $VO_{2max}$  gains are completely lost after training ceases for longer than 4 wks. Conversely, our results show that GCOM kept  $VO_{2max}$  gains even after 12 wks of DT.

Overall, our results suggest that concurrent strength and endurance school-based training programs seem more effective on both strength and endurance fitness feature of age-school girls. In other words, our study indicates that concurrent training is an effective, well-rounded exercise program that can be set up as a means to improve initial or general strength in healthy school girls. Moreover, performing simultaneously strength and endurance training in the same workout does not impair strength development in young girls, which has important practical relevance for the construction of strength training in school-based programs. The de-training period was not sufficient to reduce the overall training effects. Future studies should examine the interference effects arising from the arrangement of strength and endurance training exercises (e.g., endurance training before strength training or vice versa) on strength.

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### Corresponding author

#### Mário C. Marques

Department of Sport Sciences, University of Beira Interior (UBI), Covilhã, Portugal. Research Centre for Sport Sciences, Health and Human Development, Vila Real, Portugal. UBI - University of Beira Interior, Department of Sport Sciences, Rua Marquês D'Ávila e Bolama, 6200-001 Covilhã, Portugal

Tel: +(351) 275329153

Fax: +(351)275329157