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Effect of growth level on changing pattern of cardio–respiratory fitness index (Vo2 peak) in 8 to 14 year old non-athletic girls

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ABSTRACT

Cardiovascular respiratory endurance linearly increases since childhood and reaches its jumping point in puberty. Maximal oxygen consumption is an index of efficiency measurement for oxygen transmission system. Children and adolescents with equal chronological age have different growth levels. This biological parameter affects behavior of sex hormones, climatic conditions, genetic mutations and body composition (allometric equations related to body size). Hence, it is very important to consider growth level of puberty while drawing physico-motor fitness norms or processes of sports talent programs. Seven hundred 8 to 14 year old girl students in seven age groups were classified to three growth levels of normal, early or late. Anthropometric parameters and maximal oxygen cost were measured. In terms of anthropometric factors of height, weight and body mass index at various ages and different growth levels, no statistically significant difference was found ($p>0.05$). A significant difference was observed between three growth levels according to Vo2 peak body weight at age of 9 ($p <0.05$) and no significant difference was found at other ages. Maximal oxygen consumption tended to increase and decrease proportional to growth level in 8 to 14 year old girls in terms of absolute and relative values, respectively.

Key words: Maximal oxygen consumption, growth level, dental age.

INTRODUCTION

Physical performance is associated with development and growth. Also, knowledge of natural processes of development and growth is important for assessing and understanding role of physical activity and its impact on these processes [12]. Children and adolescents are in different growth conditions which affect fitness of their physiological organisms proportional to growth level. This point is often neglected by domestic researchers because cardiovascular respiratory endurance is among the prominent factors of physical fitness which is related to health.

Cardiovascular respiratory endurance is the ability of cardiovascular and respiratory systems to supply fuel and oxygen and is the ability of active muscles for optimal use of substrate during process of oxidation while exercising, which occurs below the lactate threshold, so that a ready person can continue his/her activities in a relatively long term without imposing excessive mechanical-physiological stress on his/her organism [12]. Maximal oxygen consumption (VO_{2max}) is an index for aerobic fitness measurement which is determined by absolute (l per min) and relative (ml oxygen proportional to components of total weight, pure mass, height and body surface area) scales.

Cross-sectional and broad VO_{2max} studies on non-grown people have indicated progressive increase in its absolute value with their age increase. This pattern has a slower rate for girls. With increased age, mean of absolute aerobic capacity linearly increases, which is higher in boys at all ages than their peer girls. The effect of gender differences on VO_{2max} changes is small and its increase is equal until age of 12 years old. But after 12 years old, VO_{2max} mean of girls becomes plateau-like while it continues to increase in boys so that, at age of 16, gender differences of VO_{2max} between these two genders exceeds 50%, even absolute VO_{2max} of girls tends to decrease from 15-18 to 20-23 years old [2].

When VO_{2max} is determined in terms of relative value of body weight, it decreases in boys from 59 ml/kg/min at 15-18 years old to 54 ml/kg/min at 20-23 years old; this physiological parameter in 12-13 year old girls reduces from 51 to 41 ml/kg/min in those aged 20-30. Differences of body composition somehow describe these gender differences in weight-dependent VO_{2max} because boys have higher lean body mass (LBM) than girls, even before puberty [2].

Growth or biological maturity is defined as the process of growing up or progress of the organism to growth and development status. Non-grown people considerably differ from each other in their speed of growth. Biological and growth development of children and adolescents does not continue proportional to their chronological age. There is dispersion in biological age or growth level of a group of same-gender children with the same chronological age so that some children may be more progressive in a growth aspect than their chronological age and some others may have delayed growth. Scientific evidence reveals that growth affects factors of strength and muscular endurance, aerobic capacity and anaerobic power [3].

Biological maturity is a determining and prominent agent of physiological responses to physical activity and exercises. Anatomical and physiological changes of organisms are involved in biological puberty. Each of the progressive structural or functional changes is an indicator for measuring biological maturity but the pattern of growth curves can be also different for anatomical and physiological variables. Growth or biological maturity is determined by morphological, gender, skeletal and dental techniques. In dental age method, the person's teeth are measured at two levels of six months to three months old and six to thirteen years old. In other words, children with early puberty have early teeth [9].

Several studies have been conducted on maximal aerobic power in boy and girl children and adolescents. For example, maximal oxygen consumption of late-puberty girls has been significantly more than other growth conditions [1]. Cross-sectional studies by Bouchard (1970) and Holtman and Ruten Franze (1982) showed that late-puberty boys and girls had more VO_{2max} than early-puberty boys and girls at the same age. Higher percentage of fat in early-puberty group shows higher body weight in them and this change in body composition imposes excessive load on oxygen transmission system and makes the weight-proportional maximal oxygen consumption of the late-puberty group higher than that of their early-puberty peers. Furthermore, lower level of cardiovascular fitness in early-puberty group may depend on decreased level of physical activity, laziness and more fat mass, resulting in metabolic syndromes or complications. However, absolute values of maximal oxygen consumption in early-puberty boys and girls have been reported more than their late-puberty peers and these differences gradually disappear at the end of maturation process [2].

Also, Malina et al. (2004) studied broad relationship of VO_{2max} and growth level in boy and girl students. The participants were separated to three groups of late, normal and early puberty. Girls' age of maturation was determined based on the beginning of menstrual period. In boys, absolute VO_{2max} with early puberty was higher in all exercises. The girls with early and normal puberty had higher absolute VO_{2max} than their peers with late puberty. These findings suggested that the time pattern of evolution of aerobic fitness during puberty corresponds to puberty [12].

Therefore, measuring children's performance, especially while exercising, should be done based on their growth as well as their chronological age and negligence of this point could lead to the imbalance between capabilities and physiological abilities relating to their growth while doing physical activity. Most scientific observations have emphasized dependence of growth changes and physico-motor fitness factors during adolescence and have revealed that this difference is slight or disappears in the late adolescence. So, it is necessary to consider components of growth or biological age in adolescents while measuring physical fitness talents and capabilities. In this regard, few studies have been conducted on the role and effect of growth on maximal oxygen consumption; thus, the present investigation included growth age levels from 8 to 14 years in a reasonable sample size because the highest difference between chronological age and growth level can be observed in this age range.

MATERIALS AND METHODS

This study was an analytical-comparative one with 2*3 factorial designs. 700 girl students aged 8 to 14 years old were selected from elementary and secondary schools of city of Qazvin using screening method. The participants' chronological age was separated to 7 levels and each age group was divided to three groups of early, normal and late puberty based on growth level. Coordinate of dental aging techniques was taught to the research by a dentist specialist using a model and three participants from growth stages of permanent teeth on lower and upper jaws [9]. Then, the people were classified in three growth levels of normal, early and late. Variables of anthropometry and aerobic capacity of the groups were compared by two-way ANOVA. The advantage of this study was in applying dental age for determining growth level. In this regard, Glutay et al. reported high correlation between dental age and criterion method (skeletal age) [4].

Kolmogorov-Smirnov test and Lone test were used for determining normal distribution of data and measuring variance homogeneity of three groups to apply parametric multivariate test, respectively. To assess parameters of body composition and maximal oxygen consumption in these three groups, multivariate analysis of variance and LSD post hoc tests were used. Then, height, weight and body mass index were calculated by standard methods. Aerobic capacity (min/ml/kg) was estimated according to field test of Curetone [7]. In one mile constant running, the participant was asked to choose either slow running or walking any time s/he felt helpless during the maximal activity. Maximal oxygen consumption was calculated according to Curetone's prediction curved equation after recording components of runtime, age, gender and body mass index.

RESULTS

First, descriptive statistics including mean, standard deviation and prediction errors were determined in age groups of 8 to 14 years old and changes of these factors were specified in the mentioned age range. Table 1 shows anthropometric characteristics of eight year old group. Then, the profile of absolute and relative VO_{2max} changes of girls was investigated at three growth levels (Table 1).

Table (1): Anthropometric characteristics of 8 year old girls

Statistical index Variable	Mean	SD	SEE	Min	Max	Range
Weight (kg)	**28.32**	**7.5**	**0.77**	**20**	**55**	**35**
Height(cm)	**129**	**0.06**	**0.006**	**0.15**	**1.49**	**0.34**
BMI(kg/m^2)	**16.6**	**2.96**	**0.303**	**12.40**	**26.19**	**13.79**
Dental age	**7.78**	**0.93**	**0.09**	**6**	**10**	**4**
Chronological age	**8**	**0**	**0**	**8**	**8**	**0**

Statistical analysis of the data showed that weight of the participants from 8 to 14 years increased by 26.64 kg and the maximum rate of change was from 10 to 11 years old as +4.95 kg. But, at age of 12, no significant difference was observed in three growth levels of the age ranges. According to multivariate ANOVA, body weight of 14 year old late-puberty participants was less than that of 12 year old group with normal puberty ($p<0.05$).

Height of 8 to 14 year old girls increased by 30 cm and, similar to weight, the maximum change was in 10-11 year old as +6 cm. Nevertheless, changes of height were not significant in each age group at three growth levels ($p> 0.05$). Also, mean height of 11 year old group with normal puberty was less than that of 14 year old group with late puberty whereas there was no significant difference between 11 year old group and each of the other age groups ($p> 0.05$). Figure (1) shows the process of height changes for 8 to 11 year old girls (Figure 1).

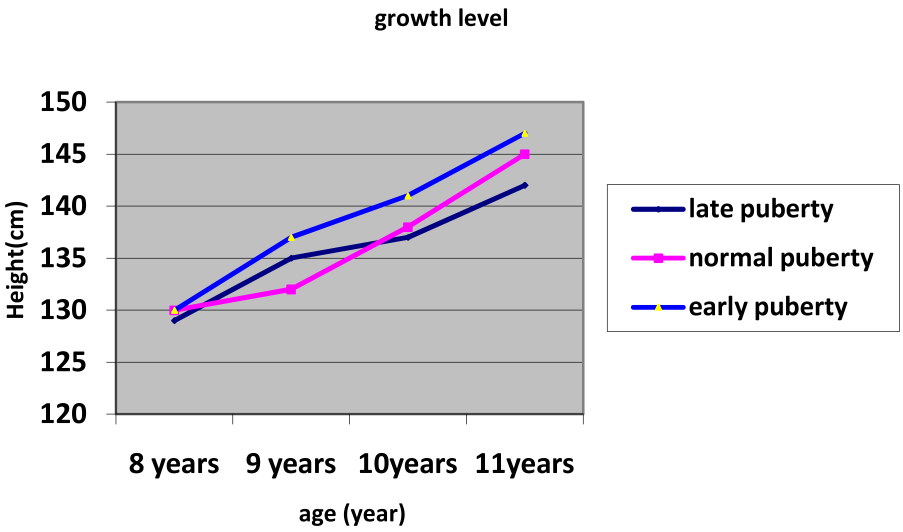

Figure (1): the process of height changes for 8 to 11 year old girls at three growth levels

And Figure (2) shows process of height changes for 8 to 14 year old girls at three growth levels.

As can be seen, body mass index was still increasing from 8 to 14 years old and the maximum change was observed from 8 to 9 years old which was equivalent to 1.16 kg/m2 (Figure 2).

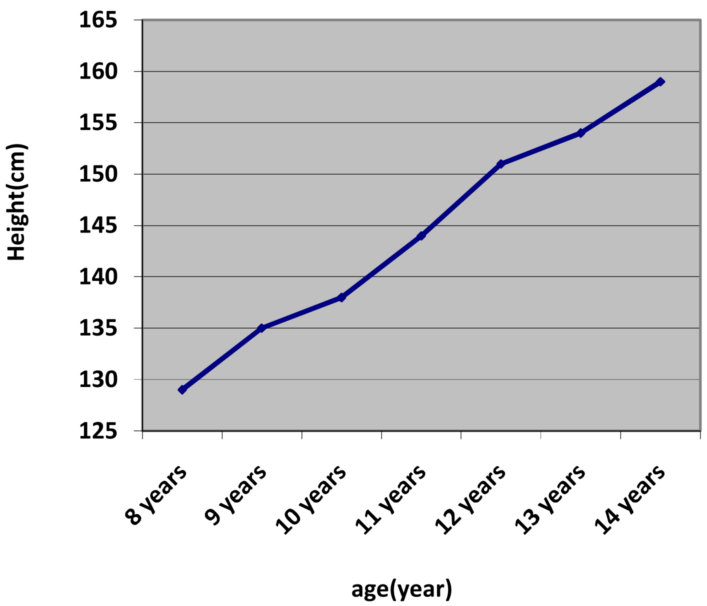

Figure (2): Process of height changes for 8 to 14 year old girls at three growth levels

Investigation of change pattern of VO_{2max} in equal age groups and different growth levels showed that the only difference was in the 9 year old group at three puberty levels; i.e. VO_{2max} (ml/kg/min) of 9 year old girls with late puberty was significantly higher than their early-puberty peers (Figure 3).

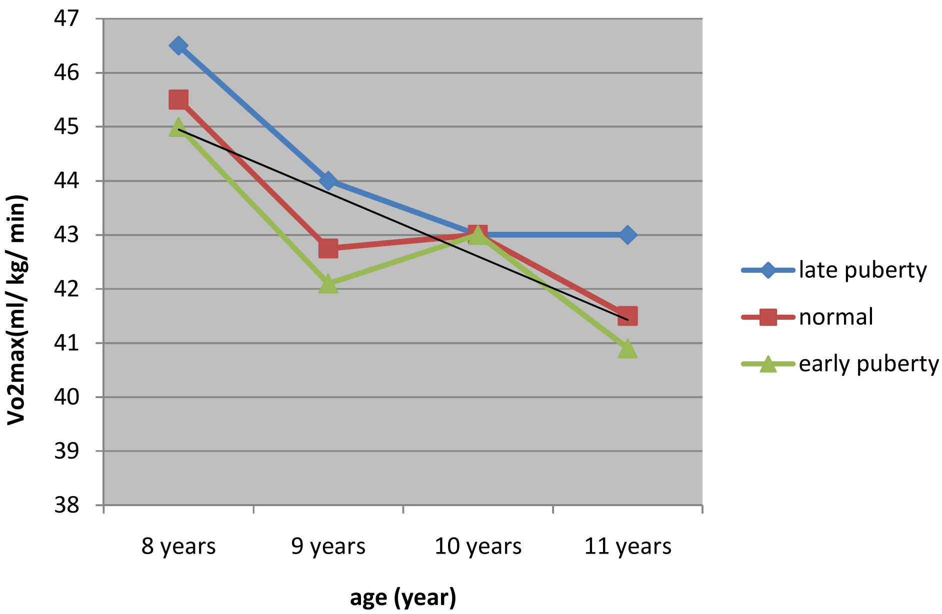

Figure (3): Process of VO_{2max} changes of 8-11 year old girls at three growth levels

Aerobic capacity of other age groups was not statistically significant at different growth levels. Figure (4) demonstrates process of VO_{2max} changes in 8-14 year old girls without intervening growth level (Figure 4).

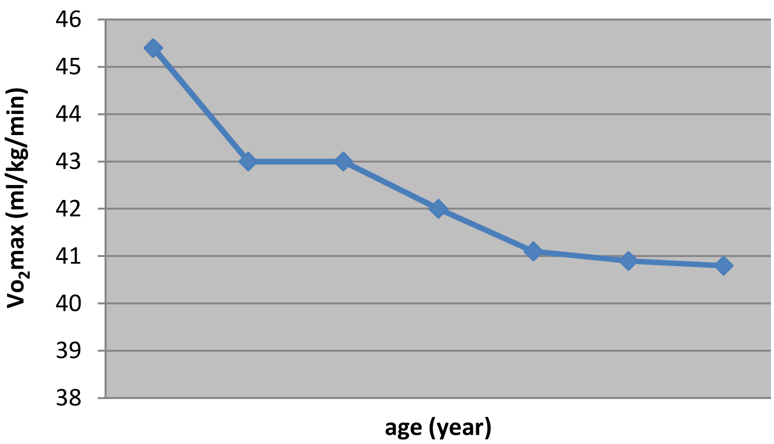

Figure (4): General changing process of maximal oxygen consumption in 8-14 year old girls in terms of relative values

Scientific evidence has shown that, with increase in age, maximal oxygen consumption tends to decrease based on weight in different races. But, the results of this study revealed that, in 13 year old late-puberty group, aerobic capacity was significantly lower than that in 8 year old group with normal and early puberty while this pattern of VO_{2max} changes was not considerable at other ages. VO_{2max} of 13 year old group was expected to be evidently less than that of 9, 10, 11 and 12 year old girls. On the other hand, VO_{2max} of 10 year old group was not significantly different at all three growth levels from that of 8-14 year old group at three growth levels ($p> 0.05$). Also, VO_{2max} of 12 year old late-puberty group was only significantly different from 8 year old late-puberty group.

Investigating the Findings:

Studies have shown that pattern of height and weight changes has rapid growth in juvenility, is relatively uniform in middle childhood, has a jump in adolescence and then mildly increases until reaching adulthood height. But weight factor is constantly changing during lifetime due to endogenous and exogenous interventions. Although initial weight increase is higher in adolescent girls so that they are heavier than their peer boys, boys take precedence from their peer girls at the developmental jumping point. This process overlaps throughout youth developmental period of both genders which is usually evident in girls two years earlier than boys. Height growth of girls ends at 16 years old; but, it continues in boys until 18. Nevertheless, height increase of some boys continues until 22. Body mass index (BMI) is commonly used based on 5 to 95 percentile ranks for children and adolescents. This index depends on total body fat and is used for analyzing height and weight proportion during the development process and prescribing diet in epidemiology and clinical studies. In addition, this index provides the possibility of measuring body composition in order to diagnose excessive weight or obesity in children, particularly from the perspective of investigating risk factors for metabolic syndrome and a sedentary lifestyle (hypo kinetic diseases) [15].

Increased fat mass in girls occurs faster than their peer boys and this pattern is continuously obvious throughout adolescence. Boys experience uniform body fat mass at 13-15 years old or in adolescence jump period while this parameter in girls is almost 1.5 times of that in boys in late adolescence and early adulthood. Role of more fat mass in girls is like excessive mechanical load which affects efficiency reduction of cardiovascular respiratory system while doing submaximal and exhaustive activities [14].

In Shatlous's study, early-puberty boys and girls had taller height and heavier weight compared to their peers at normal and late-puberty levels. In the present study, weight variable had the highest increase from 10 to 11 years old, which was in line with Tanner's study on English children [3]. In this study, the largest increase of girls' height was from 8 to 9 and from 11 to 12 years old and scientific evidence showed that girls reached the highest height from 11.5 to 12 years old. Development of initial height gradually stopped at about 14 years old but, at the end of 16, it significantly increased again [5]. In the present study, the greatest increase in girls' height was observed from 8 to 9 and from 11 to 12 years old. In anthropometric studies, body density is evaluated proportional to body size. Scientific evidence has reported mean fat density of human body at conventional temperature using biopsy method as 0.9±0.00068 kg/L. However, density of fat free mass (FFM) depends on relative amounts of water, protein and minerals (without glycogen stores). Many studies have reported that FFM density range of 2 to 18 year old boys and girls is 1.0715-1.099 kg/L which is 1.10 kg/L in adulthood without illness syndrome [12, 6].

As mentioned before, biological process of development and growth leads to structural and functional changes in living organisms. Some researchers consider applying coordinates of allometric equations ($Y=ax^b$) for calculating the confounding role of puberty (despite uncontrolled growth level) (6, 15, 13) because this mathematical method enables optimal prediction of parameters of oxygen cost, respiratory capacities, running glycoltic power (variables Y) based on anthropometric changes in weight, height, pure mass and body surface area (parameters x) using a given index [15].

Previous studies on different species of mammals with weight range of 0.07 to 500 kg have reported size of b index as 0.87 for girl and boy endurance athletes as 0.81 and 0.61, respectively, and for non-grown boy and girl non-athletics, allometric equation's index size of 0.75. Hence, authors sometimes prefer to calculate children's aerobic capacity proportional to body weight changes in $ml.kg^{-0.75}.min^{-1}$ scale compared to relative adult scale of $ml.kg^{-1}.min^{-1}$ [15].

In this study, VO_{2max} as measurement index of aerobic capacity in girls (ml/kg/min) had a descending trend from 8 to 14 years old (Figure 4). This decline was probably due to increased body size and dimensions, which corresponded to Kluvsen's (1985) and Fomon's (2007) research on 11 to 14 year old children's aerobic capacity.

The review of Mirold Bailie from four previous studies indicated reduced aerobic capacity of children [3]. In this study, changes in aerobic capacity at different levels of puberty were significantly different at three growth levels only in 9 year old girls. In contrast, Kamper et al. measured aerobic capacity of 102 male and 131 female students on a treadmill with increasing slope until 50% and constant speed of 8 km/h within six min using respiratory gas analysis. Based on Tanner's method, girls with early puberty had relatively lower VO_{2max} than peer boys due to being taller and heavier [10]. On the other hand, VO_{2max} depended on factors of height, fat free mass and body surface area in the process of development. But, intensity of this relationship with fat free mass has been reported more than 2 other factors [11].

It should be noted that, regarding allometric relations, cardiac-respiratory performance is more related to size, body weight and degree of maturity than chronological age. Although in this study, size of index b was not calculated in allometric prediction equation, results of the present study revealed that maximum oxygen consumption was statistically significant only for the 9 year old group at different growth levels.

CONCLUSION

VO_{2max} change pattern (ml/kg/min) of 8 to 14 year old girls tended to reduce in the process of growth. But, it was only remarkable for 9 year old group with early and late puberty. Nevertheless, process of aerobic capacity changes in the studied (Iranian) girls with the biological maturity intervention was in line with VO_{2max} pattern of European girls (Figure 5) [8, 15, and 14].

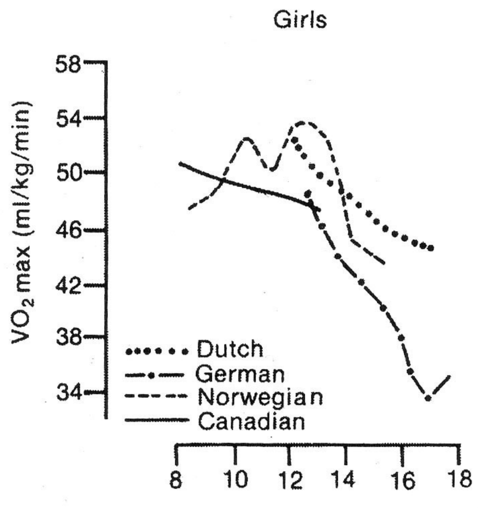

Figure (5): VO_{2max} changes from 4 longitudinal studies

Change trend of aerobic capacity in 12 year old group (equivalent to physio-metabolic events of growth period) was expected to be much faster than that of 9, 10 and 11 year old groups; but, their VO_{2max} difference was not significant. According to these findings, it appears that physical education and sports trainers should consider interaction of biological maturity and physical performance in girls because ignoring biological phenomenon is likely to show inefficiency of the trainers' understanding in evaluation of athletic talent programs or drawing motor ability levels in adolescence. Finally, in the light of these findings, it is recommended to investigate efficiency of allometric equations (with emphasis on index b) based on oxygen cost during standard submaximal activity and anthropometric confounding at growth levels of 8 to 14 year old girls.

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