EXPLOSIVE STRENGTH OF THE LOWER LIMBS IN ROPE SKIPPING EXERCISE APPLIED TO CHILDREN AND ADOLESCENTS

ORIGINAL ARTICLE
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FORÇA EXPLOSIVA DOS MEMBROS INFERIORES NO EXERCÍCIO DE PULAR CORDA APLICADO ÀS CRIANÇAS E ADOLESCENTES

FUERZA EXPLOSIVA DE LOS MIEMBROS INFERIORES EN EL EJERCICIO DE SALTO DE CUERDA APLICADO A NIÑOS Y ADOLESCENTES

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ABSTRACT

Introduction: The physical health of children and adolescents is directly related to school physical training quality. The improvement of adult sports effectiveness results from a concise protocol with standardized exercises. Rope skipping exercise lacks kinematic studies applied to children and adolescents. Objective: Provide a theoretical reference for jump rope exercise training for children and adolescents. Methods: Eight children aged six to eight years old were recruited to jump at a frequency of 80 and 120 jumps per minute controlled by a metronome. The technique was divided into three stages: impulse, suspension, and landing. Control in the knee joint exoskeleton balance was investigated by computerized baropodometry with differentiation of rotational angular velocity by rotational angular acceleration via Butterworth filter. After noise cleaning and multiplication, an adjustable amplification factor returned to the inlet with inertial compensation torque. Results: Initially, the impulsing force is about three times the individual's gravity. This value and the center of mass acceleration decrease in time. The initial force is proportional to the velocity of its decrease during the impulse, and the opposite occurs with the landing force. Higher intensity is observed when raising the frequency. Conclusion: The fluctuation in the force curve in the landing phase after 20 jumps indicates low muscle strength in lower limbs to maintain activity. A speed of 80 jumps per minute controlled by music in a playful environment is recommended for children. ***Evidence Level II; Therapeutic Studies – Investigating the results.***

Keywords: Sports; Resistance Training; Lower Limbs.

RESUMO

Introdução: A saúde física das crianças e adolescentes está diretamente relacionada à qualidade do treinamento físico escolar. O aprimoramento da eficácia esportiva adulta é resultado de um protocolo conciso com exercícios padronizados. O exercício de pular corda carece de estudos cinemáticos aplicados em crianças e adolescentes. Objetivo: Fornecer uma referência teórica para o treinamento físico de pular corda para crianças e adolescentes. Métodos: Foram recrutadas 8 crianças com idade entre 6 a 8 anos para saltos em frequência de 80 e 120 pulos por minuto controlados por um metrônomo. A técnica foi dividida em três estágios: impulso, suspensão e pouso. O controle no balanço do exoesqueleto articular do joelho foi pesquisado por baropodometria computadorizada com diferenciação de velocidade angular rotacional pela aceleração angular rotacional via filtro de Butterworth, após limpeza de ruídos e multiplicação por fator de amplificação ajustável, devolvidos à entrada de admissão com torque de compensação inercial. Resultados: Inicialmente, a força de impulso é cerca de três vezes a gravidade de cada indivíduo. Esse valor e a aceleração do centro de massa diminuem com o tempo. A força inicial é proporcional a velocidade da sua diminuição durante o impulso, ocorrendo o inverso com a força de pouso. Observa-se uma maior intensidade ao elevar a frequência. Conclusão: A flutuação na curva de força na fase de pouso após 20 pulos indica baixa força muscular em membros inferiores para manter a atividade. Recomenda-se a velocidade de 80 pulos por minuto controlada por música em ambiente lúdico para crianças. ***Nível de evidência II; Estudos Terapêuticos - Investigação de Resultados.***

Descritores: *Esportes; Treinamento de Força; Membros inferiores.*

RESUMEN

Introducción: La salud física de los niños y adolescentes está directamente relacionada con la calidad del entrenamiento físico escolar. La mejora de la eficacia deportiva del adulto es el resultado de un protocolo conciso con ejercicios estandarizados. El ejercicio de salto de cuerda carece de estudios cinemáticos aplicados a niños y adolescentes. Objetivo: Proporcionar una referencia teórica para el entrenamiento de ejercicios de salto de cuerda para niños y adolescentes. Métodos: Ocho niños de entre 6 y 8 años fueron reclutados para saltar a una frecuencia de 80 y 120 saltos por minuto controlados por un metrónomo. La técnica se dividió en tres etapas: impulso, suspensión y aterrizaje. El control sobre el equilibrio del exoesqueleto de la articulación de la rodilla se investigó mediante baropodometría

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computarizada con diferenciación de la velocidad angular rotacional por la aceleración angular rotacional a través del filtro Butterworth, después de la limpieza del ruido y la multiplicación por el factor de amplificación ajustable, devuelto a la entrada con par de compensación inercial. Resultados: Inicialmente, la fuerza de empuje es aproximadamente tres veces la gravedad de cada individuo. Este valor y la aceleración del centro de masa disminuyen con el tiempo. La fuerza inicial es proporcional a la velocidad de su disminución durante el impulso, y lo contrario ocurre con la fuerza de aterrizaje. Se observa una mayor intensidad al aumentar la frecuencia. Conclusión: La fluctuación de la curva de fuerza en la fase de aterrizaje tras 20 saltos indica una baja fuerza muscular en los miembros inferiores para mantener la actividad. Se recomienda una velocidad de 80 saltos por minuto controlada por la música en un entorno lúdico para los niños. ***Nivel de evidencia II; Estudios terapéuticos - Investigación de resultados.***

Descriptores: *Deportes; Entrenamiento de Fuerza; Miembros Inferiores.*

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INTRODUCTION

The physical quality of adolescents and children is directly related to their physical health and affects the quality of Chinese future talent training. Studies have shown that effective physical activity can improve physical fitness and athletic ability.[1] Therefore, this article uses dynamic measurement and analysis methods to analyze and discuss the basic movements of adolescents and children skipping rope. In this way, we discovered the problems in the basic movement technique of rope skipping for teenagers and children. This can provide a reference for the scientific training of children skipping sports.

METHOD

Research object

The article takes 8 children in a rope skipping training class in a university as the research object.[2] The age is 6 to 8 years old. None of the volunteers had a previous medical history. 2.2 Research methods

Before the experiment, we first collect basic information on the experimental subjects. The content includes 7 aspects: name, gender, age, height, education level, length of exercise for rope skipping, and dominant leg. In this experiment, the skipping frequency of 80 times/min and 120 times/min is selected. We divide the children's single swing rope skipping technique into three stages: kicking, flying, and landing.[3] The kicking stage is the process from the lowest point on the top of the head until both feet leave the ground. The flight phase refers to when both feet are in the air.

Research on knee joint exoskeleton swing control

We differentiate the rotational angular velocity v_s of the exoskeleton to obtain the rotational angular acceleration.[4] We performed a Butterworth low-pass filter on the angular acceleration to make the cutoff frequency ω_0 the normal swing frequency of the human leg. The filtered data is multiplied by an adjustable amplification factor I_0 and fed back to the input of the admittance model as a compensation torque. This can be used as inertia compensation.

$$H(s) = \frac{I_0 \omega_0 s}{s + \omega_0} \tag{1}$$

$$Y_e^p(s) = \frac{\omega_s(s)}{\tau_p(s)} = \frac{\dfrac{Y_e^s(s)}{1 + H(s)Y_e^s(s)}}{1 + Z_e(s)\left(\dfrac{Y_e^s(s)}{1 + H(s)Y_e^s(s)}\right)} \tag{2}$$

The impedance $Z_e(s)$ of the exoskeleton arm is:

$$Z_e(s) = \frac{I_e s^2 + b_e s + k_e}{s} \tag{3}$$

Human leg impedance $Z_h(s)$ is shown in equation (4):

$$Z_h(s) = \frac{I_h s^2 + b_h s + k_h}{s} \tag{4}$$

Assuming that the inertia compensation gain parameter I_0 is an expression related to the human leg inertia I_h and the exoskeleton inertia I_e:

$$I_0 = \alpha I_h - I_e \tag{5}$$

When the human leg is coupled with the exoskeleton mechanical leg, its closed-loop system admittance is shown in equation (6).

$$Y_e^h(s) = \frac{\omega_s(s)}{\tau_h(s)} = \frac{Y_e^p(s)}{1 + Z_h(s)Y_e^p(s)} \tag{6}$$

Methods of Mathematical Statistics

We collected the three-dimensional GRF data generated by the forward single swing rope skipping action at different frequency speeds into the EXCEL 2010 table.

RESULTS

Dynamic analysis of kicking stage

The research subjects performed single-jump rope skipping on the force plate according to the rhythm given by the metronome. The test can be stopped after obtaining stable experimental data.[5] The force plate collected kinetic data. The calculation method of the instantaneous acceleration of the center of mass of the human body is $a = F / m - g$. Where F represents the instantaneous force (N). m represents the body mass of the subject (kg). G represents the acceleration of gravity (m/s^2).

It can be seen from Table 1 that the greater the self-gravity, the greater the pedaling force required in the rope skipping movement. From the numerical point of view, the force pushing the ground is about 3

Table 1. Pushing force (N) in the process of pushing the ground.

Serial number	Gravity	Pushing force
1	226.3	623.72
2	238.4	662.23
3	261.7	822.63
4	214.6	623.25
5	443.6	1490.67
6	257.1	668.83
7	398.7	1209.5

times its gravity. That is to say, in the rope skipping exercise, and enough thrusting force is needed to make the whole body reach the airborne state.[6] Only in this way can one cycle of rope skipping be completed. Although the No. 1 research object and the No. 3 research object have big differences in their gravity and pedaling force, the force changes with time during the pedaling phase of the rope skipping movement are the same. The force is gradually reduced with the increase of time, but the force reduction rate is different. The greater the pedaling force at the same frequency, the faster the force decreases during the pedaling process.

The results of the instantaneous acceleration of the center of mass of the human body when the maximum thrust is reached. (Table 2) At this time, + and - indicate the direction of acceleration.[7] Defining the direction of g as the acceleration of the normal kicking process is perpendicular to the ground and upwards. The instantaneous acceleration of the center of mass in kicking the ground decreases with the increase of time. The decreased speed of the instantaneous acceleration of the center of mass tends to be fast and then slow. This process converts the energy in the human body into mechanical energy.

Dynamic analysis of landing stage

Research subject No. 1 did a total of about 20 single-swing rope skipping movements during the test. After removing the abnormal value, the average landing force is 612.57N. The standard deviation is 20.35. In the same way, the landing force of other research objects at a rope skipping frequency of 80 times/min is obtained.[8] It can be seen from Table 3 that the landing force is slightly smaller than the kicking force. Because of the braking effect of the eccentric muscle contraction, the landing force is slightly smaller than the kick force.

In the landing stage of single swing rope skipping movement, the landing force increases with time. The longer the time, the greater the landing force. The curve of force and time in the landing phase is not smooth.[9] The reason is that the research subjects are children aged 6 to 8 years. His legs and core muscles are insufficient. Children cannot hold the center firmly at the landing stage. Shaking occurs during the fall, causing fluctuations in the landing force. When the maximum landing force is reached, the instantaneous acceleration results of the center of mass of the human body are shown in Table 4. The evolution of the instantaneous acceleration of the center of mass in the entire pedaling process of the single-swing rope skipping movement is the same as the time evolution of the landing force, and the force and the mass determine the acceleration. Under the premise of the same mass, the acceleration will change due to the change of force.

Table 2. The instantaneous acceleration of the center of mass at the moment when the pedaling force reaches the maximum (m/s^2).

Serial number	Instantaneous acceleration of the center of mass
1	-12.56
2	-12.58
3	-12.94
4	-12.7
5	-13.16
6	-12.4
7	-12.83

Table 3. Ground pushing force during landing (N).

Serial number	Gravity	Pushing force	Landing force
1	226.3	623.72	612.57
2	238.4	662.23	647.84
3	261.7	822.63	775.17
4	214.6	623.25	619.18
5	443.6	1490.67	1339.8
6	257.1	668.83	651.78
7	398.7	1209.5	1097.84

The influence of frequency on the dynamics of skipping rope

This experiment chooses 80 times/min and 120 times/min. It can be seen from Table 5 that as the frequency of skipping rope increases, the value of the pedaling force also increases. In the process of fast rope skipping, the rope skipping action speeds up, and the time required for each rope skipping cycle becomes shorter.[10] This requires the research object to complete the same action in a shorter time and to have a higher explosive power. Volunteers must have a large kicking force in the two cycles to complete the rope skipping movement at this frequency.

Table 4. The instantaneous acceleration of the center of mass at the moment when the landing force reaches the maximum (m/s^2).

Serial number	Instantaneous acceleration of the center of mass
1	-12.06
2	-12.1
3	-12.38
4	-12.22
5	-12.59
6	-11.95
7	-12.3

Table 5. Ground pushing force at different frequencies (N).

Serial number	Gravity	Low-speed push	Fast kick force
1	226.3	623.72	1024.4
2	238.4	662.23	996.2
3	261.7	822.63	903.5
4	214.6	623.25	2138
5	443.6	1490.67	887.8
6	257.1	668.83	1168.8
7	398.7	1209.5	1223.4

DISCUSSION

The greater the child's weight, the greater the kicking force required in the rope skipping movement. In the stepping phase of rope skipping, the force change trend is that the force gradually decreases with time, but the rate of force decrease is different.[11] The greater the pedaling force at the same frequency, the faster the force decreases during the pedaling process. The instantaneous acceleration of the center of mass of the whole pedaling process in the single-swing rope skipping movement decreases with the increase of time. The direction is always vertical and upward.[12] The decreased speed of the instantaneous acceleration of the center of mass tends to be fast and then slow. This process converts the energy in the human body into mechanical energy. The force of falling ground at the same frequency is slightly smaller than kicking the ground. The landing force tends to increase with time. The longer the time, the greater the landing force. The curve of force and time in the landing phase is not smooth and has fluctuating areas. Children aged 6 to 8 have insufficient muscle strength in the legs and core parts. They can't firmly grasp its center of gravity during the landing stage. Volunteers swayed during the fall, resulting in fluctuations in the landing force.

It can play music with a strong sense of rhythm during children's daily training and fitness. We can choose a frequency of around 80 beats/min. Rope skipping exercise following the music beat can create an energetic sports atmosphere and play a role in exercise. Children should not rush for success in the training of skipping sports. We must have patience and perseverance. As time increases, children's leg, waist, and abdomen strength and coordination will significantly improve. This can also achieve the effect of physical and mental pleasure and fat reduction.

We need to pay attention to the diversification of skipping forms. Children can flexibly adapt various methods according to training needs, such as single-leg jump, double-foot jump, simultaneous jump, sequential jump, single jump, double jump, and multiple jumps. Children can also organize training activities in various ways, such as rope skipping games, rope skipping competitions, or trick rope skipping. To improve the fun of rope skipping and stimulate students' interest and enthusiasm in teaching training.

CONCLUSION

As the frequency of skipping rope increases, the value of the pedaling force also increases. As the frequency increases, the time required for each rope skipping cycle becomes shorter. At this time, a higher explosive power is required. If there is no buffer between the two weeks, a large pedaling force is required to complete the rope skipping movement at this frequency.

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