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Review

Updating on resistance training for prepubertal obese children: Resistance training for obese children

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Obesity affects a large part of world population, with an impact also in childhood. It stands out as effective ways of treating the adequacy food and regular exercise. Research has shown that resistance training (RT) has significant role in prevention and treatment of obesity and its consequences on the health and quality of life. The objective of this study was to develop a critical review about the influence of RT on parameters as indicators of prepubertal children with obesity health. Literature search was conducted in main databases Medline, PubMed and Lilacs, using the key words: resistance training, resistive training, strength, children, obesity, considering articles published between 1989 and 2010. Were selected articles that support the implementation of TR on the improvement of functional and metabolic parameters of pre-pubertal children with obesity. It was possible to say that RT has a positive effect on body composition, muscle performance and increased bone density, reflecting an improvement in daily activities and sports. However, further studies are necessary to understand the effect of RT on adipose tissue and muscle mass in childhood.

Keywords: Resistance training, child, obesity, review.

INTRODUCTION

Obesity currently affects millions of individuals, including adults and children, becoming an epidemic and, consequently, a global public health challenge (Barlow, 2007; World Health Organization, 2008; Kumayika et al., 2008). The growth rate is higher in more developed regions of the planet, increasing 0.5% annually in the United States and Brazil, and 1% in Canada, Australia and Europe. It is estimated that 10% of the population of school-age children are overweight or obese and 32% of children in America are overweight or obese (Lobstein et al., 2004; Kumayika et al., 2008). The prevalence of childhood obesity is alarming in view of its association

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with metabolic abnormalities related to dyslipidemia, hypertension and glucose intolerance, risk factors for type II diabetes mellitus and cardiovascular disease (Lobstein et al., 2004; Kumayika et al., 2008).

Although genetic factors play a significant influence on the development of obesity and its co-morbidities, environmental factors are directly related to the exponential increase in childhood obesity (Barlow, 2007; World Health Organization, 2008). Studies have shown a dose-response relationship between time watching television and obesity (Dennison et al., 2002; Brown, 2006; Nader et al., 2006; MacLeod et al., 2008). The reduction of body fat occurs as a result of decreased time spent in idle activities such as video games, combined with strategies to increase energy expenditure through physical activity (Dennison et al., 2002; Vandewater et al., 2004; Burdette and Whitaker, 2005; Brown, 2006; Nader et al., 2006). Noteworthy are the benefits of exercise with weights, also known as resistance training (RT). Included in this case, progressive loading exercise involving machines and dumbbells, as a safe form of exercise for the health of children aged between 7 and 10 years (stage 1 Tanner Scale) (Tanner, 1962; Kraemer et al., 1989; British Association of Sport and Exercise Science, 2004; Malina, 2006; Benson et al., 2007; Behm et al., 2008; Benson et al., 2008).

The scientific literature has helped to clarify aspects related to questionable TR applied in childhood. Stand out as its possible negative effects on growth interference, caused by damage to the epiphyseal plates, or failure in muscle strength associated with the absence of testosterone (Blinkie, 1989). Instead, there is reference to TR when well guided by qualified professionals, applied in early stages of child development, improves muscular strength and endurance, increasing on average 13 to 30%, resulting in programs lasting between 8 and 20 weeks (Faigenbaum et al., 2001; Nichols et al., 2001; Sadres et al., 2001; Faigenbaum et al., 2002; Vandewater et al., 2004; Faigenbaum et al., 2005; Christou et al., 2006).

The effectiveness of RT on muscle strength for children contributes to the improvement of motor capacity and prevention of injuries during sports (Hamill, 1994; Faigenbaum et al., 1999; McNeeley and Armstrong, 2002; Falk and Eliakim, 2003). The TR has also positive effect on health through improvement in lipid profile (Sung et al., 2002), beyond the motor performance (Faigenbaum, 2000; Hass et al., 2001; Falk and Eliakim, 2003). In addition, TR has direct relationship with increased bone mineral density (BMD) (Nichols et al., 2001), without negatively affecting growth maturity (Sadres et al., 2001), cardiorespiratory fitness or resting blood pressure (Blinkie, 1993; Watts et al., 2004). It also presents, effect on quality of life and motor performance in children with cerebral palsy (McBurney et al., 2003; Nader et al., 2006) and in rehabilitation of children with severe burns (Suman et al., 2001). However, its benefits are still controversial on body composition, with references to non-significant changes in body fat and lean mass (Sothern et al., 2000; Hass et al., 2001; Sadres et al., 2001) and increase in muscle mass and adiposity (Vrijens, 1978; Pfeifer and Francis, 1986; Suman et al., 2001; Yu et al., 2005; McGuigan et al., 2009). The Table 1 presents some studies published in the last 10 years showing results with TR, involving children with normal weight, overweight or obese.

To ensure its effectiveness and safety, it is necessary to emphasize the application of correct technique in combination with appropriate modulation of training variables, consistent with age and maturity, by classifying the stage of development. Included is also gender, health status and fitness level of children involved in the program. In this context, are indicated, with efficacy and safety for prepubescent children, protocols with moderate-high intensity (60-85% 1RM), with weekly sessions of two to three nonconsecutive, with 6 to 20 repetitions for averaging 8 to 12 exercises (Bradney et al., 1998; Behm et al., 2008; Benson et al., 2008).

Although well described the benefits of standardization and prescription of training programs, there is still considerable number of concepts to be clarified in relation to TR in the pediatric literature. Knowledge of adaptations and its benefits can help health professionals to better understand their effectiveness and application in different areas of health promotion and prevention and treatment of childhood obesity.

Thus, this study aimed to compile and discuss the current aspects of scientific literature on the contribution of TR in promoting health in obese prepubertal children, through knowledge of their benefits and mechanisms of adaptation, and indicate areas where further knowledge is restricted revealing perspectives for future studies.

Osteo Muscular System

The major determinant of peak bone mass is the level of bone mineral content acquired during childhood and adolescence. In both phases the pattern of physical activity and diet influence the development of bone mineral density in adulthood (Nichols et al., 2001). Bone mass is directly correlated with body weight in adults and children, although this relationship does not hold for obese children, because studies have shown lower bone mineral content in obese children (Zamboni et al., 1988; Goulding et al., 2000). Caloric restriction is an important feature to decrease the harmful effects to health caused by obesity. However, studies of obese adults show decline in bone mass and mineral density after reduction of body weight (Andersen et al., 1997; Jensen et al., 1994).

It is possible that caloric restriction in obese children

Table 1. Highlighting some studies published in the last 10 years in resistance training (RT) involving children with obesity, organized chronologically in descending order.

Reference	Casuistry Profile	Training Program	Statistical analysis	Evaluations	Results	Conclusions
McGuigan et al	- Boys = 22 = 26-Girls -Age = 9.7 years - Overweight or obese - Scale = Tanner stage 1	- Program-wave TR = Training 3 sessions / week for 8 weeks with exercise loads and intensities varied	-One-way pre-and post-training	- Dietary recall and physical activity for 3 days; - Anthropometric, body composition (fat mass, muscle and bone) by DEXA and muscle strength assessed by 1 RM test	- Height, BMI, total fat mass and bone mineral content € without significant changes; - Muscular strength, neuromotor tests, lean body mass (5,3%) € Increase; - Percentage of total fat € Decrease (2,6%)	- RT wave program promotes increase in lean mass, decrease body fat and increase strength and power in overweight or obese.
Benson et al	- Boys = 46 - Girls = 32 - age = 12.2 ± 1.3 years versus Control Group Group Training-Scale Tanner stage = 2.9	- RT program high-intensity training sessions = 2 / week for 8 weeks-Plane = 11 exercises for upper and lower limbs and trunk, and intensity control by Borg scale, between levels 15:18.	- ANOVA before and after training	-Body composition (fat mass, fat free, lean and fat percentage assessed by bioimpedance) Weight and height- -Biochemical indicators: TC, LDLc, HDLc, TG, insulin, glucose - Max endurance (VO2max) - Muscular Strength through 1RM test	- Circumference. hip ratio,% body fat and total fat € Reduction; - Muscle strength of upper and lower limbs € Increase in Group Training	- RT program of high intensity decreases fat and increases muscle strength in normal children and overweight.
Yu et al	- Boys + Girls = 82 -Age = 10.4 ± 1.0 years - Overweight or obese-control group (diet alone) vs. training group (diet + resistance training)-range = Tanner stage 1 (70) Stage 2 (12)	-Training Program TR-3 = sessions / week for 26 weeks - Plan = circuit, with an intensity of 75% to 100% for 10 MR and 10, 10-15 minute aerobic / stretching for heating / cooling	- T test for paired data before and after training	- Body composition (fat mass, fat-free lean, bone mineral content and bone mineral density, measured by DEXA) Weight and height- Diet-calorie standardized 900-1200 kcal / day	- Lean body mass (2.4%), body weight (3.9%) and bone mineral content € Increase in Group Training	- RT program relatively short, with emphasis on resistance, has significant benefits on bone and lean mass in preadolescent children with obesity.
Sung et al	- Boys-Girls = 54 = 28 = 8- Age 11 years -Obesity- Control Group vs. Group Training-Scale = Tanner stage 1 and 2	- Training Program TR-3 = sessions / week for 6 weeks -Plan = intensity between 75-100% of RM 10 and 10-15 minutes of aerobic exercise / stretching for heating / cooling	- ANOVA repeated measures before and after training	- Body composition (fat mass, lean fat free, as assessed by DEXA) Weight and height- Diet-calorie standardized 900-1200 kcal / day Biochemical indicators: TC, LDLc, HDLc, TG, apo A-1, apoB, Lp (a)	- Height (0.9%), fat-free lean mass (2.3%) € Increase in Group Training - Biochemical markers: TG (0.5%), LDL (0.5%), TG: HDL cholesterol (0.8%) and LDLc, HDLc € Reduction in Group Training	- RT program supports evidence of potential benefits on childhood obesity.

Table 1. continue

Sothern et al	- Boys = 7 Girls= 12 (Training Group) -48 Children (Control Group) Aged 12 years = 7 -Obesity Tanner-Scale = no indication	-Training Program TR- = 3 times per week for 10 weeks = series-Plane 8 to 12 repetitions, intensity 60% 1RM, with association with aerobic training with a duration of 30-45 minutes of moderate intensity (40-55 % VO2max), and exercises for flexibility	- ANOVA two-way repeated measures before and after training	-Body composition (% fat) via skinfolds and lean mass by means of predictive equations -Weight and height (stadiometer and electronic scale) Assessments of safety and ease of implementation of TR	- Total body weight, body mass index and fat% € Greater reduction in Group Training	-TR in conjunction with aerobic exercise and flexibility can be safely used in health promotion in prepubertal children with obesity. TR is most effective training method for inducing weight loss

VO2 = maximum volume of oxygen; MR = maximum resistance; DEXA = dual X-ray absortometry; TC = total cholesterol, LDL cholesterol = fraction of low-density lipoprotein, HDL-C = fraction of cholesterol of high density lipoprotein; VLDLc = fraction of cholesterol of very low density lipoprotein, TG = triglycerides, Lp (a) = lipoprotein (a), apo A-1 = apolipoprotein A1, apo B = apolipoprotein B; BMI = body mass index.

offer the potential damage to bone and muscle mass. In this case, the association of TR hypocaloric diet can prevent loss of bone and muscle mass, in addition, the TR increases muscular strength and endurance, helping to improve the functionality in daily and recreational activities and also in sports practice (Weltman et al., 1986; Rians et al., 1987; Blinkie, 1993; Lilegard et al., 1997; Faigenbaum et al., 1999; Malina, 2006). The protocols used involve loads of moderate intensity (55-65% of RM) and higher volume of repetitions (15-20) in the early stages, progressing to higher intensity (75-85% 1RM) and lower number of repetitions (8 -12) in more advanced stages of training programs (Pfeifer and Francis, 1986; Faigenbaum et al., 1999; Lilegard et al., 1997; Faigenbaum et al., 2005; Christou et al., 2006; Benson et al., 2007). These models of training protocols have shown high efficiency, such as increased muscle strength and endurance and low risk of injury, as demonstrated by Malina (Malina, 2006) in a recent review involving 22 studies in pre-adolescents, with an average of two to three training sessions per week.

However, there is constant concern about the interference of TR in cartilage growth and the consequent adverse impact on final height. However, studies have demonstrated the relationship between muscle strength and BMD, which justifies the application of RT in childhood with a view to forming a strong skeleton and a lower risk of developing osteoporosis in adulthood (Virvidakis et al., 1990; Hansen et al., 1991; Conroy et al. 1993, Heinomen et al., 2000; Hass et al., 2001). In this direction are the studies by Bass et al. (1998) where the authors observed in pre-adolescent gymnasts who have combined the high-impact training with TR, greater value for BMD and increased cortical thickness, compared with the control group. Additionally, the study showed lower growth rate in the group of gymnasts, considering the height in a sitting position and length of the femur and tibia, compared to controls. However, this difference in growth is not related to training, but may be the result of natural selection because of the advantage in sports performance by athletes of lesser stature (Daly et al., 2000; Erlandson et al., 2008; Gurd and Klentrou, 2003).

As seen, TR plays a significant effect on bone density, safety features in their application in children, and direct relationship with muscle strength and endurance, which are probably mainly responsible for the greater osteogenic stimulus of RT in comparison to other forms of exercise, such as walk (Frost, 1997). Studies involving children in TR programs show positive results in increasing bone mass (Morris et al., 1997; Bradney et al., 1998; McKay et al., 2000). In this context, Nichols et al. (2001) showed an increase of 3.67% in bone mineral density of the femoral head in adolescent girls who participated in an RT program in 15 months. Blimkie et al. (1989) also detected an increase in lumbar spine bone density in adolescents participating in a program lasting 26 weeks. Additionally, Yu et al. (2005) showed a 3.9% increase in bone mineral content and 2.4% in lean body mass in obese children subjected to 28 weeks of RT (Table 1).

Studies of TR in children and its effects on lean body mass are not conclusive. It is believed that the child has no pre-pubertal hormonal conditions suitable for the occurrence of muscle growth and, an increase in strength is due to neural adaptations. However, recent studies provide evidence that muscle hypertrophy can occur in response to TR in prepubescent children, and that the absence of positive findings on muscle mass can be in the low sensitivity of the anthropometric measurements such as skinfold technique, used studies to assess body composition in children (McGovern, 1984; Sailors and Berg, 1987; Siegel et al., 1989; Ransay et al., 1990; Ozmun et al., 1994; Benson et al., 2007). Thus, studies involving the use of more sensitive methods for assessing body composition such as MRI (magnetic ressonance), ultrasound and DEXA (dual-energy X-ray absortiometry) shows the occurrence of hypertrophy in children undergoing RT programs. Mersch and Stoboy, (1989) were the first to demonstrate, by MRI, increased cross-sectional area of the quadriceps, associated with increased isometric muscle strength of knee extensors in children. Adicionalmente, Fukunaga et al. (1992) observed by ultrasound increase in lean mass in children undergoing a program of 12 weeks of RT. Pikosky et al. (2002), with the application of DEXA, confirmed the increased fat-free lean mass in children at RT program lasting six weeks. Schwingshandl et al., (1999) demonstrated in a group of 14 boys and girls, mean age 11 years, a greater gain in fat-free lean mass than the control group after 12 weeks of RT. Another study, also using DEXA for body composition assessment, showed a 6.4% increase in total lean mass in children with severe burns undergoing a program of 12 weeks of RT (McGovern, 1984). Similar increase of 5.3% in lean body mass measured by DEXA, was demonstrated by McGuigan et al., (2009) in a recent study involving obese children participating in a program of eight weeks of TR.

In this context, it is assumed to occur in the process of muscle hypertrophy in prepubertal children undergoing RT. However, larger studies are needed to clarify the mechanisms involved in this process, including the contribution of neural adaptations responsible for increased muscle strength and its influence on bone and muscle mass and its benefits in the treatment of childhood obesity.

Body Fat

Obesity, especially before seen in adults, also currently affects younger age groups (Styne, 2001; Lobstein et al., 2004; Kumayika et al., 2008). This is a warning, since we know the duration of obesity is directly associated with mortality from cardiovascular disease (Lobstein et al., 2004; Kumayika et al., 2008). In this context, calorie restriction stands as an important resource for weight control in adults and children, but causes loss of muscle mass. It is important to consider the effect of physical exercise, especially for programs of TR, with a view to improvement in body composition and preserve or increase lean body mass in children with obesity (Table 1) (Schwingshandl et al., 1999; Pikosky et al., 2002; McGuigan et al., 2009).

Tolfrey et al (1998) found a reduction of 1.2% in body fat in children who underwent 12 weeks of training. Sailors and Berg (1987) revealed a decline of 9.9% in the sum of skinfolds of adolescents participating in the RT program for eight weeks. In a recent study, Benson et al. (2008) observed a reduction of 0.3% in the percentage of body fat and 0.8 cm in hip circumference in students aged between 7 and 10 years underwent an RT program is 8 weeks, compared with the control group. Additionally, Sothern et al. (2000) showed 10% reduction in total body fat in children with severe obesity, after 10 weeks of RT (Table 1). It is remarkable capability of RT in improving body composition, mainly for their simultaneous effect of reducing fat and increasing or preserving lean body mass. Sung et al., (2002) under the program for six weeks of TR intensity, detected an increase in lean body mass (0.8 kg) and concomitant decrease in body fat (0.7%) in children aged 8 to 11 years. Yu et al. (2005) also reproduced the simultaneous benefits on fat and muscle mass, down 2.2% and increased 5.1 kg, respectively, after the program 36 weeks of RT in children with obesity. A recent study involving children with a mean age of 9.7 years, subjected to a RT program of eight weeks, confirmed positive change in body composition, with a 5.3% increase in lean mass and decrease of 2.6% in body fat percentage (Table 1). (McGuigan et al., 2009)

Really, the peculiar effectiveness of RT in body composition, with a gain in body weight after implementation of training programs, is demonstrated in numerous studies (Vrijens, 1978; Weltman et al., 1986; Sailors and Berg, 1987; Siegel et al., 1989; Faigenbaum et al., 1999; Ransay et al., 1990; Sadres et al., 2001; Pikosky et al., 2002). However, the qualitative change in body composition due to increased muscle mass, is a major mechanism of induction of weight loss programs through TR. The resulting negative caloric balance of the energy consumed during the training sessions, coupled with the increased muscle mass and consequent increase in oxygen consumption leads to increased energy expenditure at rest, with a greater contribution of fat as energy substrate (Treuth et al., 1998; Yu et al., 2005). This is reflected in reduced adiposity and also of biochemical parameters as indicators of lipid profile (Sung et al., 2002).

Thus, studies with application of more accurate anthropometric methods are necessary to measurement of changes in body composition and its effect on the mechanisms that induce weight loss by providing information on the effectiveness of implementation of programs for children with TR obesity.

Development of Resistance Training Programs for Children

TR programs for children need to be carefully prescribed. Modulation of training variables must to consider individual differences in maturation and development using the Tanner Scale, and also the physical fitness and stress tolerance (Sothern et al., 2000; Straton et al., 2004; Malina, 2006). The medical exam generally is not performed in apparently healthy children, but recommended for those with suspected health problems (diabetes, obesity and orthopedic disorders) (Behm et al., 2008).

With the proper guidance and supervision of competent professionals, regular participation in programs of TR offers benefits for health related fitness and performance in sports, for boys and girls (Faigenbaum et al., 1996; Flanagan et al., 2002; Faigenbaum and Schram, 2004; Straton et al., 2004). Participation in programs of TR provides also a kinesthetic education opportunities(body knowledge), (Sothern et al., 2000; McBurney et al., 2003; Morton et al., 2005) apart from the possibility of diffusion of basic concepts about proper nutrition, (Tolfrey et al., 1998; Sung et al., 2002) health related physical fitness and sports (Faigenbaum et al., 1996; Flanagan et al., 2002; Faigenbaum and Schram, 2004;; Straton et al., 2004; Behm et al., 2008; Benson et al., 2008). These studies have demonstrated efficacy and low risk of injury in protocols with moderate / high intensity training programs in the form of circuit (Circuit Weight Training), and have similarities that can be applied as guidelines in drafting and implementing programs for TR children (Sothern et al., 2000; Sung et al., 2002; Straton et al., 2004; Yu et al., 2005; Malina, 2006; Benson et al., 2007; Behm et al., 2008; Benson et al., 2008). The following are some guidelines for developing and implementing programs for TR in children:

- Ensure the guidance of qualified professionals (Physical Education Teacher, Coaches ou Fitness Trainers) with knowledge in the prescription of exercises with weights;
- Consider each participant in the level of cognitive development, level of maturational development and fitness;
- Start each workout with 5 to 10 minutes warming up with dynamic exercises;
- Start with two or three training sessions per week, not consecutive, in the form of circuit;
- Start with 8 to 12 exercises for major muscle groups of upper and lower limbs and trunk;
- Adjust the machines and exercises for body measurements of children, using pads and pillows;
- Perform initial two to three sets of 15 to 20 repetitions with a load of moderate intensity (40-50% 1RM) to ensure proper technique in performing the exercises;
- Include exercises with bars and free weights that require balance and coordination;
- Continue to gradually exercise with loads that require more muscle strength (65-85% 1RM);
- At the end of sessions, conduct exercises of lower intensity (return to rest) and flexibility;
- Systematically vary the exercise routine to optimize the gains and reduce the monotony of training.

CONCLUSIONS

Preparation and oversight of TR programs to promote positive adaptations in childhood, including skeletal muscle performance and development, resulting in improved health, quality of life and sports performance. It adds up, also, its potential as preventive and therapeutic parameter of childhood obesity. These programs are applied to children with or without obesity at different ages and with various lengths of time, contributing to wide variation in results. It is notable increase in bone mineral density and lean body mass free of fat and muscle hypertrophy in response to TR in pre pubertal demonstrated by sensitive methods for assessing body composition such as MRI, ultrasound and DEXA.

It is possible that neural adaptations to participate in mechanisms involved in this process, with effect on muscle strength influencing thus the bone and muscle mass, which needs clarification. Additionally, besides preserving or increasing lean body mass, the application of TR also promotes reduction of body fat and waist circumference in children with or without obesity. It is remarkable capability of RT in improving body composition, mainly for their simultaneous effect of reducing fat and increasing muscle mass that stands as a major mechanism of induction of weight loss programs associated with TR.

In this context, accurate methods for anthropometric assessment are required to characterize and measure changes in body composition, contributing to the clarification of mechanisms that induce weight loss, and thus reveal the actual influence of TR programs in children with obesity. However, this requires identification of the individual child's profile, including your physical and cognitive development and maturity, in addition to the qualification of professionals involved in the prescription of RT for children.

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