BIOMECHANICAL ANALYSIS DURING COUNTERMOVEMENT JUMP IN CHILDREN AND ADULTS

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This study was to examine the biomechanical characteristics of children and adults during countermovement jump. Seven children and seven adult males were recruited to the study. A Peak high-speed camera (120Hz) synchronized with a force plate (600Hz) were used to record vertical jumping action. The kinetic parameters were calculated by using inverse dynamic method. Results showed that the children had both immature joint function prior to propulsion and inadequate knee and ankle joints function during propulsion. It is concluded that a lack of form in jumping strategy was performed during vertical jumpings in the children´s group in terms of the kinetic methods was performed. This information may be used in following studies about countermovement jump, avoiding some important information needed only by kinematic analysis, it will be more complete to apply kinetic analysis for children movement researches.

KEY WORDS: kinematics, kinetics, inverse dynamics, net muscle joint works.

INTRODUCTION: Jumping is one of the basic motor skills. The major aim in vertical jumping is to jump for height. It required a force that was generated by two legs to project the body up in the air. The primary challenge of jumping is enough leg strength to propel the body off the ground (Gabbard, 1992). Generally, humans would not attain master patterns of vertical jump until approximately age 5 or 6. In the total body approach, Gallahue & Ozmun (1998), and Gabbard (1992) indicated that the developmental trend of vertical jump in lower limbs was the increase in preparatory crouch, and the improvement of extension at take off. Moreover, several previous studies (Clark & Phillips, 1989; Jensen, Phillips, & Clark, 1994) have examined the differences between children and adults during the vertical jump in lower limbs. In general, these studies found out that there were significant differences in such parameters as peak angular velocity, body configuration, take off angle, and reflex activity among different kinds of ages (Clark & Phillips, 1989; Jensen *et al.*, 1994). However, it should be noted that these previous studies only focused on the kinematic parameters that were just the effects of the movements caused by the kinetic variables. Through kinetic analysis, we could really get the cause of the movement, and get some insight into movement strategies and compensations of neural system (Winter, 1990). Therefore, the purpose of this study was to investigate the age-related differences of vertical jump by analyzing the net muscle joint moments, net muscle joint powers, net muscle joint works, and some kinematic parameters.

METHODS: Seven children (6.0 ±0.41 yr, 1.20 ±0.04 m, 22.26 ±2.62 kg) and seven adult males (18.0 ±0.50 yr, 1.75 ±0.06 m, 70.81 ±9.92 kg) were recruited to the study. A Peak high-speed camera (120Hz; 1/500) was used to record the sagittal plane of vertical jump actions. A Kistler force plate (600Hz) was synchronized to collect the ground reaction forces and center of pressure when jumping. The experiment required the subjects to stand on a force plate, put their hands on their hips, and then jump as high as they could. Each subject had to succeed in two trials, and the highest value of each subject was used for subsequent statistical analysis. Segments of data for foot, leg, thigh, and head and trunk (HAT) were assessed from Jensen's (1989) polynomial regression coefficient. Five body landmarks fixed on bodied (i.e., shoulder, hip, knee, ankle, and toe of left side) and one reference point fixed at force plate were both digitized and framed by a Peak Performance for Window 95 Motus system. A Butterworth Digital Recursive Filter was used to filter the random noise in the digitizing process. While the range of motion (ROM) in crouch phase was the decrease of the joint angle from initiation of motion to the minimum of relative joint angle, the ROM in push phase was calculated from the minimum of relative joint angle to the moment of taking off. The beginning of propulsion was defined at the moment when the contraction of the extensor muscles turns from eccentric into concentric. The propulsion phase corresponds with the extensor muscles concentric contraction. The net muscle joint moments were calculated by using inverse dynamics process, where $\Sigma M_i = I_i \times g_i$ (M: Net muscle joint moment; I: Moment of inertia of the segment about the axis through the center of gravity (CG) of the segment; g: Angular acceleration of the segment related to horizontal axis). The net muscle joint powers were calculated as the $P_i = M_i \times {}_i$ (: Angular velocity of the joint). The net works of muscle joint were calculated as the $W_i = \int P_i \times dt$. Therefore, the total net works of muscle joints were estimated from initiation of movement to the moment of taking off. All kinetic parameters were adequate to body mass. Differences among mean values of all parameters were analyzed by Student's *t*-test for independent samples ($p<.05$).

RESULTS: The basic kinematic parameters are presented in Table 1. The result of adult group showed that they jumped higher than the children group ($p<.05$). In addition, the children group presented greater ($p<.05$) backward project angle in respect to a right horizontal reference in CG than the adult group at the moment of take off. There was also a significant difference ($p<.05$) between both groups in ROM with the exception of hip joints in the pushing phase ($p<.05$).

Table 1. Kinematic parameters in the vertical jumping.

	Normalized jump height (m/height)	CG project angle (degree)
Children	0.21±0.03	99.49±3.07
Adults	0.30±0.04	95.02±1.22
Significance	***	**

ROM (degree)	Crouch phase			Push phase		
	Hip	Knee	Ankle	Hip	Knee	Ankle
Children	76.83±19.90	75.51±15.87	29.14±3.96	69.77±10.73	73.39±8.65	56.10±5.73
Adults	97.90±14.12	96.47±8.30	36.74±1.70	69.47±13.40	84.88±8.78	75.85±9.50
Significance	*	**	***	NS	*	***

*** p<.001; **p<.01; *p<.05; NS= not significance

Figure 1 shows the net muscle joint moments and powers curves of one typical subject's lower limbs which are representative of each group. The polarity of net muscle joint power represented concentric or eccentric contractions of muscle group. Positive net muscular moment and mechanical power indicate that the extensors are the dominant group concerning the control of the joint movement. Furthermore, the extensor was doing concentric contraction on the propulsion phase. Figure 2 shows the mean relative times at four muscle movement phases (i.e., flexors' concentric contraction, extensors' eccentric contraction, extensors' concentric contraction, and flexors' eccentric contraction) at three joints for both groups. There was a significant difference in the curves and movement times ($p< .05$) of knees between both, children and adult groups. Moreover, there were significant differences ($p<.05$) of some kinetic parameters between both groups (Table 2).

Table 2. Kinetic parameters in the vertical jumping.

Net muscle joint moments and powers	Moment in the initiation of propulsive (Nm/kg)			Peak power in the propulsive stage (W/kg)		
	Hip	Knee	Ankle	Hip	Knee	Ankle
Children	1.84±0.31	0.25±0.19	1.25±0.24	11.18±2.80	0.94±0.87	12.67±2.49
Adults	2.44±0.39	1.55±0.20	1.75±0.30	10.85±1.17	6.25±1.09	16.62±3.03
Significance	**	***	**	NS	***	*

Net muscle joint works	Extensors' concentric contraction (J/kg)			Total work (J/kg)		
	Hip	Knee	Ankle	Hip	Knee	Ankle
Children	1.50±0.39	0.06±0.07	1.05±0.18	2.22±0.61	0.55±0.14	1.22±0.18
Adults	1.87±0.40	0.86±0.16	1.55±0.22	2.76±0.67	1.67±0.28	1.81±0.16
Significance	NS	***	***	NS	***	***

*** p<.001; **p<.01; *p<.05; NS= not significance

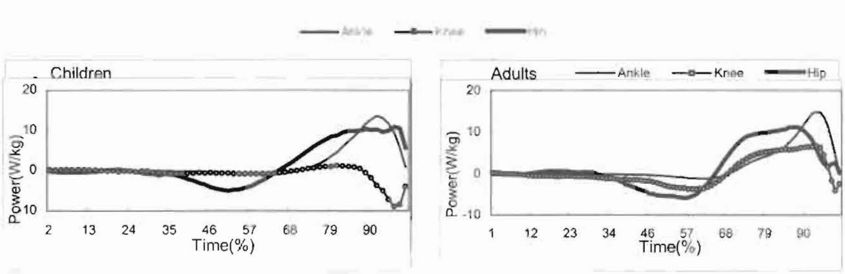

Figure 1. Changes in the net muscle joint moments and powers curves for two subjects (Left: the children group; Right: the adult group).

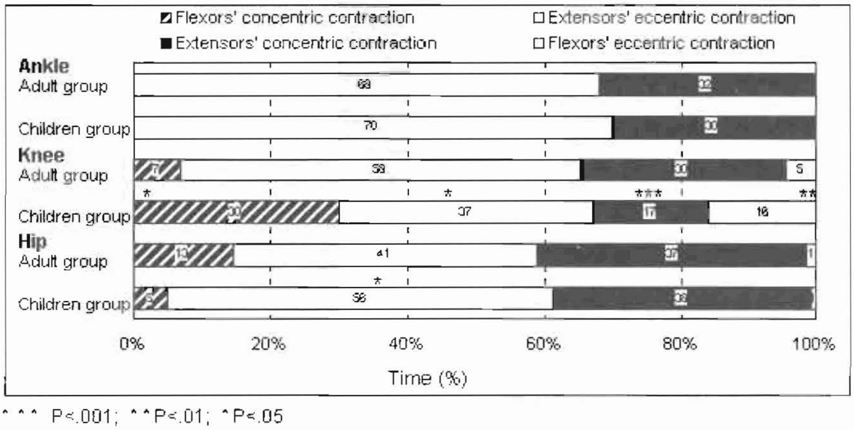

Figure 2. The mean relative times of each muscle movement phase.

DISCUSSION: In jumping, the muscle could be stretched by counter movement for storage and reutilization of elastic energy. It might allow the subject to obtain greater joint moments in the initiation of propulsion. As a consequence, joint moments were greater over the first part of the range of joint extension in jumping, so that they were able to produce more work over the first part of their shortening distance (Horita, Kitamura, & Kohno, 1991; Bobbert *et al.*, 1996). The results of the present study showed that the adult group had greater performances in jumping than the children group ($p<.05$). It seemed to be related primarily to greater hip extension moment, knee extension moment, and plantar flexion moment in the initiation of propulsion for the adult subjects. The findings of this study confirmed that the work done by ankle and knee joint, in extensors' concentric contraction, for adult group was greater than children group. The previous stretching leg extensor in the eccentric phase of the preparatory movement could enhance the adult group's performances. Therefore, the depth of preparatory crouch might have an influence on extensor stretching. In crouch phase, the children group had lower skills in terms of the ROM in hip, knee, and ankle, than the adult group. Thus, these data predicted that the lack of muscular-stretching ability for the children group in crouch phase might influence the jumping performances. The nature of jumping required the lower limb extensors prior to take off because of the need to lift and project the CG (Bobbert & Schenau, 1988). On propulsive stage, increasing the pushing distance could produce more energy to take off; it was useful to improve the CG velocity at the moment of taking off and increase the jumping height. Extending adequately the limbs before to the take-off is the important factor over the jumping, although the results of the present study indicated that the lower extremity for the children group could not be completely extended in the pushing phase (e.g., ROM of knee and ankle). The most interesting finding of this study was the immature knee joint function for the children group. The contraction divisions (i.e., flexors' concentric contraction, extensors' eccentric contraction, extensors' concentric contraction, and flexors' eccentric contraction) of knee in the children group had a significant difference ($P < 0.05$) compared to the adult group. During preparatory crouch, the children group spent more time in flexors' concentric contractions in order to create the downward motion, but less time in extensors' eccentric contractions. It might be disadvantage for the children group to stretch the leg extensor muscles. In addition, the children group showed immature joint function of the knee and ankle in the propulsive phase. Especially in the knee, the net muscle joint moment and movement time of extensors' concentric contractions were less for the children group in the propulsive phase compared with the adult group. In the children group, flexors' eccentric contractions appeared earlier, which might decrease the positive work produced in the propulsive stage. Furthermore, the children group has already accomplished the pattern of mature joint functioning of hip in the propulsive phase (e.g., ROM, peak power, and the work of extensors' concentric contractions). The greater backward project angle in CG at the moment of taking off decreased the vertical velocity of projection in the children group. Thus, this might result in the weakness of knee extension and the adequate hip functions in the propulsive phase.

CONCLUSION: This study provided the characteristics of the immature function during the vertical jumping for the children group observed by the kinetic analysis. This information may be used in studies concerning applied research to countermovement jump in children motor behavior and development.

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