DIFFERENCES IN JUMPING PERFORMANCE OF CHILDREN FROM DIFFERENT SPORTS

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The ability of high rate of force development is crucial in many high power sports. The aim of this study was to examine the possible differences in jumping skills of children participating in sports with different demands of leg strength, in order to investigate if specific training influenced different jump performances. 175 children from four different sports participated. The subjects performed squat jumps; counter movement jumps and drop jumps from 0.2 m and 0.4 m. The study showed that the nature of the sport has influence on the performance of drop jumping ability on children, though natural selection may also have an influence.

KEYWORDS: children, swimming, gymnastics, tennis, team handball, jumping. RFD.

INTRODUCTION: Jumping is a common movement pattern and a major component of many sports. The high acceleration of the bodymass, which is necessary for an effective jump, shall in many cases be produced in a very short time, e.g. 0.08-0.10 s in a sprint step, or 0.11 s in a take-off in long jump (Zatsiorsky, 1995). To be able to accelerate the body in such a short time the muscles must produce forces at a very high rate. The rate of force development (RFD) depends mainly on two important factors; the contractile properties of the muscles, i.e. fiber type distribution and cross sectional area, and the neural activation of the muscles, i.e. the number of recruited motorneurons and the firing frequency of the motor neurons. Both factors can be improved by training (e.g. Moritani, 1993).

When performing different types of jumps, the central nervous system (CNS) uses different motor programs to execute the neuromuscular coordination necessary for the specific jump. The squat jump (SJ) can be used as the most basic functional expression of explosive muscle strength, as it requires only concentric activation. The counter movement jump (CMJ) requires moderate eccentric activation followed by high concentric activation, and therefore requires a more complex coordination of the motor units. The drop jump requires high eccentric activation followed by high concentric activation, which requires a very precise coordination and extensive activation of the motor units. Thus the SJ can serve as a baseline for potential and CMJ and DJ can indicate development of potential. Since the neuromuscular coordination is developed from birth through to adulthood, it is likely that participation in sport may induce specific alterations in neuromuscular control of the lower limb muscles, depending on the nature and intensity of training. In support of that, studies have shown, that strength training of children can induce changes in neural activation and result in increased strength (Ozmun et al., 1994; Blimkie et al., 1993). By studying children from different sports and at different performance levels, the effect of specificity of training on explosive strength is investigated. The results of the study may contribute to the discussions regarding specificity of training at young age.

METHODS: 175 children took part in the study. The subjects were active in swimming, tennis, gymnastics or team handball, and they were recruited from some of the best clubs in Denmark. The clubs were selected by the National Sports Federations or by the respective national coaches as clubs with the highest national standard. The age and anthropometric data are presented in Table 1.

Within each sport, the coach had divided the children into different training groups according to performance level and talent. In the study, the children from the high performance groups were separated in the elite group (E) and the children from the less talented groups were the non-elite group (NE).

Table 1 **Anthropometric** Data

		N	Age (yrs)	Bodymass (kg)	Height (m)
Swimming	Boys	21	11.5(1.1)	41.8(6.6)	1.51(0.07)
	Girls	28	11.6 (0.9)	41.0(7.6)	1.51(0.09)
Tennis	Boys	25	11.6 (0.9)	40.7(8.2)	1.50(0.09)
	Girls	12	11.5(1.0)	41.0(8.9)	1.53(0.09)
Handball	Boys	24	12.2 (0.4)	43.1(8.0)	1.54(0.08)
	Girls	24	12.2 (0.6)	46.8(6.4)	1.57(0.07)
Gymnastics	Boys	9	12.0(1.0)	39.3(6.6)	1.47(0.09)
	Girls	32	11.6 (0.9)	35.9(6.0)	1.45(0.09)
Total		175	11.8 (0.9)	41.1(7.8)	1.51(0.09)

The data are presented as mean (SD).

The children performed three different types of jumps; squat jump (SJ), counter movement jump (CMJ) and drop jump from 0.20 m, and 0.40 m (DJ20, and DJ40, respectively). The jumps were performed on a jumping mat (Eleiko, Sweden), which measured the flight time and during DJ also the ground contact time before take-off. The jumping height was computed from the flight time (t) by the formula: $h= 1/8\ gt^2$. The subjects performed several practice jumps before the test. In the DJs the subjects were urged to "jump as high as possible with as short a ground contact as possible". Different metaphors, like "jump like a bouncing ball", were also used. Three SJ, three CMJ and three DJ from each height were recorded. The highest recorded jumps from SJ and CMJ were used for analysis. The mean ratio between flight time and contact time of the three DJ were used as a measure of explosive jumping performance. Isometric two-leg extension strength was measured in a seated position with the knee flexion of 120 degrees (Asmussen et al., 1959) in subgroups of 22 girl swimmers and 25 girl gymnasts. The subjects were instructed to extend their hips and knees as forcefully and as fast as possible. The force development was sampled and stored on a PC at 500 Hz. After lowpass filtering at 15 Hz the maximal force (MVC) was registered, and the rate of force development (RFD) expressed as the increase in force from 0 to 100 ms (RFD_{100}) and ½ MVC divided by time to ½ MVC (S-gradient (Zatsiorsky, 1995)) was calculated relative to bodymass. Non-parametric statistical analyses were used. The Kruskal-Wallis test was used to detect differences between all groups, and the Mann-Whitney test was used for comparison of two groups.

RESULTS: The handball players were taller and heavier than the other athletes ($p<0.05$), and the gymnasts were smaller and lighter than the swimmers and tennis players ($p<0.05$). The handball players were older than the other groups ($p<0.05$) (Table 1). The jumping data are shown in Table 2.

Table 2 Gender Differences within Sports

		SJ (m) median(range)	CMJ (m) median (range)	DJ20 (ratio) median (range)	DJ40 (ratio) median (range)
Swim	Boys	0.245 (0.17-0.30)	0.250 (0.17-0.31)	1.73 (1.05-2.49)	1.59 (0.89-2.59)
	Girls	0.218 (0.17-0.28)	0.228 (0.15-0.31)	1.93 (1.39-2.77) *	1.92 (1.51-2.81) *
Tennis	Boys	0.245 (0.19-0.29)	0.260 (0.20-0.36) *	2.01 (1.07-3.24)	1.78 (1.11-2.80)
	Girls	0.218 (0.20-0.26)	0.233 (0.20-0.29)	1.93 (1.47-3.44)	2.00 (1.50-2.77)
Handb	Boys	0.230 (0.19-0.33)	0.265 (0.19-0.35)	1.96 (1.23-2.93)	1.83 (1.30-2.99)
	Girls	0.235 (0.20-0.31)	0.260 (0.20-0.32)	2.03 (1.33-2.76)	1.94 (1.39-2.52)
Gymn	Boys	0.265 (0.22-0.31) *	0.270 (0.24-0.35)	2.61 (2.14-2.95)	2.55 (1.81-3.23)
	Girls	0.245 (0.18-0.30)	0.265 (0.18-0.33)	2.47 (1.81-3.60)	2.43 (1.43-3.48)

* Significant difference between gender within sport ($p<0.05$)

The boys performed better than the girls in SJ for gymnasts ($p<0.05$) and CMJ for tennis ($p<0.05$), while the girl swimmers performed DJ better than the boy swimmers ($p<0.05$). No other gender differences within the sports were found. The gymnasts showed higher drop jump ratios than the other groups ($p<0.001$), and jumped higher in CMJ and SJ than the swimmers ($p<0.01$) and jumped higher in SJ than tennis players ($p<0.05$). The handball players jumped higher in CMJ than swimmers ($p<0.05$). There were no differences between tennis and handball or tennis and swimming. Both boys and girls from all sports jumped higher in CMJ than in SJ, except for gymnastic boys. The difference between CMJ and SJ were higher for tennis players than swimmers. There were no differences in CMJ-SJ difference among the other groups. All sport groups, measuring both genders together, had lower ratios in DJ40 than in DJ20 ($p<0.05$), except for the swimmers.

Table 3 Differences of Elite and Non-Elite Performances within Sports

		SJ (m) median (range)	CMJ (m) median (range)	DJ20 (ratio) median (range)	DJ40 (ratio) median (range)
Swimming	E	0.230 (0.18-0.30)	0.245 (0.19-0.31)	1.91 (1.24-2.77)'	1.91 (1.16-2.81)
	NE	0.225 (0.17-0.28)	0.228 (0.15-0.30)	1.62 (1.05-2.42)	1.61 (0.89-2.58)
Tennis	E	0.230 (0.19-0.29)	0.245 (0.20-0.36)	2.03 (1.07-3.44)	1.94 (1.11-2.78)
	NE	0.230 (0.19-0.29)	0.245 (0.20-0.34)	1.99 (1.45-3.24)	1.78 (1.22-2.80)
Handball	E	0.245 (0.19-0.33)	0.273 (0.19-0.35)	2.12 (1.56-2.93) **	2.04 (1.40-2.99)
	NE	0.230 (0.19-0.31)	0.245 (0.19-0.32)	1.83 (1.23-2.76)	1.83 (1.30-2.52)
Gymnastics	E	0.263 (0.21-0.31)'	0.270 (0.23-0.35)	2.86 (2.14-3.26)**	2.61 (2.24-3.44)**
	NE	0.243 (0.18-0.30)	0.260 (0.18-0.32)	2.36 (1.81-3.60)	2.20 (1.43-3.481

*E significantly betterthan NE ($p<0.05$) **E significantly better than NE ($p<0.01$).

The data of the E and NE groups within the sports are presented in Table 3. In swimming the E group had a higher DJ20 ratio ($p<0.05$), than the NE. There were no differences in the tennis group, but the E handball players had higher DJ20 ratios ($p<0.01$) and a trend towards higher CMJ ($p=0.054$). The E gymnasts performed better than the NE in SJ ($p<0.05$), DJ20 ($p<0.01$) and DJ40 ($p<0.05$). Differences between E groups from different sports were similar to those in the whole sports groups; the E gymnasts performed better than the E swimmers and E tennis in all parameters, and better than the handball players in DJ. The E handball group was better than the swimmers in CMJ and DJ20, but not in DJ40. There were no differences between tennis players and swimmers.

Table 4 Isometric Strength and RFD

		N	MVC (N kg-')	RFD_{100} (N kg-')	S-gradient(~~-'kg-')
Swimming	E	16	48.3 (26.6-66.2)	14.1 (4.3-32.7)	112.4 (40.1-310.2)
	NE	6	49.7 (33.1-61.1)	17.1 (4.6-27.1)	154.9 (52.2-280.1)
Gymnastics	E	13	50.7 (35.1-70.3)	16.2 (9.1-37.3)†	189.0 (108.1-435.5) *†
	NE	12	44.5 (40.9-57.3)	13.1 (5.73-30.7)	136.3 (87.1-464.2)

*Difference between E and NE ($p<0.05$). †Difference between E gymnastics and E swimmers ($p<0.05$).

The isometric leg extension recordings showed no differences between the sports in MVC or in RFD, when comparing whole groups, but the E gymnasts showed better RFD_{100} and S-gradient than the E swimmers. The S-gradient was also larger for the E gymnasts than the NE gymnasts. There were no E-NE differences in the swimming group (table 4). A correlation analysis showed small but significant correlations between RFD (Sgradient) and DJ20 ($r=0.32$, $p<0.05$) and DJ40 ($r=0.38$, $p<0.05$). There were no significant correlations between SJ or CMJ and RFD.

DISCUSSION: The jumping performance of the subjects corresponded well with data from other studies of the same age group. The values of CMJ are higher than the mean values reported by Mero (1998) and similar to those of young male athletes, reported by Mero et al. (1990). The gymnasts showed a better potential for explosive jumping. They were superior in the most explosive jumps, the DJ's, and were also better than swimmers in CMJ and SJ. The handball players also produced good ratios in the DJ. One of the main characteristics of gymnastics is the very explosive take off, when vaulting and somersaulting. Team handball involves a large amount of maximal jumping and sprint running. Since gymnastics and handball are the two sports in this study, that involve the most jumping activity, it is very likely that the gymnasts and handball players have developed the potential for explosive jumping, which is required for the superior DJ, through their training. The importance of the skill of explosive jumping in gymnastics and team handball was also indicated by the difference in DJ performance between the talented E group and the less talented NE group in those two sports, and the lack of the same differences in swimming and tennis. The E gymnasts, though, also seem to have a better baseline potential, as indicated by the better SJ performance. However, this study has not excluded heritage and natural selection as possible explanations for at least part of the found differences.
The study showed some correlation between the S-gradient and DJ performance. The better S-gradient of the E gymnasts vs. NE gymnasts and the E gymnasts vs. E swimmers corresponds well with the differences found in the most explosive drop jumps. An explanation for the small correlation coefficient might be related to the isometric method of RFD assessment. Thus the isometric force development may involve a different motor unit activation pattern than in dynamic jumping, as suggested by Murphy and Wilson (1996).
There were only few gender differences in the study. The male gymnasts performed better than the female gymnasts in SJ, and the tennis males performed better in CMJ than the tennis females. In most studies, the differences between boys and girls occur later (e.g. Mero, 1998), due to hormonal effects on muscle mass in boys and increase in fat in girls.
The fact, that no difference in SJ was found between E and NE handball players, while the DJ showed a difference, could mean that the talent for explosiveness (e.g. the ability of instant maximal innervation and a high % of white muscle fibres) is independent of the talent for neuromuscular coordination. This hypothesis can not be supported by the gymnastics data, since they showed a difference already in SJ. The tennis group data does not show any differences between E and NE, but this may be due to the less jumping activity in tennis compared to handball. The swimming data, on the other hand, contradicts the hypothesis, since the E swimmers perform a higher DJ ratio, in spite of no difference in SJ performance.

CONCLUSIONS: The specificity of the neuromuscular demands of training during childhood influences the performance of the child. Children may develop their potential for explosive jumping through training involving many power events.

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