Effect of strength training on body composition, strength and aerobic capacity of Brazilians adolescents' handball players related with peak growth rate

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Summary

Objective: During adolescence are expected significant increases in growth rate, strength and body proportions. The purpose of this study was to examine changes in strength, body composition and aerobic capacity after a strength training during different peak growth rate periods in adolescent handball players.
Material and method: Twenty-five male adolescents' handball players performed a strength-training program for 8 weeks. The body fat percentage was estimated by Slaughter equation, and the Peak Growth Rate (PGR) defined as: 1= before peak, 2= within peak; 3= after peak. The repetition maximal test (1RM) was performance for upper (bench press) and lower-body strength (leg press). Analyze of variance and post-hoc was computed to determine differences between PGR groups, strength and aerobic capacity.
Results: No significant changes in body composition were found following after the strength-training program. Upper-body strength increased (Δ = 26.3%) in the PGR 1 significantly compared to PGR 3 (Δ = 13.4%) ($p < 0.05$). No significant changes were found between the PGR groups 1, 2 and 3 on aerobic capacity (Δ = 2.9%, 3.4% and 3.8%, respectively) and lower-body strength raise (Δ = 11.3%, 19.0% and 15.2%, respectively) after training program in all groups.
Conclusions: Changes in body composition were observed between PGR. Aerobic capacity and strength do not differ between limbs at early and average PGR. Increased VO2max, upper and lower-body strength was found in late PGR group in handball players following 8 weeks of strength training.

Key words:
Exercise.
Body composition.
Strength training.
Adolescent.

Efecto del entrenamiento de la fuerza sobre la composición corporal, fuerza y capacidad aeróbica de los jugadores adolescentes de balonmano brasileños relacionados con el pico de crecimiento

Resumen

Objetivo: Durante la adolescencia se esperan aumentos significativos en la tasa de crecimiento, la fuerza y proporciones corporales. El propósito de este estudio fue examinar los cambios en la fuerza, la composición corporal y la capacidad aeróbica posteriores a un programa de entrenamiento de la fuerza durante diferentes períodos de la tasa de crecimiento pico en jugadores de balonmano adolescentes.
Material y método: Veinticinco adolescentes, jugadores de balonmano masculinos, realizaron un programa de entrenamiento de fuerza durante 8 semanas. Se calculó el porcentaje de grasa corporal por la ecuación de Slaughter y la tasa de crecimiento pico (TCP) se definió como: 1 = pre-pico, 2= pico y 3 = post-pico. Se realizó la prueba de una repetición máxima (1RM) en los miembros superiores (press de banca) e inferiores (*press* de piernas). Se usaron pruebas de análisis de varianza (ANOVA) y los respectivos post hoc para determinar las diferencias entre los grupos de TCP para las variables de fuerza y capacidad aeróbica.
Resultados: No hubo cambios significativos en la composición corporal después del programa de entrenamiento. La fuerza en los miembros superiores aumentó (Δ% = 26.3) significativamente en el grupo de TCP1 en comparación con el grupo TCP3 (Δ% = 13,4) ($p < 0,05$). No hubo cambios significativos entre los grupos de TCP1, 2 y 3 en la capacidad aeróbica (Δ% = 2,9, 3,4 y 3,8, respectivamente) ni en la fuerza de las extremidades inferiores (Δ% = 11,3, 19,0 and 15,2, respectivamente) después del programa de entrenamiento.
Conclusiones: No se encontraron cambios en la composición corporal y la capacidad aeróbica entre los grupos de TCP. La capacidad aeróbica y la fuerza en los miembros superiores e inferiores no fue diferente en los grupos de TCP. En el grupo de jugadores de balonmano TCP3 se encontraron aumentos en VO_2máx y en la fuerza del tren inferior después de 8 semanas de entrenamiento de la fuerza.

Palabras clave:
Ejercicio.
Composición corporal.
Entrenamiento de fuerza.
Adolescentes.

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Introduction

Scientific evidence[1,2] in children and adolescents have demonstrated the positive effects of physical activity as a stimulus for growth and development as well as in reducing health risk factors. In this period the maturational development expresses itself as a key process in the transition from childhood to adulthood and is characterized by rapid morpho-physiological changes[3]. During and after puberty significant increases in physical performance are observed; these changes are explained, in part, by biomechanical factors and muscular, neural and hormonal development[4-6].

The onset of resistance training during adolescence has been a topic of great interest and debate in the scientific community[7-10]. Several encourage the participation of adolescents in the resistance training program, provided they have proper planning and supervision of a competent professional[7-10].

Research in the last two decades have provided valuable information on the responses of a young organism to such training[11,12]. Early research[11] found that the children reported relatively similar strength gains than those for mature teens and young adults following resistance training at the onset of puberty. So strength training can induce adolescents neuromuscular adaptations resulting in significant increase in muscle strength, but with little change in their anthropometric measurements[13].

Resistance training is a key factor that stimulates growth, muscle hypertrophy, motor development, bone strength and increased strength[14]. In spite of this body of evidence, it has been suggested that resistance training should be done only after peak growth rate (PGR) to avoid impairing bone growth[15,16]. It is suggested that this type of training provides hormonal changes that affect the muscle strength already in prepubertal stages[17]. As a result, this type of training is being increasingly used by health professionals and adolescents.

Therefore, the purpose of this study was to examine changes in strength, body composition and aerobic power during different periods in adolescent handball players from Brazil undergo eight weeks of resistance training.

Materials and methods

Study model

This study has a quasi–experimental design with pre and post tests.

Participants

Volunteers were 25 adolescents' male handball-players, with more than one years of expertise in handball and did not have any practice strength training at least six months prior to the program, all recruited from the community of São Bento do Sul, Brazil. They were divided into three groups according to the peak growth rate in late, average, and early.

Written informed consent was obtained from parents or legal guardians and from children participating in the study according to the Ethics Committee of the Brazil (Protocol 03682812.8.40.0117).

Adolescents were allowed to participate in the study if they met the following inclusion criteria: a) males, b) adolescents, c) handball players, and d) apparently-healthy showing no sign of physical injury in the past six months. Participants were excluded from the study if: a) presented any disease throughout the period of intervention that could interfere with testing measurements, b) did not show-up to the exercise training sessions, and c) did not complete the experimental protocol.

Procedures

Anthropometric assessment. Anthropometric measurements were obtained as described in the "Anthropometric Standardization Reference Manual"[18]. Each measurement was taken three times and averaged for statistical analyses. Body height was measured to the nearest 0.1 cm using a stadiometer fixed to a wall. Individuals stood still with their heads in the Frankfort horizontal plane, barefoot, feet together, and the back surfaces of the calcaneus, pelvic, pectoral girdles and occipital regions in contact with the measuring equipment. Body mass was measured in kg on a digital platform balance, where individuals remain in light clothing, barefoot, feet positioned in the center of the platform, arms next to their bodies. The body mass index (BMI) in was calculated using the following formula: BMI = body weight in kg/body height in m^2. A protocol by was used to estimate the body fat percentage (%BF)[19]. Tricipital and subscapular skinfold sites were measured to the nearest 0.1 mm with a clinical skinfold caliper (CESCORF). Finally, measures of waist and hip circumferences[20] were also collected using a measuring tape. Then, the waist-to-hip ratio (WHR) was calculated.

Strength and aerobic power assessment. Muscle strength was assessed by the test of one-repetition maximum (1-RM) in the upper- (flat bench) and lower-limbs (leg press, 45°). The 1-RM consists in lifting the heaviest weight in a single maximum possible effort, with a full movement and without being able to repeat it again a second time[21]. The test starts with a brief warm-up with light weight below the maximum to prevent possible injuries. After a resting period of 3-min the 1-RM trial was performed. If the first attempt was successful then the following trials were preceded by a 3-min resting interval. Thus, the loads were increased until the individual failed to make a full-motion correctly. At that time was considered that the participant achieved the 1-RM.

Aerobic power was indirectly determined with a 20-m multistage run test and maximal oxygen consumption ($ml \cdot kg^{-1} \cdot min^{-1}$) was estimated according to a previously validated equation[22].

Peak growth rate assessment. The PGR measurements included height trunk, leg length, height, weight and age. The calculation of PGR followed a pattern developed in Canada[23] and validated in a Brazilian population[14]. The equation used was PGR = -9.236 + 0.0002708 (LL x TH) – 0.001663 (A x LL) + 0.007216 (A x TH) + 0.02292 (W/H), where CP: leg length, TH: trunk height-cephalic height, A: age, W: weight, and H: height. The PGR classification is as follows: a) group 1 (more that -1 year = late), b) group 2 (between -1 and + 1 year = average), and c) group 3 (more that + 1 year = early).

Exercise training program. The resistance training program was performed in the mornings four days per week. This program was divided in two blocks, "A" and "B". Following a light walk and jogging on a treadmill the participants performed the resistance training program at 75% of

their previously determined 1-RM with resting intervals of 1 and 3 min between 3 sets and exercises, respectively. The 'A' block was performed on Monday and Wednesday and comprised the following exercises: a) bench press in a flat and inclined bench, b) peck deck, c) front shoulder press, d) lateral raise, e) Triceps pulley, f) leg press at 45°, g) "Smith" squats, h) leg extension, and i) rectus abdominis floor exercise. The block 'B' was performed on Tuesday and Friday and included: a) open and closes pull-ups, b) dumbbell fly, c) barbell curl and barbell biceps curl on a "Scott" bench, d) abductor and adductor leg exercises on a machine, e) calf exercises, and f) oblique abdominal exercises. All sessions always followed the same exercise order. All assessments and follow-up during the training sessions were performed by qualified trained staff from the Physical Activity Unit of the Universidad do Costestado (UnC).

Statistical analysis

All analyses were computed using the MedCalc statistical software (Ostend, Belgium). Descriptive statistics mean (M), standard deviation (±SD), frequencies and percentages were obtained. One-way analysis of variance (ANOVA) tests were used to determine differences between maturational stages and PGR periods. Tukey's post hoc were computed following significant ANOVA's F ratios. The variance equal Levene's test was applied, and when your attended assumptions adopted the parametric statistics. Statistical significance was set a priori at $\alpha \leq 0.05$.

Results

Participant's characteristics are presented in Table 1. Significant between-group differences were found on mean age, weight, height, BMI, and WHR (Table 1).

ANOVA results showed that the mean VO_2max was higher in the group 3 than in groups 1. Upper-body strength (in kg) was higher in groups 3 than in group 1 and 2 ($p < 0.05$) and upper-body strength increased in the PGR group 1 more than others ($p < 0.05$). Finally, mean lower-body strength was higher in the group 3 than in groups 1 and 2. (Table 2).

Table 1. Descriptive statistics for participants based on peak growth rate.

Variable	Peak Growth Rate			*P*
	Group 1 (n=7)	Group 2 (n=10)	Group 3 (n=8)	
Age (yr.)	13.5 ± 0.3	13.9 ± 0.4	14.2 ± 0.7	0.055
Body weight (kg)	38.0 ± 7.7	48.1 ± 9.0a	60.3 ± 10.7a	0.005
Body height (cm)	148 ± 2.7b	157 ± 13.7a	170.0 ± 7.3a,b	0.002
BMI (kg/m²)	18.6 ± 1.7	22.1 ± 2.3a	23.8 ± 2.3a	0.001
Body fat (%)	18.6 ± 6.2	16.8 ± 4.6	18.1 ± 4.7	0.586
WHR	0.82 ± 0.03	0.77 ± 0.03a,c	0.81 ± 0.02	0.001

Note: Group 1: late PGR; Group 2: average; Group 3: early PGR; WHR: waist to-hip ratio. $p < 0.05$, a: different from Group 1; b: different from Group 2; c: different from Group 3.

Table 2. Changes on aerobic power and strength variables after resistance training program by groups.

Variable	PGR	Pre	Post	Difference (Post – Pre)	Δ%
VO_2max (ml·kg^{-1}·min^{-1})					
	Group 1	45.6	46.9	1.3	2.9
	Group 2	48.9	50.5	1.7	3.4
	Group 3	52.1[a]	54.1[a]	2.0	3.8
Upper-body strength (kg)					
	Group 1	19.0	24.0	5.0	26.3[c]
	Group 2	27.4	33.8	6.5	23.6
	Group 3	58.9[a,b]	66.7[a,b]	7.9	13.4
Lower-body strength (kg)					
	Group 1	57.5	64.0	6.5	11.3
	Group 2	110.4	131.4	21.0	19.0
	Group 3	174.3[a,b]	200.7[a,b]	26.4	15.2

Note: $p < 0.05$, a: different from Group 1; b: different from Group 2; c: different from Group 3.

Discussion

The adolescence is a stage of life where major physical and maturational changes occur. In some individuals of the same chronological age but more mature than their respective counterparts, this stage may provide advantages in terms of sports performance due to greater strength gains and increased muscle mass[24]. In this study, strength and aerobic capacity based on the PGR following a resistance training program in adolescent handball practitioners were evaluated.

Body composition (age, body weight, height, BMI, WHR), was different between groups, with a gradual increase as the adolescents advance in their growth period; however, these changes are expected and natural once groups are in a period of growth, development and maturation[25]. In the present study, we did not observe changes in body fat percentage, which remained stable during periods of PGR. This finding may be explained by the fact that teenagers were regular practitioners of handball, and regular physical activity stabilizes body fat in adolescents[26].

The peak growth rate (PGR) considers the somatic age of adolescents, an indicator frequently used in studies for practical purposes. In this study, the PGR was found at about 14 years, similar to other reports[19] and opposite to others[27], where PGR was found close to 12 years of age.

The PGR is related to other factors connected to physical fitness and motor performance. In a longitudinal study of soccer players, the PGR was achieved at an age of 13.8 yr., with a concomitant development of VO_2max and strength of upper- and lower-limbs compared to the present study[28]. However, others[14], studied the association between PGR and motor performance and found a trend towards improvement in aerobic fitness and strength following the PGR, as corroborated in the present study. Peak force development occurs at about 1 to 1.5 years after the age of PGR of body height[29], which was evidenced in the present study.

In this study there was significant upper or lower-body strength change following a training program only for group of early develop-

ment (Table 2). Probably this changes can be because shortly after the PGR, there is a change in hormone profile, especially circulating testosterone, which is known to affect muscle strength development[30,31]. In muscle testosterone stimulates protein synthesis and inhibits protein degradation, combined, these effects account for the promotion of muscle hypertrophy and subsequent increase in muscle strength in response to resistance training[32]. Hormonal changes that accompany puberty contribute to a significant increase in strength depending on the increase in muscle mass[33].

One of the findings of the present study was the 26% of Δ variation at upper-body strength in late development group compared with early (Table 2). These findings reinforce the Lloyd *et al* (2009)[34] highlights that muscle power and strength can be developed at the beginning of the PGR to adulthood. Strength training can elicit significant gains in muscle strength above 10% when programs last from 4 to 19 weeks[35,36]. However, maturity has been found to be a significant predictor of such changes[36]. The training program used in the present study (i.e., 8 weeks), did not elicit a sufficient stimulus to produce significant changes in body composition and aerobic fitness in adolescents early or average, however the magnitude were different.

A study in prepubescent children[37], showed that resistance training during this stage is inefficient and does not lead to strength gains. This assertion can be justified with the pubertal growth, since it is influenced by the release of important hormones such as growth hormone (GH), insulin-like growth factor I (IGF-I), and sex steroids that induce increases in growth rate, muscle and bone maturation, functional ability and several metabolic adaptations[38]. These alterations can and will influence the physical development, capacity and performance during childhood and adolescence[6].

A limitation of this study was the small number of individuals evaluated; however, various studies reported in a meta-analysis[36] included smaller samples than in this study. Nevertheless, further research is needed to better understand the influence of PGR on strength training in adolescents.

Conclusion

Adolescents at different times of the PGR showed different body weight, height, BMI and WHR. Following 8 weeks of a resistance training program, no significant changes in VO_2max, upper-body strength and lower-body strength were observed in late and average PGR. In contrast players at after PGR show a significant change after the program for VO_2max, upper and lower strength gain. The early PGR show a significant magnitude variance in response to training sessions than late PGR.

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Fallecimiento del Dr. D. Ramon Balius i Juli

La Sociedad Española de Medicina del Deporte lamenta comunicar el fallecimiento de uno de sus miembros más queridos, el Dr. D. Ramón Balius i Juli. El Dr. Balius era Miembro de Honor de la Sociedad y hasta recientes fechas, y a pesar de su avanzada edad, gozó de una lucidez e inteligencia excepcionales para poder seguir obsequiando a los lectores de la Revista Archivos de Medicina del Deporte con su sección "Arte en el Estadio" que era un elemento caracterizador y exclusivo de la revista.

Fue uno de los padres de la Medicina del Deporte y desarrolló una excelente carrera profesional.

Lamentamos muy sentidamente su irreparable ausencia.

D.E.P.