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Concurrent resistance and aerobic training follow a detraining period in elementary school students.

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This document was specially accomplished as original dissertation for the purpose of obtaining the degree of PhD, in accordance with the provisions of Portuguese Decree-Law 107/2008 of 25 June.

To my mother's memory, by the moral and social example

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General Index

Tables Index

Acronyms list

%BF – body fat percentage

BF – body fat

BMI – body mass index

CMJ – counter movement jump

CMVJ - counter movement jump

CMSLJ - counter movement standing long jump

D – day

DT – detraining

GC – control group

GCOM – concurrent resistance and endurance training

GR –resistance group

M1 – pre-training

M2 – post-training

M3 – end of detraining period

MAV - maximum individual aerobic volume

MB – medicine ball

Med – medicine

PA – physical activity

PE – physical education

RM – repetition maximum

TestM – test at the middle of the period

Wk – week

Wks – weeks

Yrs – years old

Thesis resume

Students involved in physical education classes often perform strength and aerobic training concurrently in an effort to achieve specific adaptations to both forms of training. However, the scientific literature has produced inconclusive results. Additionally, interruptions in training process because holidays are normal situations in school context. This recess can produce a children's performance loss. Nevertheless, the detraining period and its consequences are not well reported in sports literature, and namely during puberty. This is important since the period of strength training cessation can produce a positive delay transformation rebound in sports specific performance, which is determinant on school performance evaluation of the student. Therefore, the general objectives of this thesis were to analyze the effects of strength training alone and concurrent strength and aerobic training on strength and aerobic performances on a large sample of healthy school subjects; and to assess the effects of a detraining period on strength, power and aerobic performances. To test our hypothesis we set 5 studies: 1 study review and 4 experimental studies. One hundred and nine healthy children (42 boys, 67 girls) recruited from a Portuguese public high school were randomly assigned into two experimental groups (8 weeks training program) and one control group as follows: one group performing strength training only (GR); another group performing combined strength and aerobic training (GCOM); and the third was the control group (GC, no training program). All sample subjects attended physical education classes twice a week. Strength and aerobic parameters were assessed prior and after a training program period and post a detraining period as well. From pre- to post-training period GCOM's subjects did not take advantage over GR's subjects in jumps, running speed and balls throwing tests. VO_2max increased significantly in GCOM and remained unchanged in both GC (except for girls) and GR groups. 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 non-adult population; training program effects persists even at the end of detraining period. Future researches should examine the interference effects arising from the order of strength and aerobic training exercises program on strength enhancement.

Resumo da tese

Amiúde, as aulas de educação física, fazem apelo ao treino concomitante da força e de resistência aeróbia. A literatura científica tem produzido resultados inconclusivos acerca desta temática. Complementarmente, as interrupções do processo de treino devido a períodos de férias são situações normais em contexto escolar. Estes períodos podem promover perda do desempenho físico. No entanto, o período de destreino e consequentes efeitos, durante a puberdade/adolescência, não estão suficientemente estudados na literatura. Assim, os objetivos gerais desta dissertação foram analisar, em contexto escolar, os efeitos do treino isolado de força e do treino concomitante de força/resistência aeróbia, na força e na resistência aeróbia numa extensa amostra de jovens em idade e contexto escolar; determinar os efeitos de destreino sobre a força e resistência aeróbia. Para testar as hipóteses definidas, definimos 5 estudos: 1 estudo de revisão e 4 estudos experimentais. Cento e nove jovens saudáveis (42 rapazes; 67 raparigas) recrutados de uma escola pública foram aleatoriamente incluídos em dois grupos experimentais e num grupo de controlo, da seguinte maneira: um grupo realizou apenas treino de força, outro realizou treino concomitante de força /resistência aeróbia e um terceiro grupo serviu de controlo (sem programa de treino). Todos os indivíduos da amostra realizaram normalmente as aulas de educação física. Os parâmetros de potência muscular e de endurance foram avaliados antes, após o programa de treino e após 12 semanas de destreino. Durante o período de treino não se verificaram diferenças significativas entre grupos experimentais no que concerne aos ganhos de desempenho nos testes de saltos, velocidade e lançamento de bolas. O VO_2max aumentou significativamente no grupo que treinou resistência aeróbia e manteve-se inalterado quer no grupo que só treinou força (exceto para as raparigas) quer no grupo de controlo. O treino concomitante é, portanto, eficaz e consubstancia-se como bom programa de treino que pode ser prescrito como meio de melhoria da força numa população não-adulta e saudável; os efeitos do programa de treino mantêm-se no final do período de destreino. Estudos futuros devem examinar os efeitos decorrentes da ordem de aplicação do treino de força e de resistência aeróbia no desenvolvimento da força e da resistência aeróbia.

Introduction

Despite of consensus among several credible organizations as The British Association of Sport & Exercise Science, (113), The American Academy of Pediatrics (2), The American College of Sports Medicine (27,65), or the National Strength and Conditioning Association (41) that strength since appropriately designed and supervised by expert personnel is beneficial to children and adolescents' athletic performance, health and fitness, there is a scarcity of robustly designed studies investigating the main factors which determine concurrent strength and aerobic training gains and detraining effect (school based) in untrained children and adolescents. Muscular strength has been recognized as an important component of fitness in the recent evidence-based physical activity guidelines for school-age youth (114). Despite there is clear data in adults (65) to support these positions, evidence-based data in children and adolescents is limited. Additionally, school is considered the primary societal institution with the responsibility for promoting physical activity in youth (22,102) and comprehensive school-based programs are specifically designed to enhance among other fitness components, muscular strength (36,40). Moreover, complementarily studies that have been properly investigated the changes in strength training-induced strength gains during detraining in pre adolescents and adolescents are still scarce and insufficient. Different results have been found on detraining effect over subject's strength gains.

These were our onset points to this thesis. Therefore, we implemented five studies to this dissertation. First study was a literature systematic review and the other four were empirical studies.

Firstly we present the abstracts of all studies. Then, we framed the origin of the problems followed by problems definition. We set up the objectives of the thesis and after this step, circumscription of study hypothesis. Then, each of the five studies was presented. After that we present a thesis conclusion and, at last, studies that were part of our PhD work plan.

Abstract 1 - Concurrent strength and aerobic training and detraining programs: effects on pre- early pubescent and post-pubescent children and adolescents physical fitness performance. Study review.

Beyond habitual physical activity, other factors influence aerobic fitness, including age, gender, heredity, and medical status. It appears that pubertal status plays the most significant role in determining the effects of training on VO_2max, but there is insufficient evidence to determine the effects of the training stimulus, particularly due to the lack of properly documented exercise intensities in past research. The critical stage of maturity where training may exert its greatest impact remains speculative. On the other hand, it is largely documented that in addition to aerobic activities, strength training can offer unique benefits for children and adolescents when appropriately prescribed and supervised. Comprehensive school-based programs are specifically designed to enhance health-related components of physical fitness, which include muscular strength. However, strength school-based programs aiming an increase in physical fitness performance are less studied and with inconclusive findings. Thus, the aim of this study was to synthesize information published in English language and to fulfil the following criteria this review included: (i) experimental studies in children or adolescents samples (aged 10-18 years old); (ii) at least one exercise intervention investigated endurance, resistance training, either in isolation or as an adjunct to an alternative treatment. A systematic database search for full-length manuscripts was performed on Sportdiscus, Springerlink, Taylor & Francis, Sciencedirect, Wiley interscience, and Pubmed for the 1980–2011 (September week 4) period. First, five keyword categorical searches were conducted: (i) 'resistance training', or 'strength training', or 'weight training'; (ii) 'child', or 'adolescent', or pediatric; (iii) 'endurance', or 'aerobic', or 'cardiorespiratory', or 'cardiovascular', 'VO_2max', or 'maximal aerobic power'; (iv) 'concurrent' and (v) 'detraining', 'recess'. The reference lists of each of

these studies and a number of review papers and position stands were manually searched to extract further studies. Concurrent training seems to be effective in pre-pubescent and post pubescent boys and girls. It can be assumed that concurrent strength and endurance training not only do not impair strength or aerobic development as seems to be an effective, well-rounded exercise program that can be used as a means to improve initial or general strength in youth. Regarding detraining effects, studies that have been properly investigated the changes in resistance training-induced strength gains during detraining in pre adolescents are still scarce and insufficient. However, it can be assumed that even after a period as long as 3 month, strength and endurance gains can be observed in untrained early to post-pubescent boys and girls.

Abstract 2 - The effects of school-based resistance training and concurrent strength and aerobic training programs on untrained boys.

The purpose of this study was to compare the effects of an 8-week training period of resistance training alone (GR), or combined strength and aerobic training (GCOM) on body composition, muscular strength, and VO_2max adaptations in a sample of adolescent school boys. Forty-two healthy boys recruited from a Portuguese public high school (age: 13.3 ± 1.04 yrs) were assigned to two experimental groups to train twice a week for 8 weeks: GR (n = 15), GCOM (n = 15), and a control group (GC: n = 12; no training program). Significant training-induced differences were observed in 1- and 3-kg medicine ball throw gains (GR: +10.3 and +9.8%, respectively; GCOM: +14.4 and +7%, respectively). Significant training-induced gains in the height and length of the countermovement (vertical-and-horizontal) jumps were observed in both the experimental groups. Time at 20m speed running decreased significantly for both intervention programs (GR: –11.5% and GCOM: –12,4%, p=0.00). After training, the VO_2max increased only significantly for GCOM (4.6%, p = 0.01). Performing strength and aerobic training in the same workout does not impair strength development in young school boys. As expected, strength training by itself does not improve aerobic capacity.

Abstract 3 - The effects of school-based resistance training and concurrent strength and aerobic training programs on untrained girls.

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 aerobic training (GCOM) on body composition, power strength and VO_2max adaptations in a schooled group of adolescent girls. Sixty-seven healthy girls recruited from a Portuguese public high school (age: 13.5±1.03 years, from 7th and 9th 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. 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. 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 treatment period. After training, VO_2max only slightly increased for GCOM (4.0%). Performing simultaneous strength and aerobic training in the same workout does not appear to negatively influence strength and aerobic fitness development in adolescent girls. Indeed, concurrent strength and aerobic 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.

Abstract 4 - The effects of detraining period after school-based resistance and concurrent strength and aerobic training programs on untrained boys.

The purpose of this study was to compare the effects of 12 weeks of detraining on body composition, strength, and VO_2max adaptations in a sample of adolescent school boys after 8-week of training period of strength training alone (GR), or combined strength and aerobic training (GCOM). The same forty-two healthy boys recruited from a Portuguese public high school (age: 13.3 ± 1.04 years) for study two were used. In 1- and 3-kg medicine ball throw tests, no significant changes were observed after a DT period in both the experimental groups. Significant training-induced gains were observed in both the experimental groups. No differences in height and length of the countermovement (vertical-and-horizontal) jumps were perceived after a DT period. In time at 20m either GR or GCOM groups kept the running speed after a DT period of 12 weeks. A VO_2max significant loss was observed in GR but not in GCOM. Training programs' effects persist even at the end of the 12 wks. of DT period.

Abstract 5 - The effects of detraining period after school-based strength and concurrent strength and endurance training programs on untrained girls.

The purpose of this study was to compare the effects of 12 weeks of detraining on body composition, strength, and VO_2max adaptations in a sample of adolescent school girls after 8-week of training period of strength training alone (GR), or combined strength and aerobic training (GCOM). The same sixty-seven healthy girls recruited from a Portuguese public high school (age: 13.5±1.03 years, from 7th and 9th grade) for study three were used. Anthropometric parameters variables as well as performance variables (strength and aerobic fitness) were assessed. In 1- and 3kg medicine ball throw tests no significant changes were observed after a DT period in any of the experimental groups. Time of 20m significantly decreased, whereas only the GR group kept the running speed after a DT period of 12 weeks. After training period VO_2max 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. The detraining period was not sufficient to reduce the girls' overall training effects.

Object of study

Regular physical activity during childhood and adolescence is associated with improvements in numerous physiological and psychological variables and it has been extensively documented in health related outcomes field (93,102,120,121). Recommendation for the amount of physical activity deemed appropriate to yield beneficial health and behavioural outcomes for school-age youth have been also widely proposed (93,114,120). As such, this thesis will focus on performance relating aerobic and muscular fitness, two physical fitness components (57).

Cardiorespiratory fitness of children aged 13 to 15 years old (yrs) is largely determined by habitual physical activity level (22,75,120), which tends to reduce with age (30,115). However, other factors are determinant on cardiorespiratory fitness development, including age, gender, heredity, and health status (120). According to a meta-analytic review (22), youth (11-13 years olds) are trainable on this parameter. To study cardiorespiratory training effects longitudinal data are clearly preferential on scientific literature (22). Additionally, research increasingly indicates that resistance training, in addition to aerobic activities, can offer unique benefits for children and adolescents when appropriately prescribed and supervised (2,9,133). In school context, children and adolescents involved in physical education classes often perform strength and endurance training concurrently in an effort to achieve specific adaptations to both forms of training (42,56,80,107), nevertheless scientific literature has produced inconclusive results.

Periods of training cessation can produce a positive delay transformation rebound in physical fitness performance (47), which is determinant on school performance evaluation of the student. The extent of performance decrease may depend on the length of the period recess in addition to training levels and performance attained by the subjects (78).

Aerobic fitness

Aerobic fitness is defined as the overall capacity to supply energy to the working muscles in order to support sustained physical activity and the ability to carry out prolonged strenuous exercise (93). This parameter is also referred as cardiorespiratory capacity (93), aerobic capacity (22), aerobic power (141), cardiovascular fitness (93), endurance fitness or maximal aerobic power (93). Aerobic fitness determines performance in a wide range of activities, and in a performance context (8,134), and aims to increase maximal oxygen uptake (VO_2max) or other indices of aerobic fitness such as lactate/ventilatory threshold or exercise efficiency (8). VO_2max is the most commonly used parameter to investigate the functional state of the oxygen transport system (8) and has long since been considered by the World Health Organization as the single best indicator of cardiorespiratory fitness (108).

As mentioned, youth (11-13 yrs) are indeed trainable, but the extent of the training response may be somewhat lower than their adult counterparts (68). It appears that pubertal status plays the most significant role in determining the effects of training on VO_2max, but there is insufficient evidence to determine the effects of the training stimulus, particularly due to the lack of properly documented exercise intensities in past research (68). The critical stage of maturity where training may exert its greatest impact remains speculative; therefore there is a need for additional inquiry to elucidate this perplexing question (68).

Muscular strength

Another component of physical fitness, muscular strength, by definition refers to the maximal force or tension that a muscle or a group of muscles can generate at a specified velocity (60,93). Resistance training refers to a specialized method of conditioning, which involves the progressive use of a wide range of resistive loads and a variety of training modalities designed to enhance health, fitness, and sports performance (40). Although the term resistance training, strength training, and weight training are sometimes used synonymously, the term resistance training encompasses a broader range of training modalities and a wide variety of training goals (40). The term weightlifting refers to a competitive sport that involves the performance of the snatch and clean and jerk lifts (40).

Scientific evidence states that strength training should be part of a comprehensive health maintenance (33,40) and physical performance (33,40) effective strategy for youth, as long as it is carefully prescribed and monitored (32,40,59,86,5,33,56,106,111). Comprehensive school-based programs are specifically designed to enhance health-related components of physical fitness, which include muscular strength (89,128). However, strength school-based programs aiming an increase in physical fitness performance are scarcely studied and with inconclusive findings.

Concurrent strength and aerobic training

Concurrent resistance and aerobic training refers to stimulate both strength and aerobic development on the same training session. On this issue, the scientific literature has produced inconclusive results. Some studies have shown that concurrent training impairs the development of muscular strength and power but does not affect the development of aerobic condition when compared with both form of stand-alone training. Some researchers have reported that concurrent training has an inhibitory effect on the development of strength and endurance (42,47,56). For example, the addition of heavy resistance training to specific team handball training skills in adolescents’ boys resulted in gains in maximal strength and throwing velocity, but it may have compromised gains in the production of explosive force in the leg and endurance running (50). Yet, the precise mechanisms that underlie the observed impairments in training adaptation during concurrent training have to be identified (78,80,124).

Differently, in adults, concurrent training produce better strength and aerobic fitness results rather than if each, strength or aerobic training methods are performed separately (18). In this line, physical education classes demands a balance between strength and aerobic capacity, and it seems important to training concurrently both capacities. Nevertheless, the effects of concurrent strength and aerobic training in elementary school untrained students have yet to be investigated.

Another important concern of this thesis is related to training effects in young schooled girls, since less research has been centered in female subjects. 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 schooled girls (37,115). Schoolgirls have been described as less active than their male age-peers (35,90) and become even less physically active as they are going through adolescence (35,115). In addition, less physically active children tend to remain less active than the majority of their peers during early adolescence (75,118). 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 (75). Fortunately, there is strong evidence that school-based interventions are effective to promote PA levels (34,114,115) and, therefore, school seems to provide an excellent setting to enhance its levels (135) by implementing physical fitness programs.

Detraining effects

The principle of training reversibility states that whereas regular physical training results in numerous physiological adaptations that enhance physical and athletic performance, stopping or markedly reducing training induces a partial or complete reversal of these adaptations, compromising performance levels. Therefore, the reversibility principle can be considered the principle of detraining (51).

Detraining is defined as the partial or complete loss of training-induced anatomical, physiological and performance adaptations, as a consequence of training reduction or cessation (85). Training cessation implies a temporary discontinuation or complete abandonment of a systematic programme of physical conditioning (85). Reduced training is a non-progressive standardised reduction in the quantity of training (84), which may result in a maintenance or even in an improvement of many of the positive physiological and performance adaptations acquired with training process (84,53).

Interruptions in training process because of illness, injury, holidays, post-season break or other factors are normal situations in numerous kind of sport (41,36,40) and in school context as well. The extent of performance level decrease may depend upon the length of the period recess in addition to training levels and performance attained by the subjects (78). Nevertheless, information about the changes in resistance training-induced strength gains during detraining in pre adolescents is still scarce (117) and insufficient studies (10,41) have investigated the effects of detraining with an inclusion of a control group to control for growth-related rises in muscular strength. This is important since the period of strength training cessation can produce a positive delay transformation rebound in sports specific performance (47), which is determinant on school performance evaluation of the student.

Summary

Performance related physical fitness studies reflects (i) the insufficient evidences to determine the effects of the training stimulus over endurance development, particularly due to the lack of properly documented exercise intensities in past research, (ii) that strength school-based programs aiming at an increase in physical fitness performance are scarcely studied and with inconclusive findings, (iii) that effects of concurrent strength and aerobic training in elementary school untrained students have yet to be investigated, and that scientific literature has produced inconclusive results on this issue, (iv) information about the changes in resistance training-induced strength gains during detraining in pre adolescents is still scarce and an insufficient number of studies have investigated the effects of detraining with an inclusion of a control group to control for growth-related rises in muscular strength, and at last (v) this kind of studies in school girls are even uncommon than in boys.

General goals

This thesis aimed to: (i) study the effects of strength training (strength training alone), and the effects of concurrent strength and aerobic training on body composition and performance variables of untrained adolescent subjects as result of a school-based program; (ii) study the effects of detraining period on body composition and performance variables of subjects which trained only strength and of subjects which trained concurrently strength and aerobic capacity.

Research problems

Scientific literature analysis accomplished shows that there are several empirical problematic questions, which justify the definition of one or more problems. We can define the follow concerns:

(i) There is insufficient evidence to determine the effects of the training stimulus, particularly due to the lack of properly documented exercise intensities in past research. Strength school-based programs aiming at an increase in physical fitness performance are scarcely studied and inconclusive findings exist.

(ii) Different studies on children have reported no significant strength and power increases after the intervention period of strength training programme. Nevertheless, other studies have shown that strength and power gains are possible.

(iii) Concurrent training promotes benefits on both strength/power and aerobic development. However, in sports sciences literature contradictory results were found regarding possible impairments due to concurrent training.

(iv) Conclusions about the changes in resistance training-induced strength gains during detraining in pre adolescents are still scarce, inconsistent and insufficient studies have investigated properly the effects of detraining on non-trained subject's physical fitness performance.

To explain the effects of strength training process performed alone or concurrently to aerobic training and to explain the detraining phenomena we defined the follows questions, which led us throughout this research:

1) Is strength training really effective in non-active adolescent subjects?
2) When trained alone, does strength training produce substantial higher muscular strength and body composition improvements than training concurrently to endurance?
3) Does concurrent resistance and endurance training impair endurance improvements?
4) Is it possible to observe similar results in both genders, regarding concurrent training and detraining periods?
5) Are twelve weeks of detraining period sufficient to lose all training improvements resulting from the training program?

Studies' specific goals

Arising from main empirical stone marks and problems, specific goals were:

1) To analyze and synthesize information published in English language and that fulfilled the following criteria: (i) experimental studies in children or adolescents samples (aged 10-18 years old); (ii) at least one exercise intervention investigated endurance, resistance training, either in isolation or as an adjunct to an alternative treatment (Study number 1: review);

2) To study the effects of a school-based resistance training program (performed alone) and the effects of a school-based concurrent strength and aerobic training on body composition and performance variables of untrained boys (Study number 2);
3) To study the effects of a school-based strength training program (performed alone) and the effects of a school-based concurrent strength and aerobic training on body composition and performance variables of untrained girls (Study number 3);
4) To study the effects of a detraining period on body composition and performance variables of boys, which trained only strength and of boys which trained concurrently strength and aerobic training (Study number 4);
5) To study the effects of a detraining period on body composition and performance variables of girls, which trained only strength, and of girls which trained concurrently strength and aerobic training (Study number 5).

Hypotheses

The following hypotheses were defined:

Hypothesis 1 – School-based strength training is really effective on non-active adolescent subjects for both genders.

Hypothesis 2 - When trained alone, strength training does not produce significant higher muscular strength increases in boys when compared with results obtained after concurrent strength and aerobic training.

Hypothesis 3 - When trained alone, strength training does not produce significant higher muscular strength increases in girls when compared with results obtained after concurrent strength and aerobic training.

Hypothesis 4 - When trained alone, strength training does not produce significant higher body composition improvements in boys when compared with results obtained after concurrent resistance and aerobic training.

Hypothesis 5 - When trained alone, strength training does not produce significant higher body composition improvements in girls when compared with results obtained after concurrent strength and aerobic training.

Hypothesis 6 - Concurrent resistance and aerobic training does not impair aerobic improvements in boys.

Hypothesis 7 - Concurrent strength and aerobic training does not impair aerobic improvements in girls.

Hypothesis 8 - Regarding concurrent training it is possible to observe significant improvements in both genders, and regarding to detraining both genders would keep improvements previously acquired during training process.

Hypothesis 9 - Twelve weeks of detraining summer period are not sufficient to induce significant losses in strength and aerobic parameters in adolescent's boys.

Hypothesis 10 - Twelve weeks of detraining summer period are not sufficient to induce significant losses in strength and aerobic parameters in adolescent's girls.

Study One: Concurrent strength and aerobic training and detraining programs: effects on adolescents' physical fitness performance. Study review.

Regular physical activity during childhood and adolescence is associated with improvements in numerous physiological and psychological variables and it has been extensively documented in health related outcomes field (101,102,120,121). Recommendation for the amount of physical activity deemed appropriate to yield beneficial health and behavioural outcomes for school-age youth have been also widely proposed (101,114,120).

In this study, we focused our article review on aerobic and muscular fitness, and on two physical fitness components (57). We present below main results and conclusions of studies which have studied cardiorespiratory fitness alone, main results and conclusions of studies which have studied resistance strength alone. Afterward we present main results and conclusions of studies which have studied the effects of concurrent resistance and endurance training program. At last, we summarize the main conclusions of studies which have investigated detraining effects on non-adults.

Cardiorespiratory fitness is defined as the overall capacity of the cardiovascular and respiratory systems and the ability to carry out prolonged strenuous exercise (93). Cardiorespiratory fitness is also referred as cardiorespiratory capacity (93), aerobic capacity (22) aerobic power, cardiovascular fitness (93), endurance fitness or maximal aerobic power (93), and is largely determined by habitual physical activity (22,120). However, other factors influence cardiorespiratory fitness, including age, gender, heredity, and medical status (120). According to a meta-analytic review (68), youth (11-13 yrs) are indeed trainable, but that the extent of the training response may be somewhat lower than their adult counterparts. It appears that pubertal status plays the most significant role in determining the effects of training on VO_2max, but there is insufficient evidence to determine the effects of the training stimulus, particularly due to the lack of properly documented exercise intensities in past research (68). Furthermore, longitudinal data are clearly preferential, particularly in studies examining the effects of training as a function of pubertal status (68). The critical stage of maturity where training may exert its greatest impact remains speculative; thus, there is a need for additional inquiry to elucidate this perplexing question (68).

By definition, muscular strength refers to the maximal force or tension a muscle or a group of muscles can generate at a specified velocity (60,93). Resistance training refers to a specialized method of conditioning, which involves the progressive use of a wide range of resistive loads and a variety of training modalities designed to enhance health, fitness, and sports performance (40). Although the term resistance training, strength training, and weight training are sometimes used synonymously, the term resistance training encompasses a broader range of training modalities and a wider variety of training goals (40). The term weightlifting refers to a competitive sport that involves the performance of the snatch and clean and jerk lifts (40).

It's largely documented that in addition to aerobic activities, research increasingly indicates that resistance training can offer unique benefits for children and adolescents when appropriately prescribed and supervised (2,9,133).

Comprehensive school-based programs are specifically designed to enhance health-related components of physical fitness, which include muscular strength (89,128). However, resistance school-based programs aiming an increase in physical fitness performance are less studied and with inconclusive findings.

Therefore, the purpose of this research was to systematically review the effects of endurance training alone, resistance training alone, concurrent resistance and endurance training over physical performance of 10 to 18 years old children and adolescents to assess current knowledge and level of evidence according to the Consolidated Standards of Reporting Trials (CONSORT) checklist guidelines (82).

Methods

Inclusion and exclusion criteria

Researches that were published in English language and fulfilled the following criteria were included in this review: (i) experimental studies in children or adolescents samples (aged 10-18 years old); (ii) at least one exercise intervention investigated endurance, resistance training (using machines, free weights, elastic bands or tubes, medicine ball, body weight or a combination of several), either in isolation or as an adjunct to an alternative treatment.

Search methodology

A systematic database search for full-length manuscripts were performed on Sportdiscus, Springerlink, Taylor & Francis, Sciencedirect, Wiley interscience, and Pubmed for the 1980–2011 (September, week 4) period.

First, five keyword categorical searches were conducted: (i) 'resistance training', or 'strength training', or 'weight training'; (ii) 'child', or 'adolescent', or pediatric; or 'paediatric' (iii) 'endurance', or 'aerobic', or 'cardiorespiratory', or 'cardiovascular', 'VO_2max', or 'maximal aerobic power'; (iv) 'concurrent' and (v) 'detraining', 'recess'. The reference lists of each of these studies and a number of review papers and position stands were manually searched to extract further studies.

Cardiorespiratory fitness training

Aerobic fitness determines performance in a wide range of activities, and in a performance context (8,134), aims to increase maximal oxygen uptake (VO_2max) or other indices of aerobic fitness such as lactate/ventilatory threshold or exercise efficiency (8).

The VO_2max is the most commonly used parameter to investigate the functional state of the oxygen transport system (8) and has long since been considered by the World Health Organization as the single best indicator of cardiorespiratory fitness (108).

Age and growth effects

It has been hypothesised that maturational factor may determine a child's potential for physiologic alterations to occur consequent to physical training (48). Thus, although young boys will respond to appropriate training programmes with increases in VO_{2peak}, the size of the changes may be less than those expected in older youths and adults (6,95).

Data on the aerobic training responses of pre-pubertal are sparse, and most studies have not assessed maturation or monitored carefully the training modality, especially the intensity of exercise (131).

In a follow up study with a school boy's untrained sample, Kobayashi et al (61) found that aerobic power increased from 45.0 to 52.2 ($ml.kg^{-1}.min^{-1}$) between the ages of 13 and 17. Therefore, beginning approximately one year prior to the age of peak height growth velocity and thereafter, training effectively increased aerobic power above the normal increase attributable to age and growth. After that, another school-based follow up study (81) also using a untrained school boy's sample, concluded that activity before adolescence causes no significant increase in VO_2max, but that adolescence is the critical period during which consistently higher rates of increase in the VO_2max of active boys result in a significantly greater adult value. In another follow up study, Kemper & Verschuur (58) controlling for chronological age observed that VO_2max increases in boys from 2.4($l.min^{-1}$) at age 12+ to 3.8 ($l.min^{-1}$) at age 17+. Girls' increase is smaller, from 2.31/min to 2.71/min over the same age range. When VO_2max is aligned on peak height velocity, their results show that the peak increase coincides roughly with the age at peak height velocity. It demonstrates that in general no discrepancy between structural and functional growth occurs in boys and girls during their teens as far as VO_2max is concerned. Concordantly, LeMura et al. (68) in an analytic review concluded that children (both genders) are indeed trainable, but the changes in VO_2max are modest and are significantly impacted by the Experimental approach of the investigation, the age of the children, and the nature of training stimulus.

Wennlöf et al. (130) also reported in a cross-sectional study a better aerobic fitness of post-pubertal boys and girls compared with their pre-pubertal peers. Others suggest that cardiovascular training will rebound as minimal changes to peak or submaximal aerobic function in young girls (129) and boys (131). Contrarily, Obert et al. (92) highlights the effectiveness of an aerobic training programme to improve the maximal power during short-term exercise in pre-pubertal male and female children. Another longitudinal study (76) shows that VO_2max can increase in pre-pubertal children after an aerobic training programme and that such an increase is of the same extent in both genders when the initial aerobic fitness is taken into account. Similarly, more recently, McNarry et al. (79) challenged the notion that differences in training status in non-adult people are only discernible once a maturational threshold has been exceeded. In same year, another study

(64), using a sample of 162 boys (aged 13–14 years) at various puberty stages, found that adolescents aged 13–14 years with moderate rates of development are characterized by higher indices of power and capacity of the aerobic energy supply system as compared to adolescents with accelerated maturation. This group of adolescents has also been observed to exhibit a lower maximal aerobic power against a background of higher capacity and efficiency of the aerobic system functioning as compared to adolescents with slow maturation. The groups of adolescents with moderate rates of maturation have been shown to exceed schoolboys groups with accelerated or slow development with respect to the power of mixed aerobic–anaerobic work. Boys aged 13–14 years with accelerated development have been found to differ from schoolboys with moderate or slow maturation by high anaerobic capacity, relatively low aerobic capacities and an increase in the tone of the parasympathetic nervous system.

Onset physical fitness level effect

The first studies found a remarkable increase in aerobic power was observed in trained boys compared with their non-trained peers (61,81). However, that marked increasing was conditioned to peak height growth velocity occurrence (61,81). In a Physical Education-based study (98) it was found that despite VO_2max improvements were independent either of initial VO_2max level and initial enrolment on sports teams, it was not from a level of habitual physical activity. In this line, Welsman et al. (129) did not find any change in VO_{2peak} in a pre-pubescent girl's sample with low levels of physical activity, after a training period of both modes aerobics and cycle ergometer. Using a sample of 16-18 year old elite handball players and untrained boys, Łuszczyk et al. (74) observed adapting changes in the circulatory system in young handball players. The group practicing handball showed a significant higher value of $O_2.HR^{-1}$ comparing with the untrained boys.

Oxygen deficit was higher in the trained group, but no statistically significant differences between both groups were observed. In a recent cross-sectional study (79) it was found that pre-pubertal, pubertal and post-pubertal girls had a higher VO_{2peak} during cycle and an upper body ergometer tests. In the same study it was also observed that trained girls also had a higher peak cardiac output during both cycle and an upper body ergometer tests, and this reached significance in pubertal and post-pubertal girls, compared with untrained girls.

Gender effects

In a 4 years follow up study, Kemper & Verschuur (58) found that when considered the absolute value of VO_2max ($l.min^{-1}$) boys increased from 2.4 $l.min^{-1}$ at age equal or more than 12 year olds to 3.8 $l.min^{-1}$ at age equal or more than 17 year olds. That increase in girls is minor (from 2.3 $l.min^{-1}$ to 2.7 $l.min^{-1}$, respectively) compared with their male peers. However, when body weight was taken in account VO_2max ($l.min^{-1}.kg^{-1}$) and considering the same age range, boys remained constant (59 $l.min^{-1}.kg^{-1}$) and in girls it gradually decreased from 50 to 45 ($ml.min^{-1}.kg^{-1}$). Girls' results are partly justified by an increase in body fat that the authors have found in female sample. Wennlöf et al (130) also found in the 15 to 16-yrs old group that boys had significant higher absolute (+.96 $l.min^{-1}$) and relative (+11.0 $ml.min^{-1}.kg^{-1}$) estimated VO_2 peak values than the girls. In 9-10 yrs-old boys and girls group it was noticed in absolute (+.18 $l.min^{-1}$) and relative (+5.3 $ml.min^{-1}.kg^{-1}$) estimated VO_2, significant higher scores in boys than girls (130). Similarly, after a 13-Week Aerobic Training Programme it was observed in a 10-11 yrs old sample that boys increased their VO_2max to a greater extent than the girls with a concomitant higher maximal stroke volume improvement (91). No alterations were observed in the stroke volume pattern from rest to maximal exercise, indicating that the increase in stroke volume rest was determinant in the improvement of maximal stroke volume and thus in VO_2max values (91). However, Rowland & Boyajian (98) in an experimental study (physical education-based endurance training program, using a 10.9-12.8 yrs old sample) observed that training improvements in VO_2max were no different in boys and girls. Different results were achieved by Mandigout et al. (76). The authors found that 10–11yr old girls significantly increased VO_2max after the training programme and that increase was significant higher in comparison with boys.

Program design

In paediatric population with equal or more than 10 years old, few studies have investigated the variables that optimize endurance program. Some experimental studies have examined the efficacy of school-based interventions (22,102), others have studied the influence of age/maturation status (58,131), gender (22,58,76,91,130) or initial physical fitness (22,98) over cardiorespiratory fitness but an exiguous number of experimental studies has properly investigated load components such as mode, frequency, session duration or intensity. Ewart, et al. (26) evaluated the effects of aerobic exercise physical education on blood pressure in high-risk adolescent girls and compared with traditional physical education classes. Nevertheless, the main aim of that study was not to optimize the endurance training design and consequently the validity of their results is limited on this context. Bogdanis et al. (12) evaluated and compared the effectiveness of two different off-season 4 week-basketball training programs on physical and technical abilities of young basketball players. The authors (12) have concluded that VO_2max similarly improved after specialized basketball and mixed basketball plus conditioning training program.

Experimental studies have been using different modes such as interval and continuous long-distance running (76,91,92), aerobics class (26,129), handball (74), indoor and outdoor aerobic games (98), basketball (12,98) or cycling (129,131). Regarding frequency, it has been used two (26,92,96), three (76,91,98,129,131) and five (12) days per week. One single study used programmes of 4 weeks (12), other two, 8 weeks (129,131), three studies used programs of 13 weeks (76,91,92), one has used 12 weeks (98), other used 16 weeks (96) and another one has used 18 weeks (26). Only one study (74) had a larger duration (2 years), however, training protocol was not described. Session durations vary from 20 to 30 minutes (96,98,131), 50 minutes (26) until more than 1 hour (12,76,91,92). Concerning training intensity, values above 80% Heart Rate Maximum (12,76,91,131) have been used. Three studies defined a Heart Rate target range from 160 to 170 beats per minute for a sample of 10.9-12.8 yrs old boys and girls (98), for a sample of 9-10 yrs old girls (129) and for a sample of 10 yrs old boys (131). Defining a common and unbending target range for every subject with different characteristics and different physical fitness level, the stimulus would be not appropriate and thus create a bias on data.

In conclusion, it is difficult to compare studies when different modes, intensities, durations (session and program) and objectives are used. Nevertheless, in all cited studies, except one (129), it was found that a training program led to a rise in VO_2max. Thus, more studies are needed to clarify what is the best methodology on endurance training in paediatric population.

Strength training

Recent findings indicate that resistance training can offer unique benefits for children and adolescents when appropriately prescribed and supervised (32,40,86,133). Indeed, improvements in muscular fitness and speed/agility, rather than cardiorespiratory fitness, seem to have a positive effect on skeletal health (93).

Strength training (also called resistance training) refers to a specialized method of physical fitness conditioning that comprises the progressive use of a wide variety of resistive loads — from medicine balls to high intensity plyometric drills — that enhance or maintain muscular fitness (3,4,15,31,32,36,40,86). Research into the effects of resistance exercise on youth has increased over the past years (4,15,31,36). Consequently, youth strength training is, nowadays, accepted by medical and fitness organizations and this qualified acceptance is becoming universal (3,4,15,31). Complementary, school physical education is the primary societal institution with the responsibility for promoting physical activity in youth (22,102) and comprehensive school-based programs, are specifically designed to enhance among other fitness components, muscular strength (36,40).

Several factors seem to have an effect over muscular strength development and studies have been used different methodologies and thus different results.

Age/growth effects

The efficacy and success of a resistance training program on children has been questioned in the past (71). Children lack adequate circulating androgens required for gains in muscular strength was appointed as an explanation for that ineffectiveness (67). Thus, different studies on children have reported no significant strength increases after the intervention period of strength training programme (23). A great range of reasons such as no inclusion of control group, testing methods different from training drills, inadequate load (resistance, repetitions, or sets), or a short study period can explain the lack of significant strength gains reported in those studies (71). Nevertheless, numerous other studies comparing strength trained children with age and sex matched controls have shown strength gains are possible (94) with no detrimental effect on growth (87,99).

Faigenbaum et al. (44) found for both genders and pre-pubescent population that twice/week strength training programme can increase significantly ($p<.001$) strength in upper and lower limbs strength [10-RM leg extension (64.5%), leg curl (77.6%), chest press (64.1%), overhead press (87.0%), and biceps curl (78.1%)] after strength training program whereas gains in the control group averaged 13.0% (range 12.2 to 14.1%) for the same tested motions. The mean gains in strength for the experimental group were significantly greater than those for the control group. In vertical jump and seated ball put, subjects submitted to training programme improved 13.8% and 4% respectively, compared with 7.7% and 3.9% observed in control group. There were no significant interaction effects on vertical jump and seated ball put; however, significant ($p<.05$) main effects (both groups combined) for time were found on both performance measures (44). Concordantly, Ozmun et al. (94) for the pre-pubescent boys and girls that significant isotonic (22.6%), and isokinetic (27.8%) strength gains and integrated EMG amplitude (16.8%) increases were found after training programme period without corresponding changes in arm circumference or skinfolds. For the authors (94) early gains in muscular strength resulting from resistance training by prepubescent children may be attributed to increased muscle activation.

The effectiveness of a strength training program in pre-pubescent boys and girls was confirmed using 6RM leg extension strength and 6RM chest press strength tests since exercise group significant increased +53.5 and 41.1%, respectively, compared with non-significant increase of 6.4 and 9.5% in controls (41). Significantly greater gains in strength during the 2nd phase of training for 6RM leg extension and 6RM chest press strength tests has been found, comparing with controls (41). After a training program of 1RM chest-press exercise for either low or high repetitions maximum, it has been found that prepubescent boys are sensitive to gains in 1RM chest-press test (38). That increase was about 52% for low repetitions maximum and 66% for high repetitions maximum, of their initial 1 RM (38). More recently the positive effect of a strength training program over strength variables was confirmed in school context for pre-pubescent population (19). This issue was specifically studied in a stone mark study (71) which investigated the efficacy of strength training in prepubescent to early post-pubescent males and females. Prepubescent to early post-pubescent boys and girls who participate in a 12 week strength training programme can significantly gain 10RM strength; increase upper and lower extremities girths measures, while decreasing skinfold thickness, increase performance in selected motor tasks (flexed arm hang, jump & reach, shuttle run, standing long jump, 30 yard dash) and enhance flexibility (71). In the same study, no significant differences in 10 RM strength gains were noted between the Tanner stage 1-2 and 3-5 groups. It also was found that the predominant main effect on motor performance was treatment. For the most part, regardless of Tanner's stage and gender, strength training groups experienced greater improvements in motor performance than control groups.

Beyond the fact that pre-pubescent subjects are respondents to strength training program, it was demonstrated that after a plyometric training program prepubescent soccer players boys can increase performance in muscle power tests such as maximal cycling power ($p<.01$), CMJ ($p<.01$), squat jump ($p<.05$), multiple 5 bounds ($p<.01$), repeated rebound jump for 15 seconds ($p<.01$) and running velocity on 20m ($p<.05$), performances increased in the treatment group without concomitant increase in controls (21). More recently, it has been found that in trained (55) and untrained (62) pre- (55,62) and early pubertal boys

(55), upper and lower body complex training (combination of dynamic constant external resistance and plyometric drills) is a time-effective training modality that confers improvements in anaerobic power and jumping, throwing and sprinting performance, and marked improvements in dynamic strength (55,62,104).

In pre-pubertal obese children it was demonstrated that an exercise programme with emphasis on strength training can result in significant beneficial effects on lean mass (133), bone mineral accretion (133), per cent and total fat mass (104). The reduction of fat mass was concomitant with significant improvements observed in static jump power, which improved by 10.5% at week 16 in the group which trained for 24 weeks (104).

The effectiveness of strength training in pre-pubescent subjects can be reached with different training program context such as sports-based (21,47), fitness club-based (41,38,55,71,133) or school based (19,36,62) and resistance modes such as child sized weight machines (41,38,44), free weights or common weight machines (47,71), body weight/tubing exercises/dumbbell exercises (19,47,104) and medicine ball (19,36,47,104).

Strength training is also effective in pubescent as well as in post-pubescent population. In a pubescent male athletes sample, upper (bench press) and lower [leg press (20,52) and vertical jump (52)] strength has been increased after training period (20,52). Tsolakis et al. (117) found that resistance training induced strength changes independent of the changes in the anabolic and androgenic activity.

A considerable number of studies have investigated the effect of strength training on adolescents. After a training period subjects significantly increase predicted 1RM squat (92%) and 1RM bench press (20%), right (10.39cm) and left (8.53cm) single-leg hop distance and vertical jump (3.3cm) and speed in a 9.1-m sprint (0.07seconds) (87). Basic strength training alone induced favourable neuromuscular and biomechanical movement changes (87,69) providing greater sport-specific training improvements (116) in high school male (87,116) and female (69) athletes. Thus, the plyometric program may further be utilised to improve muscular activation patterns (87,69). When a resistance training program was used in addition to soccer training on the physical capacities of male adolescents it resulted in significant ($p<.05$) higher 1RM bench press and 1RM leg press, squat jump and CMJ height, and 30-m speed performance (17). Contrarily, Bogdanis et al. (12) found that a specialized basketball training program, performed exclusively on-court was as effective as a basketball plus strength training program in terms of aerobic and anaerobic fitness improvement (12): trunk muscle endurance was equally increased for both groups but arms endurance was improved significantly more after basketball plus strength training program (50±11%) compared to specialized basketball training program (11±14%, $p<.05$).

Overweight adolescent males, after strength training period, can significantly increase performance in 1RM bench press and 1RM leg press while the body fat percentage (105) also significantly decreased. This finding was confirmed recently for normal weight untrained boys and girls (73): after either a free weight or elastic tubing training program, improvements were observed on their body composition concomitant with increases in performance of upper and lower body muscular strength.

A short bout of 10 to 15 minutes in each physical education class, is sufficient to achieve significant gains in the shuttle run, long jump, sit and reach flexibility, medicine ball abdominal curl, medicine ball push up and medicine ball toss (36). The introduction of manual resistance training on physical education class also resulted in curl-up test (24).

The addition of plyometric training to a resistance training program may be more beneficial than resistance training and static stretching for enhancing selected measures of upper and lower body power in boys. Faigenbaum et al. (35) has demonstrated that subjects who performed a plyometric training in addition to resistance training program made significantly ($p<.05$) greater improvements than subjects who performed resistance training only in long jump (10.8cm vs. 2.2cm), medicine ball toss (39.1cm vs. 17.7cm) and pro agility shuttle run time (-0.23sec vs. -0.02sec) following training.

An important finding highlight that performing resistance training at a moderate volume is more effective and efficient than performing at a higher volume (48): junior experienced lifters can optimize performance by exercising with only 85% or less of the maximal volume that they can tolerate.

Onset physical fitness level effect

It's well documented that resistance training is effective on muscular strength development of either untrained (19,35,36,38,39,43,44,55,62,71,73,94,104,105,117,133) or trained (12,17,20,21,36,47,69,86,116) pre-pubertal (21,31, 39,43,44,62,71,94,104,133) or pubertal/post-pubertal non-adult population (12,17,20,24,35,36,55,69, 86,105,117).

Muscular strength can be improved during childhood years, and favour a training frequency a twice/week (39), 1 set/exercise of a higher repetition maximum (15-20 reps.) training range (38) for untrained children participating in an introductory strength training program (39). Similarly, comparing with untrained subjects, highly experience (at least 6 years) adolescent athletes in different sports (basketball, soccer, and volleyball players) girls, significantly increase predicted 1RM squat and 1RM bench press performances, as well as right and left single-leg hop distance, vertical jump and speed 9.1-m running performances; rise movement biomechanics: increase knee flexion-extension range of motion during the landing phase of a vertical jump and decreased knee valgus and varus torques (86). Another research has specifically investigated the effect of sports experience on strength training adaptation in adolescent males (52): comparing with controls, experienced training subjects and novice training subjects significantly increased leg press, bench press and vertical jump after a 12 weeks, thrice a week, with free weights and machines.

Gender effects

Faigenbaum et al. (41,38,39,43,104), Faigenbaum and Mediate (36), Lubans et al. (73) and Yu et al. (133) observed increases in various training-induced strength gains in prepubescent (41,38,39,43,104,133) and pubescent (36,73) boys and girls; however, details of the detraining responses were not reported in those studies.

Cowen et al. (19) found that boys and girls revealed improvements in push up scores, curl up scores, and overall percentile ranking after a strength training program; however, the statistical difference between both genders was not reported.

Lillegard et al. (71) observed no significant 3 or 2-way (gender, Tanner's stage, treatment) interactions for any of 10 RM strength differences (barbell curl, triceps extension, bench press, lat pull, leg extension, leg curl) and for any of the 5 motor performance parameters (flexed arm hang, jump and reach, shuttle run, standing long jump, 30 yard dash). However, when it was considered the gender main effect, in 2 of the six 10RM strength measures (lat pull, leg extension), males had significantly gains than females and significant pre- and post-test genders difference occurred on shuttle run (favoured the females) (71).

Program design

Resistance training programs as short as 10-15 minutes per session (36), in addition to physical education classes have been showed to be sufficient to promote strength developments in paediatric population. Different weekly training frequency has used such as once a week (39,43,133), twice a week (17,31,35,36,38,39,44,47,62,73,105) thrice a week (20,21,24,52,55,69,71,87,94,104,116,117,133) or five days a week (12,19,48) with success on strength performances development. Resistance training programs using experienced non-adults population lasted from 4 (12) to 24 weeks (20). When we focus our analysis on untrained non-adults subjects studies, we found that the mostly used period was 8 weeks (41,38,39,43,44,73,117). Training period range has lasted from 6 (35,36) to 64 (36+28) weeks (133). However, significant gains in upper and lower limbs strength can occur during a short period as the first 4-weeks of a training program (41).

Training Frequency

Faigenbaum et al. (39) studied the effects of week frequency (1 vs. 2 sessions/wk) of strength training on upper and lower body strength in non-prior strength training experienced children. The 1-day group training at a 62.3 and 68.8% intensity (of their initial 1RM) on the chest press and leg press exercises, respectively, whereas the 2-day group trained at an intensity of 61.1 and 67.4% (of their initial 1RM), respectively (39). The authors found that in 1RM chest press strength performance, participants who trained 1 day/week increased 9.0% from their initial score whereas 2 days/week strength training group increased 11.5% [only this group made significantly ($p<.05$) greater gains in this variable as compared to the control group]. Compared with baseline scores, 1 day/week training group increased 14.2% in 1RM leg press strength whereas 2 days/week strength training group increased 24.9% (39). The control group has increased 4.4 and 2.4% in first and second variable, respectively (39). The authors proposed that the control group's strength gains may be explained by growth, maturation, and the learning effect. Despite no pre-post program significant differences between groups were observed in handgrip strength, long jump, vertical jump, and flexibility it can be assumed that muscular strength can be improved during childhood years, favouring a training frequency of twice/week for children participating in an introductory strength training program. These results have to be taken with caution as long as throughout the study period 64% of subjects in the 1-day group, 70% in the 2-day group, and 69% in the control group regularly participated (at least 2-day/week) in organized community sports programs (mainly swimming and soccer) and these last programmes were not controlled by researchers.

Other authors (20) have studied the effect of training week frequency (1 *vs*. 2 sessions/wk) in 12 wks in-season over strength gains retaining. Firstly, all subjects (including control group) attended a preseason 12 wks, thrice a week of progressive strength training. In in-season, significant differences ($p<.05$) in absolute strength scores between group which trained 2 day/wk and the control group prior to the maintenance protocol for bench press were observed. At the end of the 12-week in-season period, subjects of both weekly training frequencies (1 and 2 sessions/wk) differed significantly ($p<.05$) from the control group in absolute bench press strength scores. Additionally, significant differences (in pre- to post in-season program) between 1 and 2 sessions/wk training groups and the control group were observed. No other differences were observed between groups. During the 12- week maintenance protocol, the group which trained 1 day/wk had significant increases in strength in the bench press ($p<.05$) while the control group had significant decreases in the bench press and pull-ups. Thus, for pubescent male athletes, 1 day/wk maintenance program is sufficient to retain strength performance during the competitive season.

Training intensity and volume

Trained adolescents of both genders can benefit from a short session of strength training. A 10 to 15 minutes of medicine ball strength training program performed twice a week on physical education classes have been shown to be sufficient to significantly ($p<.05$) promote gains in long jump, medicine ball abdominal curl, medicine ball push up and medicine ball toss tests (36).

González-Badillo et al (48) found that junior resistance-trained athletes can optimize performance by exercising with only 85% or less of the maximal volume that they can tolerate. In fact, after a periodized routine using the same exercises and relative intensities but a different total number of sets and repetitions at each relative load, the authors observed that moderate-volume group showed a significant increase for the snatch, clean & jerk, and squat exercises (6.1, 3.7, and 4.2%, respectively, $p<.01$), whereas in the low-volume group and high-volume group, the increase took place only with the clean & jerk exercise (3.7 and 3%, respectively, $p<.05$) and the squat exercise (4.6%, $p<.05$, and 4.8%, $p<.01$, respectively). The increase in the snatch exercise for the moderate-volume group was significantly higher than in the low-volume group ($p=.015$). The study's (48) results showed higher strength gains in the moderate-volume group than in the high-volume group or low-volume group. There were no significant differences between the low-volume group and high-volume group training volume-induced strength gains (48). These findings are consistent with Faigenbaum et al. (43) conclusions: muscular strength and muscular endurance can be enhanced in untrained pre-pubertal boys and girls and favour the prescription of higher repetition–moderate load resistance training programs during the initial adaptation period"(43). That study's results shows that in 1RM leg extension strength a significant increase was observed in both Low-Repetition-High-Load Group (+31.0%) and High-Repetition-Moderate-Load Group (+40.9%) compared with controls. In leg extension muscular endurance both Low-Repetition-High-Load Group and High-Repetition-Moderate-Load Group significantly increased compared with controls, although gains resulting from High-Repetition-Moderate-Load Group (13.1±6.2 repetitions) were significantly greater than those resulting from Low-Repetition-High-Load Group (8.7±2.9 repetitions). In chest press 1-RM strength and chest press muscular endurance tests only the High-Repetition-Moderate-Load Group made gains (16.3% and 5.2±3.6 repetitions, respectively) than gains in the CG (43). More recently, another study (38) in untrained children who began resistance training, confirmed this thesis. Study's results (38) favour the prescription of a higher RM training range (1 set of 15-20 RM): both Low-Repetition-Maximum Group and High-Repetition-Maximum Group made significant gains on 1 RM-strength (21% and 23%, respectively), however, only the High-Repetition-Maximum Group made significantly greater gains (42%) on 15 RM local muscular endurance test (38).

Nevertheless future longstanding studies are necessary to evaluate the effects of different combination of sets and repetitions on performance measures in non-adult (38).

Training mode

Different modes such as medicine balls (19,36,47,104), weighted bags (104), exercise machines (41,38,39,43,47,48,52,71,133), dumbbells (19,52,73,104) or elastic bands/tubing (19,73,104) have been used successfully on strength training development of both trained and untrained or pre- and pubescent boys and girls. We didn't find any study that has been specifically compared the effect of different modes on strength training development.

Sport-specific training improvements

School-based strength training programs seems to be effective on greater sport-specific training improvements, even in trained adolescents male. The addition of resistance training program to soccer training greatly improved maximal strength of the upper and the lower body (1RM bench press and 1RM leg press, squat jump), vertical jump height, and 30-m speed, than soccer training alone (17). Conversely, Bogdanis et al. (12) observed similar improvement magnitude in either specialized basketball training group or mixed basketball plus conditioning training group on peak and mean anaerobic power and anaerobic capacity as well as in trunk muscle endurance. Despite that, arms endurance was improved significantly more in mixed basketball plus conditioning training group (50±11%) compared to specialized basketball training group (11±14%, p<.05). Because circuit training was also performed in each session of the mixed basketball plus conditioning training group, the authors established the duration of the fundamental skills, individual work, team work and offensive/defensive co-operations among players was 20-40% shorter in this group comparing with specialized basketball training group. Thus, this difference can explain the similar improvement magnitude observed in each group at the end of experimental period. Also the adaptation to initial training plan, which was changed after athletes have been complained, can explain that similitude. More recently, Szymanski et al. (116) found that a medicine ball training programme performed additionally to a stepwise periodized resistance training programme with bat swings provided greater sport-specific training improvements in torso rotational and sequential hip-torso-arm rotational strength for high school pubescent male baseball players. Short-term plyometric training programmes (different plyometric exercises including jumping, hurdling and skipping) additionally to their soccer training resulted in increased athletic performances in prepubescent trained boys (21). It appears that, also in an aquatic environment, strength training can enhance sports performance. Thus, eight weeks of combined dry land strength and aerobic swimming training in young competitive swimmers suggests that although cannot be clearly assumed that strength training provides an improvement in swimming performance, a tendency to progress sprint performance due to strength training was noticed (47).

Plyometric training effects

Using a combination of dynamic constant external resistance and plyometric drills on pre- and early pubescent untrained boys, it was concluded that upper and lower body complex training is a time-effective training mode that confers small improvements in anaerobic power and jumping, throwing and sprinting performance, and marked improvements in dynamic strength (55,62,86). Lephart et al. (69) investigated the effects of plyometric and basic resistance training programs on neuromuscular and biomechanical characteristics in female athletes and concluded that basic resistance training alone induced favourable neuromuscular and biomechanical changes in high school female athletes; and plyometric program may further be utilized to improve muscular activation patterns. These findings must be taken with caution since study was developed in athlete's sample and no control group was used. Faigenbaum et al. (35) specifically compared the effects of combined plyometric and resistance training or resistance training alone on fitness performance. Performing plyometric training additionally to a resistance training program may be more beneficial than resistance training for enhancing upper and lower body power (vertical jump, long jump, 9.1m sprint, ball toss) in untrained boys.

Concurrent resistance and aerobic training

Adaptations as consequence of training process are highly dependent on the specific type of training implemented (14,136). Aerobic training generally encompasses exercise volume of several minutes up to some hours at many exercise intensities, increasing the ability to sustain repetitive high-intensity, low-resistance exercise with minimal fatigue accumulation and minimal performance loss (13,88). Strength training encompasses short-duration activities at high exercise intensities, and increases the capacity to perform high-intensity, high-resistance exercise of a single or relatively few repetitions, and throwing events in school or sports field (88,137).

Many researchers have rationalised that concurrent training promotes the benefits of both strength and aerobic training (1). Nevertheless an inhibition in strength or aerobic adaptation as a consequence of concurrent training has been reported (125). Sale et al. (100) observed that concurrent strength and aerobic training applied on different 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. Briefly, the literature researches do not demonstrate the universality of the interference effect in strength development when resistance training is performed concurrently with aerobic training (103).

In the present analysis we did not considered studies which have investigated strength training concurrently to subject's sports workouts. The results and conclusion of those studies were analysed before in this article. Thus we only considered researches which have been investigated the concurrent resistance and aerobic training in untrained youth.

Concurrent resistance and aerobic training has been demonstrated to be effective even in short periods of strength training as 10 to 15 minutes for untrained adolescents of both genders. Assuming that Physical Education is mainly aerobic, subjects who participated in medicine ball training program during the first 10 - 15 minutes of each Physical Education class have significantly ($p<.05$) greater gains in the shuttle run, long jump, sit and reach flexibility, medicine ball abdominal curl, medicine ball push up and medicine ball toss as compared to the subjects who participated in Physical Education lessons but not medicine ball training (36).

Subjects who concurrently trained manual resistance and aerobic training in every Physical Education class have showed significant improvements in one-mile run ($p<.002$) and trunk lift ($p<.0001$) measures from 0-9 and 9-18 wks compared with subjects who were evolved in a strength training only program (24). Concurrent training seems to be effective also in pre-pubescent boys and girls. Cowan and Foster (19) observed significant improvements in one-mile run push up and curl up scores for both genders after a concurrent strength and aerobic training period.

Thus we can assume that concurrent strength and aerobic training not only does not impair strength neither aerobic development as seems to be an effective, well-rounded exercise program that can be used as a means to improve initial or general strength in youth.

Detraining effects

Interruptions in a training process because of illness, injury, holidays, post-season break or other factors are normal situations in numerous kinds of sport (41,36,40) and in school context as well. The extent of performance decrease may depend upon the length of the period recess in addition to training levels and performance attained by the subjects (78). Nevertheless, information about the changes in strength training-induced strength gains during detraining in pre adolescents it is still scarce (117) and insufficient studies (10,41) have investigated the effects of detraining with an inclusion of a control group to control for growth-related rises in muscular strength.

The maintenance of upper and lower body muscular strength improvements such as 1RM, muscular endurance (20) or power (21) were observed in pubescent trained boys after 8 weeks (21) or 12 weeks (20) period of reduced strength training.

At the end of 8 weeks of detraining (absolute training cessation), Faigenbaum et al. (41) observed that pre-pubescent untrained boys and girls, had significant loss 6RM leg extension (-28.1 %) and chest press (-19.3%) strength. Lower limbs muscular strength loss was made mainly during the first 4 weeks of detraining (6RM extension: -21.3%) while upper limb muscular strength loss was about half during the first 4 weeks (chest press: -8.9%) and albeit exercise group values remained significantly higher than control group values. Nevertheless, at end of the 8-week detraining period, the chest press but not leg extension strength of the subjects who have strength trained remained significantly greater than controls. Concordantly, in pre- and early pubertal untrained males the same trend can be found (117). After 8 weeks of detraining, Tsolakis et al. (117) fount that the trained subjects' strength (concentric strength of the elbow flexion in the right arm, assessed by an upper extremity dynamometer; and 10RM elbow flexion with adjustable dumbbells) decreased significantly by 9.5%, converging toward the control values. The weak degree of the initial strength gain and the detraining extent could partly explain the reversible response of strength (10). Nevertheless, despite that observed strength loss, the treatment group maintained about by 64% of the strength gained during training program, probably due to the high intensity of the training program (63), which is an important factor related to the magnitude of the improvement of the muscular strength (11).

In this line, the benefits of upper and lower body training (in pre- and early pubertal boys) are lost at similar rates to other training modalities at the end of 12 weeks of training recess (55).

Conversely, in pre- and early pubertal boys and girls swimmers, it was observed that at the end of 6 weeks of detraining period strength parameters remained stable and swimming performance still improved (47), however all the swimmers maintained the normal swimming program, without any strength training. Thus, this study cannot be compared with previous since subjects of treatment and controls continued on their usual swimming training and thereby recess effects can be biased by swimming training.

Discussion

Despite of consensus exists from The British Association of Sport & Exercise Science, (113), The American Academy of Pediatrics (2), The American College of Sports Medicine (4,27), and the National Strength and Conditioning Association (41), with other recommendations summarized by Faigenbaum et al. (40), Fulton *et al.* (46) and Twisk (119), that resistance training since appropriately designed and supervised by expert personnel is beneficial to children and adolescents' athletic performance, health and fitness, there is a scarcity of robustly designed studies investigating the main factors which determine concurrent strength and endurance training gains and detraining effect (school based) in untrained children and adolescents. Muscular strength has been recognized as an important component of fitness in the recent evidence-based physical activity guidelines for school-age youth (114). Despite there is clear data in adults (65) to support these positions, evidence-based data in children and adolescents is limited. However, available data suggest that well-designed and supervised resistance training programmes may have beneficial health outcomes associated with aerobic fitness (27,113) and it would be improvident to ignore those findings while the depth of evidence in non-adult population is being established.

Our findings are important to increase de effectiveness of endurance and strength training design of untrained children and adolescents in school context.

Aerobic training has been widely used in health related fitness training studies but researches which have specifically investigated the better load components or school-based programmes design to develop endurance training in untrained children and adolescents are scarce. In our systematic search we could find that VO_2max can increase in pre- pubescent and post-pubescent children after an aerobic training programme and that such an increase is of the same order in both genders when the initial aerobic fitness is taken into account. Comparing with untrained youth, their trained counterparts had a higher cardiac performance in ergometers' tests, and this reached significance in pubertal and post-pubertal girls. There is no consensus regarding to VO_2max related gender improvements differences in pre- and early pubescent subjects. In adolescents, it seems that males increase aerobic capacity more than their age-counterparts. The usage of different modes, intensities, durations (session and program) and objectives of the programmes makes difficult the results comparisons (n=19 studies). Nevertheless, it was found that the training program resulted in VO_2max raise. Thus, more studies are needed to clarify what is the best school-based program's methodology on endurance training in paediatric population.

When we considered the studies which have investigated strength training alone, we found that prepubescent to early post-pubescent boys and girls who participate in a resistance training programme can significantly raise upper and lower body strength performance, enhance flexibility and improve body composition as well. Different training modes are effective on strength training development of both trained and untrained or pre- and pubescent boys and girls. Moreover, performing resistance training a minimum of 10-15 minutes twice a week, at a moderate volume is more effective and efficient than performing at a higher volume. This is particularly important for school context since usual available training resources do not allow the usage of high strength loads. When considering gender effect, males seem to have greater strength improvements then females.

In concurrent strength and aerobic training analysis we only considered the research that has been investigated the concurrent strength and aerobic endurance training in untrained youth. Concurrent training seems to be effective in pre-pubescent and post pubescent boys and girls. It can be assumed that concurrent strength and endurance training not only does not impair strength or endurance development as seems to be an effective, well-rounded exercise program that can be used as a means to improve initial or general strength in youth.

At last, studies that have been properly investigated the changes in resistance training-induced strength gains during detraining in pre adolescents are still scarce and insufficient. Different results have been found on detraining effect over subject's strength gains.

This study is consistant with previous studies which highlight the role of school as the primary institution in physical fitness promoter.

Study two - The effects of school-based strength training and concurrent strength aerobic training programs on untrained boys.

The purpose of this study was to analyze the effects of power training alone and combined strength and aerobic training on body composition, power strength and aerobic training on a sample of healthy untrained school boys.

Methods

Experimental Approach to the Problem

Forty-two healthy boys recruited from a Portuguese public high school were randomly assigned into two experimental groups (8 weeks training program, twice a week, from April 13th to June 5th of 2009) and one control group as follows: one group performing strength training only (GR: n=15); another group performing combined strength and aerobic training (GCOM: n=15); and the third was the control group (GC: n=12; without a training program). All sample subjects attended physical education classes twice a week, with duration of 45 min and 90 min each class respectively. Typical physical education classes included various sports (gymnastics, team sports, athletics, dancing, and adventure sports, among others) with a clear pedagogical focus. As such, according to other researchers (110) 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. (73). Usually, these classes start with jogging run lasting 10 min to general warm up; proceed to joint mobilization and general stretches. After that the class is divided into 2 or 3 proficiency level groups to start the main activities/sports of the class, which can be a drill or a game organized in small groups. In Portugal, a physical education class has a set of 45 min and another of 90 min twice a week.

The training program was implemented additionally to physical education classes in the same outdoor sportive facility. After a 10 min warm up period, both experimental groups were submitted to a power strength training program composed by: 1 and 3 kg medicine balls throws performed as long and fast as possible; jumps onto a box (from 0.4 m to 0.6 m of height); plyometric jumps above 0.4-0.6m of height hurdle (only one foot touch on the floor among hurdles) and sets of 30 to 40m speed running. The GCOM group was complementarily administered a 20m shuttle run training exercise (66), which occurred immediately after the power strength training session. This endurance task 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 test in order to readjust the volume and intensity of the 20m shuttle run exercise. Both GR and GCOM trained on the same day of the week (with two/three days between training sessions) and at the same morning hour. Subjects were encouraged to hydrate before and at the middle of training session. All participants were familiarised with powerful drills (sprints, jumps and ball throws) as well as with the 20m shuttle run protocol. Throughout pre- and experimental periods, the subjects reported their non-involvement in additional regular exercise programs for developing or maintaining strength and aerobic performance besides institutional regular physical education classes. The same training protocol design was followed in study three. A more detailed analysis of the program can be found in table 1.

Sample groups were assessed for upper and lower body strength (overhead medicine ball throwing and counter movement horizontal and vertical jumps, respectively), running speed (20m sprint run) and VO_2max (20m shuttle run test) before and after 8-weeks of training program. Each subject was familiarised with power training tests (sprints, jumps and ball throws) as well as with the 20m shuttle run test. All data collection was performed by the same investigator and after a general warm-up of 10 minutes.

Table 1 - Training program design.

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

Legend: for the Medicine Ball Throwing and Jump onto box the 1st no. corresponds to sets and 2nd corresponds to repetitions. For Sprint Running 1st number corresponds to sets and 2nd 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).

Subjects

A sample of 42 healthy boys recruited from a Portuguese public high school (from 7th and 9th grades) was used in this study. To fulfill the ethical procedures of the Helsinki statement, an informed consent was obtained prior to all testing adolescents' parents. Efforts were made to recruit subjects for making comparable groups. Maturity level based on Tanner stages (42) was self-assessed: 51% were in Tanner Stage One and 49% were and Tanner Stage Two. There were no significant differences ($p>0.05$) between groups for age or Tanner ratings, neither in anthropometrics or performances variables at the beginning of the protocol. No subject had regularly participated in any form of strength training prior to this experiment. The following exclusion criteria were used: subjects with a chronic paediatric disease or with an orthopaedic limitation.

Testing Procedures

Assessment procedures protocol used in this study was the same used in study three, four and five.

Anthropometric assessment

Total height (m) was assessed according to international standards for anthropometric assessment (77), with a Seca 264 Stadiometer (Hamburg, Deutschland). Body composition variables were assessed using a Tanita body composition analyser; model TBF-300 (Tanita Corporation of America, Inc, Arlington Heights, IL. USA) with a range of ratio of 1%-75%. These 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 test 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 a familiarization session and was counseled on proper overhead throwing with different weighted balls. Pre, posttests and detraining measurements were conducted on maximal throwing velocity using medicine balls (Bhalla International - Vinex Sports, Meerut - India) weighing 1kg (Vinex, model VMB-001R, perimeter 0.72m) and 3kg (Vinex, model VMB-003R, perimeter 0.78m). A general warm-up period of 10 min, which included throwing the 1- and 3kg weighted balls, was allowed. While standing, subjects held medicine balls with 1 and 3kg in both hands in front of the body with arms extended. The students were instructed to throw the ball over their heads as far and as fast as possible. A counter movement was allowed during the action. One-minute of rest among 5 trials was done. Only the best throw was considered for analysis. The ball throwing distance (BTd) was recorded to the closest cm as proposed by van Den Tillaar & Marques (122). This was possible as polyvinyl chloride medicine balls were used and when it falls on the Copolymer Polypropylene floor a visible mark was made. The ICC of data for 1kg and 3 kg medicine ball throwing was 0.97 and 0.99, respectively.

Counter movement Vertical Jump (CMVJ)

To monitor the effectiveness of an athlete's conditioning program, the standing vertical jump test of leg power was used. The vertical jump test was conducted on a contact mat connected to an electronic power timer, control box and handset (Globus Ergojump, Codognè, Italy). From a standing position, with the feet shoulder-width apart and the hands placed on the pelvic girth, the boys performed a counter movement with the legs before jumping. Such movement makes use of the stretch-shorten cycle, where the muscles are pre-stretched before shortening in the desired direction (72). They were informed that they should try to jump vertically as high as possible. Each participant performed three jumps with a 1-min recovery between attempts. The highest jump (cm) was recorded. The counter movement vertical jump has shown an ICC of 0.95.

Counter movement Standing Long Jump (CMSLJ)

In a standing long jump the jumper aimed to project his body for maximum horizontal distance beyond a take-off line. The jumper started from a static standing position with feet shoulder-width apart and then generated a large take-off speed by using a counter movement coupled with the hands placed on the pelvic girth and a double-leg take-off. The take-off is characterised by a large forward lean of the body, and during the flight phase the jumper swings the legs forward underneath the body in preparation for landing. The jumper landed with a prominent forward lean of the trunk and with the feet extended well ahead of the hips. To be credited with a successful jump the jumper must retain balance after landing and not fall backwards into the pit. A standing long jump performance was quantified by the total jump distance, which is the distance from the take-off line to the nearest break in the landing area made by the heels at landing (126). A fiberglass tape measure (Vinex, MST-50M, Meerut, India) was extended across the floor and used to measure horizontal distance. Each participant completed three trials with a 1-min recovery between trials using a standardized jumping protocol to reduce inter-individual variability. The greatest distance (cm) of the two jumps was taken as the test score. The CMSLJ has shown an ICC of 0.96.

Sprint Running

This test was performed in an indoor school physical education facility with a Copolymer Polypropylene floor; subjects wore adapted indoor shoes. Time to run 20m was obtained using photocells (Brower Timing System, Fairlee, Vermont, USA). 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. At the start moment each subject trod the cell pad using the right hand with the time being recorded from when the subjects intercepted the photocell beam. 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 taken to cover the 20 m distance in the sprint test was used in data analysis. A rest period of 10 min among attempts was accomplished. The sprint running (time) has shown an ICC of 0.97.

20 Meters Shuttle Run (VO_2max)

This test involves continuous running between two lines (20m apart in time) to recorded beeps. The time between recorded beeps decreased each minute (level). We used the common version with an initial running velocity of 8.5 km/h, and increments of 0.5 km/h each minute (66). Estimated VO_{2max} ($ml.kg^{-1}.min^{-1}$) was calculated by the Léger's equation (66), which is based on the level and number of shuttles reached before boys were unable to keep up with the audio recording. The 20m Shuttle Run test has shown an ICC of 0.96.

Statistical analyses

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

Results

There were no significant differences ($p>0.05$) between groups for age or Tanner stages, neither in anthropometrics or performances variables at the beginning of the protocol ($p>0.05$). Body fat (BF) decreased significantly ($p=0.00$) from pre - to the post-training period in both GR and GCOM groups (Table 2); however, no significant differences were found between groups. No significant changes were observed for total standing height, body weight and body mass index (BMI) in both GC and GCOM groups. GR significantly changed in height (+1.2%, p=0.004), BMI (-0.4%, p=0.00) and body fat (-10%, p=0.00) whereas GCOM only decreased in body fat, but not significantly different from GR. From pre- to the post-training period no differences were observed between experimental groups for performance variables, i.e., subjects from GCOM group did not take advantage over subjects from GR group in jumps, running speed and balls throws tests. However, VO_2max increased significantly in GCOM (+4.6%, p<0.01), but remained unchanged in both GC and GR groups. The magnitude of changes in 1Kg and 3kg ball throw distance, height in CMVJ, length in CMSLJ and time to run 20 m was similar in both GR and GCOM groups (Table 3).

Table 2 - Descriptive (mean ± standard deviation) characteristics of the participants during three testing trials (M1 and M2) for all groups.

Variable	Group	M1 x±sd	M2 x±sd	*p* value (M1-M2)
Body Weight (kg)	GC	56,5±11,2	56,9±11,0	0,22
	GR	59,2±16,2	58,3±16,0	0,11
	GCOM	51,4± 8,2	51,3± 8,2	0,85
Total Standing Height (cm)	GC	163,8± 9,9	164,5± 9,8	0,06
	GR	161,8±12,2	163,6±11,5	0,00†
	GCOM	159,5± 8,1	160,2± 8,0	0,09
BMI ($kg.m^{-2}$)	GC	21,0± 3,4	21,0± 3,6	0,74
	GR	22,3± 4,6	21,6± 4,7	0,00†
	GCOM	20,1± 2,1	19,9± 2,3	0,22
Body Fat (%)	GC	15,0± 6,4	14,1± 7,1	0,11
	GR	18,2± 9,2	15,8± 8,4	0,00†
	GCOM	14,5± 4,6	12,7± 4,6	0,00†

Legend: x – mean; sd- standard deviation; M1 – before training program; M2 – After training program; p(M1-M2)- *p* value for comparison between 2nd and 1st moment; GC – Control Group, GR – resistance training group, GCOM - concurrent resistance and endurance training, † - significant changes between moments.

Table 3 – Mean ± standard deviation of CMVJ, CMSLJ, 1 and 3kg Medicine Ball Throwing, Running Speed and VO_2Max at all three test trials (M1 and M2) for each group.

	Group	M1 x±sd	M2 x±sd	*p* value (M1-M2)
CM Vertical Jump (cm)	GC	0,288±0,07	0,317±0,07	0,15
	GR	0,293±0,07	0,306±0,07	0,04†
	GCOM	0,298±0,08	0,316±0,09	0,02†
CM Standing Long Jump (m)	GC	1,70±0,37	1,63±0,33	0,26
	GR	1,49±0,27	1,56±0,30	0,00†
	GCOM	1,67±0,31	1,74±0,32	0,00†
1kg Medicine ball throwing (m)	GC	8,23±1,47	8,31±1,71	0,08
	GR	7,50±1,70	8,15±1,62	0,00†
	GCOM	7,26±1,60	7,59±1,73	0,04†
3kg Medicine ball throwing (m)	GC	5,02±0,91	5,01±1,19	0,10
	GR	4,66±0,98	5,12±1,08	0,00†
	GCOM	4,60±1,12	5,11±1,17	0,04†
Running Speed 20m (s)	GC	4,13±0,55	4,12±0,48	0,95
	GR	4,54±0,49	4,05±0,42Ŧ	0,00†
	GCOM	4,38±0,59	3,81±0,28	0,00†
VO_2Max ($mL.kg^{-1}.min^{-1}$)	GC	48,5±5,3	47,4±5,5	0,67
	GR	45,2±6,4	46,8±6,5	0,10
	GCOM	49,1±6,7	51,2±6,7	0,01†

Legend: x – mean; sd- standard deviation; CM – counter movement; M1 – before training program; M2 – After training program; *p* (M1-M2) - *p* value for comparison between 2^{nd} and 1^{st} moment, GC – Control Group, GR – resistance training group, GCOM - concurrent resistance and endurance training, Ŧ - Significant changes between GC and GR, † - significant changes between moments.

Discussion

To our best knowledge, no study prior to ours has established the effect of 8-weeks school based strength training and aerobic program and detraining on strength, power and body composition in adolescent boys, 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 primary findings of the present study indicate that both concurrent strength and aerobic training and strength raining alone may be a positive training stimulus to enhance explosive strength and aerobic condition in healthy schooled boys. Ours findings are in agreement with previous Gorostiaga et al. (50) and Chtara et al. (18) studies conducted with adults. Simultaneously our results contradict studies, which reported an impairment of concurrent training on performance variables development (107). Additionally, both training regimens also showed a positive effect on body fat loss in adolescent school boys. Therefore, the present results may suggest that concurrent strength and aerobic 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 boys. Concordantly the group submitted to strength and endurance program did not show estimated VO_2max loss in the detraining period.

The magnitude of decrease observed in BF was not significantly different between GR and GCOM groups. We did not find any change in body weight for any group. It should be highlighted that body weight does not always explain the true body composition and therefore, despite we did not find body weight changes, we found body fat significant losses in both experimental groups. However, we did not find significant differences between experimental groups. These results may suggest that there is no major positive effect of concurrent resistance and endurance training when body fat loss occurs. Furthermore, the current results are in agreement with the research conducted by Watts et al. (127) that examined an independent influence of 8 weeks of combined resistance and aerobic training in 19 obese adolescents aged 12–16 year olds. On this, although bodyweight and BMI did not change with exercise, significant improvements in central adiposity were observed following the 8-week circuit-training program (127).

A significant increasing was observed for upper limb explosive strength (e.g. medicine ball throw with 1kg and 3kg), in both GCOM and GR groups. This data may suggest a positive main effect of resistance training on explosive strength ability independently of type of treatment performed. In accordance to the upper body strength results, the explosive power of lower limbs revealed by the CMVJ and CMSLJ performance also increased significantly for both experimental groups. Few studies, however, have compared the effects of different methods of organizing training workouts. Here, for example, Sale et al. (100) could observe that concurrent strength and aerobic training applied on separate days produced superior gains to those produced by concurrent training on the same day. Although the training programs were held otherwise constant, alternate-day training was more efficient 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. Also Ingle et al. (55) using a combination of strength training and plyometric program, found the experimental group saw a small improvement in performance over the training intervention period. Our results also demonstrated that the aerobic training does not positively affect strength development in school boys. In addition, however, the present research showed that concurrent resistance and endurance training does not impair strength development.

Unfortunately, it is difficult to compare results in the scientific literature when studies differ markedly in their design factors including load characteristics, context, equipment, scheduling of training sessions and training history of subjects (70,124). 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 (100).

Running speed increased significantly in all experimental groups. In agreement with previous studies (78), these results seem to indicate that additional endurance training does not have an additional effect over strength training to enhance running speed in young boys. 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.

An inhibition in strength or aerobic adaptations as a consequence of concurrent training has been reported (124). Nevertheless, the present study could observe a significant enhancement in VO_2max ($ml.kg^{-1}.min^{-1}$) only for GCOM, suggesting that the strength training program component was not effective to a rising in aerobic fitness for young school boys. 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.

Conclusions

Our results suggest that a concurrent strength and aerobic school-based training program seems considerably effective on both strength and endurance fitness feature of age-school boys. However, the strength training program also produced identical results on strength development. In brief, the present study indicates that performing simultaneously strength and aerobic training in the same workout not only does not impair strength development in healthy school boys but also seems to be an effective, well-rounded exercise program that can be prescribed as a means to improve initial or general strength. This should be considered in designing strength training school-based programs in order to improve its efficiency.

Future researches must examine the interference effects arising from the order of strength and aerobic training exercises program for strength enhancement.

Study three - The effects of school-based strength training and concurrent strength and aerobic training programs on untrained girls.

The main purpose of the current study was to analyze the effects of strength training alone, or combined strength and aerobic training on body composition, strength and cardiovascular markers on a sample of healthy schoolgirls.

Methods

Experimental Approach to the Problem

Sixty-seven healthy girls (13.5±1.03 years old) recruited from a Portuguese public high school were divided into two experimental groups (8 weeks training program, twice a week, from April 12th to June 4th of 2010) 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). Experimental approach details, assessment and training's protocol are the same used in study two.

Subjects

A sample of 67 healthy girls recruited from a Portuguese public high school (from 7th and 9th grades) was used in this study. To fulfill the ethical procedures of the Helsinki statement (132), 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 (25) was self-assessed: 48% were in Tanner Stage One and 52% were and Tanner Stage Two. 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.

Statistical analyses

Statistical analysis used in this study was the same as used in study two.

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 4). 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 5). 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.

Table 4 - Descriptive (mean ± standard deviation) characteristics of the participants during three testing trials (M1 and M2) for all groups.

Variable	Group	M1 x±sd	M2 x±sd	*p* value (M1-M2)
Body Weight (kg)	GC	51,5±11,1	53,9±12,7	0,39
	GR	58,9±13,5	59,0±14,1	0,95
	GCOM	54,8±17,1	54,5±18,0	0,64
Total Standing Height (cm)	GC	156,8±6,5	158,3±6,9	0,06
	GR	159,4±6,1	159,4±6,0	0,14
	GCOM	157,9±8,2	158,0±7,8	0,79
BMI ($kg.m^{-2}$)	GC	20,9±4,0	21,6±4,7	0,68
	GR	23,0±4,1	23,0±4,5	0,35
	GCOM	21,6±5,3	21,6±5,4	0,24
Body Fat (%)	GC	24,34±6,5	24,29±7,8₮	0,01†
	GR	32,14±7,7	30,16±8,2	0,00†
	GCOM	26,79±9,9	24,23±10,4¥	0,00†

Legend: x – mean; sd- standard deviation; M1 – before training program; M2 – After training program; p(M1-M2)- *p* value for comparison between 2nd and 1st 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; † - significant changes between moments.

Table 5 - Mean ± standard deviation of CMVJ, CMSLJ, 1 and 3kg Medicine Ball Throwing, Running Speed and VO_2Max at all three testing trials (M1 and M2) for each group.

Variable	Group	M1 x±sd	M2 x±sd	*p* value (M1-M2)
1Kg Medicine ball throwing (m)	GC	5,91±0,83	5,76±0,57	0,29
	GR	6,43±1,26	6,80±1,34₮	0,08
	GCOM	6,14±1,00	6,67±1,16‡	0,00†
3Kg Medicine ball throwing (m)	GC	3,79±0,50	3,76±0,43	0,37
	GR	3,93±0,73	4,29±0,74₮	0,01†
	GCOM	3,89±0,64	4,25±0,73‡	0,00†
CM Vertical Jump (cm)	GC	0,26±0,07	0,26±0,06	0,13
	GR	0,25±0,06	0,27±0,07	0,01†
	GCOM	0,25±0,06	0,28±0,08	0,00†
CM Standing Long Jump (m)	GC	1,32±0,23	1,29±0,20	0,17
	GR	1,31±0,24	1, 32±0,26	0,04†
	GCOM	1,30±0,26	1,37±0,22	0,01†
Running Speed 20m (s)	GC	4,42±0,44	4,20±0,36	0,10
	GR	4,91±0,57	4,28±0,38	0,00†
	GCOM	4,80±0,53	4,25±0,34	0,00†
VO_2Max (mL.kg^{-1}.min^{-1})	GC	40,8±4,05	41,0±4,27	0,05†
	GR	39,2±4,29	40,7±3,98	0,13
	GCOM	42,5±4,37	43,7±4,09‡¥	0,01†

Legend: x – mean; sd- standard deviation; CM – counter movement; M1 – before training program; M2 – After training program; *p* (M1-M2) - *p* value for comparison between 2nd and 1st 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; † - significant changes between moments.

Discussion

The primary findings of the study showed that concurrent strength and aerobic training may be a positive training stimulus to induce power strength and aerobic fitness development and also showed a majorly positive effect on body fat loss in adolescent school girls. Therefore, the present results may suggest that concurrent strength and aerobic 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 (90). 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 (90). Furthermore, although the design of the training intervention of this study is different from the research conducted by Watts et al. (127), the current results are in agreement with their study results. Watts et al. (127) examined 19 obese adolescents aged 12–16 years independent influence of 8 weeks of concurrent 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 (135). 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 (135).

Upper body power (e.g. the medicine ball throws 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 knowledge, few studies have compared the effects of different methods of organising training workouts. For example, Sale et al. (100) 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 (106,56). 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 (127).

Running speed increased significantly in all experimental groups. These results seem to indicate that additional endurance training doesn't have an additional effect over strength training to enhance running speed in young girls. On the other hand, all students took part in various sports during Physical Education classes. Although physical education intensity can be considered low to moderate, some sports (for instance, soccer and basketball) bring 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 (1). The fact that an inhibition in strength or aerobic adaptations as a consequence of concurrent training has been reported (125). The present study, however, could observe a significant enhancement in VO_2max ($ml.kg^{-1}.min^{-1}$) for both GC and GCOM, suggesting that the aerobic 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 aerobic 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 aerobic development is observed. Clearly, the interaction between strength and aerobic 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.

Conclusions

Overall, our results suggest that concurrent strength and aerobic 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 aerobic 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. 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.

Study four - The effects of a detraining period on body composition and performance variables after school-based strength and concurrent strength and aerobic training programs on untrained boys.

The purpose of this study was to assess the effects of a detraining period on strength, power and aerobic performances as well as in body composition in boys.

Methods

Experimental Approach to the Problem

The same forty-two healthy boys recruited for study two were recruited for this study. The onset of this study was coincident with the ending of study two (study four lasted from 2009, 5th June to 2009, 28th August). Participants in all groups were asked to maintain normal eating and informal physical activity patterns over the duration of the study. This procedure was the same as Lubans et al. (73). Throughout detraining period, the subjects reported their non-involvement in formal exercise programs for developing or maintaining strength and aerobic performance.

Sample's groups were assessed for upper and lower body explosive strength (overhead medicine ball throwing and counter movement horizontal and vertical jumps, respectively), running speed (20m sprint run) and VO_2max (20m shuttle run test) after 12 weeks of study two had stopped. The DT period was coincident with the summer holidays. The assessment procedures and protocol were the same used in studies two and three and five. The testing assessment procedures were always conducted in the same indoor environment, at the same daily and weekly schedule. Each subject was familiarised with power training tests (sprints, jumps and ball throws) as well as with the 20m shuttle run test. All data collection was performed by the same investigator and after a general warm-up of 10 minutes.

Subjects

As we mentioned in the previous point the same forty-two healthy boys recruited for study two were recruited for this study. To fulfill the ethical procedures of the Helsinki statement, an informed consent was obtained prior to all testing adolescents' parents.

Testing Procedures

The assessment procedures and protocol were the same used in study two.

Statistical analyses

Standard statistical methods were used for the calculation of the means and standard deviations (x±sd). One-way analysis of variance (ANOVA) was used to determine any differences among the three groups' power strength, running speed, endurance, and anthropometry. The detraining related effects were assessed using a two-way ANOVA with repeated measures (groups x moment). The $p<0.05$ criterion was used for establishing statistical significance.

Results

Detraining period resulted in decreased body weight (-2.7%, p=0.03) for GCOM (table 6), whereas it remained constant for GR and GC groups. Body height increased significantly for GR (+0.6%, p=0.00) and GCOM (+0.7%, p=0.01). No significant changes were observed in BMI from post-training to detraining period in any group. No significant changes were observed in body fat loss in any of the experimental groups.

Table 6 - Descriptive (mean ± standard deviation) characteristics of the participants during three testing trials (M2 and M3) for all groups.

Variable	Group	M2 x±sd	M3 x±sd	*p* value (M2-M3)
Body Weight (kg)	GC	56,9±11,0	56,8± 4,9	0,14
	GR	58,3±16,0	58,9±16,7	0,28
	GCOM	51,3± 8,2	50,8± 7,3	0,03†
Total Standing Height (cm)	GC	164,5± 9,8	167,1±9,7	0,08
	GR	163,6±11,5	163,9±11,8	0,00†
	GCOM	160,2± 8,0	161,3± 7,9	0,01†
BMI ($kg.m^{-2}$)	GC	21,0± 3,6	20,6± 3,0	0,17
	GR	21,6± 4,7	22,0± 5,0	0,26
	GCOM	19,9± 2,3	20,3± 2,7	0,22
Body Fat (%)	GC	14,1± 7,1	12,8± 6,6	0,74
	GR	15,8± 8,4	17,0± 8,6	0,36
	GCOM	12,7± 4,6	12,5± 4,6	0,75

Legend: x – mean; sd- standard deviation; M2 – After training program; M3 – After detraining period; p(M2-M3) - *p* value for comparison between 3th and 2nd moment; GC – Control Group, GR – resistance training group, GCOM - concurrent resistance and endurance training; † - significant changes between moments.

No significant changes were observed in 1kg and 3kg medicine ball throw gains after the DT period in any groups (Table 7). No significant changes in vertical jump height, horizontal jump length, and time to run 20m after the DT period were observed after the detraining period (Table 7). Estimated VO_2max, however, decreased after the DT period in GR group (-6.8%, p=0.04) but not in GCOM. No significant differences were found between groups.

Table 7 - Mean ± standard deviation of CMVJ, CMSLJ, 1 and 3kg Medicine Ball Throwing, Running Speed and VO2Max at all three testing trials (M2 and M3) for each group.

	Group	M2 x±sd	M3 x±sd	*p* value (M2-M3)
CM Vertical Jump (cm)	GC	0,317±0,07	0,317±0,09	0,71
	GR	0,306±0,07	0,277±0,08	0,14
	GCOM	0,316±0,09	0,295±0,10	0,37
CM Standing Long Jump (m)	GC	1,63±0,33	1,62±0,51	0,72
	GR	1,56±0,30	1,47±0,36	0,17
	GCOM	1,74±0,32	1,54±0,43	0,12
1kg Medicine ball throwing (m)	GC	8,31±1,71	8,89±1,75	0,11
	GR	8,15±1,62	8,13±1,45	0,31
	GCOM	7,59±1,73	7,71±2,27	0,37
3kg Medicine ball throwing (m)	GC	5,01±1,19	5,35±1,30	0,15
	GR	5,12±1,08	5,10±0,99	0,29
	GCOM	5,11±1,17	5,03±1,25	0,97
Running Speed 20m (s)	GC	4,12±0,48	3,52±0,49	0,12
	GR	4,05±0,42₮	4,04±0,36	0,43
	GCOM	3,81±0,28	3,83±0,50	0,93
VO_2Max ($mL.kg^{-1}.min^{-1}$)	GC	47,40±5,5	44,4±8,1	0,52
	GR	46,80±6,5	42,1±5,2	0,04†
	GCOM	51,20±6,7	51,7±6,6	0,83

Legend: x – mean; sd- standard deviation; CM – counter movement; M2 – After training program; M3 – After detraining period; *p* (M2-M3) - *p* value for comparison between 3th and 2nd moment; GC – Control Group, GR – resistance training group, GCOM - concurrent resistance and endurance training, ₮ - Significant changes between GC and GR; † - significant changes between moments.

Discussion

Twelve consecutive weeks in summer holidays were taken as detrained period. All sample subjects had no formal physical activity (Physical Education lessons or institutional training programs) during DT period. The primary findings of the present study indicate that both training programs-regimens' effects persisted as long as upper and lower limb strength gains were kept during 12 weeks of the detraining period. Concordantly the group submitted to strength and endurance program did not show estimated VO_2max loss in detraining period.

Only the GCOM significantly decreased body weight (-1.7%, p=0.03). In Total Standing Height variable, both experimental groups had a significant increase from post-training to detraining moment. There was no significant difference in BMI on GR group from post-training to detraining moment. Additionally, there was no significant difference in BF percentage loss between GR and GCOM during the intervention period. Thus, we can assume that the sustainment of BF obtained with training programs participation is visible for several weeks after the programme has finished. Conversely to post-training moment, all groups had shown no significant loss performance on CMVJ and CMSLJ. In speed running a significant loss performance was expected but it was not found in both GR and GCOM. A possible loss was expected as speed running is strongly affected by nervous system adaptation and phosphocreatine reserves; however, it was not observed (45). In the 1 and 3 kg medicine ball throw distance test, no significant changes were observed for experimental groups, which mean a sustained effect of training in this explosive task. Our results are in disagreement with Ingle et al findings (55), which in a detraining 12-week period the experimental group saw reductions for all of the resistance exercises that ranged from -16.3 to -30.3%. The control group also had no differences in performance marks for both 1 and 3Kg medicine ball throw distance test. Therefore, it must be suggested that explosive strength gains induced by 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. (29) showed that 8 weeks of detraining led to significant losses of leg extension (-28.1 %) and chest press (-19.3%) strength whereas control group strength scores remained relatively unremarkable.

Finally, the VO_2max ($ml.kg^{-1}.min^{-1}$) remained stable for GCOM, except for GR where a significantly loss (-6.8%) was observed. Another study (83) found that changes are more moderate in recently trained subjects (compared with highly trained subjects) in the short-term, but recently acquired VO_2max gains are completely lost after training stoppage periods longer than 4 weeks. Conversely, our results show that GCOM kept VO_2max gains even after 12 weeks of DT. The detraining effect over VO_2max has been poorly studied in non-adult and non-sportive samples. Hence, due to the small sample size and the lack of a pre-study power analysis to determine adequate effect size for this study, we suggest that our subgroup analyses and results must be interpreted with caution.

Conclusions

Our results suggest that training program effects persists even at the end of detraining period. Those effects include body composition improvements, and physical fitness components as strength and aerobic capacities. School-based programs should be implemented since training programs' effects persist at the end of summer holidays on body composition and physical fitness level.

Study five - The effects of a detraining period on body composition and performance variables after school-based strength and concurrent strength and aerobic training programs on untrained girls.

The main purpose of the current study was to assess the effects of a detraining period on strength and aerobic performance of schoolgirls.

Methods

Experimental Approach to the Problem

The same sixty-seven healthy girls (13.5±1.03 yrs) recruited for study three were recruited for this study. The onset of this study was coincident with the ending of study three (study five lasted from 2010, 4th June to 2010, 27th August). Participants in all groups were asked to maintain normal eating and informal physical activity patterns over the duration of the study. This procedure was the same as Lubans et al. (73). Throughout detraining period, the subjects reported their non-involvement in formal exercise programs for developing or maintaining strength and endurance performance.

Sample groups were assessed for upper and lower body explosive strength (overhead medicine ball throwing and counter movement horizontal and vertical jumps, respectively), running speed (20m sprint run) and VO_2max (20m shuttle run test) after 12 weeks of study three had stopped. The DT period was coincident with the summer holidays. The assessment procedures and protocol were the same used in studies two, three and four. The testing assessment procedures were always conducted in the same indoor environment, at the same daily and weekly schedule. Each subject was familiarised with power training tests (sprints, jumps and ball throws) as well as with the 20m shuttle run test. All data collection was performed by the same investigator and after a general warm-up of 10 minutes.

Subjects

As we mentioned in previous point the same 67 healthy girls (from 7th and 9th grades) recruited for study three were recruited to this study. To fulfill the ethical procedures of the Helsinki statement, an informed consent was obtained prior to all testing adolescents' parents.

Testing Procedures

The assessment procedures and protocol were the same used in study three.

Statistical analyses

The same procedure as used in study four.

Results

The detraining period resulted in an increase in body weight (+1.6%, p<0.04) for GCOM (table 8), whereas remained constant for the GR and GC groups. Body height increased significantly for GR (+0.2%, p<0.03). 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 9). 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 detraining 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 8 - Descriptive (mean ± standard deviation) characteristics of the participants during three testing trials (M2 and M3) for all groups.

Variable	Group	M2 x±sd	M3 x±sd	*p* value (M2-M3)
Body Weight (kg)	GC	53,9±12,7	51,9±12,2	0,99
	GR	59,0±14,1	60,4±15,4	0,56
	GCOM	54,5±18,0	55,2±18,3	0,04†
Total Standing Height (cm)	GC	158,3±6,9	158,9±6,9	0,34
	GR	159,4±6,0	160,2±6,3	0,03†
	GCOM	158,0±7,8	158,2±7,9	0,07
BMI ($kg.m^{-2}$)	GC	21,6±4,7	20,9±4,9	0,65
	GR	23,0±4,5	23,2±5,4	0,62
	GCOM	21,6±5,4	21,8±5,6	0,12
Body Fat (%)	GC	24,29±7,8₮	22,42±8,8	0,79
	GR	30,16±8,2	31,53±8,6₮	0,30
	GCOM	24,23±10,4¥	25,34±11,1	0,30

Legend: x – mean; sd- standard deviation; M2 – After training program; M3 – After detraining period; p(M2-M3) - *p* value for comparison between 3th and 2nd 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; † - significant changes between moments.

Table 9 - Mean ± standard deviation of CMVJ, CMSLJ, 1 and 3kg Medicine Ball Throwing, Running Speed and VO_2Max at all three testing trials (M2 and M3) for each group.

Variable	Group	M2 x±sd	M3 x±sd	*p* value (M2-M3)
1Kg Medicine ball throwing (m)	GC	5,76±0,57	5,57±0,52	0,23
	GR	6,80±1,34₮	6,73±1,18₮	0,06
	GCOM	6,67±1,16‡	6,69±1,18‡	0,78
3Kg Medicine ball throwing (m)	GC	3,76±0,43	3,59±0,50	0,03†
	GR	4,29±0,74₮	4,67±1,34₮	0,23
	GCOM	4,25±0,73‡	4,25±0,74‡	0,49
CM Vertical Jump (cm)	GC	0,26±0,06	0,20±0,04	0,02†
	GR	0,27±0,07	0,26±0,06₮	0,02†
	GCOM	0,28±0,08	0,24±0,06‡	0,00†
CM Standing Long Jump (m)	GC	1,29±0,20	1,31±0,31	0,50
	GR	1, 32±0,26	1,27±0,29	0,23
	GCOM	1,37±0,22	1,31±0,30	0,05†
Running Speed 20m (s)	GC	4,20±0,36	4,25±0,36	0,03†
	GR	4,28±0,38	4,32±0,40	0,86
	GCOM	4,25±0,34	4,33±0,39	0,00†
VO_2Max ($mL.kg^{-1}.min^{-1}$)	GC	41,0±4,27	45,0±8,20	0,21
	GR	40,7±3,98	42,0±6,84	0,58
	GCOM	43,7±4,09‡¥	41,9±5,80	0,43

Legend: x – mean; sd- standard deviation; CM – counter movement; M2 – After training program; M3 – After detraining period; *p* (M2-M3) - *p* value for comparison between 3th and 2nd 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¸† - significant changes between moments.

Discussion

The detraining period coincided with the summer holidays (e.g. 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 (study three). 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 ($p<0.01$) performance during the detraining 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 detraining 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 ($ml.kg^{-1}.min^{-1}$) remained stable for all groups, except for GCOM where a significant loss (-4.3%) was observed. Mujika & 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 a period longer than 4 wks. Conversely, our results show that GCOM kept VO_2max gains even after 12 wks of DT.

Conclusions

Overall, our results suggest that the detraining period was not sufficient to reduce the overall training effects on body composition and performance variables.

Overall discussion

Aerobic training has been widely used in health related fitness training studies but researches which have been specifically investigated the better load components or school-based programmes design to develop endurance training in untrained children and adolescents are scarce. In our systematic search we could find that VO_2max can increase in children after an aerobic training programme and that such an increase is of the same order in both genders when the initial aerobic fitness is taken into account. Comparing with untrained youth, their trained counterparts had a higher aerobic performance in ergometers tests, and this reached significance in pubertal and post-pubertal girls. There is no consensus regarding to VO_2max related gender improvements differences in pre- and early pubescent subjects. In adolescent, it seems that male increase aerobic capacity more than their age-counterparts. The usage of different modes, intensities, durations (session and program) and objectives of the programmes makes difficult the results comparisons (n=19 studies). Nevertheless, it was found that training programme resulted in VO_2max raise. Thus, more studies are needed to clarify what is the best school-based program's methodology on aerobic training in paediatric population.

When we considered the studies which have investigated strength training alone, we found that prepubescent to early post-pubescent boys and girls who participate in a strength training programme can significantly raise upper and lower body strength performance, enhance flexibility and improve body composition as well. Different training modes are effective on strength training development of both trained and untrained or pre- and pubescent boys and girls. Moreover, performing resistance training a minimum of 10-15 minutes twice a week, at a moderate volume is more effective and efficient than performing at a higher volume. This is particularly important for school context since usual available training resources do not allow the usage of high strength loads. When considering gender effect, males seem to have greater strength improvements then females.

In concurrent strength and aerobic training analysis we only considered the research that has been investigated the concurrent strength and aerobic endurance training in untrained youth. Concurrent training seems to be effective in pre-pubescent and post pubescent boys and girls. It can be assumed that concurrent strength and endurance training not only does not impair strength or endurance development as seems to be an effective, well-rounded exercise program that can be used as a means to improve initial or general strength in youth.

At last, studies that have been properly investigated the changes in resistance training-induced strength gains during detraining in pre adolescents are still scarce and insufficient. Different results have been found on detraining effect over subject's strength gains. However, it can be assumed that even after a period as long as 3 month, strength and endurance gains can be observed in untrained early to post-pubescent boys and girls.

Ours study review is consistent with previous studies which highlight the role of school as the primary institution in physical fitness promoter.

Training effects

To our best knowledge, no other study has established the effect of 8-weeks school based endurance and resistance training program and detraining on strength, power and body composition in adolescent boys, 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 primary findings of the present study indicate that both concurrent resistance and endurance training and resistance training alone may be a positive training stimulus to enhance explosive strength and aerobic condition in healthy schooled boys and girls. Ours findings are in agreement with previous Gorostiaga et al. (50) and Chtara et al. (18) studies conducted with adults. Simultaneously our results contradict studies, which reported an impairment of concurrent training on performance variables development (107). Additionally, both training regimens also showed a positive effect on body fat loss in adolescent school boys and girls. Therefore, the present results may suggest that concurrent resistance 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 schoolboys. Moreover, both training programs regimens effects were persisted as long as upper and lower limb strength gains were kept during 12 weeks of detraining period. Concordantly the group submitted to strength and endurance program did not show estimated VO_2max loss in detraining period.

In girls, for 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 aerobic 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 (90). 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 (90). Furthermore, although the design of the training intervention of this study is different from research conducted by Watts et al. (127), the current results are in agreement with their study results. Watts et al. (127) 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 (135). 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 (135).

Contrarily to what was observed in girls, the magnitude of decrease observed in boy's BF was not significantly different between GR and GCOM groups. We did not find any change in body weight for any group. It should be highlighted that body weight does not always explains the true body composition and therefore, despite we did not find body weight changes, we found body fat significant losses in both experimental groups. However, we did not find significant differences between experimental groups. These results may suggest that there is no major positive effect of concurrent resistance and endurance training when body fat loss occurs. Furthermore, the current results are in agreement with the research conducted by Watts et al. (127) that examined an independent influence of 8 weeks of combined strength and aerobic training in 19 obese adolescents aged 12–16 year olds. On this, although bodyweight and BMI did not change with exercise, significant improvements in central adiposity were observed following the 8-week circuit-training program (127).

Girls' upper body 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 strength performance results, no matter with or without concurrent strength and aerobic 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 knowledge, few studies have compared the effects of different methods of organising training workouts. For example, Sale et al. (100) 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 aerobic training in schoolgirls. 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 (106;56). 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 (127).

A significant increasing was observed for males' upper limb explosive strength (e.g. medicine ball throw with 1kg and 3kg), in both GCOM and GR groups. This data may suggest a positive main effect of resistance training on explosive strength ability independently of type of treatment performed. In accordance to the upper body strength results, the explosive power of lower limbs revealed by the CMVJ and CMSLJ performance also increased significantly for both experimental groups. Few studies, however, have compared the effects of different methods of organizing training workouts. Here, for example, Sale et al. (100) could observe that concurrent resistance and endurance training applied on separate days produced superior gains to those produced by concurrent training on the same day. Although the training programs were held otherwise constant, alternate-day training was more efficient 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. Also Ingle et al. (55) using a combination of resistance training and plyometric program, found the experimental group saw a small improvement in performance over the training intervention period. Our results also demonstrated that the endurance training does not positively affect strength development in school boys. In addition, however, the present research showed that concurrent resistance and endurance training does not impair strength development.

Unfortunately, it is difficult to compare results in the scientific literature when studies differ markedly in their design factors including load characteristics, context, equipment, scheduling of training sessions and training history of subjects (70,124). 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 (100).

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

Boys' running speed increased significantly in all experimental groups. In agreement with previous studies (78), these results seem to indicate that additional endurance training has not an additional effect over strength training to enhance running speed in young boys. 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 (1). The fact that an inhibition in strength or endurance adaptation as a consequence of concurrent training has been reported (124). The present study, however, could observe a significant enhancement in girls' VO_2max ($ml.kg^{-1}.min^{-1}$) 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.

We could observe a significant enhancement in boys' VO_2max ($ml.kg^{-1}.min^{-1}$) only for GCOM, suggesting that the resistance training program component was not effective to a rising in aerobic fitness for young school boys. 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 effects

To our best knowledge, no other study has established the effect of an 8-week school based endurance and strength training program and detraining on dynamic muscular power 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 female 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.

Conversely to girls' GCOM, Boy's GCOM significantly decreased body weight (-1.7%, p=0.03). In Total Standing Height variable, both males' experimental groups had a significant increase from post-training to detraining moment. There was no significant difference in BMI on GR group from post-training to detraining moment. Additionally, there was no significant difference in BF percentage loss between GR and GCOM during the intervention period. Thus, we can assume that the sustainment of BF obtained with training programs participation is visible for several weeks after the programme has finished.

Regarding to CMVJ, all females' groups had shown a significant loss of performance trend (p<0.02). However, in CMSLJ only female GCOM had significantly reduced (p=0.00) performance during the detraining recess. This decrement was not surprising since GCOM had a higher increase (however not significantly different from GR) during the training period. Conversely to post-training moment, all boys' groups had shown no significant loss performance on CMVJ and CMSLJ.

In females' 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 boys' speed running a significant loss performance was expected but it was not found in both GR and GCOM.

In girls, for 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. (41) results show that the 8 weeks of detraining led to significant losses of leg extension (-28.1 %) and chest press (-19.3%) strength whereas the control group strength scores remained relatively similar.

In males' sample the 1 and 3 kg medicine ball throw distance test, no significant changes were observed for experimental groups, which mean a sustained effect of training in this explosive task. Our results are in disagreement with Ingle et al findings (55), which in a detraining 12-week period the experimental group saw reductions for all of the resistance exercises that ranged from -16.3 to -30.3%. Control group had also no differences in performance marks for both 1 and 3Kg medicine ball throw distance test. Therefore, it must be suggested that explosive strength gains induced by 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. (41) showed that 8 weeks of detraining led to significant losses of leg extension (-28.1%) and chest press (-19.3%) strength whereas control group strength scores remained relatively unremarkable.

Finally, the girls' VO_2max ($ml.kg^{-1}.min^{-1}$) remained stable for all groups, except for GCOM where a significant loss (-4.3%) was observed. Mujika & Padilla (83) 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.

Boys' VO_2max ($ml.kg^{-1}.min^{-1}$) remained stable for GCOM, except for GR where a significantly loss (-6.8%) was observed. Another study (107) found that changes are more moderate in recently trained subjects (compared with highly trained subjects) in the short-term, but recently acquired VO_2max gains are completely lost after training stoppage periods longer than 4 weeks. Conversely, ours results show that boys' GCOM kept VO_2max gains even after 12 weeks of DT. The detraining effect over VO_2max has been poorly studied in non-adult and non-sportive samples. Hence, due to the males' small sample size and the lack of a pre-study power analysis to determine adequate effect size for this study, we suggest that our subgroup analyses and results must be interpreted with caution.

Veracity of formulated hypotheses

The **Hypothesis 1** "school-based strength training is really effective on adolescent subjects for both genders" was confirmed. The **Hypothesis 2** "when trained alone, strength training does not produce significant higher muscular strength increases in boys when compared with results obtained after concurrent resistance and endurance training" and the **Hypothesis 3 "**when trained alone, strength training does not produce significant higher muscular power increases in girls when compared with results obtained after concurrent strength and aerobic training were also confirmed. The **Hypothesis 4** "when trained alone, strength training does not produce significant higher body composition improvements in boys when compared with results obtained after concurrent resistance and endurance training" was partially confirmed. Nevertheless, the **Hypothesis 5** "when trained alone, strength training does not produce significant higher body composition improvements in girls when compared with results obtained after concurrent resistance and aerobic training" was totally confirmed. The **Hypothesis 6** "concurrent resistance and aerobic training does not impair strength improvements in boys" and the **Hypothesis 7** "concurrent strength and aerobic training does not impair endurance improvements in girls" were also confirmed. The **Hypothesis 8** "Regarding concurrent training it is possible to observe improvements in both genders, and regarding to detraining both genders would keep improvements acquired during training process", the **Hypothesis 9 "**in boys, twelve weeks of detraining period are not sufficient to loss all training improvements resulted from training program" and the **Hypothesis 10 "**In girls, twelve weeks of detraining period are not sufficient to loss all training improvements resulted from training program" were partially confirmed.

Conclusions of the five studies

Study 1

Comparing with untrained youth, their trained counterparts had a higher aerobic performance in ergometers' tests, and this reached significance in pubertal and post-pubertal girls. There is no consensus regarding to VO_2max related gender improvements differences in pre- and early pubescent subjects. In adolescent, it seems that male increase aerobic capacity more than their age-counterparts.

When we considered the studies which have investigated strength training alone, we found that prepubescent to early post-pubescent boys and girls who participate in a resistance training programme can significantly raise upper and lower body strength performance, enhance flexibility and improve body composition as well. Different training modes are effective on strength training development of both trained and untrained or pre- and pubescent boys and girls. Moreover, performing resistance training a minimum of 10-15 minutes twice a week, at a moderate volume is more effective and efficient than performing at a higher volume.

Concurrent strength and aerobic training seems to be effective in pre-pubescent and post pubescent boys and girls. It can be assumed that concurrent strength and endurance training not only does not impair strength nor aerobic development as seems to be an effective, well-rounded exercise program that can be used as a means to improve initial or general strength in youth.

At last, studies that have been properly investigated the changes in resistance training-induced strength gains during detraining in pre adolescents are still scarce and insufficient. Different results have been found on detraining effect over subject's strength gains.

Study 2

Concurrent strength and aerobic school-based training program seems considerably effective on both strength and aerobic fitness feature of age-school boys. However, the strength-training program also produced identical results on strength development. Therefore, performing simultaneously resistance and endurance training in the same workout not only does not impair strength development in healthy school boys but also seems to be an effective, well-rounded exercise program that can be prescribed as a means to improve initial or general strength.

Study 3

Concurrent strength and aerobic school-based training programs seem to be more effective on both power strength and aerobic fitness feature of age-school girls. In agreement with the conclusion of study two, performing simultaneously strength and endurance training in the same workout does not impair strength development in young girls.

Study 4

Boys' training program effects persists even at the end of 12-wks detraining period. Those effects include body composition improvements, and physical fitness components as muscular power and aerobic fitness.

Study 5

Detraining period was not sufficient to reduce the overall training effects on girls' body composition and performance variables.

Overall Conclusion

Our results suggest that a concurrent strength and endurance school-based training program seems considerably effective on both strength and endurance fitness feature of age-school youth. 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 non-adult population. Moreover, performing simultaneously strength and endurance training in the same workout does not impair strength development in young subjects, which has important practical relevance for the construction of strength training in school-based programs. In other words, the present study indicates that concurrent training is an effective, well-rounded exercise program that can be performed to improve initial or general strength in healthy school subjects.

Our results also suggest that training program effects persists even at the end of detraining period. Those effects include body composition effects, and physical fitness components as strength and endurance. Future researches should examine the interference effects arising from the order of resistance and endurance training exercises program on strength enhancement.

Practical Applications

Performing simultaneously resistance and endurance training in the same workout not only does not impair strength development in healthy school children and adolescent but also seems to be an effective, well-rounded exercise program that can be prescribed as a means to improve initial or general strength. That should be considered in designing of strength training school-based programs in order to improve its efficiency. Furthermore, school-based programs should be implemented since training program effects persists at the end of summer holidays on body composition and physical fitness level.

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Appendices

Appendix A

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

by
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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_2max adaptations in a schooled group of adolescent girls. Methods: Sixty-seven healthy girls recruited from a Portuguese public high school (age: 13.5$\pm$1.03 years, from 7th and 9th 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_2max 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

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(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., 20100). 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 observed 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 un-trained 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 [1,2]	2x8	2x8	2x8	2x8	6x8	6x8
Chest 3 kg Medicine Ball Throw [1,2]	2x8	2x8	2x8	2x8		
Overhead 1kg Medicine Ball Throw [1,2]	2x8	2x8	2x8	2x8	6x8	6x8
Overhead 3kg Medicine Ball Throw [1,2]	2x8	2x8	2x8	2x8		
CMJ onto a box [1,2]	1x5	1x5	3x5	3x5	3x5	4x5
Plyometric Jumps above 3 hurdling[1,2]	5x4	5x4	5x4	5x4	2x3	2x3
Sprint Running (m)[1,2]	4x20m	4x20m	3x20m	3x20m	3x20m	3x20m
20m Shuttle Run (MAV)[2]	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 [1,2]						
Chest 3 kg Medicine Ball Throw [1,2]	2x5	2x5	3x5	3x5	3x5	2x5
Overhead 1kg Medicine Ball Throw [1,2]						
Overhead 3kg Medicine Ball Throw [1,2]	2x8	2x8	3x8	3x8	3x8	
CMJ onto a box [1,2]	4x5	5x5	5x5	5x5	5x5	4x5
Plyometric Jumps above 3 hurdling[1,2]	3x3	4x3	4x3	4x3	4x3	
Sprint Running (m)[1,2]	4x30m	4x30m	4x30m	4x30m	4x30m	3x40m
20m Shuttle Run (MAV)[2]	75%	TestM	75%	75%	75%	75%
Exercises	Session 13	Session 14	Session 15	Session 16		
Chest 1 kg Medicine Ball Throw [1,2]						
Chest 3 kg Medicine Ball Throw [1,2]	2x5	1x5				
Overhead 1kg Medicine Ball Throw [1,2]		3x8	2x8	2x8		
Overhead 3kg Medicine Ball Throw [1,2]	3x8					
CMJ onto a box [1,2]	4x5	2x5	2x4	2x4		
Plyometric Jumps above 3 hurdling[1,2]	4x3	3x3				
Sprint Running (m)[1,2]	3x40m	4x40m	2x30m	2x30m		
20m Shuttle Run (MAV)[2]	75%	75%	75%	75%		

For the Medicine Ball Throwing and Jump onto box the 1^{st} no. corresponds to sets and 2^{nd} corresponds to repetitions. For Sprint Running 1^{st} number corresponds to sets and 2^{nd} 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 VO_2max 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 7th and 9th 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 ± standard deviation) characteristics of the participants during three testing trials (M1, M2 and M3) for all groups

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

x – mean; σ- standard deviation; M1 – before training program; M2 – After training program; M3 – After detraining period; p(M1-M2)- p value for comparison between 2nd and 1st moment, p(M2-M3) - p value for comparison between 3th and 2nd moment; GC – Control Group, GR – resistance training group, GCOM - concurrent resistance and endurance training, Ŧ - 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 ± standard deviation of CMVJ, CMSLJ, 1 and 3kg Medicine Ball Throwing, Running Speed and VO_2Max at all three testing trials (M1, M2 and M3) for each group

Variable	Group	M1 x±σ	M2 x±σ	M3 x±σ	(M1-M2)	(M2-M3)
1Kg Medicine ball throwing (m)	GC	5,91±0,83	5,76±0,57	5,57±0,52	0,29	0,23
	GR	6,43±1,26	6,80±1,34₮	6,73±1,18₮	0,08	0,06
	GCOM	6,14±1,00	6,67±1,16‡	6,69±1,18‡	**0,00**	0,78
3Kg Medicine ball throwing (m)	GC	3,79±0,50	3,76±0,43	3,59±0,50	0,37	**0,03**
	GR	3,93±0,73	4,29±0,74₮	4,67±1,34₮	**0,01**	0,23
	GCOM	3,89±0,64	4,25±0,73‡	4,25±0,74‡	**0,00**	0,49
CM Vertical Jump (cm)	GC	0,26±0,07	0,26±0,06	0,20±0,04	0,13	**0,02**
	GR	0,25±0,06	0,27±0,07	0,26±0,06₮	**0,01**	**0,02**
	GCOM	0,25±0,06	0,28±0,08	0,24±0,06‡	**0,00**	**0,00**
CM Standing Long Jump (m)	GC	1,32±0,23	1,29±0,20	1,31±0,31	0,17	0,50
	GR	1,31±0,24	1, 32±0,26	1,27±0,29	**0,04**	0,23
	GCOM	1,30±0,26	1,37±0,22	1,31±0,30	**0,01**	**0,05**
Running Speed 20m (s)	GC	4,42±0,44	4,20±0,36	4,25±0,36	0,10	**0,03**
	GR	4,91±0,57	4,28±0,38	4,32±0,40	**0,00**	0,86
	GCOM	4,80±0,53	4,25±0,34	4,33±0,39	**0,00**	**0,00**
VO_2Max ($mL.kg^{-1}.min^{-1}$)	GC	40,8±4,05	41,0±4,27	45,0±8,20	**0,05**	0,21
	GR	39,2±4,29	40,7±3,98	42,0±6,84	0,13	0,58
	GCOM	42,5±4,37	43,7±4,09‡¥	41,9±5,80	**0,01**	0,43

x – mean; σ- 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 2nd and 1st moment,
p (M2-M3) - p value for comparison between 3th and 2nd 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.

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 VO_2max ($ml.kg^{-1}.min^{-1}$) 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 relsults 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 ($ml.kg^{-1}.min^{-1}$) 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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Appendix B

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The effects of concurrent resistance and endurance training follow a detraining period in elementary school students.

Running title: Concurrent resistance and endurance training/detraining in high school

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Abstract

The **purpose** of this study was to compare the effects of 8-weeks training period of resistance training alone (GR), or combined resistance and endurance training (GCOM), followed by 12-weeks of detraining (DT) on body composition, explosive strength and VO_2max adaptations in a large sample of adolescent schooled boys. **Methods:** Forty two healthy boys recruited from a Portuguese public high school (age: 13.3±1.04 yrs) were assigned into two experimental groups to train twice a week for 8 wk: GR (n=15), GCOM (n=15) and a control group (GC: n=12; no training program). **Results**: Significant training-induced differences were observed in 1kg and 3kg medicine ball throw gains (GR: +10.3% and +9.8% respectively; GCOM: +14.4% and +7% respectively), whereas no significant changes were observed after a DT period in both the experimental groups. Significant training-induced gains in height-and-length of the counter movement (vertical-and-horizontal) jumps were observed in both experimental groups. No differences were perceived after a DT period in lower limbs power. Time-at-20m decreased significantly for both interventions programs (GR: -11.5% and GCOM: -12,4%, <0.00), but either GR or GCOM groups kept the running speed after a DT period of 12 weeks. After training VO_2max increased only significantly for GCOM (4.6%, p=0.01). Significant loss was observed after a DT period in GR but not in GCOM. **Conclusion**: Performing resistance and endurance training in the same workout does not impair strength development in young schooled boys. As expected, strength training by itself, does not improve aerobic capacity. Our results also suggest that training program effects even persists at the end of detraining period.

Keywords: YOUTH, STRENGTH, ENDURANCE, SCHOOL, EXPERIMENTAL, DETRAINING

Introduction

There is strong evidence that school-based interventions are effective to promote physical activity levels (FAIGENBAUM, A.D. and G.D. MYER. Pediatric resistance training: benefits, concerns, and program design considerations. *Curr. Sports Med. Rep.* 9: 161-168, 2010.,FAIGENBAUM, A.D., W.L. WESTCOTT, R.L. LOUD, and C. LONG. The effects of different resistance training protocols on muscular strength and endurance development in children. *Pediatrics.* 104: 1-7, 1999.,FOX, K.R. and C. RIDDOCH. Charting the physical activity patterns of contemporary children and adolescents. *Proc. Nutr. Soc.* 59: 497-504, 2000.,SALLIS, J., T.L. MCKENZIE, J.E. ALCARAZ, B. KOLODY, N. FAUCETTE, and M.E. HOVELL. The effects of a 2-year physical education program (SPARK) on physical activity and fitness in elementary school students. *Am. J. Public Health.* 87: 1328-1334, 1997.,SHAW, B.S., I. SHAW, and G.A. BROWN. Comparison of resistance and concurrent resistance and endurance training regimes in the development of strength. *J. Strength Cond. Res.* 23: 2507-2514) by implementing well designed fitness programs (RIDGERS, N.D., G. STRATTON, S.J. FAIRCLOUGH, and J.W. TWISK. Children's physical activity levels during school recess: a quasi-experimental intervention study. *Int. J. Behav. Nutr. Phys. Act.* 4:19, 2007.,SLUIJS, E.M., A.M. MCMINN, and S.J. GRIFFIN. Effectiveness of interventions to promote physical activity in children and adolescents: systematic review of controlled trials. *Br. J. Sports Med.* 42: 653-7, 2007.,STRONG, W.B., R.M. MALINA, C.J. BLIMKIE, et al. Evidence based physical activity for school-age youth. *J. Pediatr.* 146: 732-737, 2005.,SWEETING, H.N. Measurement and definitions of obesity in childhood and adolescence: a field guide for the uninitiated. *Nutr. J.* 6: 32, 2007. ,van SLUIJS, E., A.M. MCMINN, and S.J. GRIFFIN. Effectiveness of interventions to promote physical activity in children and adolescents: systematic review of controlled trials. *B.M.J.* 335 (7622): 703, 2007.). While the majority of the pediatric research has focused on activities that enhance cardiorespiratory fitness, recent findings indicate that resistance training can offer unique benefits for children and adolescents when appropriately prescribed and supervised (FAIGENBAUM, A.D. and G.D. MYER. Pediatric resistance training: benefits, concerns, and program design considerations. *Curr. Sports Med. Rep.* 9: 161-168, 2010.,FAIGENBAUM, A.D., W.J. KRAEMER, C.J. BLIMKIE, I. JEFFREYS, L.J. MICHELI, M. NITKA, and T.W. ROWLAND. Youth resistance training: updated position statement paper from the national strength and conditioning association. *J. Strength. Cond. Res.* 23(Supplement 5): S60–S79, 2009.,MYER, G.D. and E.J. WALL. Resistance training in the young athlete. *Oper. Tech. in Sports Med.* 14: 218-230, 2006.). 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Comparison of resistance and concurrent resistance and endurance training regimes in the development of strength. *J. Strength Cond. Res.* 23: 2507-2514, 2009.). On this issue, the scientific literature has produced inconclusive results. Some studies have shown that concurrent training impairs the development of strength and power but does not affect the development of aerobic condition when compared with both form of stand-alone training. Some researchers have reported that concurrent training has an inhibitory effect on the development of strength and endurance (FAIGENBAUM, A.D., W.L. WESTCOTT, R.L. LOUD, and C. LONG. The effects of different resistance training protocols on muscular strength and endurance development in children. *Pediatrics.* 104: 1-7, 1999. ,GARRIDO, N., D.A. MARINHO, V.M. REIS, R. VAN DEN TILLAAR, A.M. COSTA, A.J. SILVA, and M.C. MARQUES. Does concurrent dry land strength and aerobic training inhibit strength and swimming performance in young competitive swimmers? *J. Sports Sci Med.* 9: 300-310, 2010.,KRAEMER, W.J., J.F. PATTON, S.E. GORDON, et al. Compatibility of high-intensity strength and endurance training on hormonal and skeletal muscle adaptations. *J. Appl. Physiol.* 78: 976-989, 1995.). For example, the addition of heavy resistance training to specific team handball training skills in adolescents boys resulted in gains in maximal strength and throwing velocity, but it may have compromised gains in the production of explosive force in the leg and endurance running (GOROSTIAGA, E.M., M. IZQUIERDO, P. ITURRALDE, M. RUESTA, and J. IBÁÑEZ. Effects of heavy resistance training on maximal and explosive force production, endurance and serum hormones in adolescent handball players. *Eur. J. Appl. Physiol.* 80: 485-493, 1999.). Yet, the precise mechanisms that underlie the observed impairments in training adaptation during concurrent training have to be identified (MARQUES, M.C., R. VAN DE TILLAAR, J.D. VESCOVI, and J.J. GONZÁLEZ-BADILLO. Changes in strength and power performance in elite senior female professional volleyball players during the in-season: a case study. *J. Strength Cond. Res.* 22: 1147-1155, 2008.,MICHAEL, L., P.J. ABERNETHY, B.K. BARRY, and P.A. LOGAN. Concurrent strength and endurance training: a review. *Sports Med.* 28: 413-427, 1999.,VILLARREAL, E.S., E. KELLIS, W.J. KRAEMER, and M. IZQUIERDO. Determining variables of plyometric training for improving vertical jump height performance: a meta-analysis. *J. Strength Cond. Res.* 2: 495-506, 2009.).

Differently, in adults, concurrent training produce better strength and endurance results rather than if each, strength or endurance training methods are performed separately (CHTARA, M., K. CHAMARI, M. CHAOUACHI, A. CHAOUACHI, D. KOUBAA, Y. FEKI, G.P. MILLET, and M. AMRI. Effects of intra-session concurrent endurance and strength training sequence on aerobic performance and capacity. *Br. J. Sports. Med.* 39: 555–560, 2005.). In this line, physical education classes demands a balance between strength and endurance, and it seems important to training concurrently both capacities. Nevertheless, the effects of concurrent resistance and endurance training in elementary school untrained male students have yet to be investigated.

Interruptions in training process because of illness, injury, holidays, post-season break or other factors are normal situations in any kind of sport (FAIGENBAUM, A.D. and P. MEDIATE. Effects of medicine ball training on fitness performance of high-school physical education students. *Phys. Ed.* 63: 160–167, 2006. ,FAIGENBAUM, A.D., W.J. KRAEMER, C.J. BLIMKIE, I. JEFFREYS, L.J. MICHELI, M. NITKA, and T.W. ROWLAND. Youth resistance training: updated position statement paper from the national strength and conditioning association. *J. Strength. Cond. Res.* 23(Supplement 5): S60–S79, 2009.,FAIGENBAUM, A.D., W.L. WESTCOTT, L.J. MICHELI, A.R. OUTERBRIDGE, C.J. LONG, R. LAROSA-LOUD, and L.D. ZAICHKOWSKT. The effects of strength training and detraining on children. *J. Strength Cond. Res.* 10: 109-114, 1996.) and also in school context. The magnitude of this reduction may depend upon the length of the detraining period in addition to training levels attained by the subject (MARQUES, M.C., R. VAN DE TILLAAR, J.D. VESCOVI, and J.J. GONZÁLEZ-BADILLO. Changes in strength and power performance in elite senior female professional volleyball players during the in-season: a case study. *J. Strength Cond. Res.* 22: 1147-1155, 2008.). Nevertheless, the detraining period and its consequences are not well reported in sports literature, and namely during puberty. This is important since the period of strength training cessation can produce a positive delay transformation rebound in sports specific performance (GARRIDO, N., D.A. MARINHO, V.M. REIS, R. VAN DEN TILLAAR, A.M. COSTA, A.J. SILVA, and M.C. MARQUES. Does concurrent dry land strength and aerobic training inhibit strength and swimming performance in young competitive swimmers? *J. Sports Sci Med.* 9: 300-310, 2010.), which is determinant on school performance evaluation of the student.

The established hypothesis raised on this paper is that young teenage boys can significantly increase parameters of power strength (speed, jump, and throws) performances by combining physical education classes with specific training programs over a consecutive 8-week period. We also hypothesized that concurrent resistance and endurance training would have a main positive effect on power strength development of untrained school boys compared with those found when power training was applied alone. Additionally, a 12-week DT period during the summer holidays may not produce significant decreases in physical performance, in both power training group and concurrent power and endurance training group, although endurance training groups would keep some strength gains after training cessation.

Therefore, the purpose of this study was twofold: (i) to analyze the effects of power training alone and combined power and endurance training on body composition, power strength and endurance training on a large sample of healthy school boys and, (ii) to assess the effects of a detraining period on strength, power and endurance performances as well as in body composition.

Methods

Experimental Design and Approach to the Problem

Forty-two healthy boys recruited from a Portuguese public high school were randomly assigned into two experimental groups (8 weeks training program, twice a week, from April 12th to June 4th of 2010) and one control group as follows: one group performing power training only (GR: n=15); another group performing combined power strength and endurance training (GCOM: n=15); and the third was the control group (GC: n=12; without a training program). All sample subjects attended physical education classes twice a week, with duration of 45 min and 90 min each class respectively. Typical physical education classes included various sports (gymnastics, team sports, athletics, dancing, and adventure sports, among others) with a clear pedagogical focus. As such, according to other researchers (SIMONS-MORTON, B.G., W.C. TAYLOR, S.A. SNIDER, et al. Observed levels of elementary and middle school children's physical activity during physical education classes. *Prev. Med.* 23: 437-441, 1994.) 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. (LUBANS, D.R., C. SHEAMAN, and R. CALLISTER. Exercise adherence and intervention effects of two school-based resistance training programs for adolescents. *Prev. Med.* 50: 56–62, 2010.). Usually these classes start with jogging run during 10 min to general warm up; proceed to joint mobilization and general stretches. After that the class is divided into 2 or 3 proficiency level groups to start the main activities/sports of the class, which can be a drill or a game organized in small groups. In Portugal, a physical education class has a set of 45 min and another of 90 min twice a week.

The training program was implemented additionally to physical education classes in the same outdoor sportive facility. After a 10 min warm up period, both experimental groups were submitted to a power strength training program composed by: 1 and 3 kg medicine balls throws performed as long and fast as possible; jumps onto a box (from 0.4 m to 0.6 m of height); plyometric jumps above 0.4-0.6m of height hurdle (only one foot touch on the floor among hurdles) and sets of 30 to 40m speed running. To the GCOM group was complementarily administered a 20m shuttle run training exercise (LÉGER, L.A., D. MERCIER, C. GADOURY, and J. LAMBERT. The multistage 20 meter shuttle run test for aerobic fitness, *J. Sports Sci.* 6: 93-101, 1988.), which occurred immediately after the power strength training session. This endurance task 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 test in order to readjust the volume and intensity of the 20m shuttle run exercise. Both GR and GCOM trained on the same day of the week (with two/three days between training sessions) and at the same morning hour. Subjects were encouraged to hydrates before and at the middle of training session. All participants were familiarised with power training drills (sprints, jumps and ball throws) as well as with the 20m shuttle run protocol. Throughout pre- and experimental periods, the subjects reported their non-involvement in additional regular exercise programs for developing or maintaining strength and endurance performance besides institutional regular physical education classes. A more detailed analysis of the program can be found in table 1.

(Insert table 1 here)

Sample groups were assessed for upper and lower body explosive strength (overhead medicine ball throwing and counter movement horizontal and vertical jumps, respectively), running speed (20m sprint run) and VO_2max (20m shuttle run test) before and after 8-weeks of training program. In order to evaluate the DT effects, all individuals were reassessed 12 weeks after training has stopped. The DT period was coincident with the 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 environment, at the same daily and weekly schedule (from March to September, 2010). Each subject was familiarised with power training tests (sprints, jumps and ball throws) as well as with the 20m shuttle run test. All data collection was performed by the same investigator and after a general warm-up of 10 minutes.

Participants

A sample of 42 healthy boys recruited from a Portuguese public high school (from 7th and 9th grades) was used in this study. To fulfill the ethical procedures of the Helsinki statement, an informed consent was obtained prior to all testing adolescents' parents. Efforts were made to recruit subjects for making comparable groups. Maturity level based on Tanner stages (FAIGENBAUM, A.D., W.L. WESTCOTT, R.L. LOUD, and C. LONG. The effects of different resistance training protocols on muscular strength and endurance development in children. *Pediatrics.* 104: 1-7, 1999.) was self-assessed. There were no significant differences ($p>0.05$) between groups for age or Tanner ratings, neither in anthropometrics or performances variables at the beginning of the protocol. No subject had regularly participated in any form of strength training prior to this experiment. The following exclusion criteria were used: subjects with a chronic paediatric disease or with an orthopaedic limitation.

Testing Procedures

Anthropometric assessment

Total height (m) was assessed according to international standards for anthropometric assessment (MARFELL-JONES, M., T. OLDS, A. STEWART, and L. CARTER. *International standards for anthropometric assessment.* ISAK: Potchefstroom, South Africa, 2006.), with a Seca 264 Stadiometer (Hamburg, Deutschland). Body composition variables were assessed using a Tanita body composition analyser; model TBF-300 (Tanita Corporation of America, Inc, Arlington

Heights, IL. USA) with a range of ratio of 1%-75%. These 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 test 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 to one familiarization session and was counseled on proper overhead throwing with different weighted balls. Pre, posttests and detraining measurements were conducted on maximal throwing velocity using medicine balls (Bhalla International - Vinex Sports, Meerut - India) weighing 1kg (Vinex, model VMB-001R, perimeter 0.72m) and 3kg (Vinex, model VMB-003R, perimeter 0.78m). A general warm-up period of 10 min, which included throwing the 1- and 3kg weighted balls, was allowed. While standing, subjects held medicine balls with 1 and 3kg in both hands in front of the body with arms extended. The students were instructed to throw the ball over their heads as far and fast as possible. A counter movement was allowed during the action. One-minute of rest among 5 trials was done. Only the best throw was considered for analysis. The ball throwing distance (BTd) was recorded to the closest cm as proposed by van Den Tillaar & Marques (van den TILLAAR, R. and M.C. MARQUES. Effect of two different throwing training programs with same workload on throwing performance with soccer ball. *Int. J. Sports Phys. Perf.* 4: 747-484, 2009.). This was possible as polyvinyl chloride medicine balls were used and when it falls on the Copolymer Polypropylene floor a visible mark was madden. The ICC of data for 1kg and 3 kg medicine ball throwing was 0.97 and 0.99, respectively.

Counter movement Vertical Jump (CMVJ)

To monitor the effectiveness of an athlete's conditioning program, the standing vertical jump test of leg power was used. The vertical jump test was conducted on a contact mat connected to an electronic power timer, control box and handset (Globus Ergojump, Italy). From a standing position, with the feet shoulder-width apart and the hands placed on the pelvic girth, the boys performed a counter movement with the legs before jumping. Such movement makes use of the stretch-shorten cycle, where the muscles are pre-stretched before shortening in the desired direction (LINTHORNE, N.P. Analysis of standing vertical jumps using a force platform. *Am J Physics* 11: 1198–1204, 2001). They were informed that they should try to jump vertically as high as possible. Each participant performed three jumps with a 1-min recovery between attempts. The highest jump (cm) was recorded. The counter movement vertical jump has shown an ICC of 0.95.

Counter movement Standing Long Jump (CMSLJ)

In a standing long jump the jumper aimed to project his body for maximum horizontal distance beyond a take-off line. The jumper started from a static standing position with feet shoulder-width apart and then generated a large take-off speed by using a counter movement coupled with the hands placed on the pelvic girth and a double-leg take-off. The take-off is characterised by a large forward lean of the body, and during the flight phase the jumper swings the legs forward underneath the body in preparation for landing. The jumper landed with a prominent forward lean of the trunk and with the feet extended well ahead of the hips. To be credited with a successful jump the jumper must retained balance after landing and not fall backwards into the pit. A standing long jump performance was quantified by the total jump distance, which is the distance from the take-off line to the nearest break in the landing area made by the heels at landing (WAKAI, M. and N.P. LINTHORNE. Optimum take-off angle in the standing long jump. *Human Movement Sci*. 24: 81-96, 2005.). A fiberglass tape measure (Vinex, MST-50M, Meerut, India) was extended across the floor and used to measure horizontal distance. Each participant completed three trials with a 1-min recovery between trials using a standardized jumping protocol to reduce inter-individual variability. The greatest distance (cm) of the two jumps was taken as the test score. The CMSLJ has shown an ICC of 0.96.

Sprint Running

This test was performed in an indoor school physical education facility with a Copolymer Polypropylene floor; subjects wore adapted indoor shoes. Time to run 20m was obtained using photocells (Brower Timing System, Fairlee, Vermont, USA). 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. At the start moment each subject trod the cell pad using the right hand with the time being recorded from when the subjects intercepted the photocell beam. 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 taken to cover the 20 m distance in the sprint test was used in data analysis. A rest period of 10 min among attempts was accomplished. The sprint running (time) has shown an ICC of 0.97.

20 Meters Shuttle Run (VO_2max)

This test involves continuous running between two lines (20m apart in time) to recorded beeps. The time between recorded beeps decreased each minute (level). We used the common version with an initial running velocity of 8.5 km/h, and increments of 0.5 km/h each minute (LÉGER, L.A., D. MERCIER, C. GADOURY, and J. LAMBERT. The multistage 20 meter shuttle run test for aerobic fitness, *J. Sports Sci.* 6: 93-101, 1988.). Estimated VO_{2max} ($ml.kg^{-1}.min^{-1}$) was calculated by the Léger's equation (LÉGER, L.A., D. MERCIER, C. GADOURY, and J. LAMBERT. The multistage 20 meter shuttle run test for aerobic fitness, *J. Sports Sci.* 6: 93-101, 1988.), which is based on the level and number of shuttles reached before boys were unable to keep up with the audio recording. The 20m Shuttle Run test has shown an ICC of 0.96.

Statistical analyses

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

Results

There were no significant differences ($p>0.05$) between groups for age or Tanner stages, neither in anthropometrics or performances variables at the beginning of the protocol ($p>0.05$). Body fat (BF) decreased significantly ($p=0.00$) from pre - to the post-training period in both GR and GCOM groups (table 2); however, no significant differences were found between groups. No significant changes were observed for total standing height, body weight and body mass index (BMI) in both GC and GCOM groups. GR significantly changed in height (+1.2%, $p=0.004$), BMI (-0.4%, $p=0.00$) and body fat (-10%, $p=0.00$) whereas GCOM only decreased in body fat, but not significantly different of GR. From pre- to the post-training period no differences were observed between experimental groups for performance variables, i.e., subjects from GCOM group did not take advantage over subjects form GR group in jumps, running speed and balls throws tests. However, VO_2max increased significantly in GCOM (+4.6%, $p<0.01$), but remained unchanged in both GC and GR groups. The magnitude of changes in 1Kg and 3kg ball throw distance, height in

CMVJ, length in CMSLJ and time to run 20 m was similar in both GR and GCOM groups (Table 3).

(Insert table 2 here)

(Insert table 3 here)

Detraining period resulted in decreased body weight (-2.7%, p=0.03) for GCOM (table 2), whereas it remained constant for GR and GC groups. Body height increased significantly for GR (+0.6%, p=0.00) and GCOM (+0.7%, p=0.01). No significant changes were observed in BMI from post-training to detraining period in any group. No significant changes were observed in body fat loss in any of the experimental groups. No significant changes were observed in 1kg and 3kg medicine ball throw gains after the DT period in any groups (Table 3). No significant changes in vertical jump height, horizontal jump length, and time to run 20m after DT period were observed after detraining period (Table 3). Estimated VO_2max, however, decreased after DT period in GR group (-6.8%, p=0.04) but not in GCOM. When compared groups, significant differences were not found.

Discussion

To our best knowledge, no other study has established the effect of 8-weeks school based endurance and resistance training program and detraining on strength, power and body composition in adolescent boys, 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 primary findings of the present study indicate that both concurrent resistance and endurance training and resistance training alone may be a positive training stimulus to enhance explosive strength and aerobic condition in healthy schooled boys. Ours findings are in agreement with previous Gorostiaga et al. (GOROSTIAGA, E.M., M. IZQUIERDO, P. ITURRALDE, M.

RUESTA, and J. IBÁÑEZ. Effects of heavy resistance training on maximal and explosive force production, endurance and serum hormones in adolescent handball players. *Eur. J. Appl. Physiol.* 80: 485-493, 1999.) and Chtara et al. (CHTARA, M., K. CHAMARI, M. CHAOUACHI, A. CHAOUACHI, D. KOUBAA, Y. FEKI, G.P. MILLET, and M. AMRI. Effects of intra-session concurrent endurance and strength training sequence on aerobic performance and capacity. *Br. J. Sports. Med.* 39: 555–560, 2005.) studies conducted with adults. Simultaneously our results contradict studies, which reported an impairment of concurrent training on performance variables development (SHAW, B.S., I. SHAW, and G.A. BROWN. Comparison of resistance and concurrent resistance and endurance training regimes in the development of strength. *J. Strength Cond. Res.* 23: 2507-2514, 2009.). Additionally, both training regimens also showed a positive effect on body fat loss in adolescent school boys. Therefore, the present results may suggest that concurrent resistance 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 boys. Moreover, both training programs regimens effects were persisted as long as upper and lower limb strength gains were kept during 12 weeks of detraining period. Concordantly the group submitted to strength and endurance program did not show estimated VO_2max loss in detraining period.

The magnitude of decrease observed in BF was not significantly different between GR and GCOM groups. We did not find any change in body weight for any group. It should be highlighted that body weight does not always explains the true body composition and therefore, despite we did not find body weight changes, we found body fat significant losses in both experimental groups. However, we did not find significant differences between experimental groups. These results may suggest that there is no major positive effect of concurrent resistance and endurance training when body fat loss occurs. Furthermore, the current results are in agreement with the research conducted by Watts et al. (WATTS, K., P. BEYE, A. SIAFARIKAS, et al. Exercise training normalises vascular dysfunction and improves central adiposity in obese adolescents. *J. Am. Coll. Cardiol.* 43: 1823-1827) that examined an independent influence of 8 weeks of combined resistance and aerobic training in 19 obese adolescents aged 12–16 year olds. On this, although bodyweight and BMI did not change with exercise, significant improvements in central adiposity were observed following the 8-week circuit-training program (WATTS, K., P. BEYE, A. SIAFARIKAS, et al. Exercise training normalises vascular dysfunction and improves central adiposity in obese adolescents. *J. Am. Coll. Cardiol.* 43: 1823-1827, 2004.).

A significant increasing was observed for upper limb explosive strength (e.g. medicine ball throw with 1kg and 3kg), in both GCOM and GR groups. This data may suggest a positive main effect of resistance training on explosive strength ability independently of type of treatment performed. In accordance to the upper body strength results, the explosive power of lower limbs revealed by the CMVJ and CMSLJ performance also increased significantly for both experimental groups. Few studies, however, have compared the effects of different methods of organizing training workouts. Here, for example, Sale et al. (SALE, D.G., J.D. MCDOUGALL, I. JACOBS, and S. GARNER. Interaction between concurrent strength and endurance training. *J. Appl. Physiol.* 68: 260-270, 1990.) could observe that concurrent resistance and endurance training applied on separate days produced superior gains to those produced by concurrent training on the same day. Although the training programs were held otherwise constant, alternate-day training was more efficient 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. Also Ingle et al. (INGLE, L., M. SLEAP, and K. TILFREY. The effect of a complex training and detraining programme on selected strength and power variables in early pubertal boys. *J. Sports Sci.* 24: 987-997, 2006.) using a combination of resistance training and plyometric program, found the experimental group saw a small improvement in performance over the training intervention period. Our results also demonstrated that the endurance training does not positively affect strength development in school boys. In addition, however, the present research showed that concurrent resistance and endurance training does not impair strength development. Unfortunately, it is difficult to compare results in the scientific literature when studies differ markedly in their design factors including load characteristics, context, equipment, scheduling of training sessions and training history of subjects (LEVERITT, M., P.J. ABERNETHY, B.K. BARRY, and P.A. LOGAN. Concurrent strength and endurance training: a review. *Sports Med.* 28: 413-427, 1999.,VILLARREAL, E.S., E. KELLIS, W.J. KRAEMER, and M. IZQUIERDO. Determining variables of plyometric training for improving vertical jump height performance: a meta-analysis. *J. Strength Cond. Res.* 2: 495-506, 2009.). 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 (SALE, D.G., J.D. MCDOUGALL, I. JACOBS, and S. GARNER. Interaction between concurrent strength and endurance training. *J. Appl. Physiol.* 68: 260-270, 1990.).

Running speed increased significantly in all experimental groups. In agreement with previous studies (MARQUES, M.C., R. VAN DE TILLAAR, J.D. VESCOVI, and J.J. GONZÁLEZ-BADILLO. Changes in strength and power performance in elite senior female professional volleyball players during the in-season: a case study. *J. Strength Cond. Res.* 22: 1147-1155, 2008.), these results seem to indicate that additional endurance training has not an additional effect over strength training to enhance running speed in young boys. 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.

An inhibition in strength or endurance adaptation as a consequence of concurrent training has been reported (VILLARREAL, E.S., E. KELLIS, W.J. KRAEMER, and M. IZQUIERDO. Determining variables of plyometric training for improving vertical jump height performance: a meta-analysis. *J. Strength Cond. Res.* 2: 495-506, 2009.). Nevertheless, the present study could observe a significant enhancement in VO_2max ($ml.kg^{-1}.min^{-1}$) only for GCOM, suggesting that the resistance training program component was not effective to a rising in aerobic fitness for young school boys. 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.

Twelve consecutive weeks in summer holidays were taken as detrained period. All sample subjects had no formal physical activity (Physical Education lessons or institutional training programs) during DT period. Only the GCOM significantly decreased body weight (-1.7%, p=0.03). In Total Standing Height variable, both experimental groups had a significant increase from post-training to detraining moment. There was no significant difference in BMI on GR group from post-training to detraining moment. Additionally, there was no significant difference in BF percentage loss between GR and GCOM during the intervention period. Thus, we can assume that the sustainment of BF obtained with training programs participation is visible for several weeks after the programme has finished. Conversely to post-training moment, all groups had shown no significant loss performance on CMVJ and CMSLJ. In speed running a significant loss performance was expected but it was not found in both GR and GCOM. A possible loss was expected as speed running is strongly affected by nervous system adaptation and phosphocreatine reserves; however, it was not observed (FOLLAND, J.P. and A.G. WILLIAMS. The adaptations to strength training morphological and neurological contributions to increased strength. *Sports Med.* 37: 145-168, 2007.). In the 1 and 3 kg medicine ball throw distance test, no significant changes were observed for experimental groups, which mean a sustained effect of training in this explosive task. Our results are in disagreement with Ingle et al findings (INGLE, L., M. SLEAP, and K. TILFREY. The effect of a complex training and detraining programme on selected strength and power variables in early pubertal boys. *J. Sports Sci.* 24: 987-997, 2006.), which in a detraining 12-week period the experimental group saw reductions for all of the resistance exercises that ranged from -16.3 to -30.3%. Control group had also no differences in performance marks for both 1 and 3Kg medicine ball throw distance test. Therefore, it must be suggested that explosive strength gains induced by 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. (FAIGENBAUM, A.D., W.L. WESTCOTT, L.J. MICHELI, A.R. OUTERBRIDGE, C.J. LONG, R. LAROSA-LOUD, and L.D. ZAICHKOWSKT. The effects of strength training and detraining on children. *J. Strength Cond. Res.* 10: 109-114, 1996.) showed that 8 weeks of detraining led to significant losses of leg extension (-28.1 %) and chest press (-19.3%) strength whereas control group strength scores remained relatively unremarkable.

Finally, the VO_2max ($ml.kg^{-1}.min^{-1}$) remained stable for GCOM, except for GR where a significantly loss (-6.8%) was observed. Another study (MUJIKA, I., S. and PADILLA. Cardiorespiratory and metabolic characteristics of detraining in humans. *Med. Sci. Sports Exerc.* 3: 413-421, 2001.) found that changes are more moderate in recently trained subjects (compared with highly trained subjects) in the short-term, but recently acquired VO_2max gains are completely lost after training stoppage periods longer than 4 weeks. Conversely, ours results show that GCOM kept VO_2max gains even after 12 weeks of DT. The detraining effect over VO_2max has been poorly studied in non-adult and non-sportive samples. Hence, due to the small sample size and the lack of a pre-study power analysis to determine adequate effect size for this study, we suggest that our subgroup analyses and results must be interpreted with caution.

Conclusions

Our results suggest that a concurrent resistance and endurance school-based training program seems considerably effective on both strength and endurance fitness feature of age-school boys. However, the resistance-training program also produced identical results on strength development. In brief, the present study indicates that concurrent training is an effective, well-rounded exercise program that can be performed to improve initial or general strength in healthy school boys. Our results also suggest that training program effects persists even at the end of detraining period. Those effects include body composition effects, and physical fitness components as strength and endurance. Future researches should examine the interference effects arising from the order of resistance and endurance training exercises program on strength enhancement.

Practical Applications

Performing simultaneously resistance and endurance training in the same workout not only does not impair strength development in healthy school boys but also seems to be an effective, well-rounded exercise program that can be prescribed as a means to improve initial or general strength. That should be considered in designing of strength training school-based programs in order to improve its efficiency. Furthermore, school-based programs should be implemented since training program effects persists at the end of summer holidays on body composition and physical fitness level.

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Table 1-Training program design.

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

Legend: for the Medicine Ball Throwing and Jump onto box the 1st no. corresponds to sets and 2nd corresponds to repetitions. For Sprint Running 1st number corresponds to sets and 2nd 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).

Table 2- Descriptive (mean ± standard deviation) characteristics of the participantsduring three testing trials (M1, M2 and M3) for all groups.

Variable	Group	M1 x±σ	M2 x±σ	M3 x±σ	*pvalue* (M1-M2)	*pvalue* (M2-M3)
Body Weight (kg)	GC	56,5±11,2	56,9±11,0	56,8± 4,9	0,22	0,14
	GR	59,2±16,2	58,3±16,0	58,9±16,7	0,11	0,28
	GCOM	51,4± 8,2	51,3± 8,2	50,8± 7,3	0,85	**0,03**
Total Standing Height (cm)	GC	163,8± 9,9	164,5± 9,8	167,1± 9,7	0,06	0,08
	GR	161,8±12,2	163,6±11,5	163,9±11,8	**0,00**	**0,00**
	GCOM	159,5± 8,1	160,2± 8,0	161,3± 7,9	0,09	**0,01**
BMI (kg.m^{-2})	GC	21,0± 3,4	21,0± 3,6	20,6± 3,0	0,74	0,17
	GR	22,3± 4,6	21,6± 4,7	22,0± 5,0	**0,00**	0,26
	GCOM	20,1± 2,1	19,9± 2,3	20,3± 2,7	0,22	0,22
Body Fat (%)	GC	15,0± 6,4	14,1± 7,1	12,8± 6,6	0,11	0,74
	GR	18,2± 9,2	15,8± 8,4	17,0± 8,6	**0,00**	0,36
	GCOM	14,5± 4,6	12,7± 4,6	12,5± 4,6	**0,00**	0,75

Legend: x – mean; σ- standard deviation; M1 – before training program; M2 – After training program; M3 – After detraining period; p(M1-M2)- *p* value for comparison between 2nd and 1st moment, p(M2-M3) -*p* value for comparison between 3th and 2nd moment; GC – Control Group, GR – resistance training group, GCOM - concurrent resistance and endurance training.

Table 3-Mean ± standard deviation of CMVJ, CMSLJ, 1 and 3kg Medicine Ball Throwing, Running Speed and VO_2Max at all three testing trials (M1, M2 and M3) for each group.

	Group	M1 x±σ	M2 x±σ	M3 x±σ	*pvalue* (M1-M2)	 (M2-M3)
CM Vertical Jump (cm)	GC	0,288±0,07	0,317±0,07	0,317±0,09	0,15	0,71
	GR	0,293±0,07	0,306±0,07	0,277±0,08	**0,04**	0,14
	GCOM	0,298±0,08	0,316±0,09	0,295±0,10	**0,02**	0,37
CM Standing Long Jump (m)	GC	1,70±0,37	1,63±0,33	1,62±0,51	0,26	0,72
	GR	1,49±0,27	1,56±0,30	1,47±0,36	**0,00**	0,17
	GCOM	1,67±0,31	1,74±0,32	1,54±0,43	**0,00**	0,12
1kg Medicine ball throwing (m)	GC	8,23±1,47	8,31±1,71	8,89±1,75	0,08	0,11
	GR	7,50±1,70	8,15±1,62	8,13±1,45	**0,00**	0,31
	GCOM	7,26±1,60	7,59±1,73	7,71±2,27	**0,04**	0,37
3kg Medicine ball throwing (m)	GC	5,02±0,91	5,01±1,19	5,35±1,30	0,10	0,15
	GR	4,66±0,98	5,12±1,08	5,10±0,99	**0,00**	0,29
	GCOM	4,60±1,12	5,11±1,17	5,03±1,25	**0,04**	0,97
Running Speed 20m (s)	GC	4,13±0,55	4,12±0,48	3,52±0,49	0,95	0,12
	GR	4,54±0,49	4,05±0,42 Ŧ	4,04±0,36	**0,00**	0,43
	GCOM	4,38±0,59	3,81±0,28	3,83±0,50	**0,00**	0,93
VO_2Max ($mL.kg^{-1}.min^{-1}$)	GC	48,5±5,3	47,4±5,5	44,4±8,1	0,67	0,52
	GR	45,2±6,4	46,8±6,5	42,1±5,2	0,10	**0,04**
	GCOM	49,1±6,7	51,2±6,7	51,7±6,6	**0,01**	0,83

Legend: x – mean; σ- 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 2nd and 1st moment, *p* (M2-M3) - *p* value for comparison between 3th and 2nd moment; GC – Control Group, GR – resistance training group, GCOM - concurrent resistance and endurance training, Ŧ - Significant changes between GC and GR.

Appendix C

EFFECTS OF CONCURRENT RESISTANCE AND ENDURANCE TRAINING/ DE-TRAINING PROGRAMS ON PUBESCENT AND ADOLESCENTS PHYSICAL FITNESS PERFORMANCE.

Running Title: CONCURRENT RESISTANCE/ENDURANCE TRAINING AND DE-TRAINING

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Abstract

Resistance training can offer unique benefits for children and adolescents when appropriately prescribed and supervised. Comprehensive school-based programs are specifically designed to enhance health-related components of physical fitness, which include muscular strength. However, resistance school-based programs aiming an increase in physical fitness performance are less studied and with inconclusive findings.

Objectives: The aim of this study was to synthesize information published in English language and fulfilled the following criteria were included in this review: (i) experimental studies in children or adolescents samples; (ii) at least one exercise intervention investigated resistance training.

Methods: A systematic database search for full-length manuscripts were performed on Sportdiscus, Springerlink, Taylor & Francis, Sciencedirect, Wiley Interscience, and Pubmed for the 1980–2011 (September week 4) period. Four keyword categorical searches were conducted: (i) ‘resistance training’, or ‘strength training’, or ‘weight training’; (ii) ‘child’, or ‘adolescent’, or ‘pediatric’; or ‘paediatric’ (iii) ‘concurrent’ and (iv) ‘de-training’, ‘recess’. The reference lists of each of these studies and a number of review papers and position stands were manually searched to extract further studies.

Conclusions: Concurrent training seems to be effective in pre- and post-pubescent boys and girls. It can be assumed that concurrent strength/endurance training not only does not impair strength or endurance development as seems to be an effective, well-rounded exercise program. Regarding to de-training effects, studies that have been properly investigated the changes in resistance training-induced strength gains during detraining in pre-adolescents are still scarce and insufficient. Even after a period as long as 3 month, strength/endurance gains can be observed in untrained early to post-pubescent youth.

Keywords: resistance, concurrent training, youth, school-based

Introduction

Regular physical activity during childhood and adolescence is associated with improvements in numerous physiological and psychological variables and it has been extensively documented in health related outcomes field (Sallis and Patrick, 1994; U.S. Department of Health and Human Services, 1996; Sallis et al., 1997; U.S. Department of Health and Human Services, 2010). Recommendation for the amount of physical activity deemed appropriate to yield beneficial health and behavioural outcomes for school-age youth have been also widely proposed (Sallis and Patrick, 1994; U.S. Department of Health and Human Services, 1996; Strong et al., 2005). Muscle strength is one of the most important health-related factors of physical fitness. By definition, muscular strength refers to the maximal force or tension a muscle or a group of muscles can generate at a specified velocity (Knuttgen and Kraemer, 1987; Ortega et al., 2008). Resistance training refers to a specialized method of conditioning, which involves the progressive use of a wide range of resistive loads and a variety of training modalities designed to enhance health, fitness, and sports performance (Faigenbaum et al., 2009). Although the term resistance training, strength training, and weight training are sometimes used synonymously, the term resistance training encompasses a broader range of training modalities and a wider variety of training goals (Faigenbaum et al., 2009). The term weightlifting refers to a competitive sport that involves the performance of the snatch and clean and jerk lifts (Faigenbaum et al., 2009). It’s largely documented that in addition to aerobic activities, research increasingly indicates that resistance training can offer unique benefits for children and adolescents when appropriately prescribed and supervised (Yu et al., 2005; American Academy of Pediatrics, 2008; Behringer et al., 2011).

Comprehensive school-based programs are specifically designed to enhance health-related components of physical fitness, which include muscular strength (Wechsler et al., 2000; National Association for Sport and Physical Education, 2005). However, resistance school-based programs aiming an increase in physical fitness performance are less studied and with inconclusive findings.

Therefore, the purpose of this research was to systematically review the effects of resistance training alone, concurrent resistance and endurance training over physical performance of 10 to 18 years old children and adolescents to assess current knowledge and level of evidence according to the Consolidated

Standards of Reporting Trials (CONSORT) checklist guidelines (Mosher et al., 2001).

Methods

Inclusion and exclusion criteria

Research that were published in English language and fulfilled the following criteria were included in this review: (i) experimental studies in children or adolescents samples (aged 10-18 years old); (ii) at least one exercise intervention investigated resistance training (using machines, free weights, elastic bands or tubes, medicine ball, body weight or a combination of several), either in isolation or as an adjunct to an alternative treatment.

Search protocol

A systematic database search for full-length manuscripts were performed on Sportdiscus, Springerlink, Taylor & Francis, Sciencedirect, Wiley interscience, and Pubmed for the 1980–2011 (September week 4) period.

First, four keyword categorical searches were conducted: (i) 'resistance training', or 'strength training', or 'weight training'; (ii) 'child', or 'adolescent', or pediatric, or 'paediatric'; (iii) 'concurrent' and (v) 'de-training', 'recess'. The reference lists of each of these studies and a number of review papers and position stands were manually searched to extract further studies.

Introduction

It's strongly documented that resistance training can offer unique benefits for children and adolescents when appropriately prescribed and supervised (Yu et al., 2005; Myer and Wall, 2006; Faigenbaum et al., 2009; Faigenbaum and Myer, 2010). Indeed, improvements in muscular fitness and speed/agility, rather than cardiorespiratory fitness, seem to have a positive effect on skeletal health (Ortega et al., 2008).

Strength training (also called resistance training) refers to a specialized method of physical fitness conditioning that comprises the progressive use of a wide variety of resistive loads — from medicine balls to high intensity plyometric drills — that enhance or maintain muscular fitness (Faigenbaum et al., 1996; American Academy of Pediatrics, 2001; British Association of Exercise and Sport Sciences, 2004; Faigenbaum and Mediate, 2006; Myer and Wall, 2006; American College of Sports Medicine, 2006; American Academy of Pediatrics, 2008; Faigenbaum et al., 2009; Faigenbaum and Myer, 2010). Research into the effects of resistance exercise on youth has increased over the past years (Faigenbaum et al., 1996; British Association of Exercise and Sport Sciences, 2004; American College of Sports Medicine, 2006; Faigenbaum and Mediate, 2006). Consequently, youth strength training is, nowadays, accepted by medical and fitness organizations and this qualified acceptance is becoming universal (Faigenbaum et al., 1996; American Academy of Pediatrics, 2001; British Association of Exercise and Sport Sciences, 2004; American College of Sports Medicine, 2006). Complementary, school physical education is the primary societal institution with the responsibility for promoting physical activity in youth (Sallis et al., 1997; Dobbins et al., 2009) and comprehensive school-based programs, are specifically designed to enhance among other fitness components, muscular strength (Faigenbaum and Mediate, 2006, Faigenbaum et al., 2009).

Several factors seem to have an effect over muscular strength and power development and studies have been used different methodologies and thus different results; which led us to this systematic search.

Youth's muscular strength trainability

The efficacy and success of a resistance training programme on children has been questioned in the past (Lillegard et al., 1997). Children lack adequate circulating androgens required for gains in muscular strength was appointed as explainer of that ineffectiveness (Legwold, 1982). Thus, different studies on children have reported no significant strength increases after the intervention period of resistance training programme (Docherty et al., 1987). A great range of reasons such as no inclusion of control group, assessment testing methods different from training drills, inadequate loads (resistance, repetitions, or sets), or a short study period can help to explain the lack of significant strength gains reported in those studies (Lillegard et al., 1997). Conversely, numerous other studies comparing strength trained children with age and sex matched controls have shown strength gains are possible (Ozmun et al., 1994) with no detrimental effect on growth (Sadres et al., 2001; Myer et al., 2005).

Pre-pubescent muscular strength trainability

Faigenbaum et al. (1993) found for both genders and pre-pubescent population that twice/wk strength training program can increase significantly ($p<.001$) strength in upper and lower limbs strength [10-RM leg extension (64.5%), leg curl (77.6%), chest press (64.1%), overhead press (87.0%), and biceps curl (78.1%)] after strength training program whereas gains in the control group averaged 13.0% (range 12.2 to 14.1%) for the same tested motions. The mean gains in strength for the experimental group were significantly greater than those for the control group. In vertical jump and seated ball put, subjects submitted to training programme improved 13.8% and 4% respectively, compared with 7.7% and 3.9% observed in control group. There were no significant interaction effects on vertical jump and seated ball put; however, significant ($p<.05$) main effects (both groups combined) for time were found on both performance measures (Faigenbaum et al., 1993).

Concordantly, Ozmun et al. (1994) for the pre-pubescent boys and girls that significant isotonic (22.6%), and isokinetic (27.8%) strength gains and integrated EMG amplitude (16.8%) increases were found after training programme period without corresponding changes in arm circumference or skinfolds. For the authors (Ozmun et al., 1994) early gains in muscular strength resulting from resistance training by prepubescent children may be attributed to increased muscle activation.

The effectiveness of strength training program in pre-pubescent boys and girls was confirmed using 6RM leg extension strength and 6RM chest press strength tests since exercise group significant increased +53.5 and 41.1%, respectively, compared with non-significant increase of 6.4 and 9.5% in controls (Faigenbaum et al., 1996). Significantly greater gains in strength during the 2nd phase of training for 6RM leg extension and 6RM chest press strength tests has been found, comparing with controls (Faigenbaum et al., 1996). After a training program of 1RM chest-press exercise for either low or high repetitions maximum, it has been found that pre-pubescent boys are sensitive to gains in 1RM chest-press test (Faigenbaum et al., 2005). That increase was about 52% for low repetitions maximum and 66% for high repetitions maximum, of their initial 1 RM (Faigenbaum et al., 2005). More recently the positive effect of strength training program over strength variables was confirmed in school context for pre-pubescent population (Cowan and Foster, 2009).

Besides pre-pubescent subjects are respondents to resistance training program, it was demonstrated that after a plyometric training programme pre-pubescent soccer players boys can increase performance in muscle power tests such as maximal cycling power ($p<.01$), CMJ ($p<.01$), squat jump ($p<.05$), multiple 5 bounds ($p<.01$), repeated rebound jump for 15 seconds ($p<.01$) and running velocity on 20m ($p<.05$). These performances' improvements in the treatment group were reached without concomitant performances' improvements in controls (Diallo et al., 2001).

As mentioned downward the effectiveness of strength training in pre-pubescent subjects can be reached with different training program context such as sports-based (Diallo et al., 2001; Garrido et al., 2010), fitness club-based (Faigenbaum et al., 1996; Lillegard et al., 1997; Faigenbaum et al., 2005; Yu et al., 2005; Ingle et al., 2006) or school based (Faigenbaum and Mediate, 2006; Kotzamanidis, 2006; Cowan and Foster, 2009) and resistance modes such as child sized weight machines (Faigenbaum et al., 1993; Faigenbaum et al., 1996, Faigenbaum et al., 2005), free weights or common weight machines (Lillegard et al., 1997; Garrido et al., 2010), body weight/tubing exercises/dumbbell exercises (Cowan and Foster, 2009; Sgro et al., 2009; Garrido et al., 2010) and medicine ball (Faigenbaum and Mediate, 2006; Cowan and Foster, 2009; Sgro et al., 2009; Garrido et al., 2010).

Post-pubescent muscular strength trainability

Strength training is also effective in pubescent and in post-pubescent population as well. In a pubescent male athletes sample, upper (bench press) and lower [leg press (DeRenne et al., 1996; Hetzler et al., 1997) and vertical jump (Hetzler et al., 1997)] strength has been increased after training period (DeRenne et al., 1996; Hetzler et al., 1997). Tsolakis et al. (2004) found that resistance training induced strength changes independently of the changes in the anabolic and androgenic activity.

A considerable number of studies has been investigated the effects of resistance training on adolescents. After a training period subjects significantly increase predicted 1RM squat (92%) and 1RM bench press (20%), right (10.39cm) and left (8.53cm) single-leg hop distance and vertical jump (3.3cm) and speed in a 9.1-m sprint (0.07seconds) (Myer et al., 2005). Basic resistance training alone induced favourable neuromuscular and biomechanical movement changes (Myer et al., 2005; Lephart et al., 2005) providing greater sport-specific training improvements (Szymanski et al., 2007) in high school male (Myer et al., 2005; Szymanski et al., 2007) and female (Lephart et al., 2005) athletes.

In summary youth are indeed trainable and a short bout of 10 to 15 minutes in each physical education class it’s sufficient to achieve significant gains in the shuttle run, long jump, sit and reach flexibility, medicine ball abdominal curl, medicine ball push up and medicine ball toss (Faigenbaum and Mediate, 2006). The introduction of manual resistance training on physical education class also resulted in curl-up test (Dorgo et al., 2009). Additionally, an important finding highlight that performing resistance training at a moderate volume is more effective and efficient than performing at a higher volume (González-Badillo et al., 2005): junior experienced lifters can optimize performance by exercising with only 85% or less of the maximal volume that they can tolerate.

Onset physical fitness level effect

It’s well documented that resistance training is effective on muscular strength development of either untrained (Faigenbaum et al., 1993; Ozmun et al., 1994; Faigenbaum et al., 1996; Lillegard et al., 1997; Faigenbaum et al.,1999; Faigenbaum et al.,2002; Tsolakis et al., 2004; Yu et al., 2005; Faigenbaum et al., 2005;

Faigenbaum and Mediate, 2006; Shaibi et al., 2006; Ingle et al., 2006; Kotzamanidis, 2006; Faigenbaum et al., 2007; Cowan and Foster, 2009; Dorgo et al., 2009; Sgro et al., 2009; Lubans et al., 2010) or trained (DeRenne et al, 1996; Hetzler et al., 1997; Diallo et al., 2001; González-Badillo et al., 2005, Lephart et al., 2005; Myer and Wall, 2006; Christou et al., 2006; Faigenbaum and Mediate, 2006; Szymanski et al., 2007; Bogdanis et al., 2007; Garrido et al., 2010) pre-pubertal (Faigenbaum et al., 1993; Ozmun et al., 1994; Faigenbaum et al., 1996; Lillegard et al., 1997; Faigenbaum et al.,1999; Diallo et al., 2001; Faigenbaum et al.,2002; Faigenbaum et al.,2005; Yu et al., 2005; Kotzamanidis, 2006; Cowan and Foster 2009; Sgro et al., 2009) or pubertal/post-pubertal non-adult population (DeRenne et al, 1996; Lillegard et al., 1997; Tsolakis et al., 2004; Lephart et al., 2005; González-Badillo et al., 2005; Ingle et al., 2006; Faigenbaum and Mediate, 2006; Christou et al., 2006; Myer and Wall, 2006; Shaibi et al., 2006; Bogdanis et al., 2007; Szymanski et al., 2007; Faigenbaum et al., 2007; Dorgo et al., 2009; Lubans et al., 2010). Comparing with untrained subjects, highly experience (at least 6 years) adolescents athletes in different sports (basketball, soccer, and volleyball players) girls, significantly increase predicted 1RM squat and 1RM bench press performances, as well as right and left single-leg hop distance, vertical jump and speed 9.1-m running performances; rise movement biomechanics: increase knee flexion-extension range of motion during the landing phase of a vertical jump and decreased knee valgus and varus torques (Myer and Wall, 2006). Another research has been specifically investigated the effect of sports experience on strength training adaptation in adolescent males (Hetzler et al., 1997): comparing with controls, experienced training subjects and novice training subjects significantly increased leg press, bench press and vertical jump after a 12 weeks, thrice a week, with free weights and machines.

Gender effects

Faigenbaum et al. (1996), Faigenbaum et al. (1999), Faigenbaum et al. (2002), Faigenbaum et al. (2005), Yu et al. (2005), Faigenbaum and Mediate (2006), Sgro et al. (2009) and Lubans et al. (2010) observed increases in various training-induced strength gains in prepubescent (Faigenbaum et al., 1996; Faigenbaum et al.,1999; Faigenbaum et al., 2002; Faigenbaum et al.,2005; Yu et al., 2005; Sgro et al., 2009) and pubescent (Faigenbaum and Mediate, 2006; Lubans et al., 2010) boys and girls; however, details of the detraining responses were not reported in those studies.

Cowen et al. (2009) found that boys and girls revealed improvements in push up scores, curl up scores, and overall percentile ranking after a strength training program; however, the statistical difference between both genders was not reported. Lillegard et al. (1997) observed no significant 3 or 2-way (gender, Tanner's stage, treatment) interactions for any of 10 RM strength differences (barbell curl, triceps extension, bench press, lat pull, leg extension, leg curl) and for any of the 5 motor performance parameters (flexed arm hang, jump and reach, shuttle run, standing long jump, 30 yard dash). However, when it was considered the gender main effect, in 2 of the six 10RM strength measures (lat pull, leg extension), males had significantly gains then females and significant pre- and post-test genders difference occurred on shuttle run (favoured the females) (Lillegard et al., 1997).

Program design

Resistance training programs as short as 10-15 minutes per session (Faigenbaum and Mediate, 2006), in addition to physical education classes have been showed to be sufficient to promote strength developments in paediatric population. Different weekly training frequency have been used such as once a week (Faigenbaum et al.,1999; Faigenbaum et al., 2002; Yu et al., 2005), twice a week (Faigenbaum et al., 1993; Faigenbaum et al., 1996; Faigenbaum et al.,2002; Faigenbaum et al.,2005; Christou et al., 2006; Faigenbaum and Mediate, 2006; Kotzamanidis, 2006; Shaibi et al., 2006; Faigenbaum et al., 2007; Garrido et al., 2010; Lubans et al., 2010;) thrice a week (Ozmun et al., 1994; DeRenne et al, 1996; Hetzler et al., 1997; Lillegard et al., 1997; Diallo et al., 2001; Tsolakis et al., 2004; Lephart et al., 2005; Myer et al., 2005; Yu et al., 2005; Ingle et al., 2006; Szymanski et al., 2007; Dorgo et al., 2009; Sgro et al., 2009) or five days a week (González-Badillo et al., 2005; Bogdanis et al., 2007; Cowan and Foster, 2009) with success on strength performances development. Strength training programs using experienced non-adults population lasted from 4 (Bogdanis et al., 2007) to 24 weeks (DeRenne et al., 1996). When we focus our analysis on untrained non-adults subjects studies, we found that the mostly used period it has been 8 weeks (Faigenbaum et al., 1993; Faigenbaum et al., 1996; Faigenbaum et al., 1999; Faigenbaum et al., 2002; Tsolakis et al., 2004; Faigenbaum et al., 2005; Lubans et al., 2010). Training period range has last from 6 (Faigenbaum and Mediate, 2006; Faigenbaum et al., 2007) to 64 (36+28) weeks (Yu et al., 2005). However, significant gains in upper and lower limbs strength can occur during a short period as the first 4-weeks of a training program (Faigenbaum et al., 1996).

Therefore, muscular strength can be improved during childhood years, and favour a training frequency a twice/week (Faigenbaum et al., 2002), 1 set/exercise of a higher repetition maximum (15-20 reps.) training range (Faigenbaum et al., 2005) for untrained children participating in an introductory strength training program (Faigenbaum et al., 2002).

Training Frequency

Faigenbaum et al. (2002) studied the effects of week frequency (1 vs. 2 sessions/wk) of strength training on upper and lower body strength in non-prior strength training experienced children. The 1-day group training at a 62.3 and 68.8% intensity (of their initial 1RM) on the chest press and leg press exercises, respectively, whereas the 2-day group trained at an intensity of 61.1 and 67.4% (of their initial 1RM), respectively (Faigenbaum et al., 2002). The authors found that in 1RM chest press strength performance, participants who trained 1 day/week increased 9.0% from their initial score whereas 2 days/week strength training group increased 11.5% [only this group made significantly ($p<.05$) greater gains in this variable as compared to the control group]. Compared with baseline scores, 1 day/week training group increased 14.2% in 1RM leg press strength whereas 2 days/week strength training group increased 24.9% (Faigenbaum et al., 2002). Control group has increased 4.4 and 2.4% in first and second variable, respectively (Faigenbaum et al., 2002). The authors proposed that the control group's strength gains may be explained by growth, maturation, and the learning effect. Despite no pre- post-program significant differences between groups were observed in handgrip strength, long jump, vertical jump, and flexibility it can be assumed that muscular strength can be improved during childhood years, favouring a training frequency of twice/week for children participating in an introductory strength training program. These results have to be taken with caution as long as throughout the study period 64% of subjects in the 1-day group, 70% in the 2-day group, and 69% in the control group regularly participated (at least 2-day/week) in organized community sports programs (mainly swimming and soccer) and these last programmes were not controlled by researchers.

Other authors (DeRenne et al, 1996) have been studied the effect of training week frequency (1 vs. 2 sessions/wk) in 12 wks in-season over strength gains retaining. Firstly, all subjects (including control group) attended to a preseason 12 wks, thrice a week of progressive strength training. In in-season, significant differences ($p<.05$) in absolute strength scores between group which trained 2 day/wk and the control group prior to the maintenance protocol for bench press were observed. At the end of the 12-week in-season period, subjects of both weekly training frequencies (1 and 2 sessions/wk) differed significantly ($p<.05$) from the control group in absolute bench press strength scores. Additionally, significant differences (in pre- to post in-season program) between 1 and 2 sessions/wk training groups and the control group were observed. No other differences were observed between groups. During the 12- week maintenance protocol, group which trained 1 day/wk had significant increases in strength in the bench press ($p<.05$) while the control group had significant decreases in the bench press and pull-ups. Thus, for pubescent male athletes, 1 day/wk maintenance program is sufficient to retain strength performance during the competitive season.

Training intensity and training volume

Trained adolescents of both genders can benefit from a short session of strength training. A 10 to 15 minutes of medicine ball strength training program performed twice a week on physical education classes have been shown to be sufficient to significantly ($p<.05$) promote gains in long jump, medicine ball abdominal curl, medicine ball push up and medicine ball toss tests (Faigenbaum and Mediate, 2006).

González-Badillo et al (2005) found that junior resistance-trained athletes can optimize performance by exercising with only 85% or less of the maximal volume that they can tolerate. In fact, after a periodized routine using the same exercises and relative intensities but a different total number of sets and repetitions at each relative load, the authors observed that moderate-volume group showed a significant increase for the snatch, clean & jerk, and squat exercises (6.1, 3.7, and 4.2%, respectively, $p<.01$), whereas in the low-volume group and high-volume group, the increase took place only with the clean & jerk exercise (3.7 and 3%, respectively, $p<.05$) and the squat exercise (4.6%, $p<.05$, and 4.8%, $p<.01$, respectively). The increase in the snatch exercise for the moderate-volume group was significantly higher than in the low-volume group ($p=.015$). The study's (González-Badillo et al., 2005) results showed higher strength gains in the moderate-volume group than in the high-volume group or low-volume group. There were no significant differences between the low-volume group and high-volume group training volume-induced strength gains (González-Badillo et al., 2005). These finding are consistent with Faigenbaum et al. (1999) conclusions: muscular strength and muscular endurance can be enhanced in untrained pre-pubertal boys and girls and favour the prescription of higher repetition–moderate load resistance training programs during the initial adaptation period"(Faigenbaum et al., 1999). That study's results shows that in 1RM leg extension strength a significant increase was observed in both Low-Repetition-High-Load Group (+31.0%) and High-Repetition-Moderate-Load Group (+40.9%) compared with controls. In leg extension muscular endurance both Low-Repetition-High-Load Group and High-Repetition-Moderate-Load Group significantly increased compared with controls, although gains resulting from High-Repetition-Moderate-Load Group (13.1±6.2 repetitions) were significantly greater than those resulting from Low-Repetition-High-Load Group (8.7±2.9 repetitions). In chest press 1-RM strength and chest press muscular endurance tests only the High-Repetition-Moderate-Load Group made gains (16.3% and 5.2±3.6 repetitions, respectively) than gains in the CG (Faigenbaum et al., 1999). More recently, another study (Faigenbaum et al., 2005) in untrained children which begin resistance training, confirmed this thesis. Study's results (Faigenbaum et al., 2005) favour the prescription of a higher RM training range (1 set of 15-20 RM): both Low-Repetition-Maximum Group and High-Repetition-Maximum Group made significant gains on 1 RM-strength (21% and 23%, respectively), however, only the High-Repetition-Maximum Group made significantly greater gains (42%) on 15 RM local muscular endurance test (Faigenbaum et al., 2005). Nevertheless future longstanding studies are necessary to evaluate the effects of different combination of sets and repetitions on performance measures in non-adult (Faigenbaum et al., 2005).

Training mode

Different modes such as medicine balls (Faigenbaum and Mediate, 2006; Cowan and Foster 2009; Sgro et al., 2009; Garrido et al., 2010;), weighted bags (Sgro et al., 2009), exercise machines (Faigenbaum et al., 1996; Hetzler et al., 1997; Lilligard et al., 1997; Faigenbaum et al.,1999; Faigenbaum et al.,2002; González-Badillo et al., 2005; Faigenbaum et al., 2005; Yu et al., 2005; Garrido et al., 2010), dumbbells (Hetzler et al., 1997; Cowan and Foster 2009; Sgro et al., 2009; Lubans et al., 2010) or elastic bands/tubing (Cowan and Foster 2009; Sgro et al., 2009; Lubans et al., 2010) have been used successfully on strength training development of both trained and untrained or pre- and pubescent boys and girls. Notwithstanding we didn't find any study that has been specifically compared de effect of different modes on strength training development.

Conclusion

Summarising, when we considered the studies which have investigated resistance training alone, we found that pre-pubescent to early post-pubescent boys and girls who participate in a resistance training programme can significantly raise upper and lower body strength performance, enhance flexibility and improve body composition as well. Different training modes are effective on strength training development of both trained and untrained or pre- and pubescent boys and girls. Moreover, performing resistance training a minimum of 10-15 minutes twice a week, at a moderate volume is more effective and efficient than performing at a higher volume. This is particularly important for school context since usual available training resources does not allow the usage of high strength loads. When considering gender effect, males seem to have greater strength improvements then females.

Concurrent resistance and endurance training

Adaptations as consequence of training process are highly dependent on the specific type of training implemented (Booth and Baldwin, 1996; Zatsiorsky and Kraemer, 2006). Endurance training generally encompasses exercise volume of several minutes up to some hours at many exercise intensities, increasing the ability to sustain repetitive high-intensity, low-resistance exercise with minimal fatigue accumulation and minimal performance loss (Nader, 2006; Bompa and Haff, 2009;). Resistance training encompasses short-duration activities at high exercise intensities, and increases the capacity to perform high-intensity, high-resistance exercise of a single or relatively few repetitions, and throwing events in school or sports field (Zatsiorsky, 2002; Nader, 2006).

Many researchers has rationalise that concurrent training promote the benefits of both resistance and endurance training (1993). Nevertheless an inhibition in strength or endurance adaptation as a consequence of concurrent training has been reported (Volpe et al., 1993). Sale et al. (1990) observed that concurrent strength and endurance training applied on different 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. Briefly, the literature researches do not demonstrate the universality of the interference effect in strength development when strength training is performed concurrently with endurance training (Santos et al., 2011).

In the present analysis we did not considered studies which has investigated resistance training concurrently to subject's sports workouts. Thus we only considered the researches that have been investigated the concurrent resistance and aerobic endurance training in untrained youth.

Concurrent resistance and endurance training has been demonstrate to be effective even in short periods of resistance training as 10 to 15 minutes for untrained adolescents of both genders. Assuming that Physical Education are mainly aerobic, subjects who participated in medicine ball training program during the first 10 - 15 minutes of each Physical Education class has significantly ($p<.05$) greater gains in the shuttle run, long jump, sit and reach flexibility, medicine ball abdominal curl, medicine ball push up and medicine ball toss as compared to the subjects who participated in Physical Education lessons but not medicine ball training (Faigenbaum and Mediate, 2006).

Subjects who concurrently trained manual resistance and cardiovascular endurance in every Physical Education session has showed significant improvements in one-mile run ($p<.002$) and trunk lift ($p<.0001$) measures from 0-9 and 9-18 wks compared with subjects who trained manual resistance training alone (Dorgo et al., 2009). Concurrent training seems to be effective also in pre-pubescent boys and girls. Cowan and Foster (2009) observed significant improvements in one-mile run, push up and curl up scores for both genders after a concurrent strength and endurance training period.

More recently, Santos et al. (2011) found that concurrent resistance and endurance training is effective on both upper and lower limbs muscular power development of pubescent girls. Only group who had included endurance exercises on strength training program has been increased endurance performance.

Conclusion

In concurrent resistance and endurance training analysis we only considered the research that has been investigated the concurrent strength and endurance training in untrained youth. Concurrent training seems to be effective in pre-pubescent and post pubescent boys and girls. It can be assumed that concurrent strength and endurance training not only does not impair strength or endurance development as seems to be an effective, well-rounded exercise program that can be used as a means to improve initial or general strength in youth.

De-training effects

Reversibility, one of the training's methodological principles, sustain that whereas regular physical training results in numerous physiological adaptations that enhance physical and athletic performance, stopping or markedly reducing training induces a partial or complete reversal of these adaptations, compromising performance levels. Therefore, the reversibility principle can be considered the principle of detraining (Hawley and Burke, 1998).

De-training is defined as the partial or complete loss of training-induced anatomical, physiological and performance adaptations, as a consequence of training reduction or cessation (Mujika and Padilla 2000). Training cessation implies a temporary discontinuation or complete abandonment of a systematic programme of physical conditioning (Mujika and Padilla 2000). Reduced training is a non-progressive standardised reduction in the quantity of training (Mujika, 1998), which may result in a maintenance or even in an improvement of many of the positive physiological and performance adaptations acquired with training process (Houmard et al., 1996; Mujika, 1998).

In this review de-training is defined as the partial or complete loss of training-induced anatomical, physiological and performance adaptations, as a consequence of systematic training cessation or reduction. Training cessation refers to a temporary discontinuation or complete abandonment of a systematic programme of physical conditioning (Mujika, 1998).

Interruptions in training process because of illness, injury, holidays, post-season break or other factors are normal situations in numerous kind of sport (Faigenbaum et al., 1996; Faigenbaum and Mediate, 2006; Faigenbaum et al., 2009) and in school context as well. The extent of performance decrease may depend upon the length of the period recess in addition to training levels and performance attained by the subjects (Marques et al., 2008). Nevertheless, information about the changes in resistance training-induced strength gains during detraining in pre-adolescents it's still scarce (Tsolakis et al., 2004) and insufficient studies (Blimkie, 1992; Faigenbaum et al., 1996) have investigated the effects of detraining with an inclusion of a control group to control for growth-related rises in muscular strength.

The maintenance of upper and lower body muscular strength improvements such as 1RM, muscular strength endurance (DeRenne et al, 1996) or muscle power (Diallo et al., 2001) were observed in pubescent trained boys after 8 weeks (Diallo et al., 2001) or 12 weeks (DeRenne et al., 1996) period of reduced strength training.

At the end of 8 weeks of detraining (absolute training cessation), Faigenbaum et al. (1996) observed that pre-pubescent untrained boys and girls, significant loss 6RM leg extension (-28.1 %) and chest press (-19.3%) strength. Lower limbs muscular strength loss was made mainly during the first 4 weeks of detraining (6RM extension: -21.3%) while upper limb muscular strength loss was about half during the first 4 weeks (chest press: -8.9%) and albeit EG values remained significantly higher than CG values. Nevertheless, at end of the 8-week detraining period, the chest press but not leg extension strength of the subjects who have strength trained remained significantly greater than controls. Concordantly, in pre- and early pubertal untrained males the same trend can be found (Tsolakis et al., 2004). After 8 weeks of detraining, Tsolakis et al. (2004) fount that the trained subjects' strength (concentric strength of the elbow flexion in the right arm, assessed by an upper extremity dynamometer; and 10RM elbow flexion with adjustable dumbbells) decreased significantly by 9.5%, converging toward the control values. The week degree of the initial strength gain and the detraining extent could partly explain the reversible response of strength

(Blimkie, 1992). Nevertheless, despite that observed strength loss, the treatment group maintained about by 64% of the strength gained during training program, probably due to the high intensity of the training program (Kraemer et al., 1989), which is an important factor related to the magnitude of the improvement of the muscular strength (Blimkie and Bar-Or, 1996).

In this line, the benefits of upper and lower body complex training (in pre- and early pubertal boys) are lost at similar rates to other training modalities at the end of 12 weeks of training recess (Ingle et al., 2006).

Conversely, in pre- and early pubertal boys and girls swimmers, it was observed that at the end of 6 weeks of detraining period strength parameters remained stable and swimming performance still improved (Garrido et al., 2010), however all the swimmers maintained the normal swimming program, without any strength training. Thus, this study cannot be compared with previous since subjects of treatment and controls continued on their usual swimming training and thereby recess effects can be biased by swimming training.

More recently and inconsistently with previous studies, it was shown that in early pubertal and adolescents untrained girls, 12 weeks of de-training period was not sufficient to reduce the overall training effects. No significant changes were observed after a recess period in any of the treatment groups (strength training group and concurrent strength and endurance training group) for medicine ball toss and sprint running. Resistance training group kept jump (horizontal and vertical distance) and concurrent strength and endurance training group maintained the endurance performance (Santos et al., 2011).

Conclusion

Studies that have been properly investigated the changes in resistance training-induced strength gains during de-training in pre-adolescents are still scarce and insufficient. Different results have been found on de-training effect over subject's strength gains. However, it can be assumed that even after a period as long as 3 month, strength and endurance gains can be observed in untrained early to post-pubescent boys and girls.

Summary and conclusions

Despite of consensus exists from The British Association of Sport & Exercise Science (Stratton et al., 2004), The American Academy of Pediatrics (2008), The American College of Sports Medicine (Faigenbaum, 2000; Lavalee, 2005), and the National Strength and Conditioning Association (1996), with other recommendations summarized by Faigenbaum et al. (2009), Fulton et al. (2004) and Twisk (2001), that resistance training since appropriately designed and supervised by expert personnel is beneficial to children and adolescents' athletic performance, health and fitness, there is a scarcity of robustly designed studies investigating the main factors which determine concurrent strength and endurance training gains and detraining effect (school-based) in untrained children and adolescents. Muscular strength has been recognized as an important component of fitness in the recent evidence-based physical activity guidelines for school-age youth (Strong et al., 2005). Despite there is clear data in adults (Lavalee, 2005) to support these positions, evidence-based data in children and adolescents are limited. However, available data suggest that well-designed and supervised resistance training programmes may have beneficial health outcomes associated with cardiorespiratory fitness (Faigenbaum, 2000; Stratton et al., 2004) and it would be improvident to ignore those findings while the depth of evidence in non-adult population is being established.

Ours findings are important to increase de effectiveness of endurance and strength training design of untrained children and adolescents in school context.

It's well documented that endurance training program results in VO_2max raise but more studies are needed to clarify what is the best school-based program's methodology on endurance training in paediatric population.

A minimum of 10-15 minutes twice week of resistance training is sufficient to improve strength and moderate volumes are more effective and efficient than higher volumes. This is particularly important for school context since usual available training resources does not allow the usage of high strength loads. When considering gender effect, males seem to have greater strength improvements then females.

Concurrent strength and endurance training not only does not impair strength or endurance development as seems to be an effective, well-rounded exercise program that can be used as a means to improve initial or general strength in youth.

Studies that have been properly investigated the changes in resistance training-induced strength gains during de-training in pre-adolescents are still scarce and insufficient. However, from published studies it can be assumed that even after a period as long as 3 month, strength and endurance gains can be observed in untrained early to post-pubescent boys and girls.

This study is consistence with previous studies which highlight the role of school as the primary institution in physical fitness promoter.

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