INFLUENCE OF THE RANGE OF MOTION ON JUMPING HEIGHT IN CHILDHOOD

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The purpose of this study was to ascertain whether during childhood, the parameters for the range of motion had more influence on jump height than parameters for application of force. Using force platform, an analysis was made of the countermovement jumps performed by 36 girls aged between 5 to 8 years old. Linear regression was used to analyze the data. The parameters for the range of motion accounted for 66% of the variance in maximum height jump, while application of force accounted for 12%. These results could indicate that the children can enhance their vertical jumping performance by increasing the range of motion rather than improving the ground reaction forces or their application.

KEY WORDS: children, jump, range of movement, ground reaction force

INTRODUCTION: The vertical jump is one of the most common skills in sports and games. The most common way to evaluate the vertical jump is by measuring the height jumped. Numerous studies show increases in jump height from childhood to adolescence (e.g. Malina, Bouchard & Bar-Or, 2004). During the fundamental movement phase of development (approximately 4 to 7 years), children acquire skills such as running, jumping, kicking, throwing and catching (Gallahue & Ozmun, 2005).
While many studies explain how the increases in jump height during development are related to changes in anthropometry or muscle force (e.g. Taylor, Cohen, Voss & Sandercock, 2010), relatively few studies have focused on the effects of movement patterns (i.e. *technique*) in increasing jump height during development (Wang et al., 2004).
The literature shows that there are no differences in the vertical jump for the coordination of movements between children and adults but there are differences in the amplitude and velocity of motion (Jensen et al., 1994). This includes differences in the magnitude of the angles, displacements, joint ranges or peak joint extension velocities used during the jump.
The range of motion of the lower limb joints is smaller in children than in adults in both the downward and upward phases (Wang et al., 2004). This lower range of motion could shorten the time of force application and consequently decrease the impulse resulting in lower take-off velocity and jump height. During the jump the legs should produce as much energy as possible before take-off. An incomplete extension could decrease the pushing distance and, consequently, reduce the energy produced which is detrimental to jump performance. Differences in the downward phase have also been observed (Wang et al., 2004) and shown to be larger than in the upward phase. This smaller downward phase may reflect the lack of children's ability to control large segments, such as the trunk, due to an immature postural control (Jensen et al., 1994).
While previous studies indicate significant differences in the range of movement between children and adults, it is not clear whether these differences are important in determining the height of the jump. Nor is it clear if the range of movement has more influence than others parameters related to application of force. For a better understanding of child development, it is necessary to identify the parameters that have most influence on height of the jump at every stage of development. Consequently, the aim of this study was to ascertain whether during childhood, the parameters for the range of motion (i.e. the *technique* related variables) had most influence on jump height than parameters for application of force (i.e. the *strength* related variables). To this end, this study compared the influence of both *technique* and *strength* related parameters on jump height in children.

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METHODS: The participants were 36 females aged between 5 to 8 years old (mean ± SD = 6.5 ± 0.9 years) with a mass of 23.0 ± 5.2 kg and a height of 1.20 ± 0.09 m. The children were chosen in this age range, since this approximates the fundamental movement phase where the development of a mature vertical jumping sequence is normally achieved (Gallahue & Ozmun, 2005). The children trained in acrobatic gymnastics twice per week. No participants had any past history of nervous system or muscular dysfunction. All children's parents/guardians signed informed consent forms for their children to participate in the study.
Participants were instructed to perform counter-movement jumps (CMJ) on a portable force platform (Quattro Jump®, Kistler Instrumente AG, Winterthur, Switzerland). Before each test, the participants performed 10 minutes of warm-up which included a brief period of low-intensity aerobic exercise, stretching exercise and 1 set of 5 sub-maximal jumps. Force data were sampled at 500 Hz. The instructions for each participant were standardised. They included a detailed verbal explanation and a demonstration by the experimenter. The importance of jumping as high as possible was emphasised. During the CMJ, the subjects initially stood upright for at least 2 seconds (during which body weight was recorded), then squatted to a self-selected depth of approximately 90° knee flexion, and jumped immediately as high as possible without pausing. For all jumps, participants retained the "hands on hips" position until the landing phase. Three successful jumps were recorded for each subject, with at least 2 minutes of rest between jumps, and the average of the three successful jumps was used for analysis.
The force- time data was divided by the mass to obtain the acceleration- time curve. This was numerically integrated using the trapezoid rule to obtain the velocity of the centre of mass (CoM). Vertical CoM displacement was derived by numerically integrating the vertical CoM velocity (Street et al., 2001).

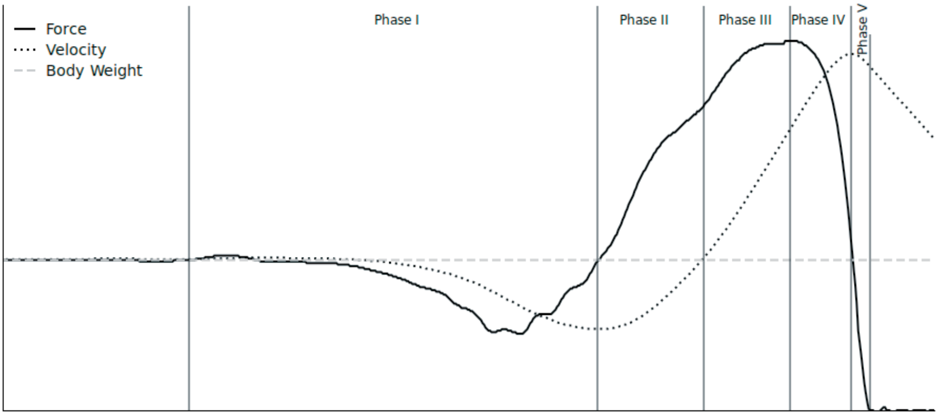

Figure 1: Definition of events and phases on the CMJ force- time graphs.

To facilitate data analysis, six events and five phases were defined during the CMJ (Figure 1). The first event was start of movement, which was detected by inspecting the force-time records to identify the first instant where the vertical ground reaction force deviated above or below BW by more than one threshold. The threshold was defined as 1.75 times the peak residual found in the 2 seconds BW averaging period. A backward search was then performed until vertical ground reaction force passed through BW (Street et al., 2001). The second event was the instant of maximum downwards velocity of CoM. The third event was the instant of zero velocity of CoM. The fourth event was the instant of maximal vertical ground reaction force (Fmax). The fifth event was the instant of maximum upwards velocity of CoM. The last event was the instant of take-off which was defined as the first intersection of vertical ground reaction force within an offset threshold where, the threshold was determined by adding the average flight time (i.e., 0.4 seconds) and the peak residual to the

offset (Street et al., 2001). Five phases were defined based on these events (Figure 1). From these events and phases were analysed the variables described in Table 1. The variables were grouped into three groups with the aim to show which group had most influence on the height jumped.
Means and standard deviations of each participant group were computed for all the measured variables. Normality of the data was verified using the Shapiro-Wilk test. Three separate stepwise (backward) multiple regression analyses were used for each group participant: 1) between hmax and range of movement variables; 2) between hmax and average force variables; 3) between hmax and individual force variables. Analyses were conducted using SPSS version 18.0.

Table 1
Definition and grouping of variables analyzed

Variable group	Variable	Description	Unit
Dependent variable	hmax	Maximal height achieved by CoM during the flight	m
Range of movement (“Technique” Variable)	LI; LII; LIII; LIV	Vertical displacement of CoM during each of the four phases I, II, III, IV.	m
Average force (“Strength” variables)	FI; FII; FIII; FIV	Average vertical ground reaction force during each of the four phases I, II, III, IV.	BW

RESULTS: Table 2 shows the means ± standard deviations of the variables studied in the jump. Figure 2(a) shows the model that predicts hmax from the parameters for application of force. The independent variables included in the model were FI, FII and FIII. Both FI and FII were negatively correlated with hmax, whereas FIII was positively correlated. These variables accounted for 12% of the variance in hmax. Figure 2(b) presents the model that predicts hmax from the parameters for the range of motion. The independent variables included in the model were LI, LII, LIII and LIV. Both LI and LII were negatively correlated with hmax, whereas LIII and LIV were positively correlated. These variables accounted for 66% of the variance in hmax. This R^2 was 0.54 higher than in the first model for the parameters for application of force; thus, when the parameters for the range of motion were added to the model, the explained variance increased by 54%.

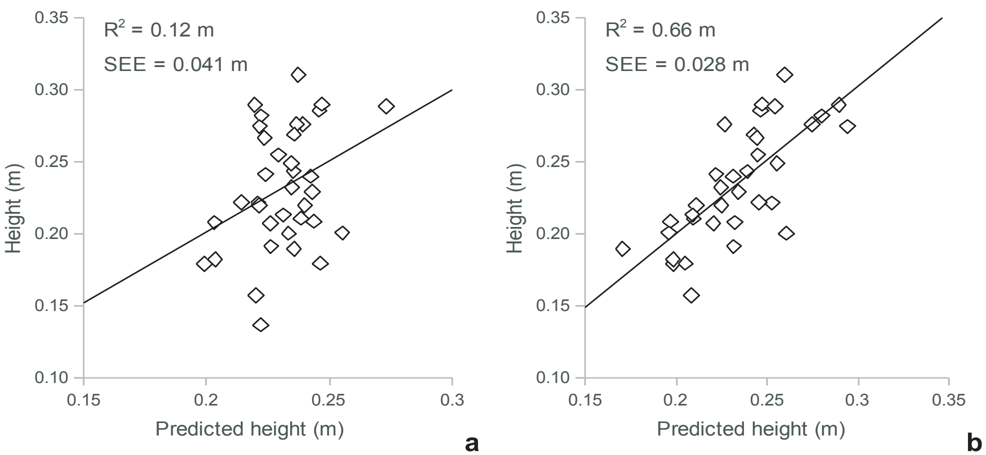

Figure 2: Multiple linear regression analysis with the parameters for application of force (a) and the parameters for the range of motion (b) as the independent variables.

Table 2
Jumps characteristics

	Phase	
hmax (m)		0.23 ± 0.04
Range of movement (m)	LI	0.11 ± 0.03
	LII	0.09 ± 0.04
	LIII	0.22 ± 0.06
	LIV	0.06 ± 0.01
Average force (BW)	FI	0.80 ± 0.07
	FII	1.58 ± 0.27
	FIII	1.99 ± 0.27
	FIV	0.48 ± 0.31

DISCUSSION: This study described the influence of range of movement and the application of force on jump height in children. The results show that the parameters for the range of motion (*technique*) had most influence on jump height than parameters for application of force (*Strength*). The importance of range of motion on jump height for adults and children has been described in previous studies. Wang et al. (2004), observed that the greatest jump height of adults compared with children could be due to a greater range of motion. Similarly, Ugrinowitsch et al. (2007), found differences in the displacement of the CoM during the jump between a group of well-trained athletes for the jump and other untrained. Well-trained subjects were able to move their bodies over a longer distance compared with untrained. An increase in the joint range of force generation can extend the net impulse during ascending phase and consequently improve the velocity at takeoff. The influence of range of motion on performance has also been studied in other skills (Hodges et al., 2005). The results of these studies have a general agreement with the present study. Hodges et al. (2005), observed as the range of motion of hip increased with the practice of kick the ball. Since the literature (e.g. Strohmeyer et al., 1991), suggests that when a child learns a skill, initially, she “freezes” the degrees of freedom of movement to facilitate the control. After reaching the initial control, the child is able to increase the range of movement of joints enabling successful consistent performance.

CONCLUSION: Based on these data, we believe that the children can enhance their vertical jumping performance by increasing of range of motion. Furthermore, the strength parameters do not seem to be relevant in achieving maximum jumping heights in childhood.

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