Scand J Med Sci Sports 2002: 12: 171–178
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SCANDINAVIAN JOURNAL OF
MEDICINE & SCIENCE
IN SPORTS

Anaerobic power and muscle strength characteristics of 11 years old elite and non-elite boys and girls from gymnastics, team handball, tennis and swimming

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Accepted for publication 8 August 2001

The aim of the present investigation was to study the possible effects of specificity of training on muscle strength and anaerobic power in children from different sports and at different performance levels in relation to growth and maturation status. Hundred and eighty-four children of both gender participating either in swimming, tennis, team handball or gymnastics were recruited from the best clubs in Denmark. Within each sport, the coach had divided the children into an elite (E) and non-elite (NE) group according to performance level and talent. Tanner stage assessment and body weight and height measurements were performed by a physician. The anaerobic performances were assessed by Wingate tests and jumping performance in squat jump (SJ), countermovement jump (CMJ) and drop jump (DJ) from two heights. Most of the differences between groups in Wingate performance disappeared when the data were normalised to body mass. The gymnasts were the best jumpers and their superiority were increased in the more complex motor coordination tasks like DJ. The results may indicate some influence of training specificity, especially on the more complex motor tasks as DJ and there may be an effect of training before puberty. The performance in the less complex motor tasks like cycling and SJ and CMJ may also be influenced by specific training, but not to the same extent, and heritance may be an important factor for performance in these anaerobic tasks.

In many sports, the short bursts of high intensity power production plays a major role in the performance. Depending on the intensity and duration of the effort different energy systems will be predominantly taxed. The very short, high intensity lasting less than 1–2 s will mostly involve the adenosine triphosphate (ATP) depots in the muscles, and the performance will depend on the cross-sectional area of the muscle fibers, the type of muscle fibers, and the central nervous ability to excite the motor units at a high rate. The high intensity activities lasting up to 5–6 s also depends on the above mentioned but in addition the ability to utilize the CrP depots. The longer but still high intensity activities will depend more on the muscle fibers ability to produce ATP through the glycolytic pathway at a high rate. The need of anaerobic power and short burst muscle strength will prevail differently in sports like gymnastics, team handball (henceforth referred to as handball), tennis and swimming.

Only few studies have investigated the effect of training on anaerobic power in children, and some of them indicate that training during prepuberty may improve the glycolytic power to some extent (Eriksson, Gollnick, Saltin, 1973), while others found no difference between trained and untrained boys (Kuno et al., 1995). Sports like handball and tennis include short supramaximal sprints, which may tax the maximal anaerobic power development, and this might cause handball and tennis children to perform better in anaerobic tests. In gymnastics, the bursts of highly intense activity are mostly so short, that it is not likely to tax the anaerobic system to any high extent, and it is therefore not likely, that children in gymnastics will perform better than normal children. There may also be demands on anaerobic power development in swimming, especially in the shorter distances, and swimmers might therefore show good anaerobic performances.

The influence of maturation on development of anaerobic fitness have been discussed since Eriksson, Karlsson, Saltin (1971) reported a moderate correlation between maximal muscle lactate and testicular volume in 13-year-old boys suggesting an effect of testosterone on maximal lactate production (Paterson, Cunningham, Bumstead, 1986; Falgairette, Bedu, Fellmann, Van-Praagh, Coudert, 1991; Falk & Bar-Or, 1993; Welsman, Armstrong, Kirby, 1994). Subsequent studies have failed to support this conclusion. Several studies show a progressive development in maximal lactate levels and anaerobic power throughout childhood, not just the period of puberty. Testosterone is suggested as a potent trigger of glycolytic development. Consequently, one would expect greater lactate production during exercise in males than in females, particularly after puberty. There has, however, not been any evidence of gender specific differences in maximal blood lactate concentration.

In shorter activity patterns like jumping, throwing or striking the muscle strength – and in particular the ability to develop it fast – plays a major role. Some investigations have shown a fairly good correlation between lower limb maximum strength and the maximal jump height (Blackburn & Morrissey, 1998). 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 countermovement jump (CMJ) requires moderate eccentric activation followed by high concentric activation, and therefore requires a more complex timing and graduation of the motor units. The drop jump (DJ) 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 the potential of explosive muscle strength and CMJ and DJ may indicate development of this potential. Since the neuromuscular system develops from birth through 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 (Blimkie, 1993; Ozmun, Mikesky, Surburg, 1994). Also during puberty muscle strength is affected by maturation as Pratt (1989) argued by showing higher correlation of strength and Tanner stage compared with chronological age. The increased production of anabolic hormones that occur during puberty are also likely to affect muscle hypertrophy. Boys increase anabolic hormone production more than girls, which may explain the lesser increase of muscle strength through puberty exhibited by girls.

While most sports require considerable use of the muscle power of both lower limbs, some sports in addition require only the use of one arm while again other sports use both arms. In handball and tennis, the players predominantly use only one arm while in swimming and gymnastics the athletes use both arms equally. It could be presumed, that training in different sports will induce different effects on arm strength, since it has been shown that training of children can increase strength (Ramsay, Blimkie, Smith, Gamer, MacDougall, Sale, 1990; Blimkie, 1993; Ozmun et al., 1994).

The aim of the present investigation was to study the possible effects of specificity of training on muscle strength and anaerobic power in children from different sports and at different performance levels in relation to growth and maturation status.

Methods

The study involved 185 children. All subjects and their parents gave their informed consent, and the study was approved by the Danish National Ethics Committee. The subjects were active in swimming, tennis, gymnastics or handball, and they were recruited from some of the most excellent clubs in Denmark, which 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 as the elite group (E) and the children from the less talented groups constituted the non-elite group (NE). The participants filled in an extensive questionnaire including questions regarding the amount of training in hours per week. The E group trained significantly ($p < 0.05$) more hours than the NE group (median (range): 9 h (2–18 h) vs. 6 (2–15.5 h), respectively). Since it is very difficult to find matched non-athletic control groups to longitudinal physiological studies the NE groups would act as age-matched control groups to the E groups.

Anthropometric measurements

The height and body mass were measured and the Tanner status was estimated by a paediatrician of same gender as the subject. The Tanner status was estimated as breast development and pubic hair for the girls, and genital development and pubic hair for the boys. The two values for each gender was combined and expressed as one value ranging from 2 to 10 (Petersen, Gaul, Stanton, Hanstock, 1999). Before the physiological tests, the subjects had a blood sample drawn to measure the amount of Insulin like Growth factor-I (IGF-I). Some of the anthropometric data are shown in Table 1.

Anaerobic power

The Wingate anaerobic test was performed on a modified Monark cycle ergometer. The subjects were vigorously encouraged to pedal as fast as possible for 30 s. The braking load was calculated according to Bar-Or (1996), i.e., $67\,g\,kg^{-1}$ BW for girls and $70\,g\,kg^{-1}$ BW for boys. The number of pedal revolutions per minute was measured by a photocell at a frequency of 20 Hz and stored on a PC. The data was subsequently processed with a running average of 0.5 s. The highest value (Watts (W)) during the 30 s was defined as peak power (PP), and the mean power (MP) was calculated as the average of all values during the 30 s. The difference between PP and the lowest value at the end was calculated relative to PP and used as fatigue index (%) (FI).

Lower limb explosive strength

The children performed three different types of jumps; squat jump (SJ), countermovement 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 were accustomed by performing several practice jumps before the test. In the DJ 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 from each height were used as a measure of explosive jumping performance (Young, Wilson, Byrne, 1999).

Arm strength measurements

Elbow extension and elbow flexion moments were measured isometrically with a Darcus dynamometer (Darcus, 1953) at 90° elbow flexion. The subject was placed in a chair next to the dynamometer and strapped to the chair with a vertical upper arm and a horizontal supinated (flexion) or pronated (extension) forearm. The subject was told to contract as forcefully as possible in order to obtain the maximal voluntary contraction moment (MVC). The signal from the Darcus dynamometer was amplified and stored on a PC at a sampling rate of 500 Hz.

Statistics

The present data were divided in different subgroups based on gender, performance level or sport. These groups did not all fulfil the requirements of parametric statistics. Therefore mainly non-parametric statistical analyses were applied. The Mann–Whitney test was used for comparison of the two gender groups and E groups vs. NE groups. Within gender and performance level the data were ranked and a one-way ANOVA was used to detect differences between sports. If differences were found the Tukey's post hoc test was used to analyse differences between the specific sports. Pearson's product moment correlation was used on all subjects to examine correlations between parameters. All statistical tests were performed using the SPSS-software (Chicago, Illinois, USA). A significance level of $p < 0.05$ was selected.

Results

There were no gender differences in age, height or weight within sports, but the E girl swimmers were older, taller and heavier than the NE girl swimmers, and they also showed a higher IGF-I concentration (Table 1).

There were several differences between sports, as shown in Table 1. The handball players were older than the other subjects in the sports, however, this difference diminished when separating in gender and performance level. Gymnasts were smaller and lighter than the other groups when comparing data for both boys and girls pooled, but within gender and performance level only the NE boy swimmers and NE handball boys and both handball girls groups were taller than the respective gymnast groups. The boy gymnasts were smaller than all the other boys, but only the handball boys were heavier than the boy gymnasts, however, the latter difference was not significant when splitting in performance level (Table 1). In addition, the handball boys showed greater concentrations of IGF-I than the boy gymnasts. The girl gymnasts were smaller than the girl swimmers and handball girls, but were not significantly smaller than the tennis girls. The handball girls were heavier than the girl swimmers and the girl gymnasts. Compared to the other girls, the IGF-I concentration tended to be largest in the handball girls. No differences in Tanner stages between the groups were found.

Wingate tests

The Wingate results are presented both in absolute values and in body mass related values in Table 2.

Table 1. Anthropometric data

Sport	Ge	E/NE	*n*	Age (years)	Height (cm)	Body mass (kg)	IGF-I (mg/l)	Tanner
Swim	B	E	9	12.0 (9.2–13.0)	153.0 (137.9–164.6)	41.7 (29.5–54.7)	301 (179–523)	3 (2–10)
		NE	13	11.4 (10.0–12.9)	150.0 (141.6–164.7)^{*g}	40.0 (30.0–52.2)	258 (196–464)^{*g}	2 (2–6)
	G	E	20	11.8 (10.9–13.9)′	154.5 (142.3–166.4)†	44.8 (32.0–53.0)$^{\dagger *g}$	435 (210–655)†	5.5 (2–9)
		NE	8	10.7 (10.2–11.5)	144.9 (133.3–156.8)	33.9 (25.1–51.8)	319 (172–453)	3 (2–6)
Tennis	B	E	12	11.9 (105–12.7)	153.4 (139.0–168.5)	43.0 (29.4–57.9)	315 (233–587)	3.5 (2–10)
		NE	12	11.1 (10.0–12.7)	145.9 (134.6–164.4)	37.1 (30.6–60.2)	267 (201–593)^{*g}	2 (2–10)
	G	E	6	11.9 (10.0–12.2)	151.7 (148.3–164.9)	38.3 (34.4–61.3)	474 (279–663)	4 (2–6)
		NE	7	11.7 (9.4–12.7)	155.5 (136.5–167.0)	42.0 (29.3–51.5)	526 (217–584)	3.5 (2–8)
Handb	B	E	12	12.5 (117–12.7)	152.9 (143.5–171.2)	42.7 (33.0–52.5)	390 (207–709)^{*g}	4 (2–10)
		NE	12	12.0 (115–12.7)	152.5 (143.7–163.7)^{*g}	39.8 (33.8–61.4)	278 (210–670)^{*g}	3 (2–10)
	G	E	12	12.3 (11.4–12.9)	159.1 (146.6–166.1)^{*g}	47.2 (38.7–53.3)^{*g}	538 (321–606)	4 (2–6)
		NE	12	12.3 (11.1–12.9)^{*s}	154.9 (140.5–166.0)^{*g}	45.4 (35.5–60.0)^{*gs}	544 (302–684)	5 (3–8)
Gymn	B	E	11	11.7 (10.8–13.8)	146.2 (127.1–162.4)	35.5 (26.7–47.0)	283 (215–729)	2 (2–10)
		NE	6	12.6 (10.8–12.7)	141.1 (136.9–144.3)	34.4 (32.9–46.2)	140 (117–163)	2.5 (2–6)
	G	E	13	11.8 (95–12.9)	146.1 (131.7–157.6)	37.1 (285–45.5)	324 (185–671)	3 (2–10)
		NE	20	11.7 (9.4–12.9)^{*s}	147.1 (128.5–161.1)	35.3 (26.0–55.2)	385 (221–627)	4 (2–6)

All data are in median (range) values. Ge indicates gender, B indicates boys and G indicates girls. E means elite performance level and NE indicates non-elite performance level. Tanner stage is indicated as combined Tanner stages, i.e., both Tanner stages in one value ranging from 2 to 10. †indicates significant difference ($p < 0.05$) from the NE-group within sport and gender. *indicates a significant difference ($p < 0.05$) from the other sports within gender. The different symbols followed by a letter indicate significant differences within gender and performance level from the sport indicated by the letter.

No differences were present between gender within sports in any parameter. However, when looking at the sports split in performance level the elite (E) boy swimmers showed higher relative peak power (PP) and mean power (MP) than the E girl swimmers.

In absolute values, the E handball girls produced the highest peak power (median 411 W) followed by the handball boys. The E handball boys performed better in absolute peak power than the gymnastic boys, and the E handball girls performed better in peak and mean absolute power than the E gymnastic girls and the E girl swimmers in mean power.

The differences between sports did to a large extent disappear when the data were normalised to body mass, but other differences emerged; only the E handball girls still performed better than the E girl swimmers in peak power when the data were normalised. The E girl swimmers had a lower fatigue index (FI) than the E handball girls. Also the E girl gymnasts had lower FI than the E handball girls.

Jumping performance

There were no differences between gender within sports in the SJ or CMJ performance (Table 3). The E handball boys were better than the NE handball boys in the SJ, and the E boy swimmers jumped higher in the CMJ than their NE counterparts. The E boy gymnasts performed better than NE boy gymnasts in both SJ and CMJ. There were no differences between E and NE girls within sports.

The E girl gymnasts jumped higher than the E girl swimmers in both SJ and CMJ.

No gender differences were found in DJ performance when looking at all subjects, but the boy gymnasts had higher flight time/ground time ratios than the girl gymnasts at both DJ heights. In handball, the E boys performed better than the NE boys at both heights. The same was the case for the girl gymnasts, while the E boy gymnasts performed better than the NE boy gymnasts only at DJ40.

When comparing the sports, the E boy gymnasts had better ratios than all the other E boy groups at both heights, while the E girl gymnasts showed better ratios than the E handball girls and the E girl swimmers. Also the NE boy gymnasts performed better than the NE boy swimmers at both heights and better than NE handball boys at DJ20. There were no differences between sports in the NE girls group.

Arm strength data

Gender differences were only found in gymnastics for the dominant (D) and non-dominant (ND) elbow extensor group, see Table 4.

Differences in strength between E and NE were only found among the swimmers. The E boy swimmers were stronger in D flexor, ND flexor and ND extensor, while the E girl swimmers were stronger in D flexor, D extensor and ND extensor, and came close to significance in ND flexor ($p = 0.06$). No major differences between the sports were seen within gender and performance level (Table 4). However, when looking at differences between D and ND arm among the sports, some variations were seen. In the boys (E and NE together), the handball players showed greater side-to-side

Table 2. Wingate data

Sport	Ge	E/NE	n	Peak power (W)	Mean power (W)	PPREL (W·kg^{-1})	MPREL (W·kg^{-1})	FI (%)
Swim	B	E	9	355 (259–528)	319 (231–423)†	8.8 (7.7–9.8)#	7.7 (6.8–8.6)†#	29.0 (217–42.6)
		NE	13	316 (248–477)	254 (220–370)	8.0 (5.2–9.1)	6.6 (4.6–7.9)	33.4 (207–48.8)
	G	E	17	339 (237–428)†	284 (220–385)†	7.9 (7.1–8.5)	7.2 (6.1–7.7)	25.9 (17.6–45.0)^{*h}
		NE	7	276 (180–332)	238 (160–301)	7.8 (7.2–9.1)	6.8 (5.6–8.2)	26.0 (14.1–54.6)^{*t}
Tennis	B	E	12	365 (218–617)	314 (205–529)	8.6 (7.4–10.7)	7.4 (6.7–9.1)	33.2 (16.9–45.6)
		NE	12	332 (263–512)	272 (232–430)^{*g}	9.0 (8.4–10.4)^{*s}	7.3 (6.7–8.3)^{*gs}	37.4 (31.1–70.9)
	G	E	6	333 (276–514)	279 (233–433)	8.3 (8.0–9.3)	7.2 (6.4–7.7)	33.8 (25.5–41.1)
		NE	7	373 (246–492)	317 (186–418)	8.8 (8.4–10.4)^{*g}	7.5 (5.9–8.8)	38.9 (29.8–48.8)
Handb	B	E	12	380 (298–537)^{*g}	310 (268–477)^{*g}	9.0 (6.1–10.2)†	8.0 (5.6–9.3)†	32.0 (23.3–43.5)
		NE	12	351 (271–507)	285 (236–432)^{*g}	8.6 (6.7–9.4)	7.3 (5.8–8.0)	37.3 (23.2–55.5)
	G	E	12	411 (330–502)^{*gs}	350 (283–395)^{*g}	8.7 (6.9–9.8)^{*s}	7.2 (6.1–8.1)	37.8 (32.9–50.2)
		NE	12	377 (268–548)^{*gs}	320 (248–447)^{*gs}	8.1 (6.9–9.8)	7.0 (6.1–8.0)	34.7 (19.7–49.2)
Gymn	B	E	11	287 (214–477)	234 (194–405)	8.1 (7.5–10.1)	7.3 (6.1–8.6)	38.3 (25.4–48.4)
		NE	6	269 (240–441)	227 (215–290)	7.9 (7.0–9.6)	6.4 (6.3–7.4)	33.6 (22.9–61.7)
	G	E	13	303 (207–384)	270 (186–333)	8.2 (6.4–8.7)	7.3 (5.8–7.7)	31.6 (19.3–38.1)^{*h}
		NE	20	274 (185–490)	249 (169–352)	7.5 (6.6–9.1)	6.6 (5.4–7.5)	27.7 (17.6–51.0)

All data are in median (range) values. Ge indicates gender, B indicates boys and G indicates girls. E means elite performance level and NE indicates non-elite performance level. †indicates significant difference ($p < 0.05$) from the NE-group within sport and gender. #indicates significant difference ($p < 0.05$) between gender within sports and performance level. *indicates a significant difference ($p < 0.05$) from the other sports within gender and performance level. The different symbols followed by a letter indicate significant differences within gender from the sport indicated by the letter.

Table 3. Jump data

Sport	Ge	E/NE	*n*	SJ (cm)	CMJ (cm)	DJ20 (ratio)	DJ40 (ratio)
Swim	B	E	9	26.0 (23–31)	27.0 (25–31)†	1.9 (1.2–2.5)	1.8 (1.2–2.6)
		NE	12	23.5 (17–28)	23.5 (17–29)	1.6 (1.1–2.4)	1.6 (0.9–2.2)
	G	E	20	22.0 (19–28)	23.0 (20–31)	1.8 (1.2–2.8)	1.9 (1.2–2.8)
		NE	8	23.0 (17–29)	23.5 (15–32)	1.9 (1.5–2.4)	2.0 (1.3–2.4)
Tennis	B	E	12	25.5 (19–29)	26.0 (21–36)	2.0 (1.1–2.8)	1.9 (1.1–2.8)
		NE	12	24.5 (19–28)	26.5 (21–34)	2.0 (1.5–3.2)^{*s}	1.8 (1.2–2.8)
	G	E	6	23.0 (22–26)	24.5 (22–27)	2.1 (17–3.4)	2.3 (17–2.8)
		NE	7	23.0 (20–30)	24.0 (20–33)	1.9 (1.5–2.9)	1.8 (1.5–2.2)
Handb	B	E	12	28.5 (20–33)†	28.5 (19–35)	2.2 (1.6–2.9)†	2.1 (1.4–3.0)†
		NE	11	23.0 (19–33)	25.0 (19–32)	1.7 (1.2–2.2)	1.6 (1.3–2.1)
	G	E	12	24.0 (21–30)	26.0 (22–33)	1.9 (17–2.6)	2.0 (1.6–2.4)
		NE	12	25.0 (20–31)	25.0 (21–33)	2.1 (1.3–2.8)	2.1 (1.4–2.5)
Gymn	B	E	11	28.0 (24–33)†	30.0 (22–38)†	2.8 (2.1–3.3)#^{*sth}	2.6 (2.3–3.2)#†^{sth}
		NE	6	23.0 (20–30)	25.0 (21–27)	2.6 (1.9–3.2)#^{*sh}	2.2 (1.7–2.7)#^{*s}
	G	E	13	26.0 (21–30)^{*s}	27.0 (23–36)^{*s}	2.4 (2.0–3.5)†^{*s}	2.3 (1.8–3.5)†^{*s}
		NE	20	25.0 (18–31)	27.0 (19–35)	2.2 (1.5–3.6)	2.1 (1.6–3.5)

All data are in median (range) values. Ge indicates gender, B indicates boys and G indicates girls. E means elite performance level and NE indicates non-elite performance level. †indicates significant difference ($p < 0.05$) from the NE-group within sport and gender. #indicates significant difference ($p < 0.05$) between gender within sports and performance level. *indicates a significant difference ($p < 0.05$) from the other sports within gender and performance level. The different symbols followed by a letter indicates significant differences within gender from the sport indicated by the letter.

Table 4. Arm strength

Sport	Ge	E/NE	*n*	D Flex (Nm)	D Ext (Nm)	ND Flex (Nm)	ND Ext (Nm)	Δ Flex (Nm)	Δ Ext (Nm)
Swim	B	E	9	30.3 (24.5–48.6)†	30.4 (24.9–51.2)	29.3 (21.1–42.2)†	31.8 (26.8–50.0)†	2.8 (−1.6–6.4)	0.7 (−8.9–3.1)
		NE	13	24.3 (16.9–28.9)	28.5 (22.2–34.2)	23.1 (17.0–34.1)	24.7 (19.5–35.4)	0.8 (−5.3–3.1)	2.7 (−5.9–8.1)
	G	E	20	24.7 (18.7–35.9)†	29.2 (23.1–37.9)†	25.0 (17.6–33.3)	27.9 (20.4–40.2)†	0.9 (−2.4–8.0)	0.9 (−6.3–9.8)
		NE	8	21.5 (14.8–28.6)	21.5 (17.6–34.6)	20.3 (14.3–27.3)	22.4 (147–33.6)	0.7 (−1.4–5.4)	1.9 (−2.2–4.3)
Tennis	B	E	12	30.0 (167–48.0)	30.7 (16.2–55.0)	21.7 (133–43.1)	28.8 (14.1–52.1)	5.7 (−2.1–14.9)	2.7 (−1.4–6.6)
		NE	13	25.6 (20.6–37.5)	28.4 (24.9–38.3)	24.9 (16.2–32.6)	28.5 (21.5–34.6)	2.8 (−0.4–11.6)	1.7 (−3.6–6.8)
	G	E	6	25.3 (21.2–45.7)	27.5 (21.8–47.2)	23.7 (17.3–40.2)	26.1 (18.8–34.6)	3.2 (0.2–5.5)	4.6 (−7.6–12.6)
		NE	6	20.1 (11.4–39.1)	28.8 (11.6–37.7)	25.3 (9.6–41.9)	27.2 (12.6–31.1)	0.4 (−12.4–7.3)	3.1 (−3.7–7.1)
Handb	B	E	12	31.1 (23.2–44.7)	34.1 (29.9–42.3)	27.1 (24.4–36.1)	30.8 (26.6–53.2)	2.1 (−1.2–9.3)	4.0 (−10–6.6)
		NE	12	28.0 (22.8–54.3)	30.1 (24.2–51.7)	24.4 (17.2–49.4)	28.6 (213–45.3)	3.2 (AA-8.3)	2.2 (4.4–10.5)
	G	E	12	31.2 (24.6–42.9)	32.3 (25.9–45.4)	26.2 (21.2–41.4)	27.7 (20.4–40.9)	4.9 (−0.9–9.7)	2.2 (0.9–11.4)
		NE	12	26.8 (16.6–38.0)	29.7 (24.0–40.7)^{*g}	27.8 (16.4–33.1)^{*g}	29.0 (16.0–40.9)^{*s}	0.6 (−5.8–8.6)	1.7 (−5.4–8.0)
Gym	B	E	11	27.3 (17.5–45.1)	31.5 (22.7–44.6)#	24.7 (17.9–33.1)	28.0 (23.5–46.4)#	1.6 (−5.8–7.5)	0.5 (−8.5–6.9)
		NE	6	25.0 (19.4–36.3)	28.4 (27.2–31.7)	24.6 (16.5–29.3)	29.9 (27.5–40.3)	0.7 (−0.4–7.0)	−2.2 (−8.6–1.4)
	G	E	13	23.3 (17.6–41.6)	24.2 (19.5–50.0)	24.4 (153–36.2)	24.4 (21.0–42.8)	2.1 (−3.4–7.6)	−1.3 (−11.6–8.9)
		NE	20	21.7 (13.9–33.8)	24.7 (14.6–33.6)	21.8 (10.8–28.7)	24.1 (14.5–32.3)	1.8 (4.4–5.2)	0.0 (4.4–4.1)

All data are in median (range) values. Ge indicates gender, B indicates boys and G indicates girls. E means elite performance level andNE indicates non-elite performance level. D indicates dominant arm, ND indicates non-dominant arm, Δ indicates difference between dominant and non-dominant arm. †indicates significant difference ($p < 0.05$) from the NE-group within sport and gender. #indicates significant difference ($p < 0.05$) between gender within sports and performance level. *indicates a significant difference ($p < 0.05$) from the other sports within gender and performance level. The different symbols followed by a letter indicate significant differences within gender from the sport indicated by the letter.

differences in extension than the gymnasts. Among the girls (E and NE together), no side-to-side differences were seen.

Discussion

The major findings in the present study points at sports specific differences in the measured parameters. The anthropometric measurements showed that the gymnasts were the smallest and lightest, but no differences in Tanner stages among all the subgroups were found. The anaerobic power was highly related to body size as only the E handball girls performed better than the E girl swimmers in the Wingate test, when the values were normalised to body mass. The gymnasts had the most explosive muscular performance as expressed by higher SJ and CMJ jumps and better DJ ratios than the other sports. The E gymnasts were also more explosive jumpers than the NE gymnasts indicating that jumping capabilities are crucial for gymnastic performance. Only few differences in arm strength were found between sports indicating that arm strength is demanded in all the sports. Only in swimming differences in arm strength were found between E and NE groups.

The handball and tennis boys showed a larger D–ND difference than gymnasts and swimmers which may be due to the very specific one-sided training in these sports.

The gymnasts were smaller and lighter than the participants of the other sports. It is in concert with Claessens, Lefevre, Beunen and Malina (1999), who showed moderate negative correlations between endomorphic and performance score, i.e., the small and light gymnast will have an advantage in the gymnastic competition. Based on the parental information, Damsgaard, Bencke, Matthiesen, Petersen, Muller, (in press) concludes that the lesser body size of the gymnasts in this study may be due to a selection of the genetically predisposed children, as also argued by (Baxter-Jones, Helms, Maffulli, Baines-Preece, Preece, 1995). The swimmers and handball players were generally the largest which may be an advantage in these sports. Since the body is floating in the water, the large swimmer may not experience as high a degree of depressed performance as a large athlete would in endurance sport on land, while he may still have the larger maximal oxygen uptake and muscle mass. Avlonitou (1994) showed that preadolescent swimmers in the shorter distances were taller and had longer body segments than the participants in the other swimming distances. As a sport with many tough contacts between players on the court, a large, but not obese, body will be an advantage in handball. Danish tests support this general opinion; no physiological differences were present between young, 17–18-year-old youth national players and the adult national team, except for a difference in body mass of 10 kg (Jensen & Johansen, 1994), though the adult team would be totally superior in performance. This may explain that the handball players are taller and heavier than the gymnasts. The differences may also be partly explained by the handball players being slightly older than the other groups. This might also be explained by the tendency for the handball girls to have a greater IGF-I concentration.

The strength data shows side differences in the two unilateral sports: handball and tennis. Several studies show effect of strength training on muscle strength in pubertal children (Blimkie, 1993; Ozmun et al., 1994). In the two sports, the load on the upper limbs will predominantly be on the dominant arm, and swinging a tennis racket or throwing a handball many times during a training session could be considered strength training, hence a side difference in these sports could be expected.

The Wingate results of the boys E groups were above the average values reported for normal Israeli boys in the same age, while the NE boys were within the average range (-7.0 and $-8.3\,\mathrm{W\,kg^{-1}}$, MP and PP, respectively) (Inbar, Bar-Or, Skinner, 1996). On the other hand both the E and NE girls were well above the reported values of -5.6 and $6.7\,\mathrm{W\,kg^{-1}}$ (NIP and PP, respectively) for normal Israeli girls. This higher degree of anaerobic fitness for the girls in the present study may be due to differences in training status, or perhaps socio-cultural differences may offer an explanation for the divergence in values for the girls.

Previous studies show that anaerobic metabolism is more developed in adults than in children (Eriksson et al., 1973; Zanconato, Buchthal, Barstow, Cooper, 1993; Kuno et al., 1995), indicating that maturation may influence anaerobic energy production. In adults, it is well known that training can increase the maximal glycolytic power, but only few studies have investigated the effect of training on anaerobic energy production in children. Eriksson et al. (1973) showed an increase in glycolytic enzyme activity in adolescent boys after training, but Kuno et al. (1995) failed to show any difference between trained and untrained boys. In the present study, the differences between sports did to a large extent disappear when the data were normalised to body mass, and this indicates that the anaerobic power is related to muscle size more than to training. Only the E handball girls showed a significantly better peak power normalised to body mass than the E girl swimmers in the Wingate test. Other studies have shown that relative mean power correlates well with short distance swimming performance for young swimmers (Hawley, Williams, Vickovic, Handcock, 1992; Duche, Falgairette, Bedu, Lac, Robert, Coudert, 1993), while relative peak power was not as powerful a predictor of swimming performance. Since the peak power, normally attained during the first 5–6 s of the test, probably relies predominantly on the phosphagen energy stores while the mean power would be more dependent on the glycolytic power. The results indicate that the handball girls are more trained for sprints and able to utilize more ATP and CrP in short sprints than the girl swimmers. However, the E girl swimmers are better able to sustain a high power development through the 30 s test than the E handball girls as expressed by the lower FI of the girl swimmers, and this could be due to an anaerobic endurance obtained through training. On the other hand, the high peak power produced by the handball girls may also be impossible to sustain after the depletion of the phosphagen stores, and this may explain the larger drop in power seen in the handball girls. These differences correspond well to the nature of the two sports, although the same differences were not found for the boys.

The SJ and CMJ heights of the subjects in the present study were higher than average values for normal children (Mero, 1998), and very similar to the values of different athletes of similar age (Mero, Kauhanen, Peltola, Vuorimaa, 1990; Mero, Jaakkola, 1991;

Viitasalo, Rahkila, Osterback, Alen, 1992). The present study shows a difference in SJ and/or CMJ between the E boys and NE boys within the different sports, except for tennis. No differences between sports among the boys were found. Mero et al. (1990) found no differences between an athletic group and controls in SJ and CMJ. However, in a later study they showed differences in jumping performance between two groups with different fiber type composition in the vastus #M. lateralis, with a better performance in the "fast" group (Mero et al., 1991). This relation between jumping performance and Muscle fiber type composition implies that jumping performance to some extent may be regarded as inherited, since the fiber type composition basically is genetically determined (Komi, Viitasalo, Havu, Thorstensson, Sjodin, Karlsson, 1977), and can only to a lesser degree be altered by training (Booth & Thomason, 1991). Early selection of the athletes with the most optimal muscle fiber type composition for the E group may therefore be a possible explanation for the differences in SJ and CMJ seen in the present study, though training also may have had an influence on the jumping performance. In contrast to the boys, no differences between E and NE groups were found for the girls, but some differences emerged when looking at the E groups of the different sports. To our knowledge, no studies have examined differences in girls between sports or performance level in jumping performance, but the present data may indicate an effect of training, since swimming as the less explosive sport was inferior to gymnasts with regard to SJ and CMJ jumping performance, but no differences were found between the E and NE within the sports.

The DJ results revealed that the gymnasts in general were the most superior. The E boy gymnasts had better ratios than all the other E boys but were only better than the NE boy gymnasts at DJ40. This indicates, that the DJ performance may be more dependent on the type and intensity of the jumping during training, since it is reasonable to assume that the differences in this neuromuscular coordination activity are more sports specific than in the other more strength dependent jumps.

The present study shows a weak relation between PP development, and SJ and CMJ performance ($r = 0.41$ and $r = 0.46$, respectively), and no relation between PP and DJ, which corroborates that different factors influence the performance in the different tests. The PP performance may depend more on the ability to use the ATP and CrP stores and these are to a high degree related to muscle size, since only few differences were seen when Peck Power (PP) was expressed relative to Bodymass (BM). The SJ and CW will also depend on maximal muscle strength but the low association between PP and jumping indicates that other factors may be very important. The neuromuscular coordination is probably very different between the Wingate test and the different types of jump, and the degree of complexity in motor coordination increases with the complexity of the jumping task. The Wingate test can be considered the least complex and the DJ40 the most complex. The differences between the sports increased as according to the complexity of the task, and this suggests that the specificity of the training with regards to motor patterns used in the specific sports accentuates the more complex neuromuscular tasks the sport demands.

Perspectives

The present study provides a new insight in the performance level and variability of anaerobic performance among children of both gender from different sports and different training status. The results may indicate some influence of training specificity, especially on the more complex motor tasks as DJ and there may be an effect of training before puberty. The performance in the less complex motor tasks like cycling and SJ and CMJ may also be influenced by specific training, but not to the same extent, and heritance may also be an important factor for performance in these anaerobic tasks.

Key words: children; anaerobic power; jump performance; training level.

Acknowledgements

This study was supported by the Danish Medical Research Counsil (project no. 9600260), the Danish Counsil of Research in Sports (project no. 970501–34) and the Sports Confederation of Denmark.

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