



UNIVERSIDADE DA BEIRA INTERIOR
Ciências Sociais e Humanas

Determinants of physical fitness in prepubescent children and its training effects

Carlos Jorge Soares de Aquino Cavaleiro Marta

Tese para obtenção do Grau de Doutor em
Ciências do Desporto
(3º ciclo de estudos)

Orientador: Prof. Doutor Mário C. Marques
Co-orientador: Prof. Doutor Daniel A. Marinho

Covilhã, Abril de 2013

Marta, C. (2013). Determinants of physical fitness in prepubescent children and its training effects. University of Beira Interior, Research Centre in Sport, Health and Human Development.

KEY WORDS: YOUTH, PHYSICAL FITNESS, SOMATOTYPE, MUSCLE POWER, ENDURANCE, CONCURRENT TRAINING, GENDER DIFFERENCES

“Um desistente nunca ganha e um vencedor nunca desiste.”

Napoleon Hill

Academic dissertation submitted with the purpose of obtaining a doctoral degree in Sport Sciences according to the provisions of Portuguese Decree-Law 107/2008 of 25 June.

Acknowledgements

I would never have been able to finish this study without the guidance of my thesis advisors, help from friends, and support from my family.

A special thanks to Professors Mário Marques and Daniel Marinho, for their excellent guidance, patience, and constant encouragement and counseling.

A very big thank you to all the students who participate in this research. This work wouldn't be possible without their dedication.

I would also like to thank Professors Mikel Izquierdo, Tiago Barbosa, and Natalina Casanova. This research would not have been possible without their cooperation.

Finally, I would like to thank my son Gui and my wife Mané. They were always there cheering me up and stood by me through the good and bad times.

List of Publications

This Doctoral Thesis was supported with the following papers:

Marta C, Marinho DA, Marques MC. Physical fitness in prepubescent children: an update. Accepted for publication in the *Journal of Physical Education and Sport*.

Marta C, Marinho DA, Costa AM, Barbosa TM, Marques MC. Somatotype is more interactive with strength than fat mass and physical activity in peripubertal children. *Journal of Human Kinetics* 2011; Special Issue: 83-91.

Marta C, Marinho DA, Barbosa TM, Izquierdo M, Marques MC. Physical fitness differences between prepubescent boys and girls. *Journal of Strength and Conditioning Research* [Published Ahead of Print] DOI: 10.1519/JSC.0b013e31825bb4aa

Marta C, Marinho DA, Barbosa TM, Izquierdo M, Marques MC. Effects of body fat and dominant somatotype on explosive strength and aerobic capacity trainability in prepubescent children. Submitted for publication to *Pediatric Exercise Science*.

Marta C, Marinho DA, Barbosa TM, Izquierdo M, Marques MC. Effects of concurrent training on explosive strength and VO_{2max} in prepubescent children. Submitted for publication to *International Journal of Sports Medicine*.

Table of Contents

Index of Figures	xi
Index of Tables	xiii
Abstract	xv
Resumo	xvii
Resumen	xix
List of Abbreviations	xxi
Chapter 1. General Introduction	1
Chapter 2. Review of Literature	5
Study 1. Physical fitness in prepubescent children: an update	5
Chapter 3. Experimental Studies	23
Study 2. Somatotype is more interactive with strength than fat mass and physical activity in peripubertal children	23
Study 3. Physical fitness differences between prepubescent boys and girls	33
Study 4. Effects of body fat and dominant somatotype on explosive strength and aerobic capacity trainability in prepubescent children	51
Study 5. Effects of concurrent training on explosive strength and VO_{2max} in prepubescent children	63
Chapter 4. General Discussion	77
Chapter 5. Conclusions	83
Chapter 6. Suggestions for future research	85
Chapter 7. References	87

Index of Figures

Study 3

Figure 1. Scatterplot between Dimension 1 and Dimension 2 by sex	46
Figure 2. Scatterplot between Dimension 2 and Dimension 3 by sex	46

Study 4

Figure 1. Effect size of fat mass, endomorphic, mesomorphic and ectomorphic on training-induced explosive strength gains: boys and girls	58
Figure 2. Effect size of fat mass, endomorphic, mesomorphic and ectomorphic on training-induced VO ₂ max gains: boys and girls	59

Study 5

Figure 1. Counter movement jump (cm) by group	71
Figure 2. Standing long jump (cm) by group	71
Figure 3. 1kg ball throwing (cm) by group	71
Figure 4. 3kg ball throwing (cm) by group	71
Figure 5. Time-at-20m (sec) by group	72
Figure 6. VO ₂ max (ml.kg ⁻¹ .min ⁻¹) by group	72
Figure 7. Counter movement jump (cm) by sex	72
Figure 8. Standing long jump (cm) by sex	72
Figure 9. 1kg ball throwing (cm) by sex	72
Figure 10. 3kg ball throwing (cm) by sex	72
Figure 11. Time-at-20m (sec) by sex	73
Figure 12. VO ₂ max (ml.kg ⁻¹ .min ⁻¹) by sex	73

Index of Tables

Study 2

Table 1. Descriptive data of FAT, BMI, ENDO, MESO, ECTO, PA and muscle strength variables	25
Table 2. Correlations between % of FAT, ENDO, MESO, ECTO, PA and strength variables	27
Table 3. Comparison between different BMI groups with respect to muscle strength variables	28
Table 4. Comparison between different TYPE groups with respect to strength variables	28
Table 5. Interaction of morphological type (TYPE), body fat (% FAT) and physical activity (PA) with strength variables: GLM-MANOVA test	29

Study 3

Table 1. Descriptive data of anthropometric and morphological parameters, physical activity indexes and physical performance measures: Overall sample	37
Table 2. Gender`s difference in physical performance: Adjusted means after MANCOVA	43
Table 3. Effect of the somatotype, physical activity and body fat factors on the physical performance of boys and girls: MANCOVA	44
Table 4. Statistical significance and effect size of sex on the physical performance variables: ANCOVA	44
Table 5. Correlations between canonical coefficients and variables	45

Study 4

Table 1. Training program design	54
Table 2. Comparison of explosive strength and endurance tests results mean (\pm SD) between experimental and control groups in pre- (T0) and post-test (T1) conditions: Boys and girls	57
Table 3. Pearson`s correlation between percentage of fat mass (%BF), endomorphic (END), mesomorphic (MES), ectomorphic (ECT), and explosive strength and VO2max gains: Boys and girls	58

Study 5

Table 1. Descriptive data of the control (GC), resistance (GR) and concurrent (GCON) groups in pre-test condition: Boys and girls (Mean \pm SD)	66
Table 2. Training program design	69
Table 3. Evolution of the explosive strength and VO ₂ max from pre- to the post-training: ANOVA	70

Abstract

The purpose of this investigation was to analyze the effect of somatotype, body fat and physical activity on overall physical fitness, explosive strength and aerobic capacity trainability in prepubescent children. Additionally, it was intended to identify the magnitude of the differences between boys and girls in physical fitness, and the effects of concurrent training on explosive strength and VO_{2max} adaptations. For the accomplishment of these purposes the following sequence was used: (i) reviewing available literature; (ii) analyzing the interaction between somatotype, body fat, physical activity and physical fitness in prepubescent children; (iii) identifying physical fitness differences between boys and girls; (iv) analyzing the interaction between somatotype, body fat and training-induced explosive strength and VO_{2max} gains; (v) and comparing the effects of 8-weeks training period of strength training alone, or combined strength and aerobic training on explosive strength and VO_{2max} adaptations. Results suggest that: (i) somatotype is the most important variable determining overall physical fitness, and training-induced explosive strength and VO_{2max} gains, in boys and girls; (ii) boys present higher values in muscular strength and endurance, velocity and aerobic capacity, and girls perform better on tests of balance and flexibility. Gender differences in the physical fitness are greater in the explosive strength and smaller in the muscular endurance and flexibility, followed by velocity and balance; (iii) performing strength and aerobic training in the same workout does not impair strength development, and allows similar neuromuscular adaptations in prepubescent boys and girls.

Key words

Youth, Physical Fitness, Somatotype, Muscle Power, Endurance, Concurrent Training, Gender Differences

Resumo

Este estudo pretendeu analisar o efeito do somatótipo, gordura corporal e atividade física na aptidão física geral, no treino de força explosiva e na capacidade aeróbia, em crianças pré-pubertárias. Adicionalmente pretendeu-se identificar a magnitude das diferenças na aptidão física entre rapazes e raparigas, e os efeitos do treino concorrente na força explosiva e VO_{2max} . Para se alcançar estes objetivos foram adotados os seguintes passos: (i) revisão da literatura; (ii) análise da interação do somatótipo, gordura corporal, atividade física e aptidão física em crianças pré-púberes; (iii) identificação das diferenças na aptidão física entre rapazes e raparigas; (iv) análise da interação do somatótipo, gordura corporal e ganhos de força explosiva e VO_{2max} induzidos pelo treino; (v) e comparação do efeito de um período de treino de oito semanas exclusivamente de força, e treino combinado de força e endurance na força explosiva e VO_{2max} . Os resultados sugerem que: (i) o somatótipo é a variável que mais influencia a aptidão física geral, e os ganhos de força explosiva e VO_{2max} induzidos pelo treino, quer em rapazes, quer em raparigas; (ii) os rapazes apresentam melhor performance na força e resistência muscular, velocidade e capacidade aeróbica, e as raparigas têm melhor desempenho em testes de equilíbrio e flexibilidade. Diferenças de género na aptidão física são maiores na força explosiva e menores na resistência muscular e flexibilidade, seguidas da velocidade e equilíbrio; (iii) realizar treino combinado de força e endurance na mesma sessão de trabalho não prejudica o desenvolvimento da força, e permite adaptações neuromusculares semelhantes em rapazes e raparigas pré-púberes.

Palavras-chave

Juventude, Aptidão Física, Somatótipo, Potência Muscular, Endurance, Treino Concorrente, Diferenças de Género

Resumen

Este estudio ha tenido como objetivo analizar el efecto del somatotipo, de la grasa corporal y la actividad física en la condición física general, en el entrenamiento de fuerza explosiva y en la resistencia aeróbica en niños prepúberes. Además se ha pretendido identificar la magnitud de las diferencias en la condición física entre niños y niñas y los efectos del entrenamiento combinado en la fuerza explosiva y VO_{2max} . Para lograr estos objetivos se han dado los siguientes pasos: (i) revisión de la literatura; (ii) análisis de la interacción del somatotipo, de la grasa corporal, actividad y condición física en niños prepúberes; (iii) identificación de las diferencias en la condición física entre niños y niñas; (iv) análisis de la interacción del somatotipo, de la grasa corporal y del aumento de la fuerza explosiva y VO_{2max} inducidos por el entrenamiento; (v) y comparación del efecto de un periodo de entrenamiento de ocho semanas sólo de fuerza y entrenamiento combinado de fuerza y resistencia en la fuerza explosiva y VO_{2max} . Los resultados sugieren que: (i) el somatotipo es la variable que más influye en la condición física general, el aumento de fuerza explosiva y VO_{2max} inducidos por el entrenamiento, sea en niños o en niñas; (ii) los niños presentan mejor rendimiento en la fuerza y resistencia muscular, velocidad y resistencia aeróbica, ya las niñas son mejores en pruebas de equilibrio y flexibilidad. Las diferencias de género en la condición física son mayores en la fuerza explosiva y menores en la resistencia muscular y flexibilidad, seguidas de la velocidad y del equilibrio; (iii) realizar entrenamiento combinado de fuerza y resistencia en la misma sesión de trabajo no afecta el desarrollo de la fuerza y permite adaptaciones neuromusculares similares en niños y niñas prepúberes.

Palabras clave

Jóvenes, Condición Física, Somatotipo, Potencia Muscular, Resistencia, Entrenamiento Concurrente, Diferencias de género

List of Abbreviations

BF	body fat
%BF	percent body fat
BMI	body mass index
ECTO	ectomorphic
ENDO	endomorphie
%FAT	percentage of fat mass
GC	control group
GCON	concurrent training group
GE	endurance group
GR	resistance group
MESO	mesomorphic
M-K	Margaria-Kalamen power stair test
PA	physical activity
TYPE	morphological typology

Chapter 1. General Introduction

Physical fitness has been recognized as a key determinant in healthy lifestyles based increasingly on criteria referenced to general health and not merely to motor performance (Ortega et al., 2007). It is related, among others, with lower prevalence of cardiovascular disease risk factors, reduces total and abdominal adiposity, improves mental and skeletal health and increases academic performance (Kvaavik et al., 2009; Ortega et al., 2007). Furthermore, physical fitness levels track from childhood to adolescence and from adolescence to adulthood (Stratton et al., 2008; Twist et al., 2000).

The recognition that physical fitness is a major marker of health status at any age (Ortega et al., 2007) has produced a wide range of studies on the influence of various factors on physical fitness levels, in particular the influence of body fat and physical activity (Artero et al., 2010; D'Hondt et al., 2009; Dumith et al., 2010; Lennox et al., 2008). However, there are few studies (Jakšić & Cvetkovic, 2009; Shukla et al., 2009; Suchomel, 2002) that link somatotype with fitness in young people. Most studies in this context refer to the influence of body mass index in the motor performance in youth, but somatotype has been found to be inherited to a greater extent than body mass index (Reis et al., 2007). One cannot exceed the limits imposed by what is a manifestation of genetic determinism, observed from the morpho-constitutional point of view, and there is evidence that by pre-puberty there already exists a fairly stable somatotype, pointing to 8 years as the age by which somatotype stability becomes manifest (Malina et al., 2004). Hence it seems relevant to examine, in this age group, the effect of the presence/absence of certain physical traits on the motor performance, and compare it with the effect of body fat and physical activity, often referenced in the literature (**Study 2 and Study 3**). On the other hand, physical fitness is often erroneously used as a synonym for aerobic fitness rather than as an umbrella term to embrace all health-related fitness components (Hands et al., 2009). The majority of studies on the physical fitness focuses on the aerobic capacity, neglecting the muscular fitness (Cepero et al., 2011), but there exist evidence that the neuromotor aptitude based on the muscular force can be as important as the aerobic capacity in the maintenance of the health (Armstrong & Welsman, 1997). As such, it will be relevant to analyze specifically the interaction of physical activity, body fat, somatotype and strength development in prepubescent children (**Study 2**).

Unfortunately, there exist evidences suggesting that physical fitness has declined worldwide in the last decades among children and adolescents (Matton et al., 2007; Tomkinson, 2007). Thus, efforts to promote physical fitness levels in youth should be a priority (Cepero et al., 2011). One of the pointed reasons for the decreased levels of physical fitness and physical

activity is that there is an apparent avoidance of children of the physical education classes and regular physical activity (Roetert, 2004). This decrease in the interest of children in physical activity and sport is due, in part, to lack of planning that takes into account the interest, motivation and success of children in the execution of the exercises, respecting the differences between them, including gender differences (Haff, 2003). Physical education classes or extracurricular activities commonly include children of both sexes. This requires teachers, coaches and trainers to establish a match between the goals they want to achieve and the means and resources available, taking into account the various constraints that may arise, such as reduced practice time per session, number of weekly sessions, lack of material resources and facilities, high numbers of students/athletes by class and variety of content to be taught, often involving the same activities for boys and girls alike.

In this respect, beyond the duty of the teacher and coaches to maximize the opportunities for practice, it is necessary to program the exercises in order to make them appealing and motivating for both boys and girls (NIH, 1996). The psychological saturation and physiological enervation that may attend on attempts to match results close to those achieved by opposite-sex colleagues in the same exercise can be alleviated when there is knowledge about which exercises and the respective capabilities they deploy can be best performed concurrently by boys and girls. One of the major reasons why many children drop out of sport and physical activity is that they feel they do not have the necessary skills to be involved. Both girls and boys tend to be reluctant to participate if their perceived level of skill is low. The proof of this is that female students reported more positive and adaptive perceptions in same-sex classes (Lyu & Gill, 2011). The knowledge, not only of the physical capabilities in which boys and girls are higher, but the magnitude of the differences between them, can help teachers, coaches and trainers in the planning and organizing of activities that take into account the success of both boys and girls, and thus, increase levels of physical activity and physical fitness (**Study 3**).

In children, because of low aerobic capacity is associated with risk factors of cardiovascular disease (Anderssen et al., 2007), a great amount of research has focused on activities that enhance cardiorespiratory fitness (Cepero et al., 2011). However, it is recognized that youth strength training approaches can be a safe and effective method of conditioning and should be an important component of youth fitness programs, health promotion objectives, and injury prevention (American Academy of Pediatrics, 2008; Faigenbaum et al., 2009). Indeed, improvements in muscular fitness and speed/agility, rather than cardiorespiratory fitness, seem to have a positive effect on skeletal health (Ortega et al., 2007). Increasing both aerobic and muscular fitness is essential for promoting health (American College of Sports Medicine, 2007) and should be a desirable goal in a training program (Taanila et al., 2011).

In order to maximize the benefits of training, some studies have reported the influence of several variables in the implementation of training programs in children and adolescents, such as the training program supervision, instruction quality and control learning, gender, age and maturity (Behringer et al., 2011; Faigenbaum et al., 2009). Nevertheless, the influence of body fat and somatotype on the effects of the implementation of training programs in young people still needs to be investigated. Body fat represents an inert load, non-contributive, associated with an increased metabolic cost (Norman et al., 2005) and the somatotype translates the expression of genetic determinism, observed from the morpho-constitutional point of view (Malina & Bouchard, 1991). These factors, therefore, may influence the execution of the planned exercises, training intensity and recovery of the performers, resulting in different effects of applying a particular training program. Additionally, both body fat and somatotype are significantly associated with the level of physical fitness achieved (Dumith et al., 2010; Jakšić & Cvetković, 2009), which appears to influence, in turn, the development of training programs in children and adolescents (Faigenbaum et al., 2009). Thus, the knowledge of the effects of body fat and somatotype on training-induced strength and endurance gains can help in designing and application of training programs for young people, in order to improve its efficiency (**Study 4**).

What often happens is that strength and endurance training are regularly performed concurrently at school or extracurricular activities (Santos et al, 2012), as well as in most exercise programs in wellness, fitness, and rehabilitative settings in an attempt to obtain gains in more than 1 physiologic system to achieve total conditioning, to meet functional demands, or to improve several health-related components simultaneously (Shaw et al., 2009). During several decades, many studies have reported an interference effect on muscle strength development when strength and endurance were trained concurrently. The majority of these studies found that the magnitude of increase in strength was higher in the group that performed only strength training compared with the concurrent training group, commonly referred to as the “interference phenomenon” (García-Pallarés & Izquierdo 2011). However, there exists a relative paucity of published reports focused on the implementation of concurrent strength and endurance training in school children (Izquierdo-Gabarren et al., 2010, García-Pallarés & Izquierdo 2011). A recent study showed that performing strength and endurance training in the same workout does not impair strength development in adolescent schooled boys (Santos et al., 2012). However, the effects of concurrent strength and endurance training in prepubescent children, according to our best knowledge, have yet to be investigated. On the other hand, physical education classes or extracurricular activities commonly include children of both sexes, as mentioned above. Therefore, it is important to verify the applicability of a concurrent training program in age-school boys and girls (**Study 5**).

General Introduction

Considering the abovementioned, the aim of this thesis was to analyze the effect of somatotype, body fat and physical activity on overall physical fitness, explosive strength and aerobic capacity trainability in prepubescent children. An additional objective was to identify the magnitude of the differences between boys and girls in physical fitness, and the effects of concurrent training on explosive strength and VO_{2max} adaptations.

Chapter 2 - Review of Literature

Study 1

Physical fitness in prepubescent children: an update

Abstract

This article provides a brief review over the state of art concerning some factors that influence physical fitness levels in children, namely the role of body fat, physical activity and somatotype, and how physical fitness might be improved, particularly in terms of strength and cardiorespiratory fitness. The major research conclusions can be summarized as follows: (i) there are significant and positive associations between physical activity levels and physical fitness; (ii) there is a negative relationship between body fat and performance on both endurance and weight-bearing tasks, whereas flexibility does not seem to differ significantly between overweight or obese children and normal-weight peers. Absolute handgrip strength appears to be better in obese children; (iii) by pre-puberty there already exists a fairly stable somatotype; (iv) Endomorphic is a limiting factor in body propulsion and lifting tasks. Mesomorphic is positively associated with strength and motor performance in general. The associations for ectomorphic were the inverse of those for endomorphic and mesomorphic; (v) the boys are superior in tasks that require strength, speed and endurance, and the girls on tasks with a predominance of balance, coordination and flexibility; (vi) the girls have higher levels of body fat than boys; (vii) the boys have higher and consistent levels of physical activity than girls; (viii) with an intensive training stimulus prepubescent children show improvements in aerobic capacity compared with controls of the same maturation; and (ix) strength training can be an effective and safe way for enhancing muscle strength in prepubescent children.

Key words: youth, body fat, physical activity, somatotype, performance

Introduction

Physical fitness is a major marker of health status at any age (Ortega et al., 2007). The recognition that physical fitness is a key determinant in healthy lifestyles based increasingly on criteria referenced to general health and not merely to motor performance has produced a wide range of studies on the influence of various factors on physical fitness levels, in particular the influence of body fat and physical activity. However, there are few studies that link somatotype with fitness in young people. Most studies in this context refer to the influence of body mass index in the motor performance in youth, but somatotype has been found to be inherited to a greater extent than body mass index (Reis et al., 2007).

Unfortunately, there exist evidences suggesting that physical activity (WHO, 2010) and physical fitness (Matton et al., 2007) has declined worldwide in the last decades among children. One of the pointed reasons for this decreased levels is that there is an apparent avoidance of children of the physical education classes and regular physical activity (Roetert, 2004) due, in part, to lack of planning that takes into account the interest, motivation and success of children in the execution of the exercises, respecting the differences between them, including gender differences (Haff, 2003). Physical education classes or extracurricular activities commonly include boys and girls, and this requires teachers, coaches and trainers to establish a match between the goals they want to achieve and the specificity of each gender (NIH, 1996).

Because of the low aerobic capacity in children is associated with risk factors of cardiovascular disease (Anderssen et al., 2007), the majority of the research has focused on activities that enhance cardiorespiratory fitness disregarding, for instance, neuromotor fitness conditions based on muscular strength (Cepero et al., 2011). However, it is recognized that youth strength training can be a safe and effective method of conditioning and should be an important component of youth fitness programs, health promotion objectives, and injury prevention (Faigenbaum et al., 2009). Increasing both aerobic and muscular fitness is essential for promoting health and should be a desirable goal in a training program (Taanila et al., 2011).

What often happens is that resistance and endurance training are regularly performed concurrently at school or extracurricular activities (Santos et al, 2012), as well as in most exercise programs in wellness, fitness, and rehabilitative settings in an attempt to obtain gains in more than 1 physiologic system to achieve total conditioning, to meet functional demands, or to improve several health-related components simultaneously (Shaw et al., 2009). So it is important to know if performing resistance and endurance training in the same workout does not affect strength development in children, usually referred to as “interference phenomenon” (García-Pallarés & Izquierdo 2011).

Physical fitness

The term physical fitness is often erroneously used as a synonym for aerobic fitness rather than as an umbrella term to embrace all health-related fitness components (Hands et al., 2009). Physical fitness in children has been defined as the aptitude to realize physic tasks without fatigue related to the cardiorespiratory general resistance, muscular specific resistance, and the levels of muscular force, extent of movement, speed and coordination (Deforche et al., 2003). The majority of studies on the physical fitness centered on the aerobic capacity, neglecting the neuromotor aptitude based on the muscular force, flexibility and speed (Cepero et al., 2011). However, the improvements in the muscular capacity, the speed and agility, instead of the aerobic capacity, seem to have a positive effect on the musculoskeletal health. Armstrong and Welsman (1997) reported that the neuromotor system can be as important as the aerobic capacity in the maintenance of the health.

Fitness has been proposed as a major marker of health status at any age (Ortega et al., 2007), and is considered to be important supportive element for the maintenance and enhancement of health and quality of life, and hence for the improvement of the holistic development of a child (Malina, 2001). Physical fitness is associated with lower prevalence of cardiovascular disease risk factors, improves mental and bone health, increases academic performance, improves motor skills, and protects against all-cause mortality (Kvaavik et al., 2009; Van Dusen et al., 2011). It also relates with psychophysical, cognitive, social and affective-emotional factors (Weineck, 2003). In addition, a strong relationship exists between physical fitness, especially cardiorespiratory fitness, and various measures of fatness in children and adolescents (Ruiz et al., 2006).

Physical fitness levels

There is evidence suggesting that physical fitness has declined worldwide in the last decades among children and adolescents (Matton et al., 2007). However, there is a lack of updated data (Lugueti et al., 2010). There are evidences that pointed out a decline in strength and cardiorespiratory fitness about 0.36% per year, since the decade of the 70th, related to social, behavioral, physical, physiological and psychological factors (Tomkinson & Olds, 2007). In a recent study, Lugueti et al. (2010) rated the performance of 7- to 16-years-old children (normative tables: PROESP-BR) in 9-min running, long jump, medicine-ball throwing and 1-min curl-ups. They observed a poor performance (often exceeding 50%) in all tests, for both boys and girls, particularly in girls. Physical fitness levels in children are influenced by factors such as age, sex, body composition, physical activity levels and biological maturity status (Huang & Malina, 2007). Additionally, children who are competent in the accomplishment of the motor skills took part more in the type of activities that can improve his/her levels of physical fitness (Barnett et al., 2008).

Regarding the differences between boys and girls in the motor performance, several studies have shown a superiority of boys in tasks that require strength, speed and endurance, and the girls on tasks with a predominance of balance, coordination and flexibility (Castro-Piñero et al., 2009; Cepero et al., 2011; Dumith et al., 2010).

Physical activity

Physical activity is widely recognized as an important behavioral characteristic for health promotion and disease prevention. However, a large portion of the population is not active enough to obtain these health benefits (WHO, 2010). In the contemporary society there are many requests for sedentary practices and simultaneously for the consumption of highly energetic food. Silently, the individuals are conducted to increasingly sedentary standards of living (Marshall et al., 2002), with a consequent increase of the risk factors for the development of many chronic hypokinetic diseases. And if the problem used to be centered on adults, the incidence in children has grown substantially. Children who have a physically active life can get a set of health benefits, including: reduction of the risk of cardiovascular disease (Andersen et al., 2006) and hypertension (Sarzynski, et al., 2010), low incidence of diabetes (Gaya et al., 2009), increased bone mineralization (Hind & Burrows, 2007), prophylactic action of disorders of the musculoskeletal system (Prentice et al., 2006); psychological well-being, and higher academic performance (Sallis et al., 2000).

Physical activity levels

It is known that the level of physical activity among young people has been decreasing considerably, and is currently below the commonly recommended (Sallis et al., 2009; WHO, 2010). For many young people the school-based physical education classes are the only way of undertaking physical activity (Coleman et al., 2004), but unfortunately, it has been observed that there is an apparent avoidance of children of the physical education classes and regular physical activity practice at school (Roetert, 2004). Portuguese children have one of the lowest rates of physical activity in European Union (Janssen et al., 2005).

There are a number of factors positively associated with the levels of physical activity in youth, including self-efficacy in one's ability to overcome barriers to physical activity, perceptions of physical or sport competence, having positive attitudes toward physical education, enjoying physical activity, and parent, sibling, and peer support (Sallis et al., 2000). There are other factors that may influence levels of physical activity, such as the socio economic and cultural environment (Kriska, 2000). Also the availability of outdoors play spaces, such as parks and playgrounds, may be especially important because time spent outdoors is strongly correlated to physical activity (Tudor-Locke et al., 2001).

Regardless of the recommendations transmitted by different international organizations, the need for all children and adolescents perform a minimum of 60 min of moderate-to-vigorous physical activity, in most days of the week, and preferably every day, is unanimously accepted (Pate et al., 2002; WHO, 2010). The National Association for Sport and Physical Education (2004) add the need to accumulate peak intensity of 15 or more minutes per day. According to the British Association of Sport and Exercise Sciences (O`Donovan et al., 2010), children and adolescents aged 5-16 years should accumulate at least 60 min of moderate-to-vigorous intensity activity per day, including vigorous-intensity aerobic activities that improve bone density and muscle strength. Although there are some evidence of a greater participation of boys in sports activity, especially with vigorous intensity, and girls in leisure activities and low intensity, in general males have higher and consistent levels of physical activity than females (Dencker et al. 2010).

Association between physical activity and physical fitness

In children, the strong and positive association between physical activity and physical fitness that occurs in adults is not so evident, and there is some controversy in studies. To this contributes a number of factors that hinder the clarification of the relationship between physical activity and physical fitness, including the difficulty in measuring the daily physical activity from large samples, the lack of longitudinal studies, the lack of consensus about the validity of different assessment methods, the various definitions of physical activity and the difficulty of assessing accurately the intensity of the physical activity (Twist et al., 2000).

Cardiorespiratory fitness has often been considered the best indicator of individual fitness, since it indirectly favors the other capabilities (Costa et al., 2000). This fact has motivated many studies about the relationship between physical activity and aerobic fitness in young people, and cross-sectional epidemiological studies have shown significant associations between these two variables, although the strength of the relationship has been generally weak. Graf et al. (2004) evaluated 668 German children (mean age 7.6 years) in their patterns of physical activity (questionnaire) and 6 min running. They noted that more active children were significantly better in the selected test. Dencker et al. (2006) evaluated the relationship between daily physical activity of 248 Swedish children, from 8 to 11 years old, and VO_{2max} (cycle ergometer). They found significant and positive associations between total physical activity and VO_{2max} ($r = .23$, boys and girls). Ara et al. (2007) explored the possible contribution of physical activity (participation in extra-curricular physical activity) in the results of the EUROFIT test battery, of 7- to 10-years-old Spanish children. The results showed that physical activity was positively related to the performance in the 12-min walking/running test. In the United States of America, a sample of 230 children between 7 and 12 years old, representative of the Illinois area, was evaluated by the FITNESSGRAM test battery, physical activity (questionnaire, interview and pedometers) and motor skills tests (Castelli &

Valley, 2007). The results showed that daily physical activity was significantly associated with FITNESSGRAM test battery ($r = .28$ to $.46$), namely the performance in the 20-m Multistage Fitness test. Dencker et al. (2008) evaluated the associations between objectively measured daily physical activity (accelerometers for 4 days and daily accumulation of moderate-to-vigorous and vigorous activity) and aerobic fitness (indirect calorimetry during a maximal cycle ergometer exercise test), in 225 children (aged 7.9-11.1 years). Significant relationships were found between vigorous activity and aerobic fitness ($r = .38$), whereas moderate-to-vigorous activity displayed weaker relationships ($r = .25$). Low daily accumulation of vigorous activity was associated with lower aerobic fitness. A similar relation was not found for daily accumulation of moderate to vigorous activity. Tovar et al. (2008) observed a significant and positive correlation ($p < 0.05$) of the self-reported physical activity levels with the performance in the aerobic multistage fitness test, among 655 boys (between 7 and 18 years) attending a private school in Bogotá, Colombia. Sveinsson et al. (2009) examined the interrelationship between aerobic fitness (bicycle ergometer) and physical activity (Actigraph activity monitors using total activity each day), in 270 participants selected from 18 primary and secondary schools in Iceland (9- and 15-year-olds). Physical activity explained a smaller proportion (0%) of the unadjusted variance in fitness for the 9-year-olds than for the 15-year-olds (19%). The authors also found that gender differences in aerobic fitness after puberty can largely be explained by gender differences in physical activity. More recently, Dencker et al. (2010) investigated by direct measurement the cross-sectional relationship between accelerometer-measured physical activity over a 4-day period and peak oxygen uptake (VO_{2peak} : $ml \cdot min^{-1} \cdot kg^{-1}$, by indirect calorimetry during a maximal treadmill exercise test), in 468 children (246 boys, 222 girls) aged 6.7 ± 0.4 years, recruited from a population-based cohort. Pearson correlation coefficients indicated a weak relationship between daily physical activity variables and VO_{2peak} in boys ($r = .15$ to $.28$), with the exception of time in sedentary and light activity, which was not related to VO_{2peak} . None of the daily physical activity variables were related to VO_{2peak} in girls, with the exception of a very weak relationship for moderate activity ($r = .14$). Multiple regression analyses indicated that the various physical activity variables explained between 2 and 8% of the variance in VO_{2peak} in boys. In this population-based cohort, most daily activity variables were positively related to aerobic fitness in boys, whereas less clear relationships were observed in girls. The authors' findings that physical activity was only uniformly related to aerobic fitness in boys partly contradict previous studies in older children and adolescents.

Beyond the association with aerobic fitness, physical activity correlates with other components of physical fitness, such as muscle strength and endurance, speed, flexibility, balance, agility and motor coordination. Wrotniak et al. (2006) examined the relationship between motor proficiency (Bruininks-Oseretsky Test of Motor Proficiency) and physical activity (accelerometer) in 8- to 10-year-old children (34 girls and 31 boys). They found that motor proficiency of children (running speed, agility, balance, standing broad jump, sit ups,

push-ups and bilateral coordination) was positively correlated with total physical activity ($r = .32$) and percentage of time spent on moderate to vigorous physical activity ($r = .30$), and inversely correlated with time spent in sedentary activities ($r = -.31$). In an investigation to explore the possible contribution of physical activity (participation in extra-curricular physical activity) in the results of the EUROFIT test battery, of 7- to 10-years-old Spanish children, Ara et al. (2007) showed that physical activity was positively related to the physical fitness of boys (Balance, sit-and-reach, standing broad jump, handgrip strength, sit ups, plate tapping, and shuttle run). In the United States of America, a sample of 230 children between 7 and 12 years old, representative of the Illinois area, was evaluated by the FITNESSGRAM test battery, and physical activity levels (questionnaire, interview and pedometers) (Castelli & Valley, 2007). The results found by the authors showed that daily physical activity was significantly associated with the FITNESSGRAM test battery performance ($r = .28$ to $.46$).

Body fat

Health problems associated with excess body fat are so common that in part replaced other health concerns of the present time, such as malnutrition and infectious diseases. The importance of health problems arising from excess weight and obesity has become more pronounced because of the incidence rates in most socioeconomically developed countries tend to increase, in addition to adults, in children and adolescents (Carmo et al., 2007). Excess body fat in children is alarming because it is closely related to the increased risk of diseases with adverse consequences for health (Daniels, 2006), which in the past were confined to the elderly, because they are typical of the normal degeneration process of aging (Pertroski, 2007).

The consequences of the excess body fat in children are well known: cardiovascular disease, elevated insulin levels, high blood pressure, high cholesterol, dyslipidemia, metabolic syndrome, asthma, sleep apnea, syndrome of hypoventilation, gastrointestinal complications, liver and kidney diseases, and some types of cancer (Daniels, 2006; Stephen, 2006), degenerative joint disease and orthopedic abnormalities (Ball et al., 2003), hormonal, neurological and immunological problems (Denney-Wilson & Baur, 2007), and deficit of self-esteem, depression, eating disorders and school failure (Denney-Wilson & Baur, 2007). Additionally, longitudinal studies of children followed into young adulthood suggested that overweight children may become overweight adults (WHO, 2007), exposed to an increased comorbidity and mortality risk (Katzmarzyk et al, 2003).

Body fat levels

Many countries are losing the battle against obesity, which is even more striking in the case of children (Wang & Lobstein, 2006). Also in Portugal, overweight and obesity have reached

epidemic proportions (Marques-Vidal & Dias, 2005). Portuguese Children have one of the highest prevalence of obesity in European Union (do Carmo et al., 2006).

Although other factors such as genetics and diet (Mota et al., 2006) play an important role in overweight-related genesis, the increased prevalence of overweight/ obesity has been associated with the reduction of physical activity and has been linked to environments that encourage sedentary behaviors (Aires et al., 2010). For many young people the school-based physical education classes are the only way of undertaking physical activity (Coleman et al., 2004). However, the quantity of time in physical educational schools programs and the interventions of the seasons have limited effects (Lobstein et al., 2004). In a longitudinal, randomized study of 5 months, to determine the effects of physical education in health-related fitness among boys and girls (aged 8 to 12 years), Cepero et al. (2011) observed that the physical activity at school is not sufficient to support an ideal level of health-related fitness. Several studies have shown higher values of body fat in girls than in boys (Cepero et al., 2011; Sveinsson et al., 2009).

Association between body fat and physical fitness

Physical fitness of overweight and obese children has extensively been documented. Numerous studies already established a negative relationship between excessive body fat and performances on both endurance and weight-bearing tasks (Dumith et al., 2010; Tovar et al., 2008), whereas flexibility does not seem to differ significantly between overweight or obese children and normal-weight peers (Casajús et al., 2007). Absolute handgrip strength even appears to be better in obese children and adolescents, given their increased fat-free mass (Casajús et al., 2007; Deforche et al., 2003).

Ara et al. (2007) investigated the association of BMI with physical activity (participation in extra-curricular physical activities), of 1068 Spanish children from 7 to 12 years of age. The results showed that the aerobic fitness (VO_{2max}) was negatively correlated with adiposity in both sexes. In the U.S., a sample of 230 children between 7 and 12 years of age, representative of the area of Illinois, was assessed by the FITNESSGRAM battery and BMI (Castelli & Valley, 2007). The results found by the authors show a low, but significant association, between BMI and the motor tests performed ($r = -.24$ to $-.29$). In an analysis of the performance in fundamental motor skills (Movement Assessment Battery for Children (M-ABC) and BMI of 117 Belgian children, from 5 to 10 years of age, D'Hondt et al. (2009) observed a significant and negative association between these two variables ($r = -.34$). Castro-Piñero et al. (2009) studied the influence of body weight (BMI) on 9 different muscular strength tests in Spanish children (1513 boys and 1265 girls) aged 6 to 17.9 years. Both underweight and normal weight children and adolescents had significantly higher performance than their overweight and obese counterparts in the standing broad jump, vertical jump and push-ups tests in boys, and bent arm hang test in both boys and girls.

Sveinsson et al. (2009) examined the interrelationship between aerobic fitness (bicycle ergometer) and body composition (logarithm of sum of four skinfolds- loge skinfolds, and BMI), in 270 participants selected from 18 primary and secondary schools in Iceland (9- and 15-year-olds). All the body composition variables explained a similar proportion of the fitness variance (35-42%) among the 9-year-olds. The authors also found that gender differences in aerobic fitness after puberty can largely be explained by gender differences in loge skinfolds. Dumith et al. (2010) undertook a study with 519 Brazilian students (age 7 to 15 years). Physical fitness was assessed using 8 tests: sit-and-reach, stationary long jump, 1-minute curl-up, modified pull-up, medicine-ball throw, 9-minute run, 20-m run, and 4-m shuttle-run. The authors found that higher values of body mass index were associated with declines in physical fitness, independent of age. Normal weight students performed better than overweight and obese students ($p < 0.01$) in all tests, except the sit-and-reach and the medicine-ball throw. Cardiorespiratory fitness had the strongest association with BMI status. Xianwen et al. (2010) investigated the association of weight status with physical fitness (standing broad jump, 50m sprint and 50m x 8 shuttle run) among 6929 Chinese children (aged 6-12 years). An inverse association of obesity with cardiorespiratory fitness, muscle explosive strength, and speed was identified. The likelihood of achieving good performance was much lower among overweight and obese children in comparison with their counterparts with normal weight (Odds ratio= .13 to .54). Recently, in a study to analyze the relationship of body fat with fitness levels (Cardiovascular Endurance Run, curl-ups, trunk lifts, push-ups and shoulder stretches) of 7000 school children in Louisiana, Joshi et al. (2012) observed that the participants with healthy BMIs have the highest levels of physical fitness.

Somatotype

The description and interpretation of human variability is a central nucleus of research in many areas of Anthropology, Medicine and Sport Science. Constitution represents a specific pattern of structural-morphological, physiologically functional and psychological cognitive-conative features of a person, which distinguish this person from all the others (Jakšić & Cvetković, 2009, Shukla et al., 2009). These characteristics are predetermined by the heredity and significantly influenced by various environmental factors (Shukla et al., 2009).

Physique refers to an individual's body form, and is probably the single aspect of constitution that is most amenable to systematic study, because it can be readily observed (Malina & Bouchard, 1991). In an attempt to classify body types, William Sheldon introduced the concept somatotype (*soma* = "body"), in the 1940s. Hence, several modifications of Sheldon's method were developed, and the resulting approach was the Health-Carter method, that uses anthropometric procedures to estimate somatotype, which is defined as representing the individual's "present morphological conformation" (Carter, 2002). According to Reis et al.

(2007) there exists a tendency for a genetic influence on the three somatotype components (endomorph, mesomorph and ectomorph). In reverse, it seems that the effect of physical activity and biological maturity is very weak in the physique of children (Malina et al., 2004).

Somatotype's stability

There is evidence that by pre-puberty there already exists a fairly stable somatotype, pointing to 8 years as the age by which somatotype stability becomes manifest (Malina & Bouchard, 1991; Malina et al., 2004). However, an analysis to changes in morphological typology of children during growth shows that in pre-puberty boys tend to show a slight increase of the mesomorphic values, and girls show an increase of the endomorphic and a slight reduction of the ectomorphic values, while the mesomorphic component does not change significantly (Malina et al., 2004). In an investigation that aimed to study the somatotype's (tri-dimensional structure) stability in children and youngsters from Madeira (Portugal), based on a stratified and proportional sample (from 309 subjects, 157 boys and 152 girls) from a mixed-longitudinal study, Maia et al (2004) found that somatotype was strongly stable over the age range of 10 to 16 years.

Association of somatotype with physical fitness

The associations between biotype and performance on a variety of motor tasks are generally weak and limited in prepubertal age (0 to about .35) (Malina & Bouchard, 1991). The most consistent relationship is a negative association between endomorphic and performance in running, jumping and agility. The excess body fatness associated with endomorphic adversely affects motor performance. On the other hand, mesomorphic and ectomorphic do not appear to be consistently related to motor performance in prepubescent children. Correlations of endomorphic and mesomorphic with muscular strength tend to be low to moderate and positive (.20 to .50), whereas correlations between ectomorphic and strength are of about the same magnitude but negative (-.20 to -.50) (Malina & Bouchard, 1991). The correlations indicate the importance of overall body size in strength tests, especially body weight, and the significant relationship between endomorphic and strength indicates the contribution of muscularity to body weight, which most likely influences endomorphic ratings. On the other hand, the linearity of physique associated with ectomorphic is indicative of less muscle mass, and in turn, lower levels of attained muscular strength (Malina & Bouchard, 1991). According to Ignjatović et al. (2009) it is logical to assume that young people who are stronger and more powerful have an advantage in motor performance. The relationships between size or physique, on the one hand, and strength and motor performance, on the other, are consistent with those for estimates of body composition. In prepubescent children, absolute and relative fat-free mass are moderately and positively related to strength and motor performance, but absolute and relative fatness are negatively related to motor items in which the body must be projected. Throwing is an exception. Absolute fat-free mass is more related to throwing

performance than relative fat-free mass, indicating the role of absolute body size in distance throwing (Malina & Bouchard, 1991)

There are few studies that relate somatotype and motor performance variables in children and adolescents. Suchomel, A. (2002) examined the relationship between the components of anthropometric somatotype and motor performance in boys and girls (8-9 and 12-13 years old) with considerably above-average and considerably below-average total score of the test battery UNIFITTEST. They found a significant positive relation between ectomorphic and the level of motor performance and, on the contrary, significant negative relation between endomorphic, as well as mesomorphic, and the level of motor performance of pubescent boys and girls. They also reported a significantly lower variability of the results of somatotype components in the high motor efficient group than in the low motor efficient one. The samples of boys and girls with a high motor performance corresponded to their somatotypes (mesomorphic-ectomorphic and ectomorphic-mesomorphic, with low level of endomorphic dominated) and on the contrary boys and girls with a low motor performance were difficult to characterize. Shukla et al (2009) conducted a cross sectional study on the morphological typology and motor quality of 900 boys, aged 10-18 years. They found that Mesomorphic component exhibited a significant and negative correlation with standing broad jump ($r = -.28$) and bend knee sit-ups ($r = -.19$). The association with the Sit-and-reach test was not significant ($r = .08$).

Regarding gender differences in the performance of prepubescent children, they reflect, in part, gender differences in size and body composition. The greater relative fatness of girls and the greater absolute and relative leanness of boys exert opposite effects on performance. Excessive fatness, as indicated above, tends to have a negative effect on most motor performance tasks, and greater fat-free mass tends to have a positive effect. As in adolescence, prepubescent boys tend to have greater strength per unit body size, especially in the upper extremities and the trunk, than girls, whereas there are negligible sex differences in lower extremity strength when body size is controlled (Malina & Bouchard, 1991).

Aerobic training

Aerobic fitness is a health-related component of physical fitness that relates to ability of the circulatory and respiratory systems to supply oxygen during sustained physical activity (US Department of Health and Human Services, 1996), and is probably the most important component of any physical fitness program because it reflects the overall capacity of the cardiovascular and respiratory systems and the ability to carry out prolonged strenuous exercise (Astrand et al., 2003). Several studies indicate that a good aerobic capacity is

associated with a lower risk of coronary heart disease, diabetes and other health problems in children (Aires et al., 2010; Kvaavik et al., 2009).

Training-induced adaptations in aerobic fitness have been extensively studied in adults, however, young people appear to respond differently to such exercise stimulus in comparison to adults (Matos & Winsley, 2007). Some exercise scientists have recommended similar training programs for young people. However, the subject of the response to aerobic training of children and adolescents is controversial, and the effects of exercise training on prepubertal children are particularly debatable. This can be partly explained by different training designs, which make comparisons between studies very problematic (Baquet et al., 2003). Several researchers have concluded that pre-pubescent children may be less adaptive to aerobic training than adolescents and adults (Baquet et al., 2003; Matos & Winsley, 2007), which was attributed to either a high inherent level of physical activity or to some unexplained limitations in the biological responsive mechanisms related to maturation (Katch, 1983).

However, some studies have shown that with an intensive training stimulus, pre-pubescent children show improvement in maximum aerobic power compared with controls of the same maturation (Baquet et al., 2004; Santos et al., 2012; Vamvakoudis et al., 2007), with improvements reported at approximately 5% (Matos & Winsley, 2007). Moreover, improvements in other variables like exercise economy or lactate threshold may occur without significant changes in peak VO_2 (Matos & Winsley, 2007). Unfortunately, despite the abundant research on aerobic training, the relationship between exercise training and adaptations in aerobic metabolism are still not well understood in prepubertal and early pubertal children (Tolfrey, 2007). In order to investigate the ability of children to improve aerobic fitness after a 12-week period of aerobic training, Rowland and Boyajian (1995) found that mean $\text{VO}_{2\text{max}}$ did not change significantly during the control period, but rose from 44.7 (5.8) to 47.6 (6.4) $\text{mL kg}^{-1}\text{min}^{-1}$ (6.5%) with training ($P < .05$). No differences in training response were observed relative to sex, pre-training $\text{VO}_{2\text{max}}$, or sports participation. The findings of this study support the concept that $\text{VO}_{2\text{max}}$ can be improved with aerobic training during the childhood years, but the degree of aerobic trainability is limited in healthy, active children. The meta-analysis of Payne and Morrow (1997) analyzed the data from 69 studies (of which 28 met the inclusion criteria) that were either a cross-sectional comparison between trained and untrained children or a pre-test/ post-test design. Greater differences between trained and untrained participants (Effect Size 0.94 ± 1.00) were seen, but less than a 5% change in peak VO_2 (approximately $2\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) were noted in the pre-post studies (Effect Size 0.35 ± 0.82). Baquet et al. (2003) argued that improvements in peak VO_2 of around 5-6% are observed when the data are analyzed independently by sex or pubertal status. These authors also stated that when only studies that reported significant changes were considered, peak VO_2 improvements rose to 8-10%. In a study in order to determine in healthy children (10

girls and 9 boys, 10-11-year-old) the effect of a 13-week well-controlled aerobic training program on cardiac function at maximal exercise and to define whether gender affects the training-induced cardiovascular response, Obert et al. (2003) observed that the training program led to a rise in VO_{2max} , brought about however, only by an increase in maximum stroke volume in both genders. Moreover, the boys increased their VO_{2max} to a greater extent than the girls (boys: +15%; girls: +8%) only because of a higher maximum stroke volume improvement (boys: +15%; girls: +11%). An increase in the left ventricular end-diastolic diameter, concomitant with an improvement in diastolic function, was observed after training and constituted an essential element in the rise in VO_{2max} after training in these children. Moreover, during maximal exercise, a decrease in systemic vascular resistances, probably indicating peripheral cardiovascular adaptive changes, might also play an important role in the increase in VO_{2max} . Rowland (2005) compiled a series of what he considered to be well-designed investigations in children and stated that the improvements in aerobic power were indeed quite small, with the greatest improvement being 10%, but the average change being 5.8%. Vamvakoudis et al. (2007) analyzed the effects of a prolonged aerobic training on maximal aerobic power of young basketball players (20 players and 18 control boys). All subjects were tested every 6 months (18 months total, 11(1/2), 12, 12(1/2), 13 years old) for VO_{2max} . The authors observed that VO_{2max} was altered in both groups on the final test, when compared to the initial test. However, the training group had a higher VO_{2max} on each of the 6-month follow-up measurements, compared to the control group ($p < 0.001$). The major implication suggested by the findings of the study was that, in order to improve the basic physical components, specific training procedures should be incorporated during the basketball training sessions. It was recommended that all children should be involved in some type of cardiovascular and resistance training program.

Regarding sex differences in aerobic trainability, at present, there are few studies which have addressed sex differences in the trainability of aerobic fitness in children, with the majority of studies recruiting boys as participants (Matos & Winsley, 2007). Single sex studies using prepubertal girls however have reported that significant improvements in peak VO_2 are possible (McManus et al., 1997), akin to that seen in boys. The data from those studies that have directly compared the sexes suggest that boys and girls demonstrate similar responses in aerobic trainability (Baquet et al. 2003), even though boys' peak VO_2 appears to be slightly higher than girls (Obert et al., 2003). Obert et al. (2003) had 10 girls and 9 boys participate in a 13-week aerobic training programme (3 x 1 hour per week) and found that significant improvements in peak VO_2 were observed for both groups; boys increased peak VO_2 by 15% and girls by 8%. Similar findings were reported by Baquet et al. (2002); 9.5% increase in peak VO_2 for the prepubertal boys being not significantly different from the 7.2% increment observed in girls.

Strength training

In addition to aerobic activities, research increasingly indicates that strength training can offer unique benefits for children when appropriately prescribed and supervised (Behringer et al., 2011; Faigenbaum et al., 2009). Furthermore strength training has been shown to be associated with several health-related benefits such as increased bone mineral density, improved body composition, improved insulin sensitivity, normalization of vascular disorders (Shabi et al., 2006, Benson et al., 2006), and enhanced mental health and well-being (Yu et al., 2008). It also increases the resistance to sports injuries and makes more effective the rehabilitation in young athletes (Kraemer & Fleck, 2005).

Although early studies suggested that strength training did not lead to significant improvements in strength, numerous studies spanning the last 50 years have shown strength training to be an effective and safe way for enhancing muscle strength in children and adolescents, if appropriately prescribed and supervised (Behringer et al., 2011). Strength gains up to 74% have been reported after 8 weeks of progressive resistance training (Faigenbaum, 1993), although gains of roughly 30% are typically observed after short-term (8-20 weeks) youth resistance training programs (Faigenbaum et al., 2009). According to Dahab and McCambridge (2009) children can improve strength between 30% and 50% after only 8 to 12 weeks of a strength training program at a frequency of at least two training times per week. Isometric and dynamic strength training are effective in increasing strength in pre-pubertal children and adolescents, with both groups showing considerable improvements (Rowland, 2005; Tolfrey, 2007). Reported relative (% change above initial levels) strength gains achieved during preadolescence are equal to if not greater than the relative gains observed during adolescence (Lillegard et al., 1997).

The mechanisms underlying strength improvements and muscle hypertrophy in adults arise through an interaction between neural and hormonal mechanisms. However, in the pre-pubescent population, muscle hypertrophy is not believed to be the primary factor in strength improvement (Tolfrey, 2007). Without corresponding increases in fat-free mass, it appears that neural adaptations (i.e., a trend toward increased motor unit activation and changes in motor unit coordination, recruitment, and firing) (Ozmun et al., 1994; Ramsay et al., 1990) and possibly intrinsic muscle adaptations (as evidenced by increases in twitch torque) (Ramsay et al., 1990) are primarily responsible for training-induced strength gains during preadolescence. Improvements in motor skill performance and the coordination of the involved muscle groups may also play a significant role because measured increases in training-induced strength are typically greater than changes in neuromuscular activation (Ozmun et al., 1994; Ramsay et al., 1990).

A compelling body of scientific evidence indicates that children and adolescents can significantly increase their strength, above and beyond growth and maturation, providing that the resistance training program is of sufficient intensity, volume, and duration. Faigenbaum et al. (2002) analyzed the effects of 1 and 2 days per week of strength training (8 weeks) on upper body strength, lower body strength, and motor performance ability in children (21 girls and 34 boys between the ages of 7.1 and 12.3 years). Only participants who strength trained twice per week made significantly greater gains in 1RM chest press strength, compared to the control group (11.5 and 4.4% respectively, $p < .05$). In a study conducted by Tsolakis et al. (2004), ten untrained preadolescent males (11-13 years old) were submitted to a 2-month resistance-training program (6 exercises, 3 x 10 repetitions maximum [RM], 3 times per week). The effectiveness of the resistance program was determined by measuring pre- and post-training differences in isometric and isotonic (10RM) strength. The authors observed significant post-training isometric strength gains (17.5%) in the experimental training group. Faigenbaum et al. (2005) compared early muscular fitness adaptations in children (23 girls and 20 boys between the ages of 8.0 and 12.3 years) in response to low repetition maximum and high repetition maximum resistance training. Children performed one set of 6 to 10 RM or one set of 15 to 20 RM on child-size exercise machines twice weekly over 8 weeks. Both experimental groups made significantly greater gains in 1RM strength (21% and 23%, respectively) as compared with the control group (1%). In order to investigate whether a whole-body vibration program results in a better strength and postural control performance than an equivalent exercise program performed without vibration (6 weeks of training at 3 times per week), in 33 Belgian competitive skiers (ages = 9-15 years), Mahieu et al. (2006) observed that both training programs significantly improved knee muscle strength and explosive strength ($p \leq 0.05$).

Regarding gender differences, there have been few studies that have looked at differences in training induced strength improvements between boys and girls, but it appears that both sexes respond similarly (Faigenbaum et al., 2003; Matos & Winsley, 2007).

Concurrent strength and aerobic training

Strength training and aerobic training are often performed concurrently in most exercise programs in wellness, fitness, and rehabilitative settings in an attempt to obtain gains in more than 1 physiologic system to achieve total conditioning, to meet functional demands, or to improve several health-related components simultaneously (Shaw et al., 2009). Furthermore, children involved in physical education classes often perform strength and aerobic training concurrently in an effort to achieve specific adaptations to both forms of training (Santos et al., 2012).

However, during several decades many studies have reported an interference effect on muscle strength development when strength and aerobic were trained concurrently (Dudley & Djamil, 1985; Hickson, 1980). The majority of these studies found that the magnitude of increase in strength was higher in the group that performed only strength training compared with the concurrent training group. This is commonly referred to as the “interference phenomenon” (García-Pallarés et al., 2009). Because strength and aerobic training elicit distinct and often divergent adaptive mechanisms, the concurrent development of both fitness components in the same training regimen can lead to conflicting neuromuscular adaptations, such as: (i) reductions in the motor unit recruitment and decreases of rapid voluntary neural activations; (ii) chronic depletion of muscle glycogen stores; (iii) skeletal muscle fibre type transformation; (iv) overtraining produced by imbalances between the training and recovery process; and (v) decreases in the cross-sectional area of muscle fibres and in the rate of muscle force production, due to the reduction in total protein synthesis following endurance training (Coffey & Hawley, 2007). Several studies have identified different factors that can influence the level or degree of interference generated by concurrent training (García-Pallarés & Izquierdo 2011). These factors include the initial training status of the subjects, exercise mode, volume, intensity and frequency of training (González-Badillo et al., 2005; Kraemer & Ratamess, 2004).

Despite all of the experimental studies, there is a lack of information about the effects of concurrent training in children, with the exception of the recent studies by Santos et al. (2011, 2012) relating exclusively to the effects of concurrent training in pubertal girls and boys, respectively. The effects of concurrent training in prepubescent children, according to our best knowledge, have yet to be investigated. The authors compared the effects of an 8-week training period of strength training alone, or combined strength and aerobic training, on power strength and VO_{2max} adaptations. Significant training-induced differences were observed in 1kg and 3kg medicine ball throw gains, and height-and-length of the counter movement jumps. Time-at-20m also decreased significantly for both interventions programs. VO_{2max} increased significantly only in the endurance training group. No significant differences were found in the post training between strength training group and combined strength and aerobic training group in any parameters of explosive strength evaluated.

Summary and future directions

There is evidence suggesting that physical fitness has declined worldwide in the last decades among children. Therefore, the efforts to promote levels of physical fitness in children should be a priority. The knowledge of the determinants of physical fitness in prepubescent children and its training effects can help achieve this goal.

The main research findings can be summarized as follows:

- (i) There are significant and positive associations between physical activity levels and physical fitness;
- (ii) There is a negative relationship between excessive body fat and performance on both aerobic and weight-bearing tasks, whereas flexibility does not seem to differ significantly between overweight or obese children and normal-weight peers. Absolute handgrip strength appears to be better in obese children;
- (iii) Endomorphic is a limiting factor in body propulsion and lifting tasks. Mesomorphic is positively associated with strength and motor performance in general. The associations for ectomorphic were the inverse of those for endomorphic and mesomorphic.
- (iv) The boys are superior in tasks that require strength, speed and aerobic capacity, and the girls on tasks with a predominance of balance, coordination and flexibility;
- (v) The girls have higher levels of body fat than boys;
- (vi) The boys have higher and consistent levels of physical activity than girls;
- (vii) During pre-puberty, the boys tend to show a slight increase of the mesomorphic and the girls show an increase of the endomorphic;
- (viii) With an intensive training stimulus, prepubescent children show improvements in aerobic capacity compared with controls of the same maturation;
- (ix) Strength training can be an effective and safe way for enhancing muscle strength in prepubescent children;
- (x) The effects of concurrent training in prepubescent children, according to our best knowledge, have yet to be investigated.

Regarding to the state of the art, researchers should aim future investigation in order to explore issues that are not completely clear in the available literature. Some of those main topics can be:

- (i) The interaction between physical activity, body fat, somatotype and physical fitness;
- (ii) The interaction between physical activity, body fat, somatotype and training-induced strength and aerobic fitness (and other physical capacities);
- (iii) The magnitude of the differences between boys and girls in physical fitness;
- (iv) The effects of concurrent training in prepubescent children.

Chapter 3 - Experimental studies

Study 2

Somatotype is more interactive with strength than fat mass and physical activity in peripubertal children

Abstract

The purpose of this study was to analyze the interaction between somatotype, body fat and physical activity in prepubescent children. This was a cross-sectional study design involving 312 children (160 girls, 152 boys) aged between 10 and 11.5 years old (10.8 ± 0.4 years old). Evaluation of body composition was done determining body mass index and body fat by means of skin-fold measurements, using the method described by Slaughter. Somatotype was computed according to the Carter's method. Physical activity was assessed with the Baecke questionnaire. The physical activity assessment employed sets of curl-ups, push-ups, standing broad jump, medicine ball throw, handgrip strength and Margaria-Kalamen power stair. There were negative associations for body fat, endomorphy and mesomorphy with curl-ups, push-ups and broad jump tests and positive associations with ball throw, handgrip strength and Margaria- Kalamen power tests. The associations for ectomorphy were the inverse of those for endomorphy and mesomorphy. Non-obese children presented higher values for curl-ups, push-ups and standing broad jump. In medicine ball throw, handgrip strength and Margaria-Kalamen power test obese children presented higher scores, followed by children who were overweight. The mesoectomorphic boys and ectomesomorphic girls performed higher in all tests. The morphological typology presented more interactions with strength than % of body fat and physical activity. These data seem to suggest that the presence/absence of certain physical characteristics is crucial in the levels of motor provision in prepubescent children.

Key words: physical fitness, motor performance, strength, anthropometric

Introduction

Children with high levels of motor competence are more active, more capable (Castelli and Vale, 2007) and spend less time on sedentary tasks (Wrotniak et al., 2006). On the other hand, improvement in the motor proficiency of children can also influence levels of habitual physical activity beyond school age, creating expectations of future maintenance of active lifestyles (Sharkey, 2002; Andersen et al., 2004) and is thus indispensable to potential decisions influencing the promotion of health (Stodden et al., 2008). Health-related fitness includes, besides others, aerobic endurance, muscular strength, and flexibility (Hands et al., 2009). On this, most studies on physical fitness have focused specially on aerobic capacity neglecting, among for instance, neuromotor fitness based on muscular strength (Cepero et al., 2011). Some studies reported positive associations between physical activity in children and adolescents with performance on tests of muscular strength and muscular endurance (Lennox et al. 2008; Martínez-Gómez et al., 2011). Added to that, an evolution of muscular strength skills throughout adolescence associated with higher levels of physical activity were also described (Zac and Szopa, 2001). Others, by contrast, report no significant associations between physical activity and performance in similar tests (Hands et al., 2009). It is also possible to find studies that negatively relate body fat with tests of strength and muscular endurance (Castro-Pistro et al. 2009; Dumith et al., 2010) or, conversely, a positive relationship in tests such as ball throwing or handgrip strength (Artero et al., 2010; D'Hondt et al. 2009).

Somatotype assessment may be used to describe changes in the human physique over the lifespan or as a result of physical activity and has been found to be inherited to a greater extent than body mass index (Reis et al., 2007). Yet, there are few studies that link somatotype with muscular strength in young people, with the exception of the recent studies by Jakšić and Cvetkovic (2009) and Shukla et al. (2009) relating this exclusively to the standing broad jump and curl-ups. Currently, efforts to promote physical fitness levels in the young ought to be a priority (Cepero et al., 2011), but clearly these cannot exceed the limits imposed by genotype, i.e., the manifestation of genetic determinism; just as important as the dimensional values are their relative degrees of presence, observed from the morpho-constitutional perspective (Malina and Bouchard, 1991). We can define the morphological typology as a complex entity that describes the overall configuration of the body, as opposed to individual anatomical characteristics (Malina and Bouchard, 1991). It is therefore pertinent to examine, in addition to the correspondence between physical activity, body composition and performance in tests of muscle strength and endurance, the correlation between somatotype and any such tests.

Therefore, the purpose of the present study was to analyze the relationship between physical activity, body fat, and somatotype with performance in tests of strength and muscular

endurance. An additional objective is to find which of the variables is most interactive with the muscular strength and endurance parameters selected. It was hypothesized that there is some kind of relationship between physical activity, body fat and somatotype with muscular strength and muscular endurance performances.

Material and Methods

Sample

The sample, cross-sectional in type, consisted of 312 prepubescent children (160 girls, 152 boys) who volunteered for this study. The age, height and weight of the whole sample were: 10.8 ± 0.4 years, 1.45 ± 0.08 m, 40.0 ± 8.7 kg, respectively (girls: 10.8 ± 0.4 years, 1.44 ± 0.07 m, 38.9 ± 8.5 kg; boys: 10.8 ± 0.4 years, 1.45 ± 0.09 m, 41.2 ± 8.8 kg). Descriptive data of the percentage of fat mass (%FAT), body mass index (BMI) endomorphy (ENDO), mesomorphy (MESO), ectomorphy (ECTO), physical activity index (PA) and muscle strength variables are presented in Table 1.

Table 1. Descriptive data of FAT, BMI, ENDO, MESO, ECTO, PA and muscle strength variables

	Male		Female		Overall sample	
	Mean	SD	Mean	SD	Mean	SD
%FAT	22.38	8.65	23.10	6.99	22.75	7.84
ENDO	3.62	1.71	3.96	1.60	3.79	1.66
MESO	4.69	1.16	3.68	1.09	4.17	1.23
ECTO	2.49	1.45	2.85	1.45	2.67	1.46
PA	8.85	1.09	8.36	0.890	8.60	1.02
Curl-ups	32.96	19.439	25.23	15.01	29.00	17.71
Push- ups	12.42	8.262	8.58	6.78	10.45	7.77
Broad jump	134.87	23.448	119.33	21.98	126.90	23.97
Medicine ball throw	244.80	36.893	219.72	37.79	231.94	39.35
Handgrip strenght R	18.18	3.987	16.903	4.49	17.52	4.29
Handgrip strenght L	16.90	3.801	15.62	4.23	16.24	4.07
M-K power stair test	42.71	13.499	34.667	12.22	38.58	13.45

Both boys and girls were in Tanner stages 1-2. Participants' parents provided their written and informed consent and the procedures were approved by the institutional review board following the Helsinki Declaration.

Procedures

Parameters of body fat, somatotype, level of physical activity and physical fitness were evaluated for all subjects participating in the study. For anthropometric measurements the

participants were barefoot and wore only underwear. Body weight was measured using the standard digital floor scale (Seca 841), body height using a precision stadiometer (Seca 214), and skinfolds using a skinfold caliper. For perimeter measurement a circumference tape was used (Seca 200).

It was assessed the bi-condyle femoral and humeral diameters (Campbell, 20, RossCraft, Canada). In the evaluation of body composition, body mass index (BMI) and body fat (%FAT) were calculated using the skinfold method described by Slaughter et al. (1988). Cohort groups were defined based in the body mass index according to the cut-off values suggested by Cole et al. (2000). The definition of morphological typology (TYPE) used the method described by Heath-Carter (1971), while the evaluation of biological maturation followed the sexual maturation stages of Tanner (1962). Individuals selected were self-evaluated as being in stages 1 and 2. The index of physical activity (PA) was measured using the Baecke et al. (1982) questionnaire. For the assessment of physical fitness, motor tests were chosen to include the assessment of muscle strength and endurance (curl-ups and push-ups: the score was the number of correct curl-ups performed at a cadence of 20 curl-ups per minute, i.e., 1 curl-up every 3 seconds), explosive strength (standing broad jump and medicine ball throw 2 kg: the score was the the furthest distance), isometric strength and anaerobic fitness (hand-grip strength - using a Jamar hydraulic hand dynamometer of 000-200 lbs: three trails were given for each hand separately and the score was recorded in kg) and muscular power (Margaria-Kalamen power stair test: $\text{Power} = \text{body mass (kg)} \times \text{vertical distance between steps}$). The test-retest reliability, as shown by the intraclass correlation coefficient (ICC) was between 0.91 and 0.94 for all measures.

Statistics

Normality of distribution was checked by applying the Kolmogorov-Smirnov tests (SPSS 17.0). Statistical analysis used the Kruskal-Wallis test in the comparison between groups. Relationship between variables was performed with the Spearman correlation. Interaction between the variables referred to the General Linear Model. The statistical significance was set at $p \leq 0.05$.

Results

There were significant negative associations between % FAT, endomorphy (ENDO) and mesomorphy (MESO) with performance on tests of curl-ups, push-ups and standing broad jump, and positive associations with medicine ball throw, handgrip strength and M-K tests. In the opposite direction, ectomorphy (ECTO) was negatively associated with left handgrip strength, and positively with curl-ups, push-ups and standing broad jump. With the exception of left handgrip strength, for which there were no significant correlations, PA was positively associated with all the variables of muscle strength and endurance (Table 2).

Table 2. Correlations between % of FAT, ENDO, MESO, ECTO, PA and strength variables

	Male		Female		Total		
	<i>rho</i>	<i>p</i>	<i>rho</i>	<i>p</i>	<i>rho</i>	<i>p</i>	
% MG	Curl-ups	-0.243	0.003 **	-0.274	0.000 **	-0.274	0.000 **
	Push- ups	-0.504	0.000 **	-0.303	0.000 **	-0.411	0.000 **
	Broad jump	-0.486	0.000 **	-0.253	0.001 **	-0.378	0.000 **
	Medicine ball throw	0.209	0.010 *	0.193	0.014 *	0.162	0.004 **
	Handgrip strenght R	0.316	0.000 **	0.171	0.030 *	0.232	0.000 **
	Handgrip strenght L	0.338	0.000 **	0.155	0.050 *	0.234	0.000 **
	M-K power stair test	0.056	0.490	0.169	0.032 *	0.073	0.201
ENDO	Curl-ups	-0.246	0.002 **	-0.277	0.000 **	-0.294	0.000 **
	Push- ups	-0.506	0.000 **	-0.308	0.000 **	-0.427	0.000 **
	Broad jump	-0.468	0.000 **	-0.168	0.034 *	-0.349	0.000 **
	Medicine ball throw	0.200	0.014 *	0.245	0.002 **	0.159	0.005 **
	Handgrip strenght R	0.326	0.000 **	0.249	0.002 **	0.264	0.000 **
	Handgrip strenght L	0.339	0.000 **	0.229	0.004 **	0.257	0.000 **
	M-K power stair test	0.048	0.553	0.213	0.007 **	0.071	0.214
MESO	Curl-ups	-0.165	0.042 *	-0.208	0.008 **	-0.085	0.134
	Push- ups	-0.296	0.000 **	-0.065	0.415	-0.060	0.291
	Broad jump	-0.339	0.000 **	-0.241	0.002 **	-0.124	0.028 *
	Medicine ball throw	0.213	0.009 **	0.009	0.907	0.218	0.000 **
	Handgrip strenght R	0.370	0.000 **	0.024	0.766	0.219	0.000 **
	Handgrip strenght L	0.385	0.000 **	-0.011	0.889	0.219	0.000 **
	M-K power stair test	0.179	0.028 *	-0.030	0.705	0.178	0.002 **
ECTO	Curl-ups	0.201	0.013 *	0.156	0.049 *	0.157	0.005 **
	Push- ups	0.366	0.000 **	0.160	0.043 *	0.219	0.000 **
	Broad jump	0.489	0.000 **	0.238	0.002 **	0.303	0.000 **
	Medicine ball throw	-0.045	0.582	-0.082	0.301	-0.094	0.098
	Handgrip strenght R	-0.145	0.075	-0.048	0.550	-0.103	0.069
	Handgrip strenght L	-0.176	0.030 *	-0.052	0.518	-0.125	0.027 *
	M-K power stair test	-0.045	0.580	-0.126	0.111	-0.104	0.067
PA	Curl-ups	0.278	0.001 **	0.098	0.219	0.225	0.000 **
	Push- ups	0.388	0.000 **	0.091	0.252	0.270	0.000 **
	Broad jump	0.384	0.000 **	0.257	0.001 **	0.366	0.000 **
	Medicine ball throw	0.210	0.010 **	0.089	0.261	0,212	0.000 **
	Handgrip strenght R	0.166	0.040 *	-0.005	0.953	0.114	0.044 *
	Handgrip strenght L	0.111	0.172	0.002	0.980	0.096	0.091
	M-K power stair test	0.306	0.000 **	0.090	0.260	0.249	0.000 **

* $p < 0,05$ ** $p < 0,01$

Comparing groups with different BMI, one can observe significant differences between normal weight, overweight, and obese children on curl-ups, push-ups, standing broad jump, medicine

ball throw, handgrip strength and M-K power test (Table 3). Normal weight children presented higher performance on curl-ups, pushups and standing broad jump, followed by children who were overweight. In medicine ball throw, handgrip strength and M-K power test, obese children presented higher scores, followed by children who were overweight (in boys, girls, and whole sample).

Table 3. Comparison between different BMI groups with respect to muscle strength variables

	Male		Female		Total	
	K	p	K	p	K	p
Curl-ups	5.041	0.080	5.442	0.066	8.773	0.012 *
Push- ups	20.216	0.000 **	10.723	0.005 **	23.445	0.000 **
Broad jump	26.479	0.000 **	1.078	0.583	14.192	0.001 **
Medicine ball throw	4.694	0.096	8.892	0.012 *	14.179	0.001 **
Handgrip strenght R	11.526	0.003 **	8.067	0.018 *	21.356	0.000 **
Handgrip strenght L	16.031	0.000 **	8.739	0.013 *	26.602	0.000 **
M-K power stair test	0.941	0.625	10.750	0.005 **	10.808	0.004 **

* p< 0,05 ** p< 0,01

The comparison between groups of different TYPE showed significant differences in the curl-ups, push-ups, standing broad jump, handgrip strength and M-K power test (Table 4). In addition, the current experiment presented higher performance values for mesoectomorphic boys and ectomesomorphic girls in all tests.

Table 4. Comparison between different TYPE groups with respect to strength variables

	Male		Female		Total	
	K	p	K	p	K	p
Curl-ups	15.206	0.055	20.961	0.034 *	33.267	0.000 **
Push- ups	43.772	0.000 **	27.985	0.003 **	67.080	0.000 **
Broad jump	37.300	0.000 **	25.003	0.009 **	44.295	0.000 **
Medicine ball throw	8.731	0.365	13.274	0.276	6.764	0.818
Handgrip strenght R	11.282	0.186	20.144	0.043 *	14.404	0.211
Handgrip strenght L	12.442	0.133	27.964	0.003 **	17.019	0.107
M-K power stair test	2.760	0.949	29.445	0.002 **	20.754	0.036 *

* p< 0,05 ** p< 0,01

MANOVA results showed that the variable TYPE presented more interactions with the muscle strength and endurance variables than % FAT and PA variables (Table 5).

Table 5. Interaction of morphological type (TYPE), body fat (% FAT) and physical activity (PA) with strength variables: GLM-MANOVA test

		Male		Female		Total	
		F	p	F	p	F	p
Curl-ups	%FAT			2.674	0.035 *		
Push- ups	TYPE					2.713	0.002 **
	%FAT	4.205	0.007 **				
Broad jump	TYPE					2.909	0.001 **
	PA					4.383	0.037 *
Medicine ball throw	%FAT					2.601	0.037 *
Handgrip strenght R	TYPE			2.135	0.023 *		
Handgrip strenght L	TYPE			2.920	0.002 **		
M-K power stair test	TYPE			3.018	0.001 **	2.408	0.007 **
	%FAT					2.762	0.028 *

* p< 0,05 ** p< 0,01

Discussion

The purpose of this study was to examine the interaction between physical activity, body fat, somatotype and performance with muscle strength and endurance. The main results suggest that in subjects undergoing pre pubescence, somatotype is a more significantly determining factor than PA and % FAT to the performance in strength tests.

The significant and negative relationship of body fat with body tasks is consistent with results of previous studies that referred to similar relationships in tests of curl-ups (Fogelholm et al. 2008; Castro-Piñero et al. 2009; D'Hondt et al., 2009; Dumith et al., 2010), standing broad jump (Artero et al., 2010; Xianwen et al., 2010), and push-ups (Castro-Piñero et al., 2009). The current results are also consistent with others researches that report positive associations of body fat with handgrip strength and ball-throwing, as evidenced by studies undertaken by Deforche et al. (2003), Casajús et al. (2007) and Artero et al. (2010), in the hand dynamometry test, and D'Hondt et al. (2009), in the basketball throw. On the other hand, Dumith et al. (2010) found no significant association of body fat with medicine ball throw. In the M-K test, it was not possible to compare the results with other studies in the literature. However, the fact that in the equation for calculating power the numerator must take into account the weight of the subject, which in addition to body fat also includes the muscle mass associated with it, might somehow explain the positive association observed in girls. Concerning the relation of somatotype with physical fitness, it should be stressed-out that, more important than the association of each major component with performance, it is the critical to consider the degree of relative presence of each component, defined by morphological typology.

ENDO was positively related only with handgrip strength, ball-throwing power and the M-K test, these being the same tests in which %FAT had a positive association. These two variables are very close, either in terms of definition, or by the way they are calculated. Here, ENDO expresses the degree of adiposity development (Malina and Bouchard, 1991). So the primary effect of this component in performance will differ depending on the type of task, being a limiting factor in body propulsion and lifting tasks in which body fat plays a similar function. Also Malina and Bouchard (1991) reported that ENDO, unlike the tasks of throwing objects, tends to negatively correlate with performance on most motor tasks, because the absolute lean body mass is more related to these tasks than the relative lean body mass. However, according to the same authors, the correlations between body type and motor performance are generally low and limited in pre pubescence.

MESO reflects muscle development positively associated with strength and motor performance in general (Malina and Bouchard, 1991). This component is only negatively correlated with tests related to the propulsion and lifting of the body, in which tasks ECTO has the advantage, since it is based on weighting index, i.e. the quotient of height by the cube root of body weight (Malina and Bouchard, 1991). While observing a positive influence for MESO in most tests, it is also necessary to consider sexual dimorphism in relation to body type component of the somatotype, reflected in the differences in the values of ECTO and MESO. These differences only begin to be observed and favorable to boys from early adolescence, thus increasing with age, while girls tend to increase the value of ENDO (Malina et al., 2004). If the analysis is carried-out according to the dominant component, the children whom the MESO and ECTO were dominant had the best results in all tests considered.

ECTO reflects linearity and muscular hypotonia (Dumith et al. 2010). On this, there were only positive associations for ECTO with propulsion and lifting body tasks, precisely the reverse of the associations for ENDO and MESO because of the negative effect of body weight in these tasks (Dumith et al. 2010; Xianwen et al., 2010). Regarding left handgrip strength, there is a negative association, since it is a different test, which does not require propulsion or lifting the body.

In the relationship of TYPE with motor performance it appears that meso-ectomorphs and ecto-mesomorphs, i.e. individuals with a predominance of the primary components of ECTO and MESO presented higher performances in all tests considered, which is consistent with the advantage of MESO, noticed in the literature, concerning the tasks that require strength and motor performance in general. By contrast, the advantage of ECTO was found in tasks related to the propulsion and lifting movements of the body. Suchomel (2002) also reported a positive association between the prevalence of these components with the total score of the battery

UNIFITT as did Jakšić and Cvetkovic (2009) with the performance analysis in the curl-ups, bent arm hang and longest jump distance.

The relationship between PA and motor performance corroborates the findings of most studies that report a positive association between PA and muscular strength and endurance as well as overall physical fitness, particularly in the standing broad jump (Lennox et al., 2008; Loko et al. 2003; Wrotniak et al., 2006), medicine ball throw (Loko et al., 2003), push-ups (Lennox et al., 2008, Tovar et al., 2008) and isometric hand dynamometry (Tovar et al., 2008). Different results were obtained by Hands et al. (2009), who found no significant associations between PA and performance in standing broad jump, curl-ups, hand dynamometry and ball throw. The greatest number of interactions of TYPE with the selected tests highlights the importance of this parameter in muscle strength and endurance in prepubescent children.

Conclusions

In summary, body fat, physical activity and somatotype determine physical fitness levels in children and adolescents. The current study presented similar data, although underlying the main role of the somatotype on muscular strength and resistance in prepubescent children. The data from this study seem to suggest that one cannot exceed the limits imposed by what is a manifestation of genetic determinism, observed from the morph-constitutional point of view, by which the presence/absence of certain physical traits determines the appropriate levels of motor performance required.

Study 3

Physical fitness differences between prepubescent boys and girls

Abstract

The purpose of this study was to analyze in which physical capabilities boys and girls are closer/ distant. An additional objective was to find which of the body fat, physical activity and somatotype factors have a greater effect on prepubescent children's physical fitness. This was a cross-sectional study involving 312 children (10.8 ± 0.4 years). The physical fitness assessment employed sets of aerobic fitness, strength, flexibility, speed, agility and balance. Boys presented higher values in all selected tests, except tests of balance and flexibility, in which girls scored better. Gender differences in the physical fitness were greatest in the explosive strength of upper ($p \leq 0.01$, $\eta_p^2 = 0.09$) and lower limbs ($p \leq 0.01$, $\eta_p^2 = 0.08$), although with a medium size effect of gender, and smaller in the abdominal ($p > 0.05$, $\eta_p^2 = 0.007$) and upper limbs ($p > 0.05$, $\eta_p^2 = 0.003$) muscular endurance, and trunk extensor strength and flexibility ($p > 0.05$, $\eta_p^2 = 0.001$). The endomorphic ($p \leq 0.01$, $\eta_p^2 = 0.26$) in the girls, and the ectomorphic ($p \leq 0.01$, $\eta_p^2 = 0.31$) and mesomorphic ($p \leq 0.01$, $\eta_p^2 = 0.26$) in the boys, had the high-sized effect on the physical fitness. The physical activity in the girls, and the endomorphic and body fat in the boys, had not a significant effect. These findings can help in the planning of activities that take into account the success and motivation of both boys and girls, and thus, increase levels of physical activity and physical fitness at school. However, in prepubescent children, one cannot neglect the influence of genetic determinism, observed from the morpho-constitutional point of view.

Key words: genders difference, somatotype, motor performance, school

Introduction

Physical fitness has been recognized as a key determinant in healthy lifestyles based increasingly on criteria referenced to general health and not merely to motor performance (Ortega et al., 2007). It has positively been related, among others, with benefits to cardiovascular, total and abdominal adiposity, skeletal health, depression, anxiety, self-esteem, and higher academic performance (Kvaavik et al., 2009; Ortega et al., 2007). However, many children and adolescents are only exposed to vigorous physical activity during school-based physical education classes (Coleman et al., 2004). That way, school seems to provide an excellent setting to enhance physical activity and physical fitness levels.

Unfortunately it has been observed that there is an apparent avoidance of children of the physical education classes and regular physical activity practice at school (Roetert, 2004). This decrease in the interest of children in physical education is due in part, to lack of planning that takes into account the interest, motivation and success of children in the execution of the exercises, respecting the differences among students, including boys and girls (Haff, 2003). Physical education classes or extracurricular activities commonly include children of both sexes. This requires teachers to establish a match between the goals they want to achieve and the means and resources available, taking into account the various constraints that may arise, such as reduced practice time per session, number of weekly sessions, lack of material resources and facilities, high numbers of students by class and variety of content to be taught, often involving the same activities for boys and girls alike.

In this respect, beyond the duty of the teacher to maximize the opportunities for practice, it is necessary to program the exercises in school in order to make them appealing and motivating for both boys and girls (NIH Consensus Development Panel on Physical Activity and Cardiovascular Health, 1996). The psychological saturation and physiological enervation that may attend on attempts to match results close to those achieved by opposite-sex colleagues in the same exercise can be alleviated where there is knowledge about which exercises and the respective capabilities they deploy can be best performed concurrently by boys and girls. One of the major reasons why many children drop out of sport and physical activity is that they feel they do not have the necessary skills to be involved. Both girls and boys tend to be reluctant to participate if their perceived level of skill is low. The proof of this is that the female students reported more positive and adaptive perceptions in same-sex classes (Lyu and Gill, 2011). Thus the knowledge, not only of the physical capabilities in which boys and girls are higher, but the magnitude of the differences between them, can help teachers in the planning and organizing of activities at school, increasing the motivational levels in the exercises, and thus, increasing levels of physical activity and physical fitness of their students. Also at the level of assessment this knowledge may add value in allowing to the teacher to better analyze and understand the results obtained in general.

On the other hand, for a better understanding of gender differences in physical fitness, will be important to understand the interaction of several factors referred in the literature with the motor performance, in both boys and girls. There are many evidences pointing to significant differences between boys and girls in motor performance (Cepero et al., 2011; Hands et al., 2009). These differences are due in large part to gender differences in levels of habitual physical activity (Sveinsson et al., 2009) and body fat (Cepero et al., 2011; Lennox et al., 2008). While body fat is associated negatively with several motor tasks, particularly those related to the propulsion and lift movements of the body (Dumith et al., 2010), higher levels of physical activity represent a gain in motor performance in general (Sola et al., 2010). However, there exists a relative paucity of published reports focused on the differences in the physical fitness between pre-pubertal boys and girls regarding his/her somatotype. Most studies in this context refers to the influence of body mass index in the motor performance in youth, but somatotype has been found to be inherited to a greater extent than body mass index (Reis et al., 2007). The values of relative adiposity, relative muscle-skeletal magnitude, (robustness) or relative thinness of the subjects (Malina & Bouchard, 1991) allow performances to vary depending on the type of motor tasks (Jakšić & Cvetković, 2009). One cannot exceed the limits imposed by what is a manifestation of genetic determinism, observed from the morpho-constitutional point of view and there is evidence that by pre-puberty there already exists a fairly stable somatotype, pointing to 8 years as the age by which somatotype stability becomes manifest (Malina & Bouchard, 1991; Malina et al., 2004). Hence it seems relevant to examine, in this age group, the effect of the presence/ absence of certain physical traits on the motor performance, and compare it with the effect of body fat and physical activity, often referenced in the literature.

The aim of this investigation was to analyze in which physical capabilities boys and girls are closer/ distant. An additional objective was to find which of the body fat, physical activity and somatotype factor is more interactive with prepubescent children's physical fitness level. It was considered the hypothesis that there is a set of exercises and physical capabilities inherent to them, in which the performance of boys and girls is very similar/ divergent. We also hypothesized that, despite the age group considered, somatotype already plays a determinant role on the performance of selected exercises, in both boys and girls.

Material and Methods

It has been observed that there is an apparent decrease in the interest of children in physical education due, in part, to lack of planning that takes into account the success of children in the execution of the exercises respecting the differences among students, including boys and girls. The knowledge of the magnitude of the differences between boys and girls in physical

fitness can help the planning of activities that promote the success and motivation of both boys and girls, and thus, improve levels of physical activity and physical fitness at school. On the other hand, the knowledge of the effect of the somatotype on the performance in the pre-puberty (comparing it with the effect of body fat and physical activity, often referenced in the literature), may also allow a better understanding of gender differences.

Three hundred and twelve students were recruited from a Portuguese public basic school (from 5th and 6th grade) to perform this study. In Portugal, a physical education class has a set of 45 min and another of 90 min twice a week. Typical physical education classes include various activities, in which participate simultaneously boys and girls, with a clear pedagogical focus, but mainly for the purpose of promoting levels of physical activity and physical fitness of students. 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.

The required data were collected (from January 4th to February 25th of 2011) from self-assessed of maturity level, anthropometric measurements, questionnaire about habitual physical activity and application of a battery of previously selected tests. All anthropometric measurements were carried out prior to any physical performance test. All participants were familiarized with physical fitness tests and the measurements were performed 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). All measurements were performed by the same investigator, in the first periods in the morning, and the testing assessment procedures were always conducted in the same indoor sportive facility (with temperature between 15°C and 18°C). In the course of conducting testing there was a constant concern to ensure the necessary security and maintenance of safe hydration levels, as well as to encourage all children to achieve the best results. Were also given clear instructions about the importance of adequate nutrition for physical activity. The following exclusion criteria were used: subjects with a chronic pediatric disease or with an orthopedic limitation. Subsequently, to minimize the effects of growth, only were selected for the sample the subjects who were self-assessed in Tanner stages 1-2.

Sample

The sample, cross-sectional in type, consisted of 312 prepubescent children (160 girls, 152 boys) all of whom volunteered for this study. The age, height and weight of the whole sample were: 10.8 ± 0.4 years, 1.45 ± 0.08 m, 40.0 ± 8.7 kg, respectively (girls: 10.8 ± 0.4 years, 1.44 ± 0.07 m, 38.9 ± 8.5 kg; boys: 10.8 ± 0.4 years, 1.45 ± 0.09 m, 41.2 ± 8.8 kg). Both boys and girls were in Tanner stages 1-2 (girls: stage 1, 53.1% and stage 2, 46.9%; boys: stage 1, 81.6% and stage 2, 18.4%). This study was approved by the institutional review boards of the University of Beira Interior (UBI) and Research Centre in Sports, Health and Human

Development (CIDESD), Portugal. To fulfill the ethical procedures of the Helsinki statement, an informed consent was obtained prior to all testing children's parents.

Procedures

Parameters of body fat, somatotype, level of physical activity and physical fitness were evaluated for all subjects participating in the study. (Table 1)

Table 1. Descriptive data of anthropometric and morphological parameters, physical activity indexes and physical performance measures: Overall sample

	<i>Min</i>	<i>Max</i>	<i>Mean</i>	<i>SD</i>
Fat mass (%)	8.54	50.92	22.75	7.84
Endomorphic	1.05	8.23	3.79	1.66
Mesomorphic	1.57	8.14	4.17	1.23
Ectomorphic	0.10	6.61	2.67	1.46
School index	2.00	3.75	2.72	0.28
Sport index	1.25	4.50	2.87	0.61
Leisure-time index	1.50	4.25	3.02	0.47
Total index	3.25	11.25	8.60	1.02
20m multistage shuttle run (a.u.)	7.00	74.00	27.81	14.03
20m sprint (s)	3.41	5.75	4.45	0.46
9.14m shuttle run (s)	10.62	16.78	13.25	1.31
Flamingo balance (faults)	0.00	35.00	8.49	5.81
Sit-and-reach R (cm)	3.00	30.00	21.48	5.81
Sit-and-reach L (cm)	6.00	30.00	20.81	6.09
Trunk lift (cm)	8.00	30.00	23.50	4.92
Curl-ups (a.u.)	0.00	75.00	29.00	17.71
Push- ups (a.u.)	0.00	39.00	10.45	7.77
Standing broad jump (cm)	64.00	197.00	126.90	23.97
Medicine ball throw (cm)	138.00	315.00	231.94	39.35
Handgrip strenght R (kg)	8.00	30.00	17.52	4.29
Handgrip strenght L (kg)	6.00	28.00	16.24	4.07
M-K power stair test	14.96	89.19	38.58	13.45

School index- index of physical activity in school; Sport index- sport during leisure time; Leisure-time index- physical activity during leisure time excluding sport; Total index- habitual physical activity index

All anthropometric measurements were assessed according to international standards for anthropometric assessment (Marfell-Jones et al., 2006). The participants were barefoot and wore only underwear. Body weight (kg) was measured to the nearest 0.1 kg using a standard digital floor scale (Seca, model 841, Germany). To evaluate body height (cm) a precision stadiometer with a range scale of 0.10 cm was used (Seca, model 214, Germany). For perimeter measurement a circumference tape was used (Seca 200). The bi-condyle femoral and humeral diameters were assessed (Campbell, 20, Ross Craft, Canada). The percentage

body fat (%FAT) from skinfold anthropometry was calculated following Slaughter et al. (1988). As such, triceps and subscapular skinfolds were determined by internationally recommended methods (Marfell-Jones et al., 2006). The definition of morphological typology (TYPE) used the method described by Heath-Carter (1971), expressed quantitatively by a score of three components: endomorphy (ENDO), mesomorphy (MESO), and ectomorphy (ECTO). Maturity level based on Tanner stages was self-assessed (Faigenbaum, 1996). Students were asked to answer to an image with corresponding legend questionnaire, in an individual booth, without interference from their teachers or school friends.

The habitual physical activity level (PA) was measured using the Baecke et al. (1982) questionnaire expressed quantitatively by a score of three indexes: physical activity in school, sport during leisure time and physical activity during leisure time excluding sport.

For the assessment of physical fitness, motor tests were chosen to include the assessment of aerobic capability (20-meter multistage shuttle-run), flexibility of the lower back and hamstrings (left and right sit-and-reach), trunk extensor strength and flexibility (trunk lift), speed (20m sprint), agility and coordination (9.14m shuttle-run), general stability (flamingo balance), muscle strength and endurance (curl-ups and push-ups), explosive strength (standing broad jump and medicine ball throw), maximum isometric strength (hand-grip strength) and anaerobic muscular power (Margaria-Kalamen power stair test). Curl-ups, push-ups, 20-meter multistage shuttle-run, sit-and-reach and trunk lift were evaluated using field tests from the FITNESSGRAM test battery (Meredith & Welk, 2007). Standing broad jump, hand grip strength and flamingo balance were assessed using EUROFIT test battery (Adam et al., 1988). Shuttle-run agility test was evaluated using the AAHPERD test battery (American Alliance for Health, Physical Education, Recreation and Dance, 1976). In the Margaria-Kalamen power stair test, the protocol was used as described by George et al. (1994). Medicine-ball throw was evaluated using the protocol described by Mayhew et al. (1997).

20-meter multistage shuttle run: This test involved continuous running between two lines 20m apart in time to recorded beeps. The subjects ran between the two lines, turning when signaled by the recorded beeps. After about one minute, a sound indicated an increase in speed, and the beep rhythm accelerated. This pattern was continued at intervals of 1-minute per rhythm level. When the participants failed to reach the line on two consecutive occasions, they were stopped and the number of completed 20m laps was recorded. The 20-meter multistage shuttle run has shown an ICC of 0.98.

Left and right sit-and-reach: Subjects were seated with their legs joined and outstretched. The soles of their feet were supported on a standardized wooden box (Well Box). By means of a trunk inflection, subjects were required to reach with the index finger (arms joined and hands superimposed) the maximum attainable distance as marked on the box. The participant was asked to stretch four times and hold the position for one second during the fourth

attempt. The furthest distance the subject was able to reach was recorded in centimeters. The ICC of data for left and right sit-and-reach was 0.96 and 0.97, respectively.

Trunk lift: The subjects raised the torso as high as possible from the floor from a prone position, while keeping the eyes on an object placed on the floor in line with the eyes. This position was held while the distance from the floor to the chin was measured. Two trials were given and the furthest distance was measured in centimeters. The trunk lift has shown an ICC of 0.94.

20-meter sprint running: In a track measuring 20 meters in length, subjects were required to cover the distance in the shortest time they could. Time to run 20m was obtained using photocells (Brower Timing System, Fairlee, Vermont, USA). Three trials were performed and the best time scored (seconds and hundredth) was registered. The sprint running (time) has shown an ICC of 0.96.

Shuttle-run agility test: Subjects were asked to tack and shift, at the fastest pace they were capable of, within an area delimited by two lines (9.14m apart each other). Two blocks were placed on the line opposite the starting line. On a given signal, the participant sprinted to the opposite line, picked up a block of wood, ran back and placed it on or beyond the starting line. Then, turning without pause, they ran back to retrieve the second block carrying it back across the finishing line. Three trials were performed and the best time scored (seconds and hundredths) was registered. This test has shown an ICC of 0.98.

Flamingo balance: Balancing on a preferred leg, the subject was required to flex the free leg at the knee with the foot of this leg held close to the buttocks. The stopwatch was stopped each time the participants lost balance (either by falling off the beam or letting go of the foot being held). The exercise was then recommenced, and again timed until balance was lost. The number of such falls occurring over 60 seconds was then counted. The Flamingo balance has shown an ICC of 0.93.

Standing long jump: The participants stood feet slightly apart (toes behind a starting line) and jumped as far forwards as possible. Three trials were given and the furthest distance was measured in centimeters from the starting line to the heel of the foot nearest to this line. The standing long jump has shown an ICC of 0.97.

Curl-ups: Participants were required to bend their knees at approximately 140 degrees, feet flat on the floor, arms straight and parallel to the trunk with palms of hands resting on the mat. The fingers were fully extended and the head placed in contact with the mat. One measuring strip was placed on the mat under the legs. The participant then curled up slowly, sliding the fingers across the measuring strip until the fingertips reached the other side, then

curled back down until the head touched the mat. The number of correct curl-ups performed in a cadence of 20 curl-ups per minute (1 curl-up every 3 seconds) was then scored. This test has shown an ICC of 0.97.

Push-ups: The participants were positioned with hands and toes touching the floor, body and legs in a straight line, feet slightly apart, arms at shoulder-width apart, extended and at right angles to the body. Keeping the back and knees straight, the subject then lowered the body to the point at which there was a 90-degree angle at the elbows, with the upper arms parallel to the floor. The total number of correct push-ups was recorded during a cadence of 20 complete push-ups per minute (one complete push-up every 3 seconds). This test has shown an ICC of 0.97.

Medicine-ball throw: Subjects were seated with the backside of the trunk in touch with a wall. They were required to hold a medicine-ball (Bhalla International- Vinex Sports, Meerut-India) weighing 2kg (Vinex, model VMB-002R) with their hands (abreast of chest) and throw it forward over the maximum distance possible. Hip inflection was not allowed nor withdrawal of the trunk away from the wall. Three trials were given and the furthest throw was measured in centimeters from the wall to the first point at which the ball made contact with floor. The medicine-ball throw has shown an ICC of 0.97.

Left and right hand grip strength: This was measured by the Jamar (0-200 lbs) hydraulic hand dynamometer. Each participant stood erect in the 90° elbow flexion position. The handle of the dynamometer was adjusted if required. Subjects were then instructed to exert maximal grip (for about 3 seconds), interrupted by brief pauses (of about 1 min.). No other body movement was allowed. Three trials were given for each hand separately and the best score recorded in kg was chosen for analysis. The ICC of data for left and right hand grip strength was 0.99 and 0.96, respectively.

Margaria-Kalamen power stair: The participant was placed ready at the starting line 6 meters in front of the first step. On command, the subject sprinted to and up the flight of steps, taking preferably three steps at a time in the attempt to mount the steps as fast as possible. The time taken to get from the third step to the ninth step was then recorded. The test was repeated three times and the fastest time recorded in hundredths of seconds. Power (kg.m.s⁻¹) was calculated as follows: Power = body mass (kg) x vertical distance between steps (m) / time(s). The Margaria-Kalamen power stair has shown an ICC of 0.97.

Statistics

Standard statistical methods were used for the calculation of the means and standard deviations. Intraclass correlation coefficient (ICC) was used to determine between-subject

reliability of selected tests. Independent samples t-test was used to check gender differences in anthropometric and morphological parameters and physical activity indexes. For the analysis of statistical differences between boys and girls on physical performance variables, a multivariate analysis of covariance (MANCOVA) was used, having as factors, in addition to sex, the maturation, and the fat mass, physical activity, endomorphic, mesomorphic and ectomorphic as covariates. The normality of the residuals of MANCOVA was checked by applying the Kolmogorov-Smirnov test and the homogeneity of variance-covariance matrix, was tested by the Box M test ($M = 435.60$, $F(315, 36950.5)=1.22$, $p \leq 0.05$). Since it was not verified this assumption we used the Pillai's Trace test statistics. It should be noted that the correlations between the dependent variables ranged between 0.006 and 0.647. When statistically significant differences were observed between boys and girls, an analysis of covariance (ANCOVA) was estimated for each dependent variable, followed by Bonferroni's post-hoc comparisons tests. By ANCOVA was also possible to analyze the statistical significance and effect size of gender in the physical performance variables. To determine which of the somatotype, physical activity and body fat factor had a greater influence on the motor performance of both boys and girls, it was estimated for each gender an MANCOVA, with the maturation as a factor and the fat Mass, physical activity and somatotype as covariates. The normality of the residuals was validated by the Kolmogorov-Smirnov univariate and the homogeneity of variance-covariance matrix was validated by the Box M test (Girls: $M = 190.47$, $F(105, 4664.4)=1.12$, $p > 0.05$; Boys: $M = 385.41$, $F(210, 5606.2)=1.14$, $p > 0.05$), so we used the Wilk's Lambda test. The reliability of physical performance was analyzed with Cronbach's alpha.

We also carried out a canonical correlation to understand which of the performance variables more explained the data variability. It was found, firstly, how many dimensions were required to understand the existing associations. The tests of dimensionality indicated the existence of three canonical dimensions statistically significant. The first dimension had a canonical correlation of 0.766, with an eigenvalue of 1.42 and an explained variance of 52.2%. The second dimension showed a canonical correlation of 0.662, representing an eigenvalue of 0.78 and an explained variance of 28.7%. The third dimension had a canonical correlation of 0.523, an eigenvalue of 0.377 and an explained variance of 13.9%. Together had a 97.7% of variance explained. Then we calculated the correlation coefficients between the canonical dimensions and the physical performance variables, and the standardized scores for each dimension were represented graphically. Data was analyzed using SPSS 15.0. The statistical significance was set at $p \leq 0.05$.

Results

Regarding gender differences in anthropometric and morphological parameters and physical activity indexes, we can observe that girls registered higher mean values of % FAT, ENDO, and ECTO. On the other hand, boys showed higher values in the MESO component and in all levels of physical activity (school, sport, leisure-time and total physical activity indexes). However, these differences were only significant in the MESO ($t = -7.897$, $p \leq 0.001$) and ECTO ($t = 2.161$, $p \leq 0.05$) components, and school ($t = -2.392$, $p \leq 0.05$), sport ($t = -5.594$, $p \leq 0.001$) and total ($t = -4.330$, $p \leq 0.001$) physical activity indexes. In %FAT, ENDO and leisure-time index, gender differences were not statistically significant.

In the analysis of gender differences in physical performance, the MANCOVA showed that physical fitness variables had a Cronbach's Alpha of 0.705, which indicates that they have a reasonable reliability for the physical performance measurement. It was observed a significant and high-sized effect of gender in all physical performance measures (Pillai's Trace = 0.28, $F(14, 291) = 8.13$, $p \leq 0.01$, $\eta_p^2 = 0.28$, Power = 1.00). However, we found that the effect of Tanner's stage was not significant (Pillai's Trace = 0.44, $F(14, 291) = 0.97$, $p > 0.05$, $\eta_p^2 = 0.04$, Power = 0.61). Through the ANCOVA, estimated for each dependent variable when statistically significant differences were observed between boys and girls, it was observed that boys were superior to girls on tests of aerobic capability, speed, agility, explosive strength and maximum isometric strength. The girls were superior in flexibility of the lower back and hamstrings and balance. (Table 2)

Regarding MANCOVA estimated for the girls, it was observed a significant and high-sized effect of endomorphic in all physical performance measures, followed by body fat, Ectomorphic and Mesomorphic, with significant but medium-sized effect. The physical Activity did not, for girls, a statistically significant effect on physical performance variables. In the boys there was a significant and high-sized effect of Ectomorphic and Mesomorphic in all physical performance measures, followed by physical activity with significant but medium-sized effect. The variables body fat and endomorphic did not, for boys, a statistically significant effect on physical performance variables. (Table 3)

Through the ANCOVA, it was observed that gender differences in physical fitness were greater in the explosive strength of upper and lower limbs (medicine ball throw and standing broad jump), although with a medium size effect of gender. In the opposite direction, gender differences were smaller in the muscle strength and endurance (curl-ups and push-ups) and trunk extensor strength and flexibility (trunk lift), followed by speed (20m run) and balance (flamingo balance). (Table 4)

Table 2. Gender`s difference in physical performance: Adjusted means after MANCOVA

		Mean	SE	95% CI		p ¹
				LB	UB	
20m shuttle run (a.u.)	Female	25.38	1.05	23.32	27.44	0.001**
	Male	31.05	1.19	28.71	33.39	
20m sprint (s)	Female	4.52	0.04	4.45	4.60	0.047*
	Male	4.40	0.04	4.31	4.48	
9.14m shuttle run (s)	Female	13.56	0.10	13.36	13.77	<0.001**
	Male	12.89	0.12	12.65	13.12	
Flamingo balance (faults)	Female	7.55	0.50	6.56	8.53	0.011*
	Male	9.70	0.57	8.58	10.82	
Sit-and-reach R (cm)	Female	22.95	0.50	21.96	23.93	0.001**
	Male	20.07	0.57	18.95	21.18	
Sit-and-reach L (cm)	Female	23.03	0.52	22.01	24.04	<0.001**
	Male	18.62	0.59	17.47	19.78	
Trunk lift (cm)	Female	23.75	0.44	22.87	24.62	0.583
	Male	23.34	0.50	22.35	24.33	
Curl-ups (a.u.)	Female	26.61	1.50	23.67	29.55	0.145
	Male	30.27	1.70	26.93	33.62	
Push- ups (a.u.)	Female	9.95	0.61	8.75	11.15	0.362
	Male	10.89	0.70	9.52	12.25	
Standing broad jump (cm)	Female	119.30	1.83	115.70	122.90	<0.001**
	Male	135.42	2.08	131.33	139.51	
Medicine ball throw (cm)	Female	218.28	3.29	211.80	224.75	<0.001**
	Male	248.91	3.74	241.56	256.27	
Handgrip strenght R (Kg)	Female	16.88	0.36	16.17	17.58	0.006**
	Male	18.53	0.41	17.72	19.33	
Handgrip strenght L (Kg)	Female	15.54	0.35	14.86	16.22	0.003**
	Male	17.27	0.39	16.50	18.04	
M-K power stair test	Female	34.62	1.16	32.35	36.90	<0.001**
	Male	43.88	1.31	41.29	46.46	

¹ Bonferroni's Test; SE - Standard Error; CI - Confidence Interval; LB - Lower Bound; UB - Upper Bound.
* $p \leq 0.05$; ** $p \leq 0.01$

Table 5 shows the correlation coefficients between the canonical dimensions and physical performance variables. The performance variables with the greatest effect on the first dimension were the endurance (0.708), explosive strength of lower limbs (0.555), abdominal muscular endurance (0.494), agility (-0.491) and speed (-0.465). In the second dimension the variables flexibility of the lower back and hamstrings (right: -0.349, and left: -0.374) and balance (0.373) were the ones that had a stronger correlation with this dimension. In the third dimension the speed (-0.515) and agility (-0.507) were the variables with the highest correlation with this dimension. (Table 5)

Table 3. Effect of the somatotype, physical activity and body fat factors on the physical performance of boys and girls: MANCOVA

	Effect	F	p	Partial Eta Squared	Observed Power
Male	Fat mass (%)	0.599	0.862	0.060	0.359
	Physical activity	2.217	0.010**	0.190	0.960
	Endomorphic	1.196	0.286	0.113	0.705
	Mesomorphic	3.379	<0.001**	0.264	0.998
	Ectomorphic	4.314	<0.001**	0.314	1,000
Female	Fat mass (%)	2.585	0.002**	0.205	0.984
	Physical activity	1.554	0.100	0.135	0.843
	Endomorphic	3.444	<0.001**	0.256	0.998
	Mesomorphic	2.131	0.013*	0.176	0.952
	Ectomorphic	2.422	0.005**	0.195	0.976

* $p \leq 0.05$; ** $p \leq 0.01$

Table 4. Statistical significance and effect size of sex on the physical performance variables: ANCOVA

Dependent Variable	F	p	Partial Eta Squared	Observed Power
20m multistage shuttle run (a.u.)	10.490	0.001**	0.033	0.898
20m sprint (s)	3.966	0.047*	0.013	0.510
9.14m shuttle run (s)	14.927	<0.001**	0.047	0.971
Flamingo balance (faults)	6.558	0.011*	0.021	0.723
Sit-and-reach R (cm)	11.869	0.001**	0.038	0.930
Sit-and-reach L (cm)	25.937	<0.001**	0.071	0.999
Trunk lift (cm)	0.302	0.583	0.001	0.085
Curl-ups (a.u.)	2.138	0.145	0.007	0.308
Push- ups (a.u.)	0.834	0.362	0.003	0.149
Standing broad jump (cm)	27.710	<0.001**	0.084	0.999
Medicine ball throw (cm)	30.933	<0.001**	0.092	1,000
Handgrip strenght R (kg)	7.529	0.006**	0.024	0.781
Handgrip strenght L (kg)	8.928	0.003**	0.029	0.846
M-K power stair test	22.827	<0.001**	0.070	0.997

* $p < 0.05$, ** $p < 0.01$

Table 5. Correlations between canonical coefficients and variables

		Canonical Dimensions ¹		
		1	2	3
Performance variables	20m shuttle run (a.u.)	0.708	-0.224	0.035
	20m sprint (s)	-0.465	0.142	-0.515
	9.14m shuttle run (s)	-0.491	0.049	-0.507
	Flamingo balance (faults)	-0.262	0.373	0.114
	Sit-and-reach R (cm)	0.139	-0.349	-0.318
	Sit-and-reach L (cm)	-0.004	-0.374	-0.262
	Trunk lift (cm)	-0.109	-0.121	-0.337
	Curl-ups (a.u.)	0.494	-0.010	0.024
	Push-ups (a.u.)	0.274	-0.026	0.031
	Standing broad jump (cm)	0.555	-0.148	0.459
	Medicine ball throw (cm)	-0.034	0.333	0.332
	Handgrip strenght R (kg)	-0.201	0.308	0.519
	Handgrip strenght L (kg)	-0.202	0.303	0.412
	M-K power stair test	0.082	0.243	0.099
Eigenvalue and variance	Eigenvalue	1.417	0.780	0.377
	% of Variance	52.2	28.7	13.9
	% of Cumulative Variance	52.2	80.9	94.8
	Canonical Correlations	0.766	0.662	0.523
	Wilks lambda	0.147	0.355	0.632
Multivariate tests	F	7.420	4.839	2.748
	DF 1	90.0	70.0	52.0
	DF 2	1643.1	1394.3	1136.9
	<i>p</i>	<0.001 **	<0.001 **	<0.001 **

¹Significant Canonical dimensions; DF 1: Hypothesis Degrees Freedom; DF 2: Error Degrees Freedom
 ** $p < 0.01$

Figure 1 shows the standardized scores for the first dimension (has the variables with the greatest positive effect the endurance, explosive strength of lower limbs and abdominal muscular endurance, in which boys have greater values than the average, and greatest negative effect the speed and agility, where boys have smaller values than the average), and second dimension (has the variable with the greatest positive effect the balance, where boys have a number of faults greater than the average, and greatest negative effect the flexibility of the lower back and hamstrings, where boys have smaller values than the average). It is observed that the scores of the boys are more concentrated in the 4th quadrant (values above the average in the first dimension, and below the average in the second dimension), while in girls the values are more concentrated in the 1st quadrant (values above the average in the second dimension and below the average in the first dimension).

Figure 1. Scatterplot between Dimension 1 and Dimension 2 by sex

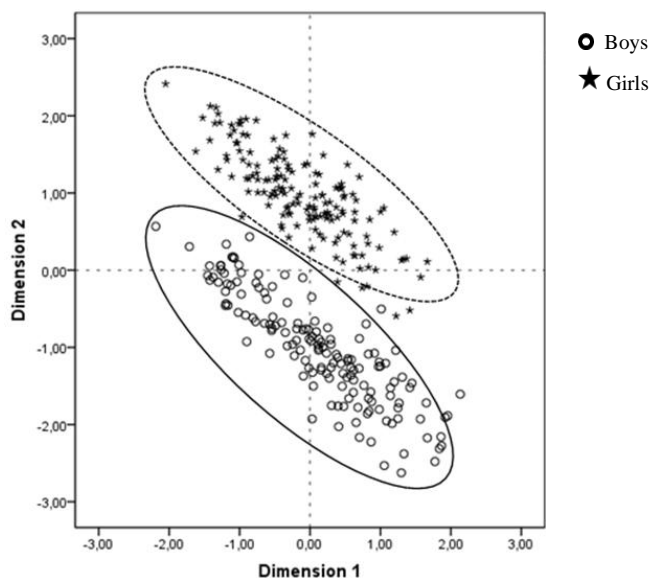
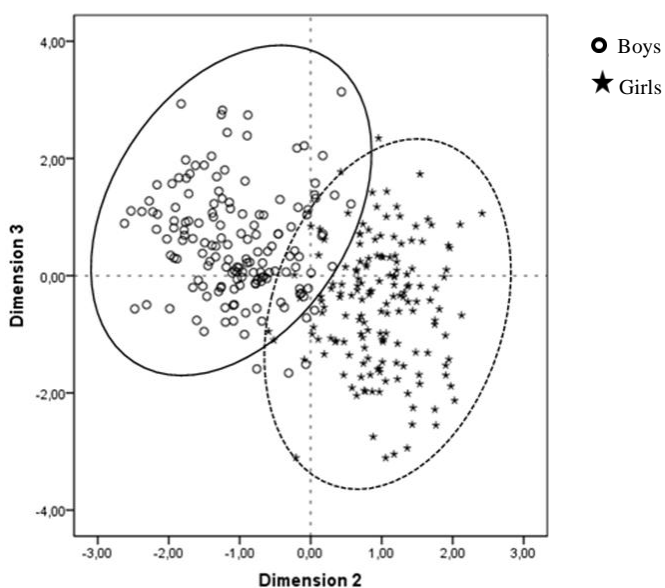


Figure 2 shows the standardized scores for the second and third dimensions. The third dimension has the variables with the greatest positive effect the maximum isometric strength and explosive strength of lower limbs, in which boys have greatest values than the average, and greatest negative effect the speed and agility, where boys have smaller values than the average. It is observed that the scores of the boys are more concentrated in the 2nd quadrant (values below the average in the second dimension, and above the average in the third dimension) while in girls the values are more concentrated in the 4th quadrant (values above the average in the second dimension and below the average in the third dimension).

Figure 2. Scatterplot between Dimension 2 and Dimension 3 by sex



Discussion

The purpose of this study was to analyze in which physical capabilities boys and girls are closer/ divergent. An additional objective was to find which of the body fat, physical activity and somatotype factor is more interactive with prepubescent children's physical fitness level. The main results suggested that the somatotype had the greatest influence on the motor performance of both boys and girls (ectomorphic and mesomorphic in the boys and endomorphic in the girls). The physical activity in the girls, and the endomorphic and body fat in the boys, had not a significant effect. The difference between boys and girls in the physical fitness was greater in the explosive strength of upper and lower limbs, and smaller in the abdominal and upper limbs muscular endurance, and trunk extensor strength and flexibility, followed by speed and balance.

The girls studied showed higher values of %FAT, ENDO, and ECTO compared to boys. The higher percentage values of body fat in girls are consistent with several studies in the literature that report higher such values for females in general (Cepero et al., 2011; Lennox et al., 2008; Sveinsson et al., 2009). ENDO expresses the degree of adiposity development (Malina & Bouchard, 1991) being a variable close to % FAT, either in terms of definition or the way they are both calculated, so that values here also show higher for girls than for boys (Malina & Bouchard, 1991). This body fat represents an inert non-contributory load and thus an increased metabolic cost for children, making them less efficient in terms of cardiorespiratory response as well as performance on tests that require lifting and propulsion tasks (Artero et al., 2010; Dumith et al., 2010; Tovar et al., 2008). ECTO represents the relative thinness of the subject (Malina & Bouchard, 1991) and therefore associates negatively with strength (Malina & Bouchard, 1991). At the chronological ages under discussion it seems that the weighting index, i.e., the quotient of height by the cube root of body weight, which is based on the ECTO (Malina & Bouchard, 1991) is in favor of girls. This becomes more noticeable if we consider that the height growth curves in male and female intersect for a time, referred to as "crossing over", when girls overtake boys in stature, a stage which coincides with pre-puberty (Malina & Bouchard, 1991). The boys showed higher values in the MESO component and in all levels of physical activity (school index, sport index, leisure-time index and total index) relative to the girls. The main literature also refers to higher MESO values (Malina & Bouchard, 1991; Malina et al., 2004) and higher levels of physical activity (Hands et al., 2009; Lennox et al., 2008; Sveinsson et al., 2009) in males subjects. MESO represents the relative skeletal-muscle magnitude (robustness), and therefore associates positively with strength and motor performance in general (Malina & Bouchard, 1991). Similarly, higher levels of physical activity are associated with a better physical fitness of children (Hands et al., 2009; Lennox et al., 2008; Reed & Metzker, 2004; Tovar et al., 2008).

The curious in this study is that the variables with no significant effect on the physical fitness of boys are the ones that had the greatest effect on the performance of girls (endomorphs and body fat). The greater robustness (Malina & Bouchard, 1991) and higher levels of physical activity (Sveinsson et al., 2009) of the boys, as well as the higher levels of body fat (Cepero et al., 2011; Lennox et al., 2008) and a more sedentary lifestyle (Sveinsson et al., 2009) of the girls seem to have influenced the effect of each of these factors on the physical fitness of boys and girls. No less interesting is that the primary components of the somatotype had the greatest influence on the motor performance of both boys and girls (ectomorphic and mesomorphic in the boys and endomorphic in the girls), and therefore the relative skeletal-muscle magnitude of the boys and the degree of adiposity development of the girls seems to have reduced the dependence of the other factors on the motor performance. This fact highlights the importance of the morphological typology in the prepubescent children's physical fitness level, and seems to suggest that one cannot neglect the limits imposed by what is a manifestation of genetic determinism, observed from the morpho-constitutional point of view, since the presence/absence of certain physical traits seems to be determinant on the physical performance of both boys and girls.

In terms of gender differences in motor performance, the results confirm those of other studies that report the superiority of boys in tests of aerobic fitness and muscular strength and of girls in tests of balance and flexibility (Cepero et al., 2011; Hands et al., 2009; Lennox et al., 2008). Additionally, our findings indicate that the difference between boys and girls in physical fitness was greater in the explosive strength of upper and lower limbs, although with a medium size effect of gender. In the opposite direction, gender differences were smaller in the muscle strength and endurance (curl-ups and push-ups) and trunk extensor strength and flexibility, followed by speed and balance. Looking for the canonical correlation, the physical performance variables that most explain the variability of the data were the endurance, velocity, agility, handgrip strength, abdominal muscular endurance and explosive strength of lower limbs, in which boys are better, and flexibility of the lower back and hamstrings and balance, in which girls scored better. According to several studies in the literature, the boys are superior to girls in aerobic fitness because, among other factors such as higher levels of physical activity (Hands et al., 2009; Lennox et al., 2008) and lower fat mass (Artero et al., 2010; Dumith et al., 2010; Ortega et al., 2007), to other factors mainly linked to the cardiac size and oxygen-carrying capacity (i.e. left ventricular inner diastolic diameter, maximal heart rate and maximal stroke volume) (Dencker et al., 2007). These factors seem to determine the difference found between boys and girls in cardiorespiratory fitness. In the same way, the fat-free mass or lean body mass statistically higher in boys and higher levels of physical activity permits a better muscular strength (Lennox et al., 2008; Tovar et al., 2008). However, the absence of statistically significant differences between boys and girls in the muscular endurance tests (curl-ups and push-ups), corroborates the results of previous studies with children of similar age (Castro-Piñero et al., 2009), and may be due to the fact that the

weight of the boys, close to the weight of girls in pre-pubertal stage (Malina & Bouchard, 1991), be an extra load to be moved during weight-bearing tasks, added to the fact that the boys still present a reduced muscle mass in pre-pubertal ages, because the effects of circulating androgens, particularly testosterone, only manifest themselves at puberty (Malina & Bouchard, 1991). Also the lower values for body fat recorded by boys give them an advantage on tests of speed (Dumith et al., 2010) and agility (Artero et al., 2010; Dumith et al., 2010) as well as the higher levels of physical activity permits better performance in the same capabilities (Reed & Metzker, 2004; Sola et al., 2010). Some approximation found in speed between boys and girls, may be due to the fact that speed is a specific capability, highly dependent on the influence of genetic factors such as neuromuscular components and muscle fiber quality (i.e., fiber type proportion), and the high degree of gene transfer implied in this aptitude is today recognized (Little & Williams, 2005). Regarding the flexibility, there are many reports than girls have larger range of motion. Some of the factors presented are the difference of extensibility of muscle and tendon tissues, the greater passive dorsiflexion angle of girls, because boys have a higher muscle volume, and dynamic property of tendon tissues (Kato et al., 2005). There are also studies in the literature referring to the absence of significant associations of this capability with physical activity (Hands et al., 2009), and skeletal-muscle magnitude (robustness), favorable to boys (Shukla et al., 2009). There are even studies that report a negative association between the physical activity levels with performance on tests of flexibility (Lennox et al., 2008). However, in this capability, the difference by gender there occupies a place emphasized during periods of rapid growth (Monyeki et al., 2005), which may explain in part the proximity between boys and girls in the trunk lift, associated to the fact that this capability is also very dependent of the upper body strength (Meredith & Welk, 2007). The study of Monyeki et al. (2005) showed that boys at this age can be more flexible than girls. Also in the balance boys and girls showed some proximity. These results may be due to the fact that in pre-pubertal period the difference in stature between boys and girls gradually decrease, due to the growth velocity of girls at this stage be higher than for boys, reaching the peak height velocity (PHV) earlier (Malina & Bouchard, 1991). A greater stature leads to a high body's center of mass, in turn responsible for increased postural instability on balance exercises (Allard et al., 2001). However, other factors absent from this study may account for the approximation/divergence of boys and girls in physical fitness. Such factors may include, among others, different practice opportunities (Thomas & French, 1985) or the preference for activities that require more endurance, strength and velocity, or balance and flexibility (Branta et al., 1984).

Conclusions

It has been observed that there is an apparent decrease in the interest of children in physical education classes and regular physical activity practice at school. This seems to be due, in

part, to lack of planning that takes into account the success of children in the execution of the exercises respecting the differences among students, including boys and girls. The knowledge of the magnitude of the differences between boys and girls in physical fitness (greater in the explosive strength of upper and lower limbs, and smaller in the abdominal and upper limbs muscular endurance and trunk extensor strength and flexibility, balance and speed), can help in the planning of activities that take into account the success of both boys and girls, and thus, increase levels of physical activity and physical fitness at school. However the results seem to suggest that one cannot neglect the influence of genetic determinism, observed from the morpho-constitutional point of view, since the presence of certain physical traits girls (ectomorphic and mesomorphic in the boys and endomorphic in the girls) shown to be determinant in prepubescent children's physical fitness level.

Study 4

Effects of body fat and dominant somatotype on explosive strength and aerobic capacity trainability in prepubescent children

Abstract

Background: The school provides an excellent setting to enhance health-related physical fitness, by implementing training programs. The purpose of our study was to analyze the influence of body fat and somatotype on explosive strength and aerobic capacity trainability in prepubescent children. Methods: One hundred twenty-five healthy children (58 boys, 67 girls), aged 10-11 years old (10.8 ± 0.4 years) were assigned into two experimental groups to train twice a week for 8 weeks: resistance group (GR: 19 boys, 22 girls), aerobic group (GE: 21 boys, 24 girls) and a control group (GC: 18 boys, 21 girls; no training program). Results: Fat mass ($r = -.45$ to $-.68$) and endomorphic ($r = -.50$ to $-.70$) were significantly associated with training-induced gains in vertical (girls) and horizontal jumps, running speed and aerobic capacity (boys and girls). The associations for ectomorphic ($r = .42$ to $.81$) were the inverse of those for fat mass and endomorphic. The mesomorphic ($r = -.44$ to $-.68$) was only negatively associated with training-induced VO_{2max} gains. The mesomorphic had the high-sized effect on the training-induced explosive strength gains, in both boys ($\eta_p^2 = 0.458$) and girls ($\eta_p^2 = 0.446$), and the ectomorphic on the VO_{2max} gains, also in boys ($\eta_p^2 = 0.214$) and girls ($\eta_p^2 = 0.144$). Conclusions: We cannot neglect the effect of somatotype and body fat on explosive strength and aerobic capacity trainability. At this point, it seems that the presence/ absence of certain physical traits can be a crucial factor in prepubescent children.

Key words: school, intervention, power, aerobic, health-related physical fitness

Introduction

During the last decade physical activity participation among young people has been decreasing considerably, being below the WHO recommendation for health-status and well-being (World Health Organization, 2010). Many children and adolescents are only exposed to vigorous physical activity during school-based physical education classes (Evenson et al., 2009), and the majority of them do not participate in any organized physical activity during non-school hours (Centers for Disease Control and Prevention, 2003). Thus, it is important to ensure that during these classes students are exposed to physical activities that promote health-related physical fitness development and an active lifestyle. School seems to provide an excellent setting to enhance and promote physical activity and physical fitness levels (Burgeson et al., 2001; Strong et al., 2005) by implementing training programs (Evenson et al., 2009; Stenevi-Lundgren et al., 2009). In children, because of low aerobic capacity is associated with risk factors of cardiovascular disease (Anderssen et al., 2007), a great amount of research has focused on activities that enhance cardiorespiratory fitness disregarding, for instance, neuromotor fitness based on muscular strength (Cepero et al., 2011). However, it is recognized that youth strength training approaches can be a safe and effective method of conditioning and should be an important component of youth fitness programs, health promotion objectives, and injury prevention (Faigenbaum et al., 2009). Indeed, improvements in muscular fitness and speed/agility, rather than cardiorespiratory fitness, seem to have a positive effect on skeletal health (Ortega et al., 2007). Increasing both aerobic and muscular fitness is a desirable goal in a training program (Taanila et al., 2011).

In order to maximize the benefits of training, some studies have reported the influence of several variables in the implementation of training programs children and adolescents, such as the training program, supervision, instruction quality and control learning, gender, age and maturity (Faigenbaum et al., 2009; Behringer et al., 2011). However, the influence of body fat and somatotype on the effects of the implementation of training programs in young people still needs to be elucidated. Body fat represents an inert load, non-contributive, associated with an increased metabolic cost (Norman et al., 2005) and the somatotype translates the expression of genetic determinism, observed from the morpho-constitutional point of view (Malina & Bouchard, 1991). These factors, therefore, may influence the execution of the planned exercises, training intensity and recovery of the performers, resulting in different effects of applying a particular training program. Additionally, both body fat and somatotype are significantly associated with the level of physical fitness achieved (Dumith et al., 2010; Jakšić & Cvetković, 2009) and appears to influence the development of a training program in children and adolescents (Faigenbaum et al., 2009). Moreover, according to Ignjatovic et al. (2009) it would be logical to assume that young people who are stronger and more powerful would have an advantage for the strength training, so it will be interesting to verify this presupposition, given that during

preadolescence the neural adaptations are the primarily responsible for training-induced strength gains (Ramsay et al., 1990).

The purpose of the present study was to analyze the influence of body fat and somatotype on the training of explosive strength and aerobic in prepubescent children. It was hypothesized that somatotype and body fat have a significant effect on the training-induced strength and aerobic gains in prepubescent untrained school children.

Material and Methods

Sample

The sample consisted of 125 prepubescent children, aged between 10 and 11 years old, all of whom volunteered for this study. The age, height and weight of the whole sample were: 10.8 ± 0.4 years, 1.43 ± 0.08 m, and 39.7 ± 9.0 kg, respectively (boys: 10.8 ± 0.5 years, 1.42 ± 0.07 m, 39.7 ± 9.3 kg; girls: 10.8 ± 0.4 years, 1.42 ± 0.07 m, 39.6 ± 8.5 kg). Both boys and girls were in Tanner stages 1-2 (boys: stage 1, 81% and stage 2, 19%; girls: stage 1, 53.7% and stage 2, 46.3%). 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 pediatric disease or with an orthopedic limitation. Subsequently, to minimize the effects of growth, only were selected for the sample the subjects who were self-assessed in Tanner stages 1-2.

Procedures

One hundred twenty-five healthy children recruited from a Portuguese public basic school (from 5th and 6th grade) were divided into two experimental groups (8 weeks training program, twice a week, from January 9th to March 2th of 2012) and one control group as follows: one group performing power training (GR: 19 boys, 22 girls); another group performing aerobic training (GE: 21 boys, 24 girls), and the third was the control group (GC: 18 boys, 21 girls; without a training program). There were no significant differences ($p > 0.05$) between groups for age or Tanner ratings, neither in anthropometric, morphological or performance variables at the beginning of the protocol, in both boys and girls.

In 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), the GR group was submitted to a strength training program composed by: 1 and 3 kg medicine ball throws; jumps onto a box (from 0.3 m to 0.5 m); plyometric jumps above 0.3-0.5 m of height hurdle and; sets of 30 to 40m speed running. The GE group was subjected to a 20m shuttle run exercise. This aerobic 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, GE subjects were reassessed using 20m shuttle run tests in order to readjust the volume and intensity of the 20m shuttle run exercise. Throughout pre- and experimental periods, the subjects reported their non-involvement in additional regular exercise programs for developing or maintaining strength and aerobic performances. Each subject was familiarized with all tests. All data collection was performed by the same investigator. A more detailed analysis of the program can be found in table 1.

Table 1. Training program design:

Sessions						
Exercises	1	2	3	4	5	6
Chest 1Kg Medicine Ball Throw ¹	2x8	2x8	2x8	2x8	6x8	6x8
Chest 3Kg Medicine Ball Throw ¹	2x8	2x8	2x8	2x8		
Overhead 1Kg Medicine Ball Throw ¹	2x8	2x8	2x8	2x8	6x8	6x8
Overhead 3Kg Medicine Ball Throw ¹	2x8	2x8	2x8	2x8		
Counter Movement Jump onto a box ¹	1x5	1x5	3x5	3x5	3x5	4x5
Plyometric Jumps above 3 hurdling ¹	5x4	5x4	5x4	5x4	2x3	2x3
Sprint Running (m) ¹	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 1Kg Medicine Ball Throw ¹						
Chest 3Kg Medicine Ball Throw ¹	2x5	2x5	3x5	3x5	3x5	2x5
Overhead 1Kg Medicine Ball Throw ¹						
Overhead 3Kg Medicine Ball Throw ¹	2x8	2x8	3x8	3x8	3x8	
Counter Movement Jump onto a box ¹	4x5	5x5	5x5	5x5	5x5	4x5
Plyometric Jumps above 3 hurdling ¹	3x3	4x3	4x3	4x3	4x3	
Sprint Running (m) ¹	4x30m	4x30m	4x30m	4x30m	4x30m	3x40m
20m Shuttle Run (MAV) ²	75%	TestM	75%	75%	75%	75%
Sessions						
Exercises	13	14	15	16		
Chest 1Kg Medicine Ball Throw ¹						
Chest 3Kg Medicine Ball Throw ¹	2x5	1x5				
Overhead 1Kg Medicine Ball Throw ¹		3x8	2x8	2x8		
Overhead 3Kg Medicine Ball Throw ¹	3x8					
Counter Movement Jump onto a box ¹	4x5	2x5	2x4	2x4		
Plyometric Jumps above 3 hurdling ¹	4x3	3x3				
Sprint Running (m) ¹	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 children 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. MAV- maximum individual aerobic volume. 1= power strength training protocol (GR). 2= aerobic training protocol (GE).

All anthropometric measurements were assessed according to international standards for anthropometric assessment (Marfell-Jones et al., 2006) and were carried out prior to any physical performance test. Body weight (kg) was measured to the nearest 0.1 kg using a standard digital floor scale (Seca, model 841, Germany). To evaluate body height (cm) a precision stadiometer with a range scale of 0.10 cm was used (Seca, model 214, Germany). For perimeter measurement a circumference tape was used (Seca 200). It was assessed the bi-condyle femoral and humeral diameters (Campbell, 20, Ross Craft, Canada). The percent body fat (%BF) from skinfold anthropometry was calculated by using the method of Slaughter et al. (1988). As such, triceps and subscapular skinfolds were determined by internationally recommended methods (Marfell-Jones et al., 2006). The principal components of the morphological typology, endomorphic (ENDO), mesomorphic (MESO), and ectomorphic (ECTO), were calculated using the method described by Heath-Carter (1971). Maturity level based on Tanner stages was self-assessed (Faigenbaum et al., 1996). To assess upper and lower body explosive strength (medicine ball throwing and standing long jump and vertical jump, respectively), running speed (20m sprint run) and VO_{2max} (20m shuttle run test) the following tests were used:

Counter movement Vertical Jump: This 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 children 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, 2001). Each participant performed three jumps and the highest jump (cm) was recorded. (ICC = 0.94)

Standing long jump: This test was assessed using EUROFIT test battery (Adam et al., 1988). The participants stood feet slightly apart (toes behind a starting line) and jumped as far forwards as possible. Three trials were given and the furthest distance was measured in centimeters from the starting line to the heel of the foot nearest to this line. (ICC = 0.94)

Medicine-ball throwing: This test was performed according to the protocol described by Mayhew et al. (1997). Subjects were seated with the backside of the trunk in touch with a wall. They were required to hold a 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) with their hands (abreast of chest) and throw it forward over the maximum distance possible. Hip inflection was not allowed nor withdrawal of the trunk away from the wall. Three trials were given and the furthest throw was measured in centimeters from the wall to the first point at which the ball made contact with floor. (ICC = 0.94 and 0.97, respectively)

20-meter sprint running: In a track measuring 20 meters in length, subjects were required to cover the distance in the shortest time they could. Time to run 20m was obtained using photocells (Brower Timing System, Fairlee, Vermont, USA). Three trials were performed and the best time scored (seconds and hundredth) was registered. (ICC = 0.97)

20-meter multistage shuttle run: This test involved continuous running between two lines 20m apart in time to recorded beeps. The subjects ran between the two lines, turning when signaled by the recorded beeps. After about one minute, a sound indicates an increase in speed, and the beeps will be closer together. This continues 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 et al., 1988). When the participants failed to reach the line on two consecutive occasions, they were stopped and the number of completed 20m laps was recorded. Estimated VO_{2max} ($ml.kg^{-1}.min^{-1}$) was calculated by the Léger's equation (Léger et al., 1988), which is based on the level reached before boys were unable to keep up with the audio recording. (ICC = 0.97)

Statistics

Standard statistical methods were used for the calculation of the means and standard deviations. Normality of distribution was checked by applying the Kolmogorov-Smirnov test. The between-subject reliability of aerobic and power tests was determined by the Intraclass correlation coefficient (ICC). The training related effects in the control and experimental groups were assessed using a paired-samples t-test. The relationships between body fat, primary components of the somatotype, and training-induced gains were performed with the Pearson's correlation. To determine which of the somatotype and body fat factor had a greater influence on training-induced gains in all the explosive strength measures it was estimated, through the multivariate analysis of covariance (MANCOVA), the effect size (Partial Eta Squared) of each independent variable. To determine which of those factors had a greater influence on the VO_{2max} gains, it was estimated an analysis of covariance (ANCOVA).. Data was analyzed using SPSS 15.0. The statistical significance was set at $p \leq 0.05$.

Results

At baseline, there were no significant differences between the control and experimental groups in the explosive strength measures for either the counter movement vertical jump (boys: $t = 0.522$, $p = 0.605$; girls: $t = 0.835$, $p = 0.409$), standing long jump (boys: $t = 1.718$, $p = 0.095$; girls: $t = 1.899$, $p = 0.065$), 1Kg (boys: $t = 0.339$, $p = 0.737$; girls: $t = 1.699$, $p = 0.097$) and 3Kg medicine ball throwing (boys: $t = 0.123$, $p = 0.903$; girls: $t = 0.301$, $p = 0.765$) or the running

speed (boys: $t= 0.583$, $p= 0.423$; girls: $t= -0.687$, $p= 0.496$). Similarly, there were no significant differences between groups for baseline VO_{2max} values (boys: $t= -0.604$, $p= 0.550$; girls: $t= 1.333$, $p= 0.190$). In the post-test, also there were no significant differences between control and experimental groups, in both boys and girls.

Compared with the values of the beginning of the protocol, the 8-week training programs produced significant improvements in all power strength ($p \leq 0.05$) and aerobic measures ($p \leq 0.01$) for both boys and girls. No significant changes were observed in GC group ($p > 0.05$). (Table 2)

Table 2. Comparison of explosive strength and aerobic tests results mean ($\pm SD$) between experimental and control groups in pre- (T0) and post-test (T1) conditions: Boys and girls

	Group	T0	T1	Gains ¹	p
Boys					
Counter Movement Jump (cm)	GC	23.43 \pm 5.2	24.35 \pm 6.1	0.91	0.095
	GR	22.50 \pm 5.6	23.55 \pm 6.4	1.04	0.033*
Standing Long Jump (cm)	GC	140.16 \pm 21.9	145.16 \pm 27.4	5.00	0.117
	GR	129.68 \pm 14.6	136.21 \pm 16.8	6.52	<0.001*
1Kg Medicine Ball Throwing (cm)	GC	375.33 \pm 74.5	380.11 \pm 77.9	4.77	0.096
	GR	367.52 \pm 65.6	389.36 \pm 68.7	21.84	<0.001*
3Kg Medicine Ball Throwing (cm)	GC	233.22 \pm 44.5	237.16 \pm 46.3	3.94	0.238
	GR	231.52 \pm 39.0	250.36 \pm 42.2	18.84	<0.001*
20m Sprint Running (s)	GC	4.37 \pm 0.2	4.34 \pm 0.27	0.02	0.086
	GR	4.30 \pm 0.2	4.20 \pm 0.26	0.09	<0.001*
20m Shuttle Run (ml.kg ⁻¹ .min ⁻¹)	GC	45.20 \pm 3.9	45.70 \pm 4.4	0.50	0.195
	GE	45.90 \pm 3.3	47.52 \pm 4.1	1.61	<0.001*
Girls					
Counter Movement Jump (cm)	GC	21.06 \pm 3.8	21.43 \pm 4.1	0.37	0.216
	GR	20.20 \pm 2.8	21.33 \pm 3.7	1.12	0.005*
Standing Long Jump (cm)	GC	127.95 \pm 15.6	130.28 \pm 17.3	2.33	0.314
	GR	120.36 \pm 14.1	126.81 \pm 11.7	6.45	<0.001*
1Kg Medicine Ball Throwing (cm)	GC	353.14 \pm 35.2	357.14 \pm 39.8	4.00	0.096
	GR	330.77 \pm 49.5	349.72 \pm 54.3	18.95	<0.001*
3Kg Medicine Ball Throwing (cm)	GC	221.00 \pm 37.6	230.33 \pm 39.0	9.33	0.081
	GR	217.50 \pm 38.5	235.13 \pm 40.6	17.63	<0.001*
20m Sprint Running (s)	GC	4.38 \pm 0.2	4.37 \pm 0.2	0.01	0.420
	GR	4.43 \pm 0.1	4.33 \pm 0.2	0.01	<0.001*
20m Shuttle Run (ml.kg ⁻¹ .min ⁻¹)	GC	44.11 \pm 2.8	44.23 \pm 2.8	0.12	0.703
	GE	43.01 \pm 2.6	44.33 \pm 3.5	1.32	0.002*

¹absolute gains; GC- control group; GR- resistance training group; GE- aerobic training group; *significant difference from T0 to T1 ($p < 0.05$)

After applying the training programs, one can note that %BF and ENDO were significantly and negatively associated with training-induced gains in vertical (girls) and horizontal jumps, running speed and aerobic capacity (boys and girls). ECTO was positively associated with training-induced gains in vertical (girls) and horizontal jumps, running speed and aerobic capacity (boys and girls). MESO was only negatively associated with training-induced VO_{2max} gains (boys and girls). (Table 3)

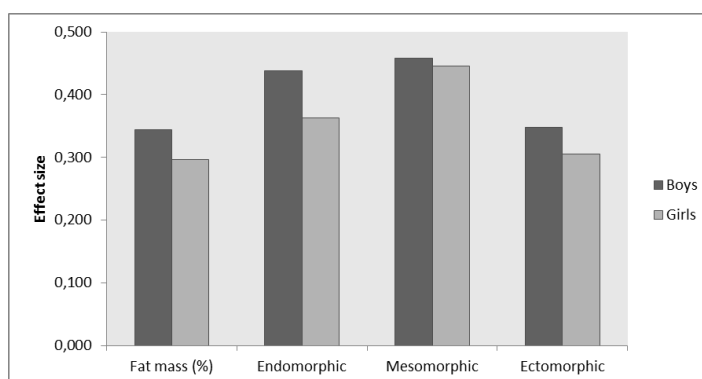
Table 3. Pearson`s correlation between percentage of fat mass (%BF), endomorphic (ENDO), mesomorphic (MESO), ectomorphic (ECTO), and explosive strength and VO_{2max} gains: Boys and girls

	Boys				Girls			
	%BF	ENDO	MESO	ECTO	%BF	ENDO	MESO	ECTO
Counter Movement Jump (cm)	-.40	-.42	.18	.08	-.45*	-.50*	-.31	.42*
Standing Long Jump (cm)	-.68**	-.70**	.37	.55*	-.65**	-.69**	-.33	.57**
1Kg Med. Ball Throwing (cm)	-.24	-.25	.40	-.03	-.06	-.09	.36	-.17
3Kg Med. Ball Throwing (cm)	-.16	-.15	.33	-.02	-.10	-.05	.21	-.18
20m Sprint Running (s)	-.53*	-.54*	-.25	.47*	-.45*	-.50*	-.17	.53*
20m Shuttle Run (ml.kg ⁻¹ .min ⁻¹)	-.59**	-.59**	-.68**	.81**	-.51*	-.54**	-.44*	.55**

* $p < 0,05$ ** $p < 0,01$

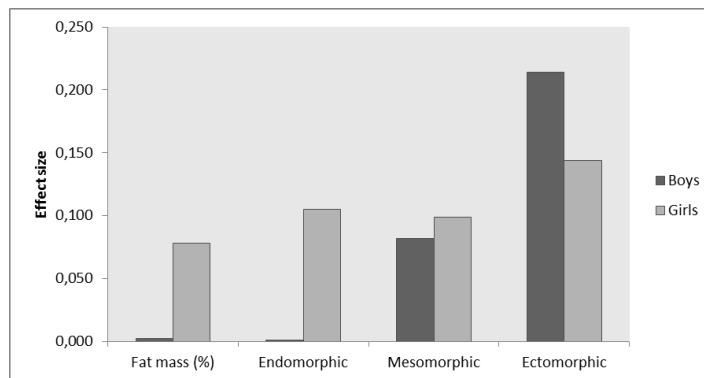
Comparing the effect of the somatotype and body fat on the training-induced strength and aerobic gains, through the MANCOVA, we found that MESO had the high-sized effect on training-induced explosive strength gains, in both boys ($\eta_p^2 = 0.458$) and girls ($\eta_p^2 = 0.446$). The estimated ANCOVA, that disaggregate the whole effect of the explosive strength variables, show that this effect is mainly due to the influence of MESO on training-induced 1Kg ($p = 0.011$, $\eta_p^2 = 0.380$) and 3Kg ($p = 0.019$, $\eta_p^2 = 0.333$) ball throwing gains, in boys, and running speed gains ($p = 0.022$, $\eta_p^2 = 0.271$), in girls. The variables %BF (boys: $\eta_p^2 = 0.344$, girls: $\eta_p^2 = 0.296$) and ECTO (boys: $\eta_p^2 = 0.347$ and girls: $\eta_p^2 = 0.305$) had the smaller size effect on the explosive strength gains. (Figure 1)

Figure 1. Effect size of fat mass, endomorphic, mesomorphic and ectomorphic on training-induced explosive strength gains: boys and girls



ECTO had the high-sized effect on the training-induced VO_{2max} gains, in both boys ($\eta_p^2 = 0.214$) and girls ($\eta_p^2 = 0.144$). Only in this variable the effect size is greater in boys than in girls. In the boys, %BF ($\eta_p^2 = 0.002$) and ENDO ($\eta_p^2 = 0.001$) had almost no effect on the training-induced aerobic gains. In the girls, %BF ($\eta_p^2 = 0.078$) and MESO ($\eta_p^2 = 0.099$) had the smaller size effect on the aerobic gains. The %BF, MESO and ENDO variables had a greater effect on the training-induced VO_{2max} gains in girls than in boys. (Figure 2)

Figure 2. Effect size of fat mass, endomorphic, mesomorphic and ectomorphic on training-induced VO_{2max} gains: boys and girls



Discussion

At a first moment, the significant increasing observed for explosive strength of upper limbs (e.g. medicine ball throw with 1kg and 3kg) and lower limbs (e.g. standing long jump and counter movement vertical jump) as well as in 20-meter sprint running, indicates that the implementation of a strength training program at school can be a positive stimulus to enhance explosive strength in healthy prepubescent children. The current results also showed a significant enhancement in VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$), highlighting the potential of the application of aerobic training programs in this age group, in untrained boys and girls. These findings are consistent with the results of previous studies conducted with children and adolescents, in which were applied strength (Dorgo et al., 2009; Santos & Janeira, 2008) and aerobic training programs (Sandbakk et al., 2011; Santos et al., 2012).

After applying training programs can be observed that ECTO was positively associated with training-induced gains in vertical and horizontal jumps, running speed and VO_{2max} , these being the same capabilities with which %BF and ENDO had a negative association. These results seem to show that the inert non-contributory load imposed by body fat, which represents an increased metabolic cost for children (Norman et al., 2005), makes them less efficient in the performing of the proposed training program, as well as in terms of cardiorespiratory response. ENDO and %BF variables are very close, either in terms of definition, or by the way

they are calculated. The excess body fatness associated with ENDO adversely affects motor performance (Malina & Bouchard, 1991), being a limiting factor especially in projection body tasks and aerobic fitness (Suchomel, 2002), in which body fat plays a similar function (Dumith et al., 2010; Castro-Piñero et al., 2009). On the contrary, the relative linearity associated with ECTO (Malina & Bouchard, 1991), seems to contribute significantly on the development of training programs to improve the explosive strength and cardiorespiratory fitness. Because of the negative effect of body weight on the propulsion tasks and motor items in which the body must be projected (Dumith et al., 2010; Castro-Piñero et al., 2009), the ECTO component has the advantage (Jakšić & Cvetković, 2009), since it is based on weighting index, i.e. the quotient of height by the cube root of body weight (Malina & Bouchard, 1991). Also Chaouachi et al. (2005) reported the greatest gains in the aerobic capacity for the individuals with a predominance of the ECTO component. It is important to stress that MESO, which reflects the relative muscle-skeletal magnitude (Malina & Bouchard, 1991), only associated significantly and negatively with the training-induced VO_{2max} gains. At this point, the literature also reports negative associations of MESO with propulsion tasks (Shukla et al., 2009), in which ECTO has the advantage (Chaouachi et al., 2005), as mentioned above. Regarding the association of MESO with the explosive strength gains, must be taken into account that during preadolescence, beyond the small muscle mass of the girls, the boys still present a reduced muscle mass, because the effects of circulating androgens, particularly testosterone, only manifest themselves at puberty (Malina & Bouchard, 1991). Additionally, it appears that during preadolescence the neural adaptations (i.e., a trend toward increased motor unit activation and changes in motor unit recruitment, and firing) and possibly intrinsic muscle adaptations (as evidenced by increases in twitch torque) are primarily responsible for training-induced strength gains in this age group (Ramsay et al., 1990; Ozmun et al., 1994). A better motor coordination of the involved muscle groups may also play a significant role (Ozmun et al., 1994). These facts are corroborated by the results of some studies in the literature that reported no significant associations of strength training with increases in gross limb morphology (Ramsay et al., 1990; Ozmun et al., 1994).

Comparing the effect of somatotype and body fat on the training-induced changes in performance after training interventions, the high-sized effect of MESO registered on the explosive strength gains, as well as the high-sized effect of ECTO on the VO_{2max} gains, in both boys and girls, highlights the importance of the morphological typology on the training of these capabilities in prepubescent children. There is evidence that by pre-puberty there already exists a fairly stable somatotype, pointing to 8 years as the age by which somatotype stability becomes manifest (Malina & Bouchard, 1991; Malina et al., 2004). However, an analysis to changes in morphological typology of children during growth shows that in pre-puberty boys tend to show a slight increase of the mesomorphic values, and girls show an increase of the endomorphic and a slight reduction of the ectomorphic values, while the mesomorphic component does not change significantly (Malina et al., 2004), so the effect of

the MESO component on the training-induced explosive strength gains, in the boys, and ECTO on the VO_{2max} gains, in the girls, can be even more evident.

Conclusions

Our results suggest that school-based strength and aerobic training programs seems considerably effective on both explosive strength and cardiorespiratory fitness feature of age-school children. It seems that the relative musculoskeletal development, on the explosive strength, and the relative linearity, on the aerobic capacity, can be a crucial factor on training-induced gains, in both boys and girls.

The school provides an excellent setting to enhance health-related physical fitness, by implementing training programs. Increasing both aerobic and muscular fitness is essential for promoting health, and should be a desirable goal in a training program. However, despite the many constraints existing in school (e.g. reduced practice time per session, number of weekly sessions, lack of material resources and facilities, or a large number and diversity of students), it is unacceptable the standardization of any form of training. One of the principles of training is the biological individuality. Physically, each subject has its own configuration, which makes him different from the others, commonly designated as somatotype, which is defined as representing the individual's present morphological conformation. The knowledge of the influence of certain physical traits on the training-induced strength and aerobic gains can help to bring the training closer to the individual characteristics, and thus improving the results achieved.

Study 5

Effects of concurrent training on explosive strength and VO_{2max} in prepubescent children

Abstract

The purpose of this study was to compare the effects of 8-weeks training period of resistance training alone (GR), combined resistance and endurance training (GCON) and a control group (GC) on explosive strength and VO_{2max} in a large sample of prepubescent boys and girls. Methods: One hundred twenty-five healthy children (58 boys, 67 girls), aged 10-11 years old (10.8 ± 0.4 years) were assigned into two training groups to train twice a week for 8 weeks: GR (19 boys, 22 girls), GCON (21 boys, 24 girls) and a control group (GC: 18 boys, 21 girls; no training program). Results: It was observed a significant but medium-sized increase from pre- to the post-training in the vertical jump ($F= 33.35$, $p < .01$), standing long jump ($F= 81.77$, $p < .01$) and VO_{2max} ($F= 25.15$, $p < .01$). A significant high-sized increase in the 1 kg ($F= 244.73$, $p < .01$) and 3 kg ($F= 150.63$, $p < .01$) ball throwing and running speed ($F= 148.9$, $p < .01$). The training group (GR and GCON) and sex factors did not significantly influence the evolution of strength variables from pre- to the post-training. The VO_{2max} increased significantly only in GCON. Conclusion: Concurrent training is equally effective on training-induced explosive strength, and more efficient than resistance training only for VO_{2max} , in prepubescent boys and girls. This should be taken into consideration to optimize strength training school-based programs.

Key words: youth, exercise school-based programs, power, endurance

Introduction

Nowadays, the efforts to promote levels of physical fitness and physical activity in youth should be a priority. Physical fitness and physical activity are considered to be important supportive elements for the maintenance and enhancement of health and quality of life, and hence for the improvement of the holistic development of a child (Kvaavik et al., 2009; Ortega et al., 2007). Unfortunately, there exist evidences suggesting that physical fitness and physical activity have declined worldwide in the last decades among children and adolescents (Matton et al., 2007). Many children and adolescents are only exposed to vigorous physical activity during school-based physical education classes (Coleman et al., 2004). Therefore, it is important to ensure that during these classes students are exposed to physical activities that promote health-related physical fitness development and an active lifestyle (Dorgo et al., 2009). School seems to provide an excellent setting to enhance and promote physical activity and physical fitness levels, by implementing training programs (Marques et al., 2011; Stenevi-Lundgren et al., 2009).

Because of the low aerobic capacity in children is associated with risk factors of cardiovascular disease (Anderssen et al., 2007), the majority of the research has focused on activities that enhance cardiorespiratory fitness disregarding, for instance, neuromuscular fitness conditions based on muscular strength (Cepero et al., 2011). However, it is recognized that youth strength training can be a safe and effective method of conditioning and should be an important component of youth fitness programs, health promotion objectives, and injury prevention (Faigenbaum et al., 2009). Increasing both aerobic and muscular fitness is essential to promote health (American College of Sports Medicine, 2006) and should be a desirable goal in a training program (Taanila et al., 2011).

Due to various school constraints (i.e. reduced practice time per session, number of weekly sessions or lack of material resources and facilities), children and adolescents involved in physical education classes often perform concurrently strength and endurance training (Santos et al., 2012) in an attempt to reach different physical fitness goals (Anderson & Haraldsdottir, 1995) at the same time. However, during several decades many studies have reported an interference effect on muscle strength development when strength and endurance were trained concurrently (Dudley & Djamil, 1985; Izquierdo-Gabarren et al., 2010). The majority of these studies found that the magnitude of increase in strength was higher in the group that performed only strength training compared with the concurrent training group. This is commonly referred to as the “interference phenomenon” (García-Pallarés & Izquierdo, 2011). On the other hand, physical education classes or extracurricular activities commonly include children of both sexes, and therefore it is important to verify the applicability of a concurrent training program in age-school boys and girls. There exists a small body of evidences about the effect of concurrent resistance and endurance training

implemented in school environment (Izquierdo-Gabarren et al., 2010). A recent study showed that performing resistance and endurance training in the same workout does not impair strength development in adolescent schooled boys (Santos et al., 2012). However, the effects of concurrent resistance and endurance training in prepubescent students, according to our best knowledge, have yet to be investigated.

The purpose of the present study was to analyze the effects of power strength training alone and combined power strength and endurance training in the selected sample. It was hypothesized that concurrent resistance and endurance training would have a main positive effect on power strength development of untrained school children, compared with those found when power training was applied alone.

Material and Methods

Sample

The sample consisted of 125 prepubescent children, aged between 10 and 11 years old, all of whom volunteered for this study. Before data collection and the start of the training, each participant reported any health problems, physical limitations, physical activity habits, and training experiences for the last 6 months. The following exclusion criteria were used: subjects with a chronic pediatric disease or with an orthopedic limitation and subjects with regular oriented extra-curricular physical activity (e.g. practice of some sport in a club). Subsequently, to minimize the effects of growth, only were selected for the sample children who were self-assessed in Tanner stages 1-2 (boys: GC, stage 1, 77.8% and stage 2, 22.2%; GR, stage 1, 73.7% and stage 2, 26.3%; GCON, stage 1, 90.5% and stage 2, 9.5%; girls: GC, stage 1, 47.6% and stage 2, 52.4%; GR, stage 1, 50% and stage 2, 50%; GCON, stage 1, 62.5% and stage 2, 37.5%). No subject had regularly participated in any form of strength training program prior to this experiment. Subjects were carefully informed about the design of the study and subsequently the children's parents signed an informed consent document prior to the start of the study. The study was conducted according to the ethical standards of the International Journal of Sports Medicine (Harriss & Atkinson, 2011) and to the declaration of Helsinki, and was approved by the institutional review boards of the University of Beira Interior (UBI) and Research Centre in Sports, Health and Human Development (CIDESD), Portugal. Parameters of body dimensions and physical performance measures were evaluated for all subjects in pre-test. (Table 1)

Table 1. Descriptive data of the control (GC), resistance (GR) and concurrent (GCON) groups in pre-test condition: Boys and girls (Mean \pm SD)

	Boys			Girls		
	GC	GR	GCON	GC	GR	GCON
Decimal age	10.8 \pm 0.5	10.7 \pm 0.4	10.7 \pm 0.5	10.9 \pm 0.4	10.8 \pm 0.4	10.75 \pm 0.4
Height (cm)	139.5 \pm 7.0	141.6 \pm 5.9	146.7 \pm 8.3	140.8 \pm 6.3	144.8 \pm 8.0	142.7 \pm 7.2
Weight (kg)	37.8 \pm 7.6	38.9 \pm 10.7	42.0 \pm 9.0	37.4 \pm 6.9	41.3 \pm 9.8	39.7 \pm 9.4
CM jump	23.4 \pm 5.2	22.5 \pm 5.6	24.5 \pm 2.9	21.0 \pm 3.8	20.2 \pm 2.8	20.3 \pm 3.8
SL jump	140.1 \pm 21.9	129.6 \pm 14.6	140.7 \pm 10.6	127.9 \pm 15.6	120.3 \pm 10.1	121.8 \pm 17.6
1Kg ball throw	375.3 \pm 74.5	367.5 \pm 65.6	389.3 \pm 60.7	353.1 \pm 35.2	330.7 \pm 49.5	331.0 \pm 51.2
3Kg ball throw	233.2 \pm 44.5	231.5 \pm 39.0	243.2 \pm 39.1	221.0 \pm 37.6	217.5 \pm 38.5	208.0 \pm 35.4
20m Sprint	4.37 \pm 0.2	4.30 \pm 0.2	4.25 \pm 0.1	4.38 \pm 0.2	4.43 \pm 0.1	4.50 \pm 0.2
VO _{2max}	45.2 \pm 3.9	45.8 \pm 3,4	45.9 \pm 3,3	44.1 \pm 2.8	42.4 \pm 1.7	43.0 \pm 2.6

CM jump - counter movement jump (cm); SL jump - standing long jump (cm); 1kg ball throw - 1 kg medicine ball throwing (cm); 3kg ball throw - 3 kg medicine ball throwing (cm); 20m sprint - 20m sprint running (sec); VO_{2max} - 20m multistage shuttle run (ml.kg⁻¹.min⁻¹); ** p< 0.01

Procedures

One hundred twenty-five healthy children recruited from a Portuguese public elementary school (from 5th and 6th grade), which volunteered to take part in this study, were randomly assigned into two training groups (8 weeks training program, twice a week) and one control group as follows: one group performing power training only (GR: 19 boys, 22 girls); another group performing combined power strength and endurance training (GCON: 21 boys, 24 girls); and the third was the control group (GC: 18 boys, 21 girls; that followed the physical education classes curriculum, without a specific training program).

Prior to training, subjects warmed up for approximately 10 minutes with low to moderate intensity exercises (e.g., running, stretching and joint specific warm-up). Joint-rotations included slow circular movements, both clockwise and counter-clockwise, until the entire joint seems to move smoothly. Stretching exercises included back and chest, shoulders and side stretch, as well as quadriceps, calf, groin, and hamstring stretches. At the end of the training sessions, subjects performed 5 minutes of static stretching exercises. After the warm-up period, both GR and GCON groups were submitted to a strength training program composed by: 1 and 3 kg medicine ball throws; jumps onto a box (from 0.3 m to 0.5 m); plyometric jumps above 0.3-0.5 m of height hurdle and; sets of 30 to 40m speed running. After finishing strength training for both GR and GCON groups, the GCON group was further subjected to a 20m shuttle run exercise. 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, GCON subjects were reassessed using 20m shuttle run tests in order to readjust the volume and intensity of the 20m shuttle run exercise. Each training session

lasted approximately between 45` (resistance training) to 60` (concurrent training). The rest period between sets was 1` and between exercises 2`. Before the start of the training, subjects completed two familiarization sessions to practice the drill and routines they would further perform during the training period (i.e., power training exercises and 20m shuttle run test). During this time, the children were taught about the proper technique on each training exercise, and any of their questions were properly answered to clear out any doubts. In the course of conducting training there was a constant concern to ensure the necessary security and maintenance of safe hydration levels, as well as to encourage all children to do their best to achieve the best results. Clear instructions about the importance of adequate nutrition were also delivered. The same researcher conducted the training program and the anthropometric and physical fitness assessments. The instructions for each exercise were reported in accordance with the description of each test presented below. For the 20-m shuttle run, the instructions were given with the aid of a multi-stage fitness test audio CD, of the FITNESSGRAM® test battery. Throughout pre- and experimental periods, the subjects reported their non-involvement in additional regular exercise programs for developing or maintaining strength and endurance performance. There were no injuries resulting from the implementation of the training programs. A more detailed analysis of the program can be found in table 2.

All anthropometric measurements were assessed according to international standards for anthropometric assessment (Marfell-Jones et al., 2006) and were carried out prior to any physical performance test. The participants were barefoot and wore only underwear. Body weight (in kg) was measured to the nearest 0.1 kg using a standard digital floor scale (Seca, model 841, Germany). To evaluate body height (in cm) a precision stadiometer with a range scale of 0.10 cm was used (Seca, model 214, Germany). Maturity level based on Tanner stages was self-assessed (Duke et al., 1980).

Sample groups were assessed for upper and lower body explosive strength (medicine ball throwing and standing long jump and vertical jump, respectively), running speed (20-m sprint run) and VO_{2max} (20-m multistage shuttle run test) before and after 8-weeks of training program. Each subject was familiarized with all tests. All data collection was performed by the same researcher.

Counter movement Vertical Jump: This 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 subjects 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, 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 (in cm) was recorded. The counter movement vertical jump has shown an Intraclass Correlation Coefficient (ICC) of 0.94.

Standing long jump: This test was assessed using EUROFIT test battery (Adam et al., 1988). The participants stood feet slightly apart (toes behind a starting line) and jumped as far forwards as possible. Three trials were given and the furthest distance was measured (in cm) from the starting line to the heel of the foot nearest to this line. The standing long jump has shown an ICC of 0.94.

Medicine-ball throwing: This test was performed according to the protocol described by Mayhew et al. (1997). Subjects were seated with the backside of the trunk in touch with a wall. They were required to hold a 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) with their hands (abreast of chest) and throw it forward over the maximum distance possible. Hip inflection was not allowed nor withdrawal of the trunk away from the wall. Three trials were given and the furthest throw was measured (in cm) from the wall to the first point at which the ball made contact with floor. One-minute of rest among 3 trials was done. The ICC of data for 1kg and 3 kg medicine ball throwing was 0.94 and 0.97, respectively.

20-meter sprint running: In a 20 m length track, subjects were required to cover such distance in the shortest time they could. Time (in sec) to run 20m was obtained using photocells (Brower Timing System, Fairlee, Vermont, USA). Three trials were performed and the best time scored (seconds and hundredth) was registered. The sprint running (time) has shown an ICC of 0.97.

20-meter multistage shuttle run: This test involved continuous running between two lines 20m apart in time to recorded beeps. The subjects ran between the two lines, turning when signaled by the recorded beeps. After about one minute, a sound indicates an increase in speed, and the beeps will be closer together. This continues each minute (level). It was used the common version with an initial running velocity of 8.5 km/h, and increments of 0.5 km/h each minute (Léger et al., 1988). When the participants failed to reach the line on two consecutive occasions, they were stopped and the number of completed 20m laps was recorded. Estimated $VO_2\text{max}$ ($\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) was calculated by Léger's equation (Léger et al., 1988), which is based on the level reached before boys were unable to keep up with the audio recording. The 20m Shuttle Run test has shown an ICC of 0.97.

Table 2. Training program design:

Sessions						
Exercises	1	2	3	4	5	6
Chest 1Kg Medicine Ball Throw ^{1,2}	2x8	2x8	2x8	2x8	6x8	6x8
Chest 3Kg 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		
Counter Movement Jump 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 1Kg Medicine Ball Throw ^{1,2}						
Chest 3Kg 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	
Counter Movement Jump 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 1Kg Medicine Ball Throw ^{1,2}						
Chest 3Kg 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					
Counter Movement Jump 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 children 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. MAV- maximum individual aerobic volume. 1= power strength training protocol (GR). 2= concurrent training (GCON).

Statistics

Standard statistical methods were used for the calculation of the means and standard deviations. The between-subject reliability of endurance and power tests was determined by the Intraclass Correlation Coefficient (ICC). One-way analysis of variance ANOVA, followed by Scheffe's post-hoc multiple comparison tests, was used to find the differences in the explosive strength and endurance among the control and experimental groups. ANOVA with repeated

measures were performed for all dependent variables, with group as factor and sex as covariate. Partial eta squared as well effect size was calculated. The normality of the residuals was validated by the Kolmogorov-Smirnov test. The assumption of sphericity was validated by the Mauchly's Test of Sphericity. The statistical significance was set at $p \leq 0.05$.

Results

There were no significant differences ($p > 0.05$) between groups for age or Tanner ratings. Neither there was in anthropometric or performance variables at the beginning of the protocol, in both boys and girls. ANOVA with repeated measures showed a significant, but medium-sized increase from pre- to the post-training in the counter movement vertical jump ($F(1, 121) = 33.35, p < .01$), standing long jump ($F(1, 121) = 81.77, p < .01$) and VO_{2max} ($F(1, 121) = 25.15, p < .01$). There was a significant and high-sized increase in the 1 Kg ($F(1, 121) = 244.73, p < .01$) and 3 kg ($F(1, 121) = 150.63, p < .01$) medicine-ball throwing. Plus, there was a significant and high-sized decrease in time-at-20m from pre- to the post-training ($F(1, 121) = 148.9, p < .01$). (Table 3)

Table 3. Evolution of the explosive strength and VO_{2max} from pre- to the post-training: ANOVA

	F	df	p	Partial η^2	Effect size
CM jump	33.35	1	<0.001 **	0.216	0.213
CM jump * group	0.75	2	0.473	0.012	0.010
CM jump * sex	0.57	1	0.453	0.005	0.004
SL jump	81.77	1	<0.001 **	0.407	0.387
SL jump * group	4.93	2	0.009 **	0.077	0.047
SL jump * sex	0.40	1	0.526	0.003	0.002
1kg ball throwing	244.73	1	<0.001 **	0.669	0.573
1kg ball throwing * group	29.60	2	<0.001 **	0.329	0.139
1kg ball throwing * sex	1.85	1	0.176	0.015	0.004
3kg ball throwing	150.63	1	<0.001 **	0.555	0.513
3kg ball throwing * group	10.88	2	<0.001 **	0.152	0.074
3kg ball throwing * sex	0.12	1	0.728	0.001	0.000
20m sprint	148.9	1	<0.001 **	0.552	0.481
20m sprint * group	19.9	2	<0.001 **	0.247	0.128
20m sprint * sex	0.1	1	0.829	0.000	0.000
VO_{2max}	25.15	1	<0.001 **	0.172	0.154
VO_{2max} * group	7.07	2	0.001 **	0.105	0.087
VO_{2max} * sex	2.56	1	0.112	0.021	0.016

CM jump - counter movement jump (cm); SL jump - standing long jump (cm); 1kg ball throwing - 1 kg medicine ball throwing (cm); 3kg ball throwing - 3 kg medicine ball throwing (cm); 20m sprint - 20m sprint running (s); VO_{2max} - 20m multistage shuttle run ($ml \cdot kg^{-1} \cdot min^{-1}$); ** $p < 0.01$

In the boys the training-induced strength gains ranged from 2.9% to 8.30% (GR), and from 1.08% to 8.30% (GCON). In the girls strength gains ranged from 2.25% to 8.10% (GR), and from 2% to 9.11% (GCON). In both boys and girls the poorest gains were in the time-at-20m and the best ones in the 3 kg medicine ball throwing. The training-induced VO_{2max} gains ranged from 3.06% (girls) to 8.30% (boys). In the post-test, there were no statistically significant differences between the GR and GCON groups in the explosive strength and VO_{2max} measures.

Regarding the effect of the group factor on the evolution of strength and aerobic capacity from pre- to the post-training, there was no statistically significant influence of this factor on the evolution of the vertical jump ($F(2, 121) = 0.75, p \geq .05$). It was observed a significant, but small-sized effect of the group on the evolution of the standing long jump ($F(2, 121) = 4.93, p < .01$), 3 kg medicine-ball throwing ($F(2, 121) = 10.88; p < .01$) and VO_{2max} ($F(2, 121) = 7.07, p < .01$). There was a significant and medium-sized effect of the group on the evolution of the 1 kg medicine-ball throwing ($F(2, 121) = 26.60; p < .01$) and running velocity ($F(2, 121) = 19.9; p < .01$). However, the ANOVA with repeated measures for each group showed that the positive influence of the group on the standing long jump, 1 kg and 3 kg medicine-ball throwing and running speed was due to significant increases from pre- to the post-training in GR and GCON. In the control group there were no significant differences between the two moments. The VO_{2max} increased significantly only in GCON. (Figures 1 to 6).

Figure 1. Counter mov. jump (cm) by group

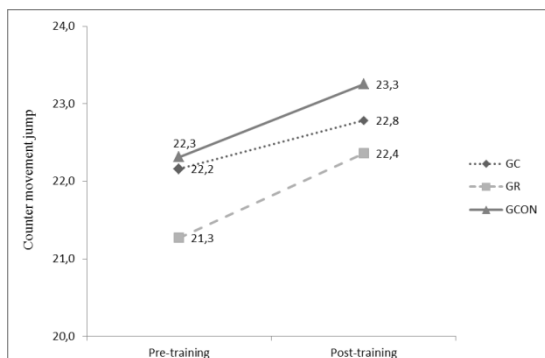


Figure 2. Standing long jump (cm) by group

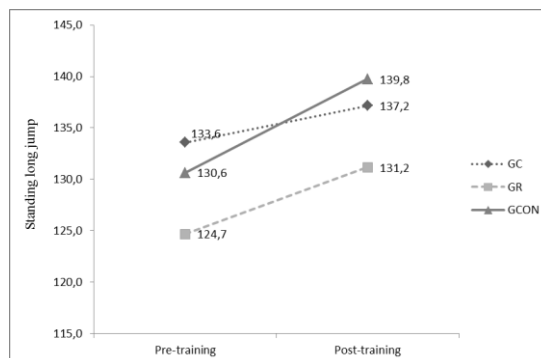


Figure 3. 1kg ball throwing (cm) by group

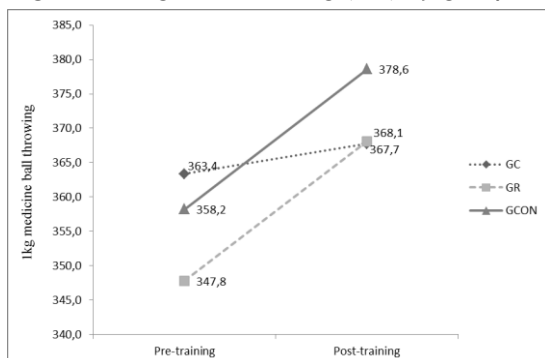


Figure 4. 3kg ball throwing (cm) by group

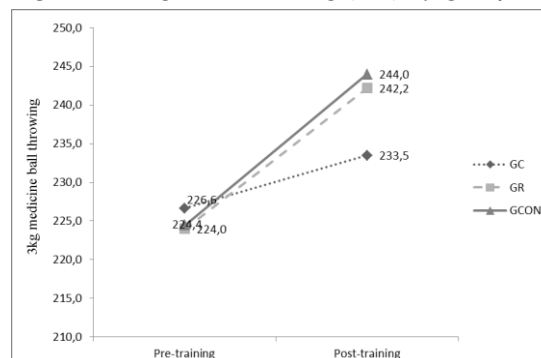


Figure 5. Time-at-20m (sec) by group

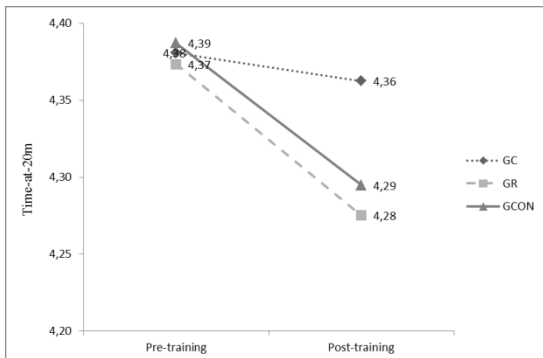
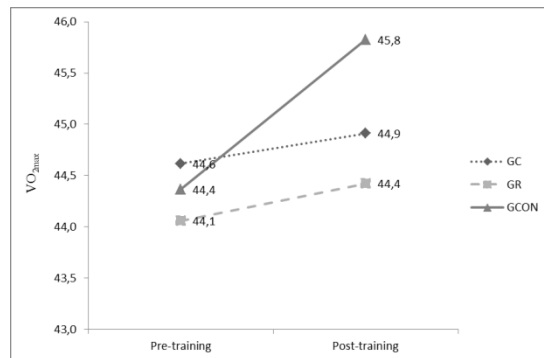


Figure 6. VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$) by group



Regarding sex factor, it did not significantly influence the evolution from pre- to the post-training of the vertical jump ($F(1, 121) = 0.57, p \geq .05$), standing long jump ($F(1, 121) = 0.40, p \geq .05$), 1 kg ($F(1, 121) = 1.85, p \geq .05$) and 3 kg ($F(1, 121) = 0.18, p \geq .05$) medicine-ball throwing, running speed ($F(1, 121) = 0.1, p \geq .05$), and VO_{2max} ($F(1, 121) = 2.56, p \geq .05$). When used data was normalized to body mass, ANOVA with repeated measures showed similar trend (Figures 7 to 12).

Figure 7. Counter mov. jump (cm) by sex

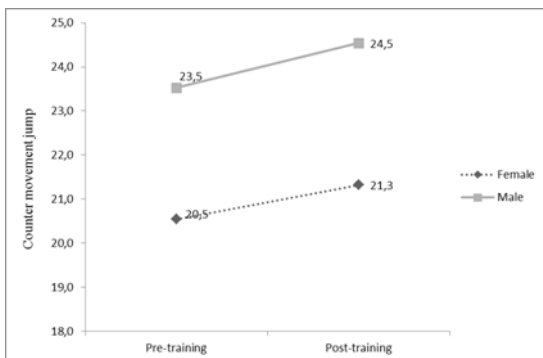


Figure 8. Standing long jump (cm) by sex

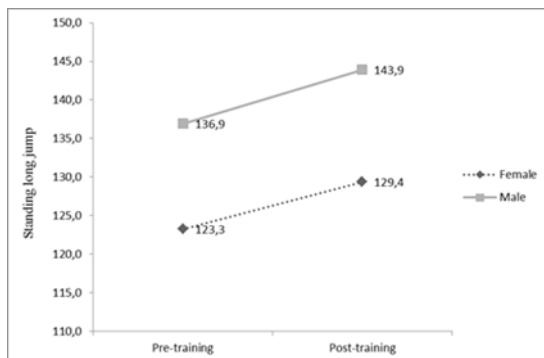


Figure 9. 1kg ball throwing (cm) by sex

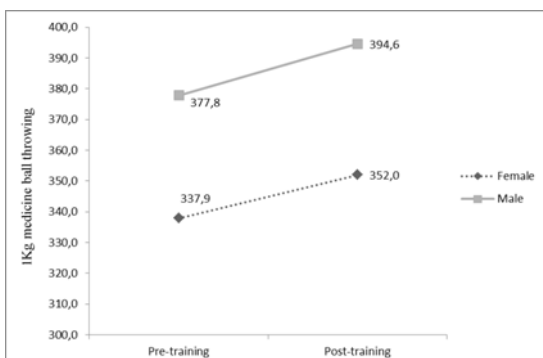


Figure 10. 3kg ball throwing (cm) by sex

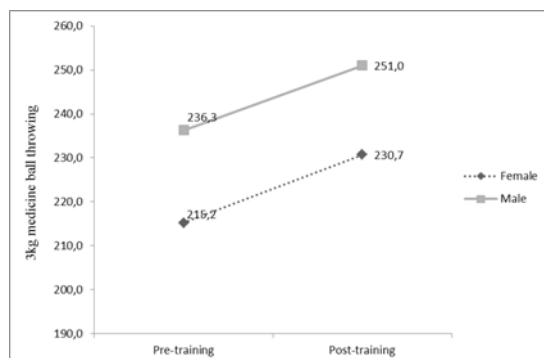
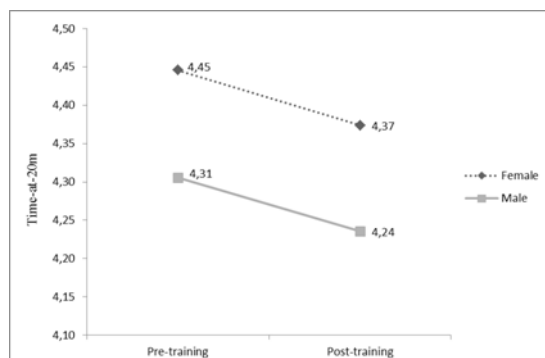
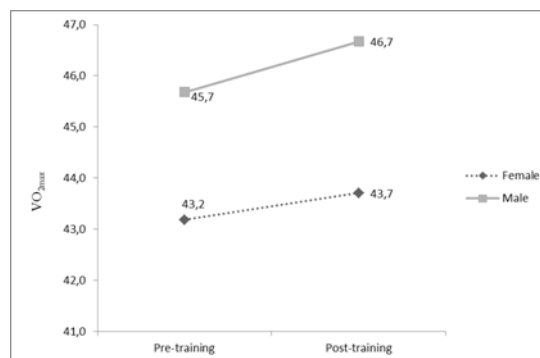


Figure 11. Time-at-20m (sec) by sex

Figure 12. VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$) by sex

Discussion

The purpose of the study was to analyze the effect of power strength training alone and combined power strength and endurance training in a large sample of prepubescent boys and girls. The main results suggested that concurrent training is an effective, well-rounded exercise program that can be performed to improve initial and/or general strength in healthy prepubescent boys and girls. Additionally, data suggests that sex does not have a significant effect on training-induced explosive strength and VO_{2max} of prepubescents. These results have a meaningful interest to optimized well-round exercise programs in childhood.

The significant increasing observed in both training groups for explosive strength of upper and lower limbs (e.g. medicine ball throw with 1kg and 3kg, standing long jump and counter movement vertical jump) as well as in 20-meter sprint running indicates that both concurrent resistance and endurance training and resistance training alone may be a positive training stimulus to enhance explosive strength in healthy prepubescent children. These findings are consistent with the results of previous studies in this area conducted with young people (Faigenbaum & Mediate, 2006; Santos & Janeira, 2011), who were also subjected to training programs using medicine balls and jumps (6 and 10 weeks training programs, respectively, twice per week on nonconsecutive days). Similar results were reported by Faigenbaum et al. (2005), using child-size exercise machines twice weekly over a 8 weeks period, while Dorgo et al. (2009) conducted a 9 and 18 weeks of manual resistance training, respectively. Additionally, no significant differences were found in the post training between GR and GCON groups in any variable related to explosive strength selected. This fact seems to suggest that endurance training does not positively affect strength development in school-age children, but also does not seem to impair strength development. There exists a relative paucity of published reports focused on the implementation of concurrent resistance and endurance training in school children (Izquierdo-Gabarren et al., 2010). The studies conducted by Santos et al. (2011, 2012) are an exception, but relates exclusively to the implementation of concurrent training programs in pubertal school girls and boys, respectively. Using a very similar training program design (i.e., resistance training using medicine balls, endurance

training through the 20-m multistage shuttle-run test, twice weekly for 8 weeks), the authors found significant training-induced gains in ball throw, running speed and height-and-length of the jumps, in both strength training alone, and combined strength and aerobic training. No significant differences were found in the post training between these experimental training groups.

However, a training program design different than in this particular study, or different methods of organizing training workouts, can lead to different results, due to several factors that can influence the level or degree of interference generated by concurrent training (García-Pallarés & Izquierdo, 2011). These factors include the initial training status of the subjects (Kraemer & Ratamess, 2004), exercise mode, volume, intensity and frequency of training (García-Pallarés et al., 2009; González-Badillo et al., 2005; Izquierdo et al., 2005). E.g., Sale et al. (1990) could observe that concurrent resistance and endurance training applied on separate days produced higher gains to those produced by concurrent training on the same day. Strength and endurance training elicit distinct and often divergent adaptive physiological mechanisms. The concurrent development of both fitness components in the same training regimen can lead to conflicting neuromuscular adaptations, such as reductions in the motor unit recruitment, decreases of rapid voluntary neural activations, chronic depletion of muscle glycogen stores, skeletal muscle fibre type transformation, decreases in the cross-sectional area of muscle fibres and in the rate of muscle force production due to the reduction in total protein synthesis (Coffey & Hawley, 2007; Hawley, 2009).

The current results also showed a significant enhancement in VO_{2max} only for GCON. In agreement with previous studies (Dorgo et al., 2009; Santos et al., 2011; Santos et al., 2012), these finding seems to indicate that resistance training program component was not effective to an improvement of the aerobic fitness in prepubescent school children. After 18-weeks of manual resistance training, Dorgo et al. (2009) observed that only the subjects who were exposed to additional cardiovascular endurance training achieved significant improvements for the 1-mile run performance. The subjects who performed only manual resistance training showed some improvement from pre- to midterm- and pre- to post-test. But these changes were not statistically significant. Similarly, Santos et al. (2011, 2012) found that VO_{2max} increased significantly only in the endurance training group, after 8-weeks.

Regarding the gender gap, the results seem to suggest that there is no significant effect on training-induced strength and VO_{2max} adaptations. These data corroborate the results of previous studies conducted with children, reporting no significant differences in aerobic training response related to sex. Rowland and Boyajian (1995) observed no significant differences relative to sex in maximal oxygen uptake after an endurance training program (three 30-minute sessions of aerobic activity weekly for 12 weeks at an intensity-producing a mean heart rate of 166 beats per minute). Similarly, Obert et al. (2003) found that sex did

not affect training-induced cardiovascular response in prepubescent children (13-week endurance training program, 3 x 1h week⁻¹, intensity: > 80% heart rate maximum). Aerobic training increased VO_{2max} in children, no matter the sex, mediated by an improvement in maximum stroke volume Obert et al. (2003). Similar mechanisms, including loading conditions and cardiac morphology, appear to be involved in both boys and girls in order to explain such an improvement Obert et al. (2003). According to Vinet et al. (2003) during pre-adolescence there are no significant sex differences in maximal heart rate and arteriovenous oxygen, and although the stroke volume is significantly higher in boys than in girls, when expressed relative to lean body mass, the difference is no longer significant.

The observed similarity between boys and girls in training-induced strength is also consistent with findings of previous studies conducted with prepubescent children. After applying a 12-week progressive resistance program Lillegard et al. (1997) found significant main effects favoring strength gains in males, only in lat pull and leg extension (three sets of ten repetitions of 10RM on barbell curl, triceps extension, bench press, lat pull, leg extension and leg curl exercises, three 1-hour session per week). There were no significant post training sex differences in jumping and running speed. Siegel et al. (1989) also observed that following a similar training period, but using hand-held weights, stretch tubing, balls, and self-supported movements, training responses of boys and girls were similar, although they have been reported significant differences in favor of boys on all initial strength evaluation. Training-induced strength gains during and after puberty in males are associated with increases in fat-free mass, due to the effect of testosterone on muscle hypertrophy. In reverse, smaller amounts of testosterone in females (resulting from enzymatic conversion of androgenic precursors in the adrenal gland) seem to limit the magnitude of training-induced strength gains (Kraemer et al., 1989). However, during preadolescence, beyond the small muscle mass of the girls, the boys still present a reduced muscle mass, because the effects of circulating androgens, particularly testosterone, only manifest themselves at puberty (Ramsay et al., 1990).

Conclusions

In brief, our data suggest that a concurrent resistance and endurance school-based training program seems to be effective on both strength and endurance fitness feature of age-school children. The results also indicates that sex does not affect explosive strength improvement, either in the resistance training alone, or combined resistance and endurance training. In this sense, and assuming various school constraints (i.e. reduced practice time per session, number of weekly sessions or lack of material resources and facilities) in order to increase the physical education classes efficiency, combined training programs of resistance and endurance should be considered in school-based programs.

It can be considered as main limitations: (i) different training program design or different methods of organizing training workouts, can lead to different training-induced outcomes; (ii) different methods of evaluating pre- and post-training muscular strength and aerobic capacity may also lead to data bias.

Chapter 4. General Discussion

The main purpose of this investigation was to analyze the effect of somatotype, body fat and physical activity on overall physical fitness, explosive strength and aerobic capacity trainability in prepubescent children. Additionally, it was intended to verify in which physical capabilities boys and girls are closer/ distant, and the effects of concurrent training on explosive strength and aerobic adaptations. Results suggest that: (i) somatotype is a crucial factor on overall physical fitness, and training-induced explosive strength and VO_{2max} gains, in both boys and girls; (ii) physical fitness differences between boys and girls are greater in the explosive strength; (iii) concurrent training is an effective program that can be performed to improve strength in prepubescent children; and (iv) gender does not have a significant effect on training-induced explosive strength and VO_{2max} adaptations.

Physical Fitness has been recognized as a major marker of health status at any age (Ortega et al., 2007). This recognition has produced a wide range of studies on the influence of various factors on physical fitness levels, in particular the influence of body fat and physical activity. There is evidence that by pre-puberty there already exists a fairly stable somatotype, pointing to 8 years as the age by which somatotype stability becomes manifest (Malina et al., 2004), however there are few studies that link somatotype with fitness in young people. As such, we sought to examine the effect of the presence/ absence of certain physical traits on physical fitness and compare it with the effect of body fat and physical activity, often referenced in the literature (**Study 2 and Study 3**). Because most studies on physical fitness have focused specially on cardiorespiratory fitness, neglecting the muscular fitness (Cepero et al., 2011), we have placed great emphasis on strength development.

The significant and negative associations found between body fat and tasks that require propulsion or lifting of the body mass are consistent with results of previous studies conducted in school-aged children, that referred to similar relationships in tests of curl-ups, standing broad jump, push-ups and running (Dumith et al., 2010; Fogelholm et al. 2008). By contrast, the better performance of children with high body fat observed in the throw ball test and handgrip strength, also described in the literature (Castro-Piñero et al., 2009; D'Hondt et al., 2009), might be explained by their increased fat-free mass. Overweight and obese individuals appeared to have more body fat, but also more fat-free mass, than those with normal weight (Wells et al., 2006). Also the positive association found between physical activity and muscular strength corroborates the findings of several studies that report a positive association between this variable and overall physical fitness (Lennox et al., 2008; Tovar et al., 2008). However, different results were obtained by Dumith et al. (2010), who found no significant associations between body fat and ball throwing, and Hands et al. (2009),

between physical activity and performance in standing broad jump, curl-ups, hand dynamometry and ball throw. Regarding the somatotype, we observed that endomorphic has similar associations to those presented by body fat. Endomorphic expresses the degree of adiposity development (Malina and Bouchard, 1991), so the primary effect of this component in performance will differ depending on the type of task, being a limiting factor in propulsion and lifting body tasks, in which body fat plays a similar function. Mesomorphic reflects the robustness (Malina and Bouchard, 1991) and was only negatively correlated with tests related to the propulsion and lifting movements, in which the ectomorphic has the advantage (Jakšić & Cvetković, 2009; Suchomel, 2002), because of the negative effect of body weight in these tasks (Dumith et al. 2010; Xianwen et al., 2010). On this, the associations observed for ectomorphic, that reflects the relative linearity of build (Malina and Bouchard, 1991), were precisely the reverse of those found for endomorphic and mesomorphic. The greatest number of interactions of the somatotype with muscular strength and strength tests, as well as the greatest influence of the somatotype on overall physical fitness of both boys and girls (ectomorphic and mesomorphic in the boys and endomorphic in the girls), compared with body fat and physical activity, seem to suggest that one cannot neglect the influence of genetic determinism, observed from the morpho-constitutional point of view, by which the presence/absence of certain physical traits determines the appropriate levels of motor performance required.

Unfortunately, there are evidences suggesting that physical fitness has declined worldwide in the last decades among young people (Matton et al., 2007; Tomkinson, 2007). One of the reasons for the decreased levels of physical fitness and physical activity is that there is an apparent avoidance of children of the physical education classes and extracurricular activities (Roetert, 2004) due, in part, to lack of planning that takes into account the motivation and success of children in the execution of the exercises, respecting the differences between them, including gender differences (Haff, 2003). Thus the knowledge of the magnitude of the differences between boys and girls can help teachers, coaches and trainers in the planning of activities that take into account the success of both boys and girls, and thus, increase levels of physical activity and physical fitness (**Study 3**).

In terms of gender differences in motor performance, the results confirm those of other studies that report the superiority of boys in tests of aerobic fitness and muscular strength and of girls in tests of balance and flexibility (Cepero et al., 2011; Hands et al., 2009). Additionally, our findings indicate that the difference between boys and girls in physical fitness was greater in the explosive strength, although with a medium size effect of gender. In the opposite direction, gender differences were smaller in muscular endurance tests and flexibility, followed by speed and balance. The fat-free mass statistically higher in boys permits a better muscular strength (Lennox et al., 2008; Tovar et al., 2008). However, the absence of statistically significant differences between boys and girls in muscular endurance

tests, reported in the literature with children of similar age (Castro-Piñero et al., 2009), may be due to the fact that the weight of the boys, close to the weight of the girls in pre-pubertal stage (Malina & Bouchard, 2001), is an extra load to be moved during weight-bearing tasks, added to the fact that the boys still present a reduced muscle mass in pre-pubertal ages (Malina & Bouchard, 2001). Some approximation found in speed between boys and girls, may be due to the fact that speed is a specific capability, highly dependent on the influence of genetic factors such as neuromuscular components and muscle fiber quality (i.e., fiber type proportion). The high degree of gene transfer implied in this aptitude is today recognized (Little & Williams, 2005). Regarding the flexibility, there are many reports that girls have larger range of motion. Some of the factors presented are the difference of extensibility of muscle and tendon tissues, the greater passive dorsiflexion angle of girls, because boys have a higher muscle volume, and dynamic property of tendon tissues (Kato et al., 2005). However, in this capability, the difference by gender there occupies a place emphasized during periods of rapid growth. At this age the boys can be more flexible than the girls (Monyeki et al., 2005). Also in the balance boys and girls showed some proximity. These results may be due to the fact that in pre-pubertal period the difference in stature between boys and girls gradually decreases, due to the growth velocity of girls at this stage that is higher than for boys, reaching the peak height velocity (PHV) earlier (Malina & Bouchard, 2001). A greater stature leads to a high body's center of mass, in turn responsible for increased postural instability on balance exercises (Allard et al., 2001).

In children, because of low aerobic capacity is associated with risk factors of cardiovascular disease (Anderssen et al., 2007), a great amount of research has focused on activities that enhance cardiorespiratory fitness (Cepero et al., 2011). However, it is recognized that youth strength training approaches should be an important component of youth fitness programs and health promotion objectives (Faigenbaum et al., 2009). The knowledge of the influence of body fat and somatotype on training-induced strength and aerobic gains can help in designing and application of training programs for young people in order to improve its efficiency (**Study 4**).

The significant increasing observed for explosive strength and VO_{2max} indicates that the implementation of strength and aerobic training programs can be a positive stimulus to enhance these capacities in prepubescent children. These findings are consistent with the results of previous studies conducted with children and adolescents, in which were applied strength (Dorgo et al., 2009; Santos & Janeira, 2008) and aerobic training programs (Sandbakk et al., 2011; Santos et al., 2012). After applying training programs can be observed that the ectomorphic was positively associated with training-induced gains in vertical and horizontal jumps, running speed and VO_{2max} , these being the same capabilities with which body fat and endomorphic had a negative association. These results seem to show that the inert non-contributory load imposed by body fat, which represents an increased metabolic cost for

children makes them less efficient in the performing of the proposed training program, as well as in terms of cardiorespiratory response (Norman et al., 2005). Mesomorphic associated significantly and negatively with training-induced VO_{2max} gains, because the negative association of this component with propulsion tasks (Shukla et al., 2009), in which ectomorphic has the advantage (Chaouachi et al., 2005), as mentioned above. The absence of significant associations of the mesomorphic with strength gains may be justified because prepubescent children still present a reduced muscle mass, due to the effects of circulating androgens only manifest themselves at puberty (Malina & Bouchard, 1991). As such, during preadolescence, the neural adaptations are primarily responsible for training-induced strength gains (Ozmun et al., 1994; Ramsay et al., 1990). The high-sized effect of mesomorphic registered on the explosive strength gains, as well as the high-sized effect of ectomorphic on the VO_{2max} gains, in both boys and girls, highlights the importance of the morphological typology on training-induced strength and aerobics gains in prepubescent children.

On the other hand, due to various constraints, children and adolescents involved in physical education classes or extracurricular activities often perform concurrently strength and aerobic training (Santos et al, 2012), in an attempt to reach different physical fitness goals (Anderson & Haraldsdottir, 1995). However, the effects of concurrent strength and aerobic training in prepubescent children, according to our best knowledge, still needs to be investigated (**Study 5**).

Because strength and aerobic training elicit distinct and often divergent adaptive mechanisms, the concurrent development of both fitness components in the same training regimen can lead to conflicting neuromuscular adaptations (Coffey et al., 2007; Hawley, 2009), commonly referred to as the “interference phenomenon” (García-Pallarés and Izquierdo 2011). Our results, which are consistent with the results of previous studies in this area, but conducted with pubertal children (Santos et al., 2012), seems to suggest that aerobic training does not positively affect strength development in prepubescent boys and girls, but also does not seem to impair strength development. However, it is important to stress that a training program design different than in this particular study, e.g. exercise mode, volume, intensity and frequency of training (González-Badillo et al., 2005; García-Pallarés et al., 2009), can lead to different results, due to several factors that can influence the level or degree of interference generated by concurrent training (García-Pallarés and Izquierdo 2011).

Some main limitation of this thesis can be addressed:

- (i) The physical fitness comprises other components absent from this study, as for example motor coordination (Lämmle et al., 2010);
- (ii) It was only applied field tests. Laboratory tests with a higher control standard might presented more accurate data (Faigenbaum et al., 2009);
- (iii) A training program design different, or different methods of organizing training workouts, can lead to different results (García-Pallarés & Izquierdo 2011);
- (iv) There are other biological and behavior variables that might also determine physical fitness differences between boys and girls (e.g., different practice opportunities) (Branta et al., 1984; Thomas & French, 1985).

Chapter 5. Overall Conclusions

The main findings of this work emphasize the importance of the presence/absence of certain physical characteristics on overall physical fitness, explosive strength and aerobic capacity trainability, in prepubescent children. They also show that physical fitness differences between boys and girls are greater in the explosive strength, and that concurrent training can be performed to improve strength in this age group:

- i. in subjects undergoing pre pubescence, the somatotype has the greatest influence on the motor performance of both boys and girls, i.e., ectomorphic and mesomorphic in the boys and endomorphic in the girls;
- ii. mesomorphic has the high-sized effect on training-induced explosive strength gains, and ectomorphic on VO_{2max} gains, in both boys and girls. Endomorphic and body fat have the smaller size effect on training-induced explosive strength gains. Endomorphic and body fat in boys, and mesomorphic and body fat in girls, have the smaller size effect on the VO_{2max} gains;
- iii. physical fitness differences between boys and girls are greater in the explosive strength of upper and lower limbs, and smaller in the abdominal and upper limbs muscular endurance, and trunk extensor strength and flexibility, followed by speed and balance;
- iv. concurrent training is an effective, well-rounded exercise program that can be performed to improve initial or general strength in healthy prepubescent boys and girls;
- v. gender does not have a significant effect on training-induced explosive strength and VO_{2max} adaptations in this age group.

Chapter 6. Suggestions for future research

Some suggestions are highlighted in order to encourage future research:

- i. Replicate the study with pubertal children (given that during adolescence the boys tend to show a slight increase of the mesomorphic values, and the girls show an increase of the endomorphic and a slight reduction of the ectomorphic values);
- ii. Use other physical fitness components (health-related physical fitness and/or skill-related fitness);
- iii. Check the effect of the implementation of a concurrent training program on the cardiorespiratory fitness (we only analyzed the effect on the explosive strength);
- iv. Perform aerobic training before strength training or the scheduling of both types of training on alternate days (we performed strength training before aerobic training, in the same workout).

Chapter 7. References

Chapter 1

- American Academy of Pediatrics: Council on Sports Medicine and Fitness. Strength training by children and adolescents. *Pediatrics* 2008; 121: 835-840.
- American College of Sports Medicine. *Guidelines for Exercise Testing and Prescription* (7th ed.). Philadelphia, PA: Lippincott, Williams & Wilkins, 2007.
- Anderssen SA, Cooper AR, Riddoch C, Sardinha LB, Harro M, Brage S, Andersen LB. Low cardiorespiratory fitness is a strong predictor for clustering of cardiovascular disease risk factors in children independent of country, age and sex. *Eur J Cardiovasc Prev Rehabil* 2007; 14: 526-531.
- Armstrong N, Welsman J. *Young people and physical activity*. Oxford: Oxford University Press, 1997.
- Behringer M, Vom Heede A, Matthews M, Mester J. Effects of Strength Training on Motor Performance Skills in Children and Adolescents: A Meta-Analysis. *Pediatr Exerc Sci* 2011; 23: 186-206.
- Cepero M, López R, Suárez-Llorca C, Andreucabrera E, Rojas F. Fitness test profiles in children aged 8-12 years old in Granada (Spain). *J Hum Sport Exerc* 2011; 6: 135-146.
- Dumith S, Ramires V, Souza M, Moraes D, Petry F, Oliveira E, Ramires S, Hallal P. Overweight/Obesity and Physical Fitness Among Children and Adolescents. *J Phys Act Health* 2010; 7: 641-648.
- Faigenbaum AD, Kraemer WJ, Blimkie CJR, Jeffreys I, Micheli LJ, Nitka M, Rowland, TW. Youth resistance training: Updated position statement paper from the National Strength and Conditioning Association. *J Strength Cond Res* 2009; 23: S60-S79.
- García-Pallarés J, Izquierdo M. Strategies to Optimize Concurrent Training of Strength and Aerobic Fitness for Rowing and Canoeing. *Sports Med* 2011; 41: 329-343.
- Haff, GG. Roundtable discussion: Youth resistance training. *Strength Cond J* 2003; 25: 49-64.
- Hands B, Larkin D, Parker H, Straker L, Perry M. The relationship among physical activity, motor competence and health-related fitness in 14-year-old adolescents. *Scand J Med Sci Sports* 2009; 19: 655-663.

References

- Izquierdo-Gabarren M, Exposito R, Garcia-Pallarés J, Sánchez-Medina L, De Villareal ES, Izquierdo M. Concurrent endurance and strength training not to failure optimizes performance gains. *Med Sci Sports Exerc* 2010; 42: 1191-1199
- Jakšić D, Cvetković M. Neural network analysis of somatotype differences among males related to the manifestation of motor abilities. *Acta Kinesiologica* 2009; 3: 107-113.
- Kvaavik E, Klepp KI, Tell GS, Meyer HE, Batty GD. Physical fitness and physical activity at age 13 years as predictors of cardiovascular disease risk factors at ages 15, 25, 33, and 40 years: extended follow-up of the Oslo Youth Study. *Pediatrics* 2009; 123: e80-e86.
- Lyu M, Gill D. Perceived physical competence, enjoyment and effort in same-sex and coeducational physical education classes. *J Educ Psychol* 2011; 31: 247-260.
- Malina R, Bouchard C. *Growth maturation and physical activity*. Champaign, Illinois: Human Kinetics, 1991.
- Malina R, Bouchard C, Bar-Or O. *Growth, maturation and physical activity*. Champaign, Illinois: Human Kinetics, 2004.
- Matton L, Duvigneeaud N, Wijndaele K, Philippaerts R, Duquet W, Beunen G, Claessens A, Thomis M, Lefevre J. Secular trends in anthropometric characteristics, physical fitness, physical activity and biological maturation in flemish adolescents between 1969 and 2005. *Am J Hum Biol* 2007; 19: 326-624.
- NIH Consensus Development Panel on Physical Activity and Cardiovascular Health. Physical activity and cardiovascular health. *J Am Med Assoc* 1996; 276: 241-246.
- Norman A, Drinkard B, McDuffie J, Ghorbani S, Yanoff L, Yanovski J. Influence of excess adiposity on exercise fitness and performance in overweight children and adolescents. *Pediatrics* 2005; 115: 690-696.
- Ortega B, Tresaco B, Ruiz J, Moreno L, Matillas M, Mesa J, Warnberg J, Bueno M, Tercedor P, Gutiérrez A, Castillo M. Cardiorespiratory fitness and sedentary activities are associated with adiposity in adolescents. *Obesity* 2007; 15: 1589-1599.
- Reis VM, Machado JV, Fortes MS, Fernandes PR, Silva AJ, Dantas PS, Filho JF. Evidence for higher heritability of somatotype compared to body mass index in female twins. *J Physiol Anthropol* 2007; 26: 9-14.
- Roetert, EP. The lack of childhood activity in the United States. *Strength Cond J* 2004; 26: 22-23.

- Santos A, Marinho DA, Costa AM, Izquierdo M, Marques MC. The effects of concurrent resistance and endurance training follow a detraining period in elementary school students. *J Strength Cond Res* 2012; 26: 1708-1716
- Shaw BS, Shaw I, Brown GA. Comparison of resistance and concurrent resistance and endurance training regimes in the development of strength. *J Strength Cond Res* 2009; 23: 2507-2514.
- Stratton G, Canoy D, Boddy LM, Taylor SR, Hackett AF, Buchan IE. Cardiorespiratory fitness and body mass index of 9-11-year-old English children: A serial cross-sectional study from 1998 to 2004. *Int J Obes (Lond)* 2008; 32: 1-11.
- Taanila H, Hemminki A, Suni J, Pihlajamäki H, Parkkari J. Low physical fitness is a strong predictor of health problems among young men: a follow-up study of 1411 male conscripts. *BMC Public Health* 2011; 11: 590.
- Tomkinson GR, Olds TS, Kang SJ, Kim DY. Secular trends in the aerobic fitness test performance and body mass index of Korean children and adolescents (1968-2000). *Int J Sports Med* 2007; 28: 314-320.
- Twist J, Kemper H, Van Mechelen W. Tracking of activity and fitness and the relationship with cardiovascular disease risk factors. *Med Sci Sports Exerc* 2000; 32: 1455-1461.

Chapter 2

Study 1

- Aires L, Silva P, Silva G, Santos M, Ribeiro J, Mota J. Intensity of Physical Activity, Cardiorespiratory Fitness, and Body Mass Index in Youth. *J Phys Activ Health* 2010; 7: 54-59.
- Andersen LB, Harro M, Sardinha L, Froberg K, Ekelund U, Brage S, Anderssen S. Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study). *Lancet* 2006; 368: 299-304.
- Anderssen SA, Cooper AR, Riddoch C, Sardinha LB, Harro M, Brage S, Andersen LB. Low cardiorespiratory fitness is a strong predictor for clustering of cardiovascular disease risk factors in children independent of country, age and sex. *Eur J Cardiovasc Prev Rehabil* 2007; 14: 526-531.
- Ara I, Moreno L, Leiva M, Gutin B, Casajús J. Adiposity, physical activity and physical fitness among children from Aragón, Spain. *Obesity* 2007; 15: 1918-1924.

References

- Armstrong N, Welsman J. *Young people and physical activity*. Oxford: Oxford University Press, 1997.
- Astrand PO, Rodahl K, Dahl H, Stromme S. *Textbook of work physiology*. New York: McGraw-Hill, 2003.
- Ball G, Marshall J, McCargar L. Fatness and fitness in obese children at low and high health risk. *Pediatr Exerc Sci* 2003; 15: 392-405.
- Baquet G, Berthoin S, Dupont G, Blondel N, Fabre C, Van Praagh E. Effects of high intensity intermittent training on peak VO₂ in prepubertal children. *Int J Sports Med* 2002; 23: 439-444.
- Barnett LM, Van Beurden E, Morgan PJ, Brooks LO, Beard JR. Does children motor skill proficiency predict adolescent fitness? *Med Sci Sport Exerc* 2008; 40: 2137-44.
- Behringer M, Vom Heede A, Matthews M, Mester J. Effects of Strength Training on Motor Performance Skills in Children and Adolescents: A Meta-Analysis. *Pediatr Exerc Sci* 2011; 23: 186-206.
- Benson A, Torade M, Singh, MA. Muscular strength and cardiorespiratory fitness is associated with higher insulin sensitivity in children and adolescents. *Int J Pediatr Obes* 2006; 1: 222-231.
- Carmo I, Santos O, Camolas J, Vieira J, Carreira M, Medina L, Reis L, Myatt J, Galvão-Teles A. National prevalence of obesity. Overweight and obesity in Portugal: Nacional prevalence in 2003-2005. *Obes Rev* 2007; 9: 11-19.
- Carter JL. *The heath-carter anthropometric somatotype. Instruction manual*. San Diego, USA: Department of Exercise and Nutritional Sciences, San Diego State University, 2002
- Casajús J, Leivia M, Villarroya A, Legaz A, Moreno, L. Physical performance and school physical education in overweight Spanish children. *Ann Nutr Metab* 2007; 51: 288-296.
- Castelli DM, Valley JA. The relationship of physical fitness and motor competence to physical activity. *J Teach Phys Educ* 2007; 26: 358-374.
- Castro-Piñero J, González-Montesinos J, Mora J, Keating X, Girela-Rejón M, Sjöström, M, Ruiz J. Percentile values for muscular strength field tests in children aged 6 to 17 years: influence of weight status. *J Strength Cond Res* 2009; 23: 2295-2310.
- Cepero M, López R, Suárez-Llorca C, Andreucabrera E, Rojas F. Fitness test profiles in children aged 8-12 years old in Granada (Spain). *J Hum Sport Exerc* 2011; 6: 135-146.
- Coffey VG, Hawley JA. The molecular bases of training adaptation. *Sports Med* 2007; 37: 737-763.

- Coleman KJ, Heath EM, Alcala IS. Overweight and aerobic fitness in children in the United States/Mexico border region. *Rev Panam Salud Públ / Pan Am J Public Health* 2004; 15: 262-271.
- Costa R, Guerra S, Ribeiro J, Leandro C, Duarte J, Mota, J. Aptidão cardiorespiratória de uma população pediátrica da zona do grande Porto. *Rev Port Med Desp* 2000; 18: 27-40.
- Daniels S. The consequences of childhood overweight and obesity. *Future Child* 2006; 16(1): 47-67.
- Dahab KS, McCambridge TM. Strength Training in Children and Adolescents: Raising the Bar for Young Athletes? *Sports Health* 2009; 1: 223-226.
- Deforche B, Lefevre J, De Bourdeaudhuij I, Hills A, Duquet W, Bouckaert J. Physical fitness and physical activity in obese and nonobese Flemish youth. *Obes Res* 2003; 11: 434-441.
- Dencker M, Bugge A, Hermansen B, Andersen L. Objectively measured daily physical activity related to aerobic fitness in young children. *J Sports Sci* 2010; 28: 139-145.
- Dencker M, Thorsson O, Karlsson M, Lindén C, Svensson J, Wollmer P. Daily physical activity and its relation to aerobic fitness in children aged 8-11 years. *Eur J Appl Physiol* 2006; 96: 587-592.
- Dencker M, Thorsson O, Karlsson M, Lindén C, Wollmer P, Andersen L. Daily physical activity related to aerobic fitness and body fat in an urban sample of children. *Scand J Med Sci Spor* 2008; 18: 728-735.
- Denney-Wilson E, Baur L. Clinical correlates of overweight and obesity. In A Hills, N King & N Byrne (Eds), *Children, obesity and exercise: Prevention, treatment and management of childhood and adolescent obesity*. Washington, USA: Routledge, 2007: 25-36.
- D`Hont E, Deforche B, Bourdeaudhuij I, Lenoir M. Relationship between motor skill and Body Mass Index in 5-to 10-year-old children. *Adapt Phys Act Q* 2009; 26: 21-37.
- Do Carmo I, Santos O, Camolas J, Vieira J, Carreira M, Medina L, Reis L, Galvão-Teles A. Prevalence of obesity in Portugal. *Obes Rev* 2006; 7: 233-237.
- Dudley GA, Djamil R. Incompatibility of endurance and strength training modes of exercise. *J Appl Physiol* 1985; 59: 1446-1451.
- Dumith S, Ramires V, Souza M, Moraes D, Petry F, Oliveira E, Ramires S, Hallal P. Overweight/Obesity and Physical Fitness Among Children and Adolescents. *J Phys Act Health* 2010; 7: 641-648.

References

- Faigenbaum AD. The effects of twice per week strength training in children. *Pediatr Exerc Sci* 1993; 5: 339-346.
- Faigenbaum AD, Kraemer WJ, Blimkie CJR, Jeffreys I, Micheli LJ, Nitka M, Rowland, TW. Youth resistance training: Updated position statement paper from the National Strength and Conditioning Association. *J Strength Cond Res* 2009; 23(Supplement 5): S60-S79.
- Faigenbaum A, Milliken L, LaRosa Loud R, Burak B, Doherty C, Westcott W. Comparison of 1 day and 2 days per week of strength training in children. *Res Q Exerc Sport* 2002; 73: 416-424.
- Faigenbaum A, Milliken L, Moulton L, Westcott W. Early muscular fitness adaptations in children in response to two different resistance training regimens. *Pediatr Exerc Sci* 2005; 17: 237-248.
- García-Pallarés J, Izquierdo M. Strategies to Optimize Concurrent Training of Strength and Aerobic Fitness for Rowing and Canoeing. *Sports Med* 2011; 41: 329-343.
- García-Pallarés J, Sánchez-Medina L, Carrasco L, Diaz A, Izquierdo M. Endurance and neuromuscular changes in world-class level kayakers during a periodized training cycle. *Eur J Appl Physiol* 2009; 106: 629-638.
- Gaya A, Alves A, Aires L, Martins C, Ribeiro J, Mota J. Association between time spent in sedentary, moderate to vigorous physical activity, body mass index, cardiorespiratory fitness and blood pressure. *Ann Hum Biol* 2009; 36: 379-387.
- González-Badillo JJ, Gorostiaga EM, Arellano R, Izquierdo M. Moderate resistance training volume produces more favorable strength gains than high or low volumes. *J Strength Cond Res* 2005; 19: 689-97.
- Graf C, Koch B, Kreetschmann-Kandel E, Falkowski G, Christ H, Coburguer S, Lenhmacher W, Bjarnason-Weherens B, Platen P, Tokarski W, Predel H, Dordel, S. Correlation between BMI, leisure habits and motor abilities in childhood (CHILT-Project). *Int J Obes* 2004; 28: 22-26.
- Haff, GG. Roundtable discussion: Youth resistance training. *Strength Cond J* 2003; 25: 49-64.
- Hands B, Larkin D, Parker H, Straker L, Perry M. The relationship among physical activity, motor competence and health- related fitness in 14-year-old adolescents. *Scand J Med Sci Sports* 2009; 19: 655-663.
- Hickson RC. Interference of strength development by simultaneously training for strength and endurance. *Eur J Appl Physiol Occup Physiol* 1980; 45: 255-263.

- Hind K, Burrows M. Weight-bearing exercise and bone mineral accrual in children and adolescents: a review of controlled trials. *Bone* 2007; 40: 14-27.
- Huang Y, Malina R. (2007). BMI and health-related physical fitness in Taiwanese youth 9-18 years. *Med Sci Sports Exerc* 2007; 39: 701-708.
- Ignjatović A, Stanković R, Radovanović D, Zivorad MZ, Cvecka J. Resistance training for youths. *Facta Universitatis* 2009; 1: 189-196.
- Jakšić D, Cvetković M. Neural network analysis of somatotype differences among males related to the manifestation of motor abilities. *Acta Kinesiologica* 2009; 3, 107-113.
- Janssen I, Katzmarzyk PT, Boyce WF, Vereecken C, Mulvihill C, Roberts C, Currie C, Pickett W. Comparison of overweight and obesity prevalence in school-aged youth from 34 countries and their relationships with physical activity and dietary patterns. *Obes Rev* 2005; 6: 123-132.
- Joshi P, Bryan C, Howat H. Relationship of body mass index and fitness levels among schoolchildren. *J Strength Cond Res* 2012; 26: 1006-1014.
- Katch V. Physical conditioning of children. *J Adolesc Health Care* 1983; 3: 241-246.
- Katzmarzyk P, Janssen I, Ardern, C. Physical activity, excess adiposity and premature mortality. *Obesity Review* 2003; 4: 257-290.
- Kraemer WJ, Fleck SJ. *Strength training for young athletes* (2nd Ed.). Champaign, Ill: Human Kinetics, 2005.
- Kraemer WJ, Ratamess NA. Fundamentals of resistance training: progression and exercise prescription. *Med Sci Sports Exerc* 2004; 36: 674-88.
- Kriska A. Ethnic and cultural issues in assessing physical activity. *Res Q Exerc Sport* 2000; 71: 47-53.
- Lillegard W, Brown E, Wilson D, Henderson R, Lewis E. Efficacy of strength training in prepubescent to early postpubescent males and females: Effects of gender and maturity. *Pediatr Rehabil* 1997; 1: 147-157.
- Lobstein T, Baur L, Uauy R. Obesity in children and young people: a crisis in public health. *Obes rev* 2004; 5: 4-85.
- Lugueti C, Ré A, Böhme M. Indicators of physical fitness in school children from the midwest region of São Paulo City. *Rev Bras Cineantropom Desempenho Hum* 2010; 12: 331-337.

References

- Mahieu N, Witvrouw E, Van de Voorde D, Michildsens D, Arbyn V, Vvan den Broecke W. Improving strength and postural control in young skiers: Whole-body vibration versus equivalent resistance training. *J Athl Training* 2006; 41: 286-293.
- Maia J, Silva, Freitas D, Beunen G, Lefevre J, Claessens A, Marques A, Thomis M. Modeling stability in the somatotype of children and youngsters from 10 to 16 years of the Madeira growth study (Portugal). *Rev Bras Cineantropom Desempenho Hum* 2004; 6: 36-45.
- Malina R. Physical activity and fitness : pathways from childhood to adulthood. *Am J Hum Biol* 2001; 13: 162-172.
- Malina R, Bouchard C. *Growth maturation and physical activity*. Champaign, Illinois: Human Kinetics, 1991.
- Malina R, Bouchard C, Bar-Or O. *Growth, maturation and physical activity*. Champaign, Illinois: Human Kinetics, 2004.
- Marques-Vidal P, Dias C. *Trends in overweight and obesity in Portugal: The National Health Surveys 1995-6 and 1998-9*. *Obes Res* 2005; 13: 1141-1145.
- Marshall SJ, Biddle SH, Sallis JF, Mckenzie TL, Conway TL. Clustering of sedentary behaviors and physical activity among youth : a cross-national study. *Pediatr Exerc Sci* 2002; 14: 401-417.
- Matos N, Winsley RJ. Trainability of young athletes and overtraining. *J Sports Sci Med* 2007; 6: 353-367.
- Matton L, Duvigneeaud N, Wijndaele K, Philippaerts R, Duquet W, Beunen G, Claessens A, Thomis M, Lefevre J. Secular trends in anthropometric characteristics, physical fitness, physical activity and biological maturation in flemish adolescents between 1969 and 2005. *Am J Hum Biol* 2007; 19: 326-624.
- McManus A, Armstrong N, Williams C. Effect of training on the aerobic power and anaerobic performance of prepubertal girls. *Acta Paediatr* 1997; 86: 456-459.
- Mota J, Flores L, Flores L, Ribeiro J, Santos M. Relationship of single measures of cardiorespiratory fitness and obesity in young schoolchildren. *Am J of Hum Biol* 2006; 18: 335-341.
- National Association for Sport and Physical Education. *Physical activity for children: A statement of guidelines for children ages 5-12*. Reston, VA: National Association for Sport and Physical Education Publications, 2004.

- NIH Consensus Development Panel on Physical Activity and Cardiovascular Health. Physical activity and cardiovascular health. *J Am Med Assoc* 1996; 276: 241-246.
- Obert P, Mandigouts S, Nottin S, Vinet A, N'Guyen LD, Lecoq AM. Cardiovascular responses to endurance training in children: effect of gender. *Eur J Clin Invest* 2003; 33: 199-208.
- O`Donovan G, Blazeovich A, Boreham C, Cooper A, Crank H, Ekelund U, Fox K, Gately P, Giles-Corti B, Gill J, Hamer M, McDermott I, Murphy M, Mutrie N, Reilly J, Saxton J, Stamatakis E. The ABC of Physical Activity for Health: A consensus statement from the British Association of Sport and Exercise Sciences. *Journal of Sports Sciences* 2010; 28: 573-591.
- Ortega B, Tresaco B, Ruiz J, Moreno L, Matillas M, Mesa J, Warnberg J, Bueno M, Tercedor P, Gutiérrez A, Castillo M. Cardiorespiratory fitness and sedentary activities are associated with adiposity in adolescents. *Obesity* 2007; 15: 1589-1599.
- Ozmun J, Mikesky A, Surburg P. Neuromuscular adaptations following prepubescent strength training. *Med Sci Sports Exerc* 1994; 26: 510-514.
- Pate R, Freedson P, Sallis J, Taylor WC, Sirard J, Trost SG, Dowda M. Compliance with physical activity guidelines: prevalence in a population of children and youth. *Ann Epidemiol* 2002; 12: 303-308.
- Payne V, Morrow J, Johnson L, Dalton S. Resistance training in children and youth: Meta-analysis. *Res Q Exerc Sport* 1997; 68: 80-88.
- Pertroski, E. Diagnóstico de obesidade infantil. In A Silva, J Neto, M Monteiro & V Reis (Eds), *Medidas e Avaliação*. Montes Claros: Editora CGB Artes Gráficas, 2007: 53-75.
- Prentice A, Schoenmakers I, Laskey MA, de Bono, S, Ginty F, Goldberg GR. Nutrition and bone growth and development. *Proc Nutr Soc* 2006 65: 348-360.
- Ramsay J, Blimkie C, Smith K, Garner S, MacDougall J, Sale D. Strength training effects in prepubescent boys. *Med Sci Sports Exerc* 1990; 22: 605-614.
- Reis VM, Machado JV, Fortes MS, Fernandes PR, Silva AJ, Dantas PS, Filho JF. Evidence for higher heritability of somatotype compared to body mass index in female twins. *J Physiol Anthropol* 2007; 26: 9-14.
- Roetert, EP. The lack of childhood activity in the United States. *Strength Cond J* 2004; 26: 22-23.
- Rowland TW. *Children's Exercise Physiology*. Champaign, IL: Human Kinetics, 2005.
- Rowland TW, Boyajian A. Aerobic Response to Endurance Exercise Training in Children. *Pediatrics* 1995; 96: 654-658.

References

- Ruiz JR., Rizzo NS, Hurtig-Wennlof A, Ortega FB, Warnberg J, Sjostrom M. Relations of total physical activity and intensity to fitness and fatness in children: The European Youth Heart Study. *Am J Clin Nutr* 2006; 84, 299-303.
- Sallis J, Rosemberg D, Kerr J. Early physical activity, sedentary behavior and dietary patterns. In L Heinberg & J Thompson, J. (Eds), *Obesity in Youth: Causes, consequences and cures*. American Psychological Association, 2009: 37-53.
- Sallis J, Prochaska J, Taylor W. A review of correlates of physical activity of children and adolescents. *Med Sci Sports Exerc* 2000; 32: 963-975.
- Santos A, Marinho DA, Costa AM, Izquierdo M, Marques MC. The Effects of concurrent resistance and endurance training follow a specific detraining cycle in young school girls. *J Hum Kinet* 2011; Special Issue: 93-103.
- Santos A, Marinho DA, Costa AM, Izquierdo M, Marques MC. The effects of concurrent resistance and endurance training follow a detraining period in elementary school students. *J Strength Cond Res* 2012; 26: 1708-1716
- Sarzynski M, Eisenmann J, Welk G, Tucker J, Glenn K, Rothschild M, Heelan K. ACE I/D genotype, habitual physical activity, and blood pressure in children. *Pediatr Exerc Sci* 2010; 22: 301-313.
- Shabi G, Cruz M, Ball G, Weigensberg M, Salem G, Crespo N, Goran M. Effects of resistance training on insulin sensitivity in overweight Latino adolescent males. *Med Sci Sports Exerc* 2006; 38: 1208-1215.
- Shaw BS, Shaw I, Brown GA. Comparison of resistance and concurrent resistance and endurance training regimes in the development of strength. *J Strength Cond Res* 2009; 23: 2507-2514.
- Shukla M, Venugopal R, Mitra M. A cross sectional study of body composition somatotype and motor quality of rural and urban boys of Chhattisgarh. *Int J Fitness* 2009; 5: 1-7.
- Stephen R. The consequences of childhood overweigh and obesity. *Future Child* 2006; 16: 47-67.
- Suchomel A. Relation between anthropometric somatotype and motor performance in prepubescent and pubescent Czech. *Anthropologie* 2002; 40: 193-201.
- Sveinsson T, Arngrimsson S, Johannsson E. Association between aerobic fitness, body composition, and physical activity in 9- and 15-year-olds. *Eur J Sport Sci* 2009; 9: 141-150.

- Taanila H, Hemminki A, Suni J, Pihlajamäki H, Parkkari J. Low physical fitness is a strong predictor of health problems among young men: a follow-up study of 1411 male conscripts. *BMC Public Health* 2011; 11: 590.
- Tolfrey K. Responses to training. In: N Armstrong (Eds), *Pediatric exercise science: Advances in sport and exercise science series*. Edinburgh: Churchill Livingstone Elsevier, 2007: 213-234.
- Tomkinson GR, Olds TS. Secular changes in pediatric aerobic fitness test performance: The global picture. *Med Sport Sci* 2007; 50: 46-66.
- Tovar G, Poveda J, Pinilla M, Lobelo F. Relationship between overweight, physical activity and physical fitness in school-aged boys in Bogotá Colombia. *Arch Latinoam Nutr* 2008; 58: 265-273.
- Tsolakis C, Vagenas G, Dessypris A. Strength adaptations and hormonal responses to resistance training and detraining in preadolescent males. *J Strength Cond Res* 2004; 18: 625-629.
- Tudor-Locke C, Ainsworth BE, Popkin BM. Active commuting to school: an overlooked source of children's physical activity. *Sports Med* 2001; 31: 309-313.
- Twist J, Kemper H, Van Mechelen W. Tracking of activity and fitness and the relationship with cardiovascular disease risk factors. *Med Sci Sports Exerc* 2000; 32: 1455-1461.
- US Department of Health and Human Services. *Physical Activity and Health: A Report of the Surgeon General*. Atlanta, GA: US Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, 1996.
- Vamvakoudis E, Vrabas IS, Galazoulas C, Stefanidis P, Metaxas TI, Mandroukas K. Effects of basketball training on maximal oxygen uptake, muscle strength, and joint mobility in young basketball players. *J Strength Cond Res* 2007; 21: 930-936.
- Van Dusen DP, Kelder SH, Kohl HW, Ranjit N, Perry CL. Associations of Physical Fitness and Academic Performance Among Schoolchildren. *J Sch Health* 2011; 81:733-740.
- Wang Y, Lobstein T. Worldwide trends in childhood overweight and obesity. *Int J Pediatr Obes* 2006; 1: 11-25.
- Weineck J. *Atividade física e esporte: Para quê?* Barueri, Brasil: Ed. Manole, 2003.
- World Health Organization European Office. *The challenge of obesity in the WHO European Region and strategies for response*. WHO, 2007.

References

World Health Organization (WHO). *Global Recommendations on Physical Activity for Health*. Geneva: WHO, 2010.

Wrotniak B, Epstein L, Dorn J, Jones K, Kondilis V. The relationship between motor proficiency and physical activity in children. *Pediatrics* 2006; 118: 1758-1765.

Xianwen S, Ailing L, Yanping L, Xiaoqi H, Lin D, Jun M, Guifa X, Ying L, Hongwei G, Guansheng M. The association of weight status with physical fitness among Chinese children. *Int J Pediatr* 2010; 1-6. doi:10.1155/2012/943653

Yu C, Sung R, Hau K, Lam P, Nelson E, So R. The effect of diet and strength training on obese children's physical self concept. *J Sports Med Phys Fitness* 2008; 48: 76-82.

Chapter 3

Study 2

Andersen L, Hasseltrom H, Gronfeldt V, Hansen S, Karsten K. The relationship between physical fitness and clustered risk, and tracking of clustered risk from adolescence to young adulthood: Eight years follow-up in the Danish Youth and Sport Study. *Int J Behav Nutr Phys Act* 2004; 1: 6.

Artero E, España-Romero V, Ortega F, Jiménez-Pavón D, Ruiz J, Vicente-Rodríguez G, Bueno M, Marcos A, Gómez-Martínez S, Urzanqui A, González-Gross M, Moreno L, Gutiérrez A, Castillo M. Healthrelated fitness in adolescents: underweight, and not only overweight, as an influencing factor. The AVENA study. *Scand J Med Sci Spor* 2010; 20: 418-427.

Baecke J, Burema J, Frijters J. A short questionnaire for the measurement of habitual physical activity in epidemiological studies. *Am J Clin Nutr* 1982; 36: 936-942.

Casajús J, Leivia M, Villarroya A, Legaz A, Moreno L. Physical performance and school physical education in overweight Spanish children. *Ann Nutr Metab* 2007; 51: 288-296.

Castelli D, Valley J. The relationship of physical fitness and motor competence to physical activity: Chapter 3. *J Teach Phys Educ* 2007; 26: 358-374.

Castro-Piñero J, González-Montesinos J, Mora J, Keating X, Girela-Rejón M, Sjöström M, Ruiz J. Percentile values for muscular strength field tests in children aged 6 to 17 years: influence of weight status. *J Strength Cond Res* 2009; 23: 2295-2310.

Cepero M, López R, Suárez-Llorca C, Andreucabrera E, Rojas F. Fitness test profiles in children aged 8-12 years old in Granada (Spain). *J Hum Sport Exerc* 2011; 6: 135-146.

- Cole T, Bellizzi M, Flegal K, Dietz W. Establishing a standard definition for child overweight and obesity worldwide: International survey. *Brit Med J* 2000; 320: 1240-1243.
- Deforche B, Lefevre J, De Bourdeaudhui I, Hills A, Duquet W, Bouckaert J. Physical fitness and physical activity in obese and nonobese Flemish youth. *Obes Res* 2003; 11: 434-441.
- D`Hont E, Deforche B, Bourdeaudhuij I, Lenoir M. Relationship between motor skill and Body Mass Index in 5-to 10-year-old children. *Adapt Phys Act Q* 2009; 26: 21-37.
- Dumith S, Ramires V, Souza M, Moraes D, Petry F, Oliveira E, Ramires S, Hallal P. Overweight/Obesity and physical fitness among children and adolescents. *J Phys Act Health* 2010; 7: 641-648.
- Fogelholm M, Stigman S, Huisman T, Metsämuuronen J. Physical fitness in adolescents with normal weight and overweight. *Scand J Med Sci Sport* 2008; 18: 162-170.
- Heath H, Carter L. Growth and somatotype patterns of Manus children, Territory of Papua and New Guinea: Application of a modified somatotype method to the study of growth patterns. *Am J Phys Anthropol* 1971; 35: 49-67.
- Hands B, Larkin D, Parker H, Straker L, Perry M. The relationship among physical activity, motor competence and health-related fitness in 14-year-old adolescents. *Scand J Med Sci Sport* 2009; 19: 655-663.
- Jakšić D, Cvetković M. Neural network analysis of somatotype differences among males related to the manifestation of motor abilities. *Acta Kinesiologica* 2009; 3: 107-113.
- Lennox A, Pienaar A, Wilders C. Physical fitness and the physical activity status of 15-year-old adolescents in a semi-urban community. *S Afr J Res Sport Phys Educ Recreation* 2008; 30: 59-73.
- Loko J, Aule R, Sikkut T, Erelina J, Viru A. Age differences in growth and physical abilities in trained and untrained girls 10-17 years of age. *Am J Hum Biol* 2003; 15: 72-77.
- Malina R, Bouchard C. *Growth maturation and physical activity*. Champaign, Illinois: Human Kinetics, 1991.
- Malina R, Bouchard C, Bar-Or O. *Growth, maturation and physical activity*. Champaign, Illinois: Human Kinetics, 2004.
- Martínez-Gómez D, Welk G, Puertollano M, del-Campo J, Moya J, Marcos A, Veiga O. Associations of physical activity with muscular fitness in adolescents. *Scand J Med Sci Sport* 2011; 21: 310-318.

References

- Reis VM, Machado JV, Fortes MS, Fernandes PR, Silva AJ, Dantas PS, Filho JF. Evidence for higher heritability of somatotype compared to body mass index in female twins. *J Physiol Anthropol* 2007; 26: 9-14.
- Sharkey, BJ. *Fitness & Health*. Hong Kong: Human Kinetics, 2002.
- Shukla M, Venugopal R, Mitra M. A cross sectional study of body composition somatotype and motor quality of rural and urban boys of Chhattisgarh. *Int J Fitness* 2009; 5: 1-7.
- Slaughter M, Lohman T, Boileau R, Horswill C, Stillman R, VanLoan M, Bemben D. Skinfold equations for estimation of body fatness in children and youth. *Hum Biol* 1988; 60: 709-723.
- Stodden D, Goodway J, Langendorfer S, Robertson M, Rudisill M, et al. A developmental perspective on the role of motor skill competence in physical activity: An emergent relationship. *Quest* 2008; 60: 290-306.
- Suchomel A. Relation between anthropometric somatotype and motor performance in prepubescent and pubescent Czech. *Anthropologie* 2002; 40: 193-201.
- Tanner JM. *Growth at adolescence*. Oxford: Blackwell Scientific Publications, 1962.
- Tovar G, Poveda J, Pinilla M, Lobelo F. Relationship between overweight, physical activity and physical fitness in school-aged boys in Bogotá Colombia. *Arch Latinoam Nutr* 2008; 58(3): 265-273.
- Wrotniak B, Epstein L, Dorn J, Jones K, Kondilis V. The relationship between motor proficiency and physical activity in children. *Pediatrics* 2006; 118: 1758-1765.
- Xianwen S, Ailing L, Yanping L, Xiaoqi H, Lin D, Jun M, Guifa X, Ying L, Hongwei G, Guansheng, M. The association of weight status with physical fitness among Chinese children. *Int J Pediatr* 2010; 1-6. doi:10.1155/2012/943653
- Zak S, Szopa J. Effects of diversified motor activity on the level of motor fitness in children and Youth from Cracow (Poland). *J Hum Kinetic* 2001; 6: 47-58.

Study 3

- Adam C, Klissouras V, Ravassolo M, Renson R, Tuxworth W, Kemper H, Van Mechelen W, Hlobil H, Beunen G, Levarlet-Joye H, Van Lierde A. *Eurofit: Handbook for the Eurofit Test of Physical Fitness*. Rome: Council of Europe. Committee for the Development of Sport, 1988.

- Allard P, Nault M, Hinse S, Leblawc R, Labelle H. Relationship between morphologic somatotypes and standing posture equilibrium. *Ann Hum Biol* 2001; 28: 624-633.
- American Alliance for Health, Physical Education, Recreation and Dance. *Youth fitness test manual*. Washington: AAHPERD, 1976.
- Artero EG, España-Romero V, Ortega FB, Jiménez-Pavón D, Ruiz JR, Vicente-Rodríguez G, Bueno M, Marcos A, Gómez-Martínez S, Urzanqui A, González-Gross M, Moreno L, Gutiérrez A, Castillo, MJ. Health-related fitness in adolescents: underweight, and not only overweight, as an influencing factor. The AVENA study. *Scand J Med Sci Spor* 2010; 20: 418-427.
- Baecke JA, Burema J, Frijters JE. A short questionnaire for the measurement of habitual physical activity in epidemiological studies. *Am J Clin Nutr* 1982; 36: 936-942.
- Branta C, Haubenstricker J, Seefeldt V. Age changes in motor skills during childhood and adolescence. *Exercise Sport Sci Rev* 1984; 12: 467-520.
- Castro-Piñero J, González-Montesinos JL, Mora J, Keating XD, Girela-Rejón MJ, Sjöström M, Ruiz JR. Percentile values for muscular strength field tests in children aged 6 to 17 years: influence of weight status. *J Strength Cond Res* 2009; 23: 2295-2310.
- Cepero MR, López R, Suárez-Llorca C, Andreu-cabrera E, Rojas FJ. Fitness test profiles in children aged 8-12 years old in Granada (Spain). *J Hum Sport Exerc* 2011; 6: 135-146.
- Coleman KJ, Heath EM, Alcalá IS. Overweight and aerobic fitness in children in the United States/Mexico border region. *Rev Panam Salud Públ / Pan Am J Public Health* 2004; 15: 262-271.
- Dencker M, Thorsson O, Karlsson M, Lindén C, Eiberg S, Wollmer P, Andersen B. Gender differences and determinants of aerobic fitness in children aged 8-11 years. *Eur J Appl Physiol* 2007; 99: 19-26.
- Dumith SC, Ramires VV, Souza MA, Moraes DS, Petry FG, Oliveira ES, Ramires SV, Hallal PC. Overweight/Obesity and physical fitness among children and adolescents. *J Phys Act Health* 2010; 7: 641-648.
- Faigenbaum AD, Westcott WL, Micheli LJ, Outerbridge AR, Long CJ, LaRosa-Loud R, Zaichkowsky LD. The Effects of Strength Training and Detraining on Children. *J Strength Cond Res* 1996; 10: 109-114.
- George JD, Fisher AG, Vehrs, PR. *Laboratory experiences in exercise science*. Boston: Jones & Bartlett Publishers, Inc, 1994.
- Haff GG. Roundtable discussion: Youth resistance training. *Strength Cond J* 2003; 25: 49-64.

References

- Hands B, Larkin D, Parker H, Straker, L, Perry M. The relationship among physical activity, motor competence and health- related fitness in 14-year-old adolescents. *Scand J Med Sci Sports* 2009; 19: 655-663.
- Heath BH, Carter, JEL. Growth and somatotype patterns of Manus children, Territory of Papua and New Guinea: Application of a modified somatotype method to the study of growth patterns. *Am J Phys Anthropol* 1971; 35: 49-67.
- Jakšić D, Cvetković M. Neural network analysis of somatotype differences among males related to the manifestation of motor abilities. *Acta Kinesiologica* 2009; 3: 107-113.
- Kato E, Oda T, Chino K, Kurihara T, Nagayoshi T, Fukunaga T, Yasuo Kawakami Y. Musculotendinous Factors Influencing Difference in Ankle Joint Flexibility between Women and Men. *Int J Sport Health Sci* 2005; 3(Special Issue): 218-225.
- Kvaavik E, Klepp KI, Tell GS, Meyer HE, Batty GD. Physical fitness and physical activity at age 13 years as predictors of cardiovascular disease risk factors at ages 15, 25, 33, and 40 years: extended follow-up of the Oslo Youth Study. *Pediatrics* 2009; 123: e80-e86.
- Lennox A, Pienaar AE, Wilders, C. Physical fitness and the physical activity status of 15-year-old adolescents in a semi-urban community. *S Afr J Res Sport Phys Educ Recreation* 2008; 30: 59-73.
- Little T, Williams AG. Specificity of acceleration, maximum speed, and agility in professional soccer players. *J Strength Cond Res* 2005; 19:76-78.
- Lyu M, Gill D. Perceived physical competence, enjoyment and effort in same-sex and coeducational physical education classes. *J Educ Psychol* 2011; 31: 247-260.
- Malina RM, Bouchard C. *Growth maturation and physical activity*. Champaign, Illinois: Human Kinetics, 1991.
- Malina RM, Bouchard C, Bar-Or, O. *Growth, maturation and physical activity*. Champaign, Illinois: Human Kinetics, 2004.
- Marfell-Jones M, Olds T, Stewart A, Carter L. *International standards for anthropometric assessment*. Potchefstroom, South Africa: ISAK, 2006.
- Mayhew JL, Ware JS, Johns RA, Bemben MG. Changes in upper body power following heavy-resistance strength training in college men. *Int J Sports Med* 1997; 18: 516-520.
- Meredith MD, Welk GJ. *FITNESSGRAM / ACTIVITYGRAM Test Administration Manual* (4th Ed). Champaign, IL: Human Kinetics, 2007.

- Monyeki MA, Koppes LJ, Kemper HG, Monyeki KD, Toriola AL, Pienaar AE, Twisk JW. Body composition and physical fitness of undernourished South African rural primary school children. *Eur J Clin Nutr* 2005; 59:877-83.
- NIH Consensus Development Panel on Physical Activity and Cardiovascular Health. Physical activity and cardiovascular health. *J Am Med Assoc* 1996; 276, 241-246.
- Ortega FB, Tresaco B, Ruiz JR, Moreno LA, Matillas M, Mesa JL, Warnberg J, Bueno M, Tercedor P, Gutiérrez A, Castillo MJ. Cardiorespiratory fitness and sedentary activities are associated with adiposity in adolescents. *Obesity* 2007; 15: 1589-1599.
- Reed JA, Metzker A. Relationships between physical activity and motor skills in middle school children. *Percept Motor Skill* 2004; 99: 483-494.
- Reis VM, Machado JV, Fortes MS, Fernandes,PR, Silva AJ, Dantas PS, Filho JF. Evidence for higher heritability of somatotype compared to body mass index in female twins. *J Physiol Anthropol* 2007; 26: 9-14.
- Roetert EP. The lack of childhood activity in the United States. *Strength Cond J* 2004; 26: 22-23.
- Shukla M, Venugopal R, Mitra M. A cross sectional study of body composition somatotype and motor quality of rural and urban boys of Chhattisgarh. *Int J Fitness* 2009; 5: 1-7.
- Slaughter MH, Lohman TG, Boileau RA, Horswill CA, Stillman RJ, VanLoan MD, Bembem DA. Skinfold equations for estimation of body fatness in children and youth. *Hum Biol* 1988; 60: 709-723.
- Sola K, Brekke N, Brekke M. An activity-based intervention for obese and physically inactive children organized in primary care: feasibility and impact on fitness and BMI a one-year follow-up study. *Scand J Prim Health* 2010; 28: 199-204.
- Sveinsson T, Arngrimsson SA, Johannsson E. Association between aerobic fitness, body composition, and physical activity in 9- and 15-year-olds. *Eur J Sport Sci* 2009; 9: 141-150.
- Thomas JR, French KE. Gender differences across age in motor performance: A meta-analysis. *Psychol Bull* 1985; 98: 260-282.
- Tovar G, Poveda JG, Pinilla MI, Lobelo F. Relationship between overweight, physical activity and physical fitness in school-aged boys in Bogotá Colombia. *Arch Latinoam Nutr* 2008; 58: 265-273.

Study 4

- Adam C, Klissouras V, Ravassolo M, Renson R, Tuxworth W, Kemper H, Van Mechelen W, Hlobil H, Beunen G, Levarlet-Joye H, Van Lierde A. *Eurofit: Handbook for the Eurofit Test of Physical Fitness*. Rome: Council of Europe. Committee for the Development of Sport, 1988.
- Anderssen SA, Cooper AR, Riddoch C, Sardinha LB, Harro M, Brage S, Andersen LB. Low cardiorespiratory fitness is a strong predictor for clustering of cardiovascular disease risk factors in children independent of country, age and sex. *Eur J Cardiovasc Prev Rehabil* 2007; 14: 526-531.
- Behringer M, Vom Heede A, Matthews M, Mester J. Effects of strength training on motor performance skills in children and adolescents: A Meta-Analysis. *Pediatr Exerc Sci* 2011; 23: 186-206.
- Burgeson CR, Wechsler H, Brener ND, Young JC, Spain CG. Physical Education and Activity: Results from the School Health Policies and Programs Study 2000. *J Sch Health* 2001; 71: 279-293.
- Castro-Piñero J, González-Montesinos J, Mora J, Keating X, Girela-Rejón M, Sjöström, M, Ruiz J. Percentile values for muscular strength field tests in children aged 6 to 17 years: influence of weight status. *J Strength Cond Res* 2009; 23: 2295-2310.
- Centers for Disease Control and Prevention. Physical activity levels among children aged 9-13 years - United States, 2002. *Morb Mort Wk Rep* 2003; 52: 785-788.
- Cepero MR, López R, Suárez-Llorca C, Andreu-cabrera E, Rojas FJ. Fitness test profiles in children aged 8-12 years old in Granada (Spain). *J Hum Sport Exerc* 2011; 6: 135-146.
- Chaouachi M, Chaouachi A, Chamari K, Chtara M, Feki Y, Amri M, Trudeau F. Effects of dominant somatotype on aerobic capacity trainability. *Br J Sports Med* 2005; 39: 954-959.
- Dorgo S, King GA, Candelaria NG, Bader JO, Brickey GD, Adams CE. Effects of manual resistance training on fitness in adolescents. *J Strength Cond Res* 2009; 23: 2287-2294.
- Dumith S, Ramires V, Souza M, Moraes D, Petry F, Oliveira E, Ramires S, Hallal P. Overweight/Obesity and Physical Fitness Among Children and Adolescents. *J Phys Act Health* 2010; 7: 641-648.
- Evenson KR, Ballard K, Lee G, Ammerman A. Implementation of a School-Based State Policy to Increase Physical Activity. *J Sch Health*. 2009; 79: 231-238.

- Faigenbaum AD, Kraemer WJ, Blimkie CJR, Jeffreys I, Micheli LJ, Nitka M, Rowland, TW. Youth resistance training: Updated position statement paper from the National Strength and Conditioning Association. *J Strength Cond Res* 2009; 23: S60-S79.
- Faigenbaum AD, Westcott WR, Micheli, L. The Effects of Strength Training and Detraining on Children. *J Strength Cond Res* 1996; 10: 109-114.
- Heath BH, Carter JEL. Growth and somatotype patterns of Manus children, Territory of Papua and New Guinea: Application of a modified somatotype method to the study of growth patterns. *Am J Phys Anthropol* 1971; 35: 49-67.
- Ignjatović A, Stanković R, Radovanović D, Zivorad MZ, Cvecka J. Resistance training for youths. *Facta Universitatis* 2009; 7: 189-196.
- Jakšić D, Cvetković M. Neural network analysis of somatotype differences among males related to the manifestation of motor abilities. *Acta Kinesiologica* 2009; 3: 107-113.
- Léger LA, Mercier D, Gadoury C, Lambert J. The multistage 20 meter shuttle run test for aerobic fitness. *J Sports Sci* 1988; 6: 93-101.
- Linthorne NP. Analysis of standing vertical jumps using a force platform. *Am J Physics* 2001; 69: 1198-1204.
- Malina R, Bouchard C. *Growth maturation and physical activity*. Champaign, Illinois: Human Kinetics, 1991.
- Malina R, Bouchard C, Bar-Or O. *Growth, maturation and physical activity*. Champaign, Illinois: Human Kinetics, 2004.
- Marfell-Jones M, Olds T, Stewart A, Carter L. *International standards for anthropometric assessment*. Potchefstroom, South Africa: ISAK, 2006.
- Mayhew JL, Ware JS, Johns RA, Bembem MG. Changes in upper body power following heavy-resistance strength training in college men. *Int J Sports Med* 1997; 18: 516-520.
- Norman A, Drinkard B, McDuffie J, Ghorbani S, Yanoff L, Yanovski J. Influence of excess adiposity on exercise fitness and performance in overweight children and adolescents. *Pediatrics* 2005; 115: 690-696.
- Ortega B, Tresaco B, Ruiz J, Moreno L, Matillas M, Mesa J, Warnberg J, Bueno M, Tercedor P, Gutiérrez A, Castillo M. Cardiorespiratory fitness and sedentary activities are associated with adiposity in adolescents. *Obesity* 2007; 15: 1589-1599.
- Ozmun J, Mikesky A, Surburg P. Neuromuscular adaptations following prepubescent strength training. *Med Sci Sports Exerc* 1994; 26: 510-514.

References

- Ramsay J, Blimkie C, Smith K, Garner S, Macdougall J, Sale D. Strength training effects in prepubescent boys. *Med Sci Sports Exerc* 1990; 22: 605-614.
- Sandbakk Ø, Welde B, Holmberg HC. Endurance training and sprint performance in elite junior cross-country skiers. *J Strength Cond Res* 2011; 25: 1299-1305.
- Santos E, Janeira M. Effects of complex training on explosive strength in adolescent male basketball players. *J Strength Cond Res* 2008; 22: 903-909.
- Santos A, Marinho DA, Costa AM, Izquierdo M, Marques MC. The effects of concurrent resistance and endurance training follow a detraining period in elementary school students. *J Strength Cond Res* 2012; 26: 1708-16.
- Shukla M, Venugopal R, Mitra M. A cross sectional study of body composition somatotype and motor quality of rural and urban boys of Chhattisgarh. *Int J Fitness* 2009; 5: 1-7.
- Slaughter MH, Lohman TG, Boileau RA, Horswill CA, Stillman RJ, VanLoan MD, Bembien DA. Skinfold equations for estimation of body fatness in children and youth. *Hum Biol* 1988; 60: 709-723.
- Stenevi-Lundgren S, Daly RM, Lindén C, Gärdsell P, Karlsson MK. Effects of a daily school based physical activity intervention program on muscle development in prepubertal girls. *Eur J Appl Physiol* 2009; 105(4): 533-541.
- Strong WB, Malina RM, Blimkie CJ, Daniels SR, Dishman RK, Gutin B, Hergenroeder AC, Must A, Nixon PA, Pivarnik JM, Rowland T, Trost S, Trudeau F. Evidence based physical activity for school-age youth. *Pediatrics* 2005; 146: 732-737.
- Suchomel A. Relation between anthropometric somatotype and motor performance in prepubescent and pubescent Czech. *Anthropologie* 2002; 40: 193-201.
- Taanila H, Hemminki A, Suni J, Pihlajamäki H, Parkkari, J. Low physical fitness is a strong predictor of health problems among young men: a follow-up study of 1411 male conscripts. *BMC Public Health*. 2011; 11: 590.
- World Health Organization (WHO). *Global Recommendations on Physical Activity for Health*. Geneva: World Health Organization, 2010.

Study 5

- Adam C, Klissouras V, Ravassolo M, Renson R, Tuxworth W, Kemper H, Van Mechelen W, Hlobil H, Beunen G, Levarlet-Joye H, Van Lierde A. *Eurofit: Handbook for the Eurofit Test of Physical Fitness*. Rome: Edigraf Editoriale Grafica, 1988.

- American College of Sports Medicine. *Guidelines for Exercise Testing and Prescription*. 7th ed. Philadelphia, PA: Lippincott Williams & Wilkins, 2006.
- Anderson LB, Haraldsdottir J. Coronary heart disease risk factors, physical activity, and fitness in young Danes. *Med Sci Sports Exerc* 1995; 27: 158-163.
- Anderssen SA, Cooper AR, Riddoch C, Sardinha LB, Harro M., Brage S, Andersen LB. Low cardiorespiratory fitness is a strong predictor for clustering of cardiovascular disease risk factors in children independent of country, age and sex. *Eur J Cardiovasc Prev Rehabil* 2007; 14: 526-531.
- Cepero MR, López R, Suárez-Llorca C, Andreu-cabrera E, Rojas FJ. Fitness test profiles in children aged 8-12 years old in Granada (Spain). *J Hum Sport Exerc* 2011; 6: 135-146.
- Coffey VG, Hawley JA. The molecular bases of training adaptation. *Sports Med* 2007; 37: 737-63.
- Coleman KJ, Heath EM, Alcalá IS. Overweight and aerobic fitness in children in the United States/Mexico border region. *Rev Panam Salud Publica* 2004; 15: 262-271.
- Dorgo S, King GA, Candelaria NG, Bader JO, Brickey GD, Adams CE. Effects of manual resistance training on fitness in adolescents. *J Strength Cond Res* 2009; 23: 2287-2294.
- Dudley GA, Djamil R. Incompatibility of endurance- and strengthtraining modes of exercise. *J Appl Physiol* 1985; 59: 1446-1451.
- Duke PM, Litt IR, Gross RT. Adolescents' self-assessment of sexual maturation. *Pediatrics* 1980; 66: 918-920.
- Faigenbaum AD, Kraemer WJ, Blimkie CJR, Jeffreys I, Micheli LJ, Nitka M, Rowland TW. Youth resistance training: Updated position statement paper from the National Strength and Conditioning Association. *J Strength Cond Res* 2009; 23: S60-S79.
- Faigenbaum A, Mediate P. The effects of medicine ball training on physical fitness in high school physical education students. *Phys Educ* 2006; 63: 160-167.
- Faigenbaum A, Milliken L, Moulton L, Westcott W. Early muscular fitness adaptations in children in response to two different resistance training regimens. *Pediatr Exerc Sci* 2005; 17: 237-248.
- García-Pallarés J, Izquierdo M. Strategies to Optimize Concurrent Training of Strength and Aerobic Fitness for Rowing and Canoeing. *Sports Med* 2011; 41: 329-343.

References

- García-Pallarés J, Sánchez-Medina L, Carrasco L, Diaz A, Izquierdo M. Endurance and neuromuscular changes in world-class level kayakers during a periodized training cycle. *Eur J Appl Physiol* 2009; 106: 629-638.
- González-Badillo JJ, Gorostiaga EM, Arellano R, Izquierdo M. Moderate resistance training volume produces more favorable strength gains than high or low volumes. *J Strength Cond Res* 2005; 19: 689-697.
- Harriss DJ, Atkinson G. Update-Ethical standards in sport and exercise science research. *Int J Sports Med* 2011; 32: 819-821.
- Hawley JA. Molecular responses to strength and endurance training: are they incompatible? *Appl Physiol Nutr Metab* 2009; 34: 355-361.
- Hickson RC. Interference of strength development by simultaneously training strength and endurance. *Eur J Appl Physiol* 1980; 45: 255-263.
- Izquierdo-Gabarrén M, Exposito R, Garcia-Pallarés J, Sánchez-Medina L, De Villareal ES, Izquierdo M. Concurrent endurance and strength training not to failure optimizes performance gains. *Med Sci Sports Exerc* 2010; 42: 1191-1199.
- Izquierdo M, Häkkinen K, Ibáñez J, Kraemer WJ, Gorostiaga EM. Effects of combined resistance and cardiovascular training on strength, power, muscle cross-sectional area, and endurance markers in middle-aged men. *Eur J Appl Physiol* 2005; 94: 70-75.
- Kraemer W, Fry A, Frykman P, Conroy B, Hoffman J. Resistance training and youth. *Pediatr Exerc Sci* 1989; 1: 336-350.
- Kraemer WJ, Ratamess NA. Fundamentals of resistance training: progression and exercise prescription. *Med Sci Sports Exerc* 2004; 36: 674-688.
- Kvaavik E, Klepp KI, Tell GS, Meyer HE, Batty, GD. Physical fitness and physical activity at age 13 years as predictors of cardiovascular disease risk factors at ages 15, 25, 33, and 40 years: extended follow-up of the Oslo Youth Study. *Pediatrics* 2009; 123: e80-e86.
- Léger LA, Mercier D, Gadoury C, Lambert J. The multistage 20 meter shuttle run test for aerobic fitness. *J Sports Sci* 1988; 6: 93-101.
- Lillegard WA, Brown EW, Wilson DJ, Henderson R, Lewis E. Efficacy of strength training in prepubescent to early postpubescent males and females: *effects of gender and maturity*. *Pediatr Rehabil* 1997; 1: 147-157.
- Linthorne, NP. Analysis of standing vertical jumps using a force platform. *Am J Physics* 2001; 11: 1198-1204.

- Marfell-Jones M, Olds T, Stewart A, Carter L. *International standards for anthropometric assessment*. Potchefstroom, South Africa: ISAK, 2006.
- Marques MC, Zajac A, Pereira A, Costa AM. Strength training and detraining in different populations: Case studies. *J Hum Kinet* 2011; (Special Issue): 7-14.
- Matton L, Duvigneaud N, Wijndaele K, Philippaerts R, Duquet W, Beunen G, Claessens A, Thomis M, Lefevre J. Secular trends in anthropometric characteristics, physical fitness, physical activity and biological maturation in Flemish adolescents between 1969 and 2005. *Am J Hum Biol* 2007; 19: 326-624.
- Mayhew JL, Ware JS, Johns RA, Bembem MG. Changes in upper body power following heavy-resistance strength training in college men. *Int J Sports Med* 1997; 18: 516-520.
- Obert P, Mandigouts S, Nottin S, Vinet A, N'Guyen LD, Lecoq AM. Cardiovascular responses to endurance training in children: effect of gender. *Eur J Clin Invest* 2003; 33: 199-208.
- Ortega FB, Tresaco B, Ruiz JR, Moreno LA, Matillas M, Mesa JL, Warnberg J, Bueno M, Tercedor P, Gutiérrez A, Castillo MJ. Cardiorespiratory fitness and sedentary activities are associated with adiposity in adolescents. *Obesity* 2007; 15: 1589-1599.
- Ramsay J, Blimkie C, Smith K, Garner S, Macdougall J, Sale D. Strength training effects in prepubescent boys. *Med Sci Sports Exerc* 1990; 22: 605-614.
- Rowland TW, Boyajian A. Aerobic Response to Endurance Exercise Training in Children. *Pediatrics* 1995; 96: 654-658.
- Sale DG, McDougall J.D, Jacobs I, Garner S. Interaction between concurrent strength and endurance training. *J Appl Physiol* 1990; 68: 260-270.
- Santos E, Janeira, M. The effects of plyometric training followed by detraining and reduced training periods on explosive strength in adolescent male basketball players. *J Strength Cond Res* 2011; 25: 441-452.
- Santos A, Marinho DA, Costa AM, Izquierdo M, Marques MC. The Effects of concurrent resistance and endurance training follow a specific detraining cycle in young school girls. *J Hum Kinet* 2011; Special Issue: 93-103.
- Santos A, Marinho DA, Costa AM, Izquierdo M, Marques MC. The effects of concurrent resistance and endurance training follow a detraining period in elementary school students. *J Strength Cond Res* 2012; 26: 1708-1716.
- Siegel JA, Camaione DN, Manfredi TG. The effects of upper body resistance training on prepubescent children. *Pediatr Exerc Sci* 1989; 1: 145-154.

References

- Stenevi-Lundgren S, Daly RM, Lindén C, Gärdsell P, Karlsson MK. Effects of a daily school based physical activity intervention program on muscle development in prepubertal girls. *Eur J Appl Physiol* 2009; 105: 533-541.
- Taanila H, Hemminki A, Suni J, Pihlajamäki H, Parkkari J. Low physical fitness is a strong predictor of health problems among young men: a follow-up study of 1411 male conscripts. *BMC Public Health* 2011; 11: 590.
- Vinet A, Mandigout S, Nottin S, Nguyen L, Lecoq N, Courteix D, Obert P. Influence of Body Composition, Hemoglobin Concentration, and Cardiac Size and Function of Gender Differences in Maximal Oxygen Uptake in Prepubertal Children. *Chest* 2003; 124: 1494-1499.

Chapter 4

- Allard P, Nault M, Hinse S, Leblawc R, Labelle H. Relationship between morphologic somatotypes and standing posture equilibrium. *Ann Hum Biol* 2001; 28: 624-633.
- Andersen LB, Haraldsdottir J. Changes in physical activity, maximal isometric strength and maximal oxygen uptake from late teenage to adulthood. An 8-year follow-up study of adolescents in Denmark. *Scand J Med Sci Sports* 1994; 4: 19-25.
- Anderssen SA, Cooper AR, Riddoch C, Sardinha LB, Harro M, Brage S, Andersen LB. Low cardiorespiratory fitness is a strong predictor for clustering of cardiovascular disease risk factors in children independent of country, age and sex. *Eur J Cardiovasc Prev Rehabil* 2007; 14: 526-531.
- Branta C, Haubenstricker J, Seefeldt V. Age changes in motor skills during childhood and adolescence. *Exercise Sport Sci Rev* 1984; 12: 467-520.
- Castro-Piñero J, González-Montesinos J, Mora J, Keating X, Girela-Rejón M, Sjöström, M, Ruiz J. Percentile values for muscular strength field tests in children aged 6 to 17 years: influence of weight status. *J Strength Cond Res* 2009; 23: 2295-2310.
- Cepero M, López R, Suárez-Llorca C, Andreucabrera E, Rojas F. Fitness test profiles in children aged 8-12 years old in Granada (Spain). *J Hum Sport Exerc* 2011; 6: 135-146.
- Chaouachi M, Chaouachi A, Chamari K, Chtara M, Feki Y, Amri M, Trudeau F. Effects of dominant somatotype on aerobic capacity trainability. *Br J Sports Med* 2005; 39: 954-959.
- Coffey VG, Hawley JA. The molecular bases of training adaptation. *Sports Med* 2007; 37: 737-63.

- D`Hont E, Deforche B, Bourdeaudhuij I, Lenoir M. Relationship between motor skill and Body Mass Index in 5-to 10-year-old children. *Adapt Phys Act Q* 2009; 26: 21-37.
- Dorgo S, King GA, Candelaria NG, Bader JO, Brickey GD, Adams CE. Effects of manual resistance training on fitness in adolescents. *J Strength Cond Res* 2009; 23: 2287-2294.
- Dumith S, Ramires V, Souza M, Moraes D, Petry F, Oliveira E, Ramires S, Hallal P. Overweight/Obesity and Physical Fitness Among Children and Adolescents. *J Phys Act Health* 2010; 7: 641-648.
- Faigenbaum AD, Kraemer WJ, Blimkie CJR, Jeffreys I, Micheli LJ, Nitka M, Rowland, TW. Youth resistance training: Updated position statement paper from the National Strength and Conditioning Association. *J Strength Cond Res* 2009; 23: S60-S79.
- Fogelholm M, Stigman S, Huisman T, Metsämuuronen J. Physical fitness in adolescents with normal weight and overweight. *Scand J Med Sci Sports* 2008; 18: 162-170.
- García-Pallarés J, Izquierdo M. Strategies to Optimize Concurrent Training of Strength and Aerobic Fitness for Rowing and Canoeing. *Sports Med* 2011; 41: 329-343.
- García-Pallarés J, Sánchez-Medina L, Carrasco L, Diaz A, Izquierdo M. Endurance and neuromuscular changes in world-class level kayakers during a periodized training cycle. *Eur J Appl Physiol* 2009; 106: 629-638.
- González-Badillo JJ, Gorostiaga EM, Arellano R, Izquierdo M. Moderate resistance training volume produces more favorable strength gains than high or low volumes. *J Strength Cond Res* 2005; 19: 689-97.
- Haff, GG. Roundtable discussion: Youth resistance training. *Strength Cond J* 2003; 25: 49-64.
- Hands B, Larkin D, Parker H, Straker L, Perry M. The relationship among physical activity, motor competence and health-related fitness in 14-year-old adolescents. *Scand J Med Sci Sports* 2009; 19: 655-663.
- Hawley JA. Molecular responses to strength and endurance training: are they incompatible? *Appl Physiol Nutr Metab* 2009; 34: 355-361.
- Jakšić D, Cvetković M. Neural network analysis of somatotype differences among males related to the manifestation of motor abilities. *Acta Kinesiologica* 2009; 3: 107-113.
- Kato E, Oda T, Chino K, Kurihara T, Nagayoshi T, Fukunaga T, Yasuo Kawakami Y. Musculotendinous Factors Influencing Difference in Ankle Joint Flexibility between Women and Men. *Int J Sport Health Sci* 2005; 3: 218-225.

References

- Lämmle L, Tittlbach S, Oberger J, Worth A, Bös K. A two-level model of motor performance Ability. *J Exerc Sci Fit* 2010; 8: 41-49.
- Lennox A, Pienaar A, Wilders C. Physical fitness and the physical activity status of 15-year-old adolescents in a semi-urban community. *S Afr J Res Sport Phys Educ Recreation* 2008; 30: 59-73.
- Little T, Williams AG. Specificity of acceleration, maximum speed, and agility in professional soccer players. *J Strength Cond Res* 2005; 19: 76-78.
- Malina R, Bouchard C. *Growth maturation and physical activity*. Champaign, Illinois: Human Kinetics, 1991.
- Malina R, Bouchard C, Bar-Or O. *Growth, maturation and physical activity*. Champaign, Illinois: Human Kinetics, 2004.
- Matton L, Duvigneeaud N, Wijndaele K, Philippaerts R, Duquet W, Beunen G, Claessens A, Thomis M, Lefevre J. Secular trends in anthropometric characteristics, physical fitness, physical activity and biological maturation in Flemish adolescents between 1969 and 2005. *Am J Hum Biol* 2007; 19: 326-624.
- Monyeki MA, Koppes LJ, Kemper HG, Monyeki KD, Toriola AL, Pienaar AE, Twisk, JW. Body composition and physical fitness of undernourished South African rural primary school children. *Eur J Clin Nutr* 2005; 59:877-883.
- Norman A, Drinkard B, McDuffie J, Ghorbani S, Yanoff L, Yanovski J. Influence of excess adiposity on exercise fitness and performance in overweight children and adolescents. *Pediatrics* 2005; 115: 690-696.
- Ortega B, Tresaco B, Ruiz J, Moreno L, Matillas M, Mesa J, Warnberg J, Bueno M, Tercedor P, Gutiérrez A, Castillo M. Cardiorespiratory fitness and sedentary activities are associated with adiposity in adolescents. *Obesity* 2007; 15: 1589-1599.
- Ozmun J, Mikesky A, Surburg P. Neuromuscular adaptations following prepubescent strength training. *Med Sci Sports Exerc* 1994; 26: 510-514.
- Ramsay J, Blimkie C, Smith K, Garner S, MacDougall J, Sale D. Strength training effects in prepubescent boys. *Med Sci Sports Exerc* 1990; 22: 605-614.
- Roetert, EP. The lack of childhood activity in the United States. *Strength Cond J* 2004; 26: 22-23.
- Sandbakk Ø, Welde B, Holmberg HC. Endurance training and sprint performance in elite junior cross-country skiers. *J Strength Cond Res* 2011; 25: 1299-1305.

- Santos E, Janeira, M. The effects of plyometric training followed by detraining and reduced training periods on explosive strength in adolescent male basketball players. *J Strength Cond Res* 2011; 25: 441-452.
- Santos A, Marinho DA, Costa AM, Izquierdo M, Marques MC. The effects of concurrent resistance and endurance training follow a detraining period in elementary school students. *J Strength Cond Res* 2012; 26: 1708-1716
- Shukla M, Venugopal R, Mitra M. A cross sectional study of body composition somatotype and motor quality of rural and urban boys of Chhattisgarh. *Int J Fitness* 2009; 5: 1-7.
- Suchomel A. Relation between anthropometric somatotype and motor performance in prepubescent and pubescent Czech. *Anthropologie* 2002; 40: 193-201.
- Thomas JR, French KE. Gender differences across age in motor performance: A meta-analyses. *Psychol Bull* 1985; 98: 260-282.
- Tomkinson GR, Olds TS, Kang SJ, Kim DY. Secular trends in the aerobic fitness test performance and body mass index of Korean children and adolescents (1968-2000). *Int J Sports Med* 2007; 28: 314-320.
- Tovar G, Poveda J, Pinilla M, Lobelo F. Relationship between overweight, physical activity and physical fitness in school-aged boys in Bogotá Colombia. *Arch Latinoam Nutr* 2008; 58: 265-273.
- Wells JC, Fewtrell MS, Williams JE, Haroun D, Lawson MS, Cole TJ. Body composition in normal weight, overweight and obese children: matched case-control analyses of total and regional tissue masses, and body composition trends in relation to relative weight. *Int J Obes (Lond)* 2006; 30: 1506-1513.
- Xianwen S, Ailing L, Yanping L, Xiaoqi H, Lin D, Jun M, Guifa X, Ying L, Hongwei G, Guansheng M. The association of weight status with physical fitness among Chinese children. *Int J Pediatr* 2010; 1: 1-6. doi:10.1155/2012/943653