HIGH INTENSITY SPORTS PROMOTE THE DEVELOPMENT OF HEALTHY BONE TISSUE

ESPORTES DE ALTA INTENSIDADE PROMOVEM O DESENVOLVIMENTO DE TECIDO ÓSSEO SAUDÁVEL

DEPORTES DE ALTA INTENSIDAD PROMUEVEN EL DESARROLLO DEL TEJIDO ÓSEO SALUDABLE

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Zhonghu Fu[1]
(Physical Education Professional)
Lijun Gao[1]
(Physician)

1. Competitive Sports Center, Chongqing College of Mobile Communications, Chongqing, 401520,China.

Correspondence
Zhonghu Fu
Chongqing, China, 401520.
fzh282468598@163.com

ABSTRACT

Introduction: Physical exercise can promote the growth and development of bones and delay bone loss; it is more effective when started young. Objective: This paper analyzes the impact of human exercise on human bone health. Methods: A questionnaire survey was conducted on elementary school students, and basic physical fitness monitoring was conducted. The physical fitness monitoring indicators covered ten items such as height and weight. Results: After the questionnaire survey and physical examination, it was found that there are differences in various physiological indicators between students who exercise frequently compared with students who exercise less frequently. Conclusion: Physical exercise can promote skeletal tissue development, therefore, young people should increase the practice of physical exercise. ***Level of evidence II; Therapeutic studies - investigation of treatment results.***

Keywords: Bone Growth; Sports; Growth Hormone.

RESUMO

Introdução: O exercício físico pode promover o crescimento e desenvolvimento de ossos e postergar a perda óssea; é mais eficaz quando iniciado na infância. Objetivo: Este estudo analisa o impacto do exercício na saúde óssea humana. Métodos: Um questionário de sondagem foi conduzido com alunos do ensino básico; um monitoramento de preparo físico básico foi feito. Os indicadores do monitoramento de preparo físico cobriam dez itens, como altura e peso. Resultados: Após o questionário de sondagem e exame físico, verificou-se que havia diferenças em vários indicadores fisiológicos entre os alunos que faziam exercícios com frequência e aqueles que se exercitavam com menor frequência. Conclusão: O exercício físico pode promover o desenvolvimento do tecido esquelético. Portanto, jovens devem aumentar a prática de exercícios físicos. ***Nível de evidência II; Estudos terapêuticos – investigação de resultados de tratamento.***

Descritores: *Desenvolvimento ósseo; Esportes; Hormônio do Crescimento.*

RESUMEN

Introducción: El ejercicio físico puede promover el crecimiento y desarrollo de huesos y retardar la pérdida ósea, y es más eficaz cuando iniciado en la infancia. Objetivo: Este estudio analiza el impacto del ejercicio físico en la salud ósea humana. Métodos: Se condujo una encuesta de sondeo con alumnos de la enseñanza básica y se hizo un monitoreo de la preparación física básica. Los indicadores del monitoreo de preparación física abarcaban diez ítems, como altura y peso. Resultados: Tras la encuesta de sondeo y examen físico, se verificó que había diferencias en varios indicadores fisiológicos entre los alumnos que hacían ejercicios con frecuencia y aquellos que se ejercitaban con menor frecuencia. Conclusión: El ejercicio físico puede promover el desarrollo del tejido esquelético. Por lo tanto, jóvenes deben aumentar la práctica de ejercicios físicos. ***Nivel de evidencia II; Estudios terapéuticos – investigación de resultados de tratamiento.***

Descriptores: *Desarrollo óseo; Deportes; Hormona del Crecimiento.*

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INTRODUCTION

Exercise can significantly promote the growth and development of adolescent bones. Starting exercise in adolescence has a more pronounced effect on the bones than when starting exercise in adulthood. At present, most of the literature reports on the influence of exercise on the growth and development of bones are experimental studies of exercise intervention, and most of our lives are leisure and entertainment-based exercises.[1] What kind of effect does this exercise have on the growth and development of bones during puberty? What mechanism does it achieve? In addition, the growth and development of puberty is a continuous and dynamic process. At present, there are few longitudinal tracking studies in this area. Therefore, this subject will track and measure bones' growth and development characteristics and related influencing factors. This provides a new attempt to study the growth and development of bones in adolescence and the influencing factors.

METHODS

Research object

The subjects are elementary school students. After a physical examination confirming that there is no history of diseases affecting bone metabolism, 165 students are eligible.[2] Their average age is 11.0±0.8 years.

The height is 142±7.7 cm, and the weight is 38.6±8.1 kg. We introduced the experiment process to the subjects and parents, and the experiment started after the parents' consent and the cooperation of the students.

Experimental design

This experiment is divided into two parts: questionnaire survey and experimental measurement. The questionnaire survey mainly understands the participants' usual participation in sports and makes corresponding scores.[3] We conducted a total of 3 experimental measurements. We tested the subjects' height (H), weight (W), fat content (FM), lean mass content (LM), body bone density (BMD), bone mass (BMC), and bone area (BA). At the same time, volunteers also need to test serum estradiol (E2), IGF-I, and leptin (Le).

Test content and method

Testing of general indicators

The weight and height adopt the "Height and Weight Electronic Measuring Instrument." The weight measurement is accurate to 0.1 kg. The value of height measurement is accurate to 0.5 cm.

Determination of whole-body bone density, bone mass, bone area, and body composition

Whole-body bone density, bone mass, bone area, fat content, and lean body mass content were measured with dual-energy X-ray absorptiometry (DEXA) (WIUSA). The measurement error of bone mass is 0.6%. The measurement error of bone area is 0.8%.

Determination of hormones

Specimen preparation Blood specimens are collected on an empty stomach at 6-8 a.m[4] After the blood was collected, the blood was left to solidify and centrifuged. The serum was extracted and stored in a -200C refrigerator for analysis.

Questionnaire survey of exercise

The exercise status of the subjects used the scoring standard of the World Health Organization to evaluate the exercise status. The questionnaire mainly investigates the three favorite sports, the duration, intensity of each kind of sport, and the number of times to participate in sports each week.[5] The exercise score is calculated according to the following formula: exercise score = (frequency × intensity index × duration × load mode).

Movement analysis and simulation of human lower limb exoskeleton

We use the multi-rigid body kinematics method to establish the Denavit Hartenberg model of the lower extremity exoskeleton. Q_1, Q_2, Q_3 is the center of the hip joint, the center of the knee joint, and the center of the ankle joint. We establish the base coordinate system $O_O - X_0Y_0Z_0$ between the hip joint and the torso and establish the link coordinate system in turn. The homogeneous coordinate equation of the joint transformation of the two connecting rods is:

$$\begin{bmatrix} r_i \\ I \end{bmatrix} = M_{ij} \begin{bmatrix} r_j \\ I \end{bmatrix} \quad (1)$$

In the formula, $r_i = [x_i, y_i, z_i]T$ is the space coordinate value of the i connecting rod. $r_j = [x_j, y_j, z_j]T$ is the space coordinate value of the j link.[6] The transformation matrix M_{ij} of two adjacent links is:

$$M_{i-1i} = \begin{bmatrix} c\theta_i & -s\theta_i \cdot ca_i & s\theta_i \cdot sa_i & l_i c\theta_i \\ s\theta_i & c\theta_i \cdot ca_i & -c\theta_i \cdot a_i & l_i s\theta_i \\ 0 & sa_i & ca_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (2)$$

According to the movement of the exoskeleton of the lower limbs in the sagittal plane and the established D-H model, the parameters of the transformation matrix can be determined as:

$$M_{0n} = M_{01} \cdot M_{12} \cdots M_{i-1i} \cdots M_{n-1n} \quad (3)$$

The kinematics analysis of the hip, knee, and ankle joints is to find their movement rules during the gait cycle. We bring the known parameters into equation (1) to find the spatial positions of the three joints in the sagittal plane, and the calculation is as follows:

$$\begin{bmatrix} x_1 \\ y_1 \\ 0 \\ 1 \end{bmatrix} = M_{01}^{-1} \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix} = \begin{bmatrix} c\theta_1 & -s\theta_1 & 0 & l_1 c\theta_1 \\ s\theta_1 & c\theta_1 & 0 & l_1 s\theta_1 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}^{-1} \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix} \quad (4)$$

$$\begin{bmatrix} x_2 \\ y_2 \\ 0 \\ 1 \end{bmatrix} = M_{02}^{-1} \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix} = \begin{bmatrix} c\theta_{12} & -s\theta_{12} & 0 & l_1 c\theta_1 + l_2 c\theta_{12} \\ s\theta_{12} & c\theta_{12} & 0 & l_1 s\theta_1 + l_2 s\theta_{12} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}^{-1} \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix} \quad (5)$$

$$\begin{bmatrix} x_3 \\ y_3 \\ 0 \\ 1 \end{bmatrix} = M_{03}^{-1} \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix} = \begin{bmatrix} c\theta_{123} & -s\theta_{123} & 0 & l_1 c\theta_1 + l_2 c\theta_{12} + l_3 c\theta_{123} \\ s\theta_{123} & c\theta_{123} & 0 & l_1 s\theta_1 + l_2 s\theta_{12} + l_3 s\theta_{123} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}^{-1} \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix} \quad (6)$$

Putting the $\Theta_1(t) - t$, $\Theta_2(t) - t$, $\Theta_3(t) - t$ obtained in the second section into equations (4) to (6), the relationship between the spatial positions of the hip, knee, and ankle joints to time can be obtained respectively, namely $x_1(t) - t$, $y_1(t) - t$, $x_2(t) - t$, $y_2(t) - t$, $x_3(t) - t$, $y_3(t) - t$.

Data processing

We use SAS (Statistics Analysis System) statistical software to analyze the data. We performed T-tests on the indicators between the frequent and infrequent exercise groups in the first, second and third time, respectively.[7] Data analysis is carried out based on a relevant theoretical basis, rather than relying solely on data results. The data are reported using the mean ± standard deviation (SD). p<0.05 is considered significant.

RESULTS

Comparison of relevant indicators in the basic measurement between the frequent and infrequent exercise groups

We performed a T-test on the basic measurement values of related indicators between regular and infrequent exercise groups. The results showed no significant differences in height, weight, BMI, FM, LM and BMD, BMC, BA, serum leptin, estradiol, and IGF-I between the regular exercise group and the infrequent exercise group. (Table 1)

Comparison of related indicators in the second measurement of the frequent and infrequent exercise group

To explore whether exercise habits have an important influence on the growth and development of adolescents during the rapid growth stage of adolescence, we conducted a statistical analysis of the second measurement results of the regular exercise group and the infrequent exercise group.[8] Calculate whether the differences in indicators between the two groups are significant. The results showed that BMD and BMC in the regular exercise group were significantly higher than those in the infrequent group. (Table 2)

Comparison of the third relevant indicators of the frequent and infrequent exercise groups

We also performed a T-test on the third measurement results of the regular exercise group and the infrequent exercise group. Compare whether the differences in indicators between the two groups are significant. The results showed that the regular exercise group LM and BMC was significantly higher than the infrequent exercise group. Still, there were no significant differences between the two groups in BA and serum leptin, estradiol, and IGF-I. (Table 3)

Table 1. Comparison of various indicators in the basic measurement between the regular exercise group and the infrequent exercise group.

Project	Infrequent exercise group	SD	Regular exercise group	SD	P
Age	10.9	0.7	11	0.8	0.384
Whole-body					
Height (cm)	141	7.8	142.5	8.7	0.165
Weight (kg)	37.9	7.8	38.5	6.8	0.65
FM (kg)	10.4	4.9	9.8	3.9	0.437
LM (kg)	26.1	3.9	27.5	3.9	0.078
BMI (kg/ m^2)	17.9	2.7	17.7	2.3	0.664
Whole body bones	910	61	929	54	0.087
BMD (g/ cm^2)					
BMC (mg)	1336	259	1425	265	0.097
BA (cm^2)	1414	191	1480	210	0.116
Serum					
Le (nmol/ml)	18.7	14.1	19.6	15.1	0.729
E2 (pmol/ml)	109	60	121	71	0.31
IGF-I (ng/ml)	242	98	252	98	0.534

Table 2. Comparison of various indicators in the second measurement between the regular exercise group and the infrequent exercise group.

Project	Infrequent exercise group	SD	Regular exercise group	SD	P
Age	11.8	0.7	11.9	0.7	0.441
Whole-body					
Height (cm)	146.5	6.8	148.0	7.8	0.262
Weight (kg)	42.5	9.7	43.6	7.8	0.524
FM (kg)	13.8	4.9	13.0	5.8	0.534
BMI (kg/ m^2)	18.5	3.1	18.5	2.5	0.391
Whole-body bones					
BMD (g/ cm^2)	900	76	922	79	0.010
BMC (mg)	1421	364	1636	262	0.039
BA (cm^2)	1517	249	1722	266	0.175
Serum					
Le (nmol/ml)	17.4	14.3	18.1	15.0	0.510
E2 (pmol/ml)	166	109	176	69	0.553
IGF-I (ng/ml)	325	91	366	94	0.563

Table 3. Comparison of indicators in the third measurement between the regular exercise group and the infrequent exercise group.

Project	Infrequent exercise group	SD	Regular exercise group	SD	P
Age	12.9	0.7	12.9	0.8	0.516
Whole-body					
Height (cm)	153	5.8	154	6.8	0.34
Weight (kg)	48.6	9.7	49	7.8	0.805
FM (kg)	13.7	6.8	12.8	4.9	0.417
LM (kg)	33.1	3.9	34.5	3.9	0.019
BMI (kg/ m^2)	19.5	3.2	19.4	2.7	0.813
Whole-body bones					
BMD (g/ cm^2)	995	77	1028	66	0.009
BMC (mg)	1812	331	1916	300	0.01
BA (cm^2)	1755	208	1798	192	0.204
E2 (pmol/ml)	160	68	179	93	0.427
IGF-I (ng/ml)	363	71	357	96	0.715

DISCUSSION

This experiment aims to explore whether the development of good exercise habits during adolescence has a good effect on the growth and development of adolescents' bones and the mechanism of this effect. The results showed that the bone density, bone mass, and lean mass content of the teenagers in the regular exercise and infrequent exercise groups were significantly different in the second and third measurements. However, the difference in the bone area, serum E2, Le, IGF-I was not obvious.[9] This suggests that puberty is a sensitive period for bones to exercise. Good exercise habits can promote the growth and development of bones. The main mechanism by which muscle tension generated during exercise achieves this effect. Exercise is an important factor that regulates the growth and development of bones. Medium and short-term exercise (8-10 months) can significantly promote the accumulation of bone minerals. The effect of exercise on bones can be explained from the "mechanical load theory."

The study results showed no significant differences in age, height, weight, fat content, lean mass content, hormones, and corresponding bone indicators between the girls in the regular exercise group and the infrequent exercise group at the beginning of the experiment (Table 1). During the two years of growth and development of volunteers, various physical indicators changed significantly (Tables 2, 3). During this period, teenagers who regularly participate in sports have about 4% higher body BMD than those of the same age who do not like sports. This shows that exercise is beneficial to the accumulation of bone minerals in adolescents during this period.

There is no significant difference in total BA between the regular exercise group and the infrequent exercise group. This suggests that moderate and low-intensity exercises may not significantly affect the geometry of bones but have a more significant promotion effect on the deposition of bone minerals. Under the action of muscle strength, the bone tissue is constantly adjusted to adapt to the mechanical force exerted on it for trabecular bone reconstruction and other changes.

The results also showed no significant difference in hormones (serum E2, Le, IGF-I) between the two groups.

CONCLUSION

Develop good exercise habits during adolescence will have a positive effect on the growth and development of bones. This kind of good promotion is mainly realized by the tension of the muscles during exercise, not by the changes of circulating endocrine hormones.

All authors declare no potential conflict of interest related to this article

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