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ORIGINAL ARTICLE

Morphological characteristics of Olympic slalom canoe and kayak paddlers

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Abstract

Sidney and Shephard (1973) were the first to report on the morphology of slalom paddlers and characterized them as having "a substantial standing height and lean body mass, good general muscle development with particular emphasis on the leg muscles". The purpose of this study was to analyse the morphological characteristics of Olympic slalom kayak and canoe paddlers to determine whether they possess unique physique or structural characteristics that provide an advantage for their sport. Thirty-one male and 12 female slalom paddlers were measured using a battery of 36 anthropometric dimensions in the 15-day period before competition at the 2000 Olympic Games. Male slalom paddlers were older, lighter, shorter, and leaner than previously reported slalom paddlers and had similar height and weight to a reference population of non-athletes. Compared with Olympic sprint paddlers, male slalom paddlers were older, lighter and shorter, and had similar body fat and almost identical proportionality characteristics. Female slalom paddlers were taller, lighter, older, and less fat than those reported previously. They were taller and lighter than the reference population of non-athletes and of similar age and height but lighter and leaner than the Olympic sprint paddlers. While a high brachial index was reported for both male and female slalom paddlers, the Best male paddlers (those ranked in the top 10 placings) were more compact, had smaller proportional hip girth, and showed a tendency for smaller proportional hip breadth but a larger proportional waist girth than the Rest (those not ranked in the top 10 placings). Changes to the technical aspect of the events and to competition rules and the nature and approach to training were explored as possible reasons for some of these differences. We outline the contribution this research makes to talent identification and highlight the need for further research.

Keywords: *Olympic, slalom, paddler, morphology, proportionality*

Introduction

Slalom is said to have been born in Switzerland in 1932. The first world championships in slalom for men and women under the patronage of the International Canoe Federation were conducted in 1949 in Geneva and subsequent world championships were held every 2 years until 1999 and, from 2002, annually except for the Olympic years. Slalom was first introduced into the Olympic Games in 1972 at Munich (at Augsburg), on the world's first artificial course. It was not until 1992 in Barcelona that the slalom event returned to the Olympic programme. Slalom events were also conducted at Atlanta in 1996, Sydney in 2000, and at the Hellonika site in Greece in 2004.

Reports on the morphology of male and female slalom paddlers are almost as haphazard as the staging of the slalom event at the Olympic Games. It was not until 1973 that Sidney and Shephard first reported on the morphology of ten male and two female nationally ranked canoe paddlers. They reported that the successful paddler is characterized by "a substantial standing height and lean body mass, good general muscle development with particular emphasis on the leg muscles" (p. 55). At the 1983 World Championships, the USA won gold medals in the C1 (one canoe competitor) and C2 (two canoe competitors) individual and C1 team events and a bronze medal in the C2 team event. Vaccaro and colleagues (Vaccaro, Gray, Clarke, &

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Morris, 1984) reported that this 13-man US slalom team was predominantly mesomorphic, with a pronounced musculature, fairly low on endomorphy, and typical of normal young men on ectomorphy. Reports by Freeman and colleagues (Freeman, Chennells, Sandstrom, & Briggs, 1987) and Sklad and colleagues (Sklad, Krawczyk, & Majle, 1994) provided information on the morphology of nationally ranked male and female paddlers from Australia and male slalom kayakers from Poland respectively. While both reports referred to the mesomorphic nature of these athletes, Sklad *et al*. (1994) also referred to the robustness of the skeleton.

As there is a paucity of information on the morphological characteristics of elite slalom paddlers, Olympic slalom kayak and canoe paddlers were examined in the present study to determine if they possess unique physique or structural characteristics that may provide an advantage for their sport. If particular characteristics can be identified, it might be possible to use them for talent identification purposes.

Methods

Participants

Altogether, 31 male (kayak and canoe: nine of whom had a world ranking of 10 or lower) and 12 female (kayak: three of whom had a world ranking of 10 or lower) slalom paddlers were measured using a battery of 36 anthropometric dimensions before competing at the 2000 Olympic Games. Of the male paddlers, 12 competed in the K1 event (one kayak competitor), seven in the C1 event (one canoe competitor), and 12 in the C2 event (two canoe competitors). All the women competed in the K1 event. While initial contact was made through team officials, the athletes were invited to take part in this study on an individual basis. All participants read and signed a consent form before measurement and the study received approval from the Human Rights Committee of the University of Western Australia.

Data collection

Before data collection, the inter-tester technical error of measurement for each of the participating anthropometrists [ISAK (International Society for the Advancement of Kinanthropometry) levels 2 and 3] compared with the criterion anthropometrist (ISAK level 4) were calculated for every variable to determine whether they met the ISAK reference standards for levels 2 and 3 (Norton & Olds, 1996). For inclusion on the measurement team, anthropometrists were required to demonstrate inter-tester technical errors of measurement of less than 5% for skinfolds and less than 1% for the other measures of segment lengths, breadths, and girths. Further assistants were recruited to act as data recorders and marshals during the test phase.

A laboratory was established at the accommodation venue so that paddlers could be measured in a single session during a rest period within their training schedule. All paddlers were measured in the 15-day period before competition. Before being measured, each paddler completed demographic information and was photographed to assist with the somatotype rating.

Anatomical landmarks were located and marked by the criterion anthropometrist before the athlete was directed to one of five stations for the measurement of 9 skinfolds, 10 direct lengths, 12 segment girths, 6 breadth measurements, and body mass (Norton & Olds, 1996). All variables were measured on the right side of the body in duplicate (when time permitted) and the mean value was recorded. On occasions when the athlete's time was limited, single measures for length and breadth variables were recorded. The standard procedures for each measurement, as supported by ISAK and reported in Bloomfield *et al*. (Bloomfield, Ackland, & Elliott, 2003) and Norton and Olds (1996), were followed at all times.

Finally, as a service to the participants, personal profiles were produced and forwarded before the end of competition. These profiles provided individual data as well as a comparison to normative values for the entire sample.

Data analysis

Absolute body size information was reported for all Olympic slalom kayak and canoe paddlers regardless of their event, though separately for male and female competitors. Information regarding relative size was gained through calculation of proportionality indices (Bloomfield *et al*., 2003) and phantom Z-scores (Ross & Marfell-Jones, 1991). These variables indicate the relative magnitude of a physical characteristic with respect to the participant's stature. The somatotype was calculated using the method of Carter and Heath (1990).

The male sample was arbitrarily stratified for comparison of those competitors ranked in the top 10 placings at the 2000 Olympics (Best) with the competitors filling the remaining positions (Rest). The male sample was also used to compare paddlers in the canoe class with those in the kayak class. A series of univariate analyses of variance was used for these comparisons. The female sample was too small for these particular analyses. Statistical significance was set at $P < 0.05$, and the statistical power was calculated for each analysis.

Results and discussion

Absolute body size and somatotype

Descriptive statistics for absolute size parameters are presented in Table I. Male paddlers were not a particularly tall (mean 1.77 m, $s = 0.07$) or heavy (72.5 kg, $s = 5.8$) group of athletes and they were similar in mean height and mass to a reference population of non-athletes (Norton & Olds, 1996). Male paddlers were older (28.1 years, $s = 5.2$), lighter, and shorter than the successful American World Champions in 1983 (age: 20.1 years, $s = 2.1$; mass: 76.3 kg, $s = 6.1$; height: 1.80 m, 0.07), nationally ranked Australian paddlers (age: 23.4 years, $s = 1.1$; mass: 75.7 kg, $s = 5.9$; height: 1.82 m, $s = 0.06$), and nationally ranked Polish paddlers (age: 19.2 years, $s = 2.2$; mass: 73.8 kg, $s = 6.0$; height: 1.78 m, $s = 0.07$), and had lower sums of skinfold values ($\Sigma 4$ skinfolds: 23.7 mm, $s = 4.1$; $\Sigma 6$ skinfolds: 35.5 mm, $s = 6.4$) than either the Americans ($\Sigma 4$ skinfolds: 38.0 mm) or Australians ($\Sigma 6$ skinfolds: 46.9 mm, $s = 9.0$) (Freeman *et al*., 1987; Sklad *et al*., 1994; Vaccaro *et al*., 1984). Compared with the Sydney Olympic sprint paddlers (age: 24.7 years, $s = 2.9$; mass: 84.8 kg, $s = 6.2$; height: 1.85 m, $s = 0.06$; $\Sigma 8$ skinfolds: 55.4 mm, $s = 16.2$) (Ackland, Ong, Kerr, & Ridge, 2003), the slalom paddlers were also older, lighter, and shorter but with similar sums of skinfolds.

The female slalom paddlers were taller (mean 1.68 m, $s = 0.05$) but somewhat lighter (59.0 kg, $s = 4.5$) than the mean of the reference population of non-athletes reported in Norton and Olds (1996). The female paddlers were older (26.3 years, $s = 4.8$), taller, lighter, and had a considerably lower sum of skinfolds ($\Sigma 6$ skinfolds: 44.8 mm, $s = 9.8$; $\Sigma 8$ skinfolds: 68.9 mm, $s = 13.9$) than the Australian ranked paddlers (age: 24.6 years, $s = 1.9$; height: 1.63 m, $s = 0.05$; mass: 61.9 kg, $s = 6.5$; $\Sigma 6$ skinfolds: 90.5 mm, $s = 3.8$) studied by Freeman *et al*. (1987). Compared with the Sydney Olympic sprint paddlers (mass: 67.3 kg, $s = 5.9$; $\Sigma 8$ skinfolds: 78.5 mm, $s = 16.8$) (Ackland *et al*., 2003), the female slalom paddlers were of similar age and height, but were lighter and had lower sums of skinfolds.

The mean somatotype for the male slalom paddlers (1.7–5.4–2.5) demonstrates that these athletes were predominantly mesomorphic. Compared with the members of the successful US slalom team in 1983 (2.9–5.2–2.4) and the nationally ranked Australians (2.1–4.7–3.0), the men displayed a lower rating for endomorphy, a higher rating for mesomorphy, and similar ratings for ectomorphy. The observed differences in endomorphy and mesomorphy may relate to changes in competition rules, since performance time has been reduced from approximately 210 s to approximately 100 s with the same or a greater number of gates. The event is now more technical, requiring greater stop/start activity and the production of even higher explosive power. A more professional approach to training and competition by these athletes may also contribute to these differences (M. Druce, personal communication, 22 November 2005). When the mean somatotype for male slalom paddlers was compared with that of other elite athletes who use the upper extremities for propulsion, the Sydney Olympic sprint paddlers (1.6–5.7–2.2) showed the highest ratings for mesomorphy (Ackland *et al*., 2001; Carter & Ackland, 1994) (see Figure 1). Anecdotal observation of present-day elite sprint and slalom paddlers support this view. Perhaps sprint performance relates more to absolute and repeated power generation than does slalom performance.

The female slalom paddlers from the Sydney Olympics (2.4–4.1–3) were leaner, less robust musculoskeletally, and less compact than the small cohort of nationally ranked Australian paddlers (3.6–4.6–1.6) reported by Freeman *et al*. (1987). When the mean somatotype for female slalom paddlers was compared with that of other elite athletes who use their upper extremities for propulsion, the slalom paddlers were inferior to the sprint paddlers, but generally superior to other athletes when ranked on mesomorphy. A detailed comparison is given in Figure 2. The limits of the somatotype distribution for both male and female slalom paddlers are shown in Figure 3. Both areas are somewhat ovoid in shape, parallel to the ectomorphy axis, with the female distribution somewhat lower on the mesomorphy axis than the male distribution.

Relative body size

Proportionality characteristics of male slalom paddlers are displayed in Figure 4. In contrast to the Sydney Olympic sprint paddlers (Ackland *et al*., 2003), the body proportions for successful slalom paddlers are, with the exception of chest girth, almost identical regardless of the differences in the sprint and slalom events.

The mean sitting height/stature ratio for the male slalom paddlers was 52.4% ($s = 1.75$), which was similar to that of elite slalom paddlers (51.9%: Freeman *et al*., 1987; 52.8%: Sklad *et al*., 1994) and elite sprint paddlers (52.4%: Freeman *et al*., 1987; 52.5%: Ackland *et al*., 2003; Carter, 1982; 52.1% for canoeists and 53.8% for kayakers: Sklad *et al*., 1994) reported elsewhere. However, these values are mid-range compared with those of the athletes reported by Norton and Olds (1996), which ranged from <51% for basketball players and marathoners to >55% for weightlifters, and not dissimilar to the mean of the reference population of

Table I. Absolute size characteristics of Olympic slalom paddlers.

Variable	Female paddlers ($n = 12$)			Male paddlers ($n = 31$)			Male kayak paddlers ($n = 12$)			Male canoe paddlers ($n = 19$)		
	mean	*s*	range	mean	*s*	range	mean	*s*	range	mean	*s*	range
Age (years)	26.3	4.8	20.0–35.0	28.1	5.2	19.3–43.0	27.8	3.9	21.7–35.1	28.2	5.9	19.3–43.0
Body mass (kg)	59.0	4.5	53.3–68.6	72.5	5.8	59.6–84.3	71.7	4.8	62.7–79.0	73.1	6.5	59.6–84.3
Sum 6 skinfolds[a] (mm)	44.8	9.8	31.0–68.0	35.5	6.4	23.0–45.8	31.3	5.7	23.0–40.5	38.1	5.5	26.6–45.8
Sum 8 skinfolds[b] (mm)	68.9	13.9	46.0–99.0	52.7	10.7	32.4–73.7	45.8	9.0	32.4–63.5	57.1	9.4	38.8–73.7
Height (m)	1.68	0.05	1.58–1.76	1.77	0.07	1.59–1.94	1.77	0.05	1.72–1.90	1.77	0.08	1.59–1.94
Sitting height (cm)	89.7	3.3	84.7–95.1	92.8	3.3	82.3–97.9	92.5	2.2	90.1–97.9	93.0	3.9	82.3–97.9
Arm span (cm)	167.6	4.8	161.6–177.1	182.9	7.3	163.5–199.1	181.5	6.3	174.5–197.9	183.8	7.9	163.5–199.1
Arm length (cm)	31.5	1.0	30.3–33.6	34.2	1.6	31.1–38.3	34.2	1.5	32.5–37.5	34.3	1.7	31.1–38.3
Forearm length (cm)	24.0	0.7	22.6–24.6	26.2	1.3	23.1–28.8	26.2	1.0	24.8–28.8	26.3	1.5	23.1–28.8
Thigh length (cm)	44.1	2.4	40.3–48.5	46.1	2.3	40.4–50.0	45.6	2.4	40.4–50.0	46.3	2.3	49.7–41.9
Leg length (cm)	43.8	1.3	42.1–46.1	47.5	2.4	39.8–52.2	47.8	1.7	44.7–51.5	47.2	2.8	39.8–52.2
Shoulder breadth (cm)	37.4	1.2	35.9–39.4	41.1	1.5	36.3–43.6	41.2	1.5	38.9–43.6	41.0	1.7	36.3–43.2
A-P chest depth (cm)	18.0	1.6	15.4–20.9	20.1	1.7	16.4–23.6	19.8	1.7	16.9–22.3	20.3	1.7	16.4–23.6
Humerus breadth (cm)	6.3	0.2	6.0–6.7	7.2	0.3	6.7–7.7	7.2	0.3	6.8–7.6	7.2	0.3	6.7–7.7
Femur breadth (cm)	8.9	0.4	8.4–9.3	9.7	0.4	8.7–10.5	9.7	0.4	8.7–10.4	9.7	0.4	9.0–10.5
Flexed arm girth (cm)	30.1	1.0	28.1–31.9	35.0	1.6	31.2–38.2	35.2	1.5	32.3–38.2	34.8	1.8	31.2–36.9
Chest girth (cm)	91.0	3.6	84.1–96.1	102.9	4.1	93.6–109.9	102.9	4.9	93.6–109.9	102.8	3.6	94.4–109.7
Waist girth (cm)	69.9	2.6	65.8–73.4	80.2	3.4	74.6–85.0	79.8	3.2	75.0–84.6	80.6	3.6	74.6–85.0
Hip girth (cm)	89.7	2.7	85.3–93.5	91.8	3.3	83.8–96.4	90.5	3.8	83.8–96.1	92.5	2.8	87.0–96.4
Thigh girth (cm)	52.9	2.1	49.9–56.6	53.5	2.0	48.5–56.6	52.6	1.8	49.1–55.0	54.0	2.0	48.5–56.6
Calf girth (cm)	34.1	1.2	32.3–36.4	35.7	1.3	31.9–37.7	35.7	1.1	33.8–37.2	35.6	1.5	31.9–37.7

[a] Sum of triceps, subscapular, supraspinale, calf, abdominal, and thigh.
[b] Sum of triceps, subscapular, supraspinale, calf, abdominal, thigh, biceps, and iliac crest.

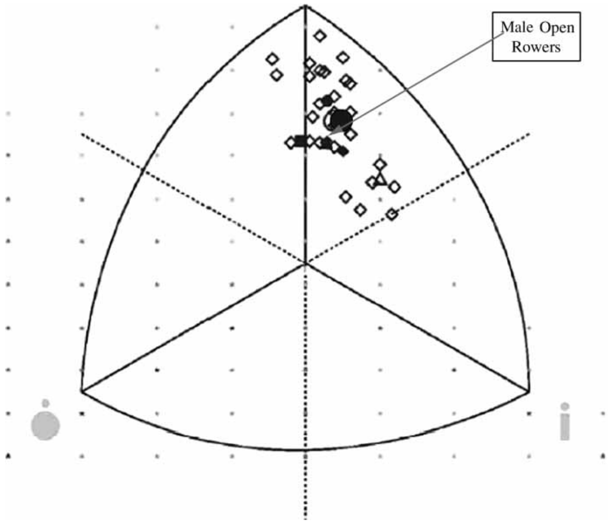

Figure 1. Somatoplots of male Olympic slalom paddlers and means for elite male athletes who use their upper extremities for propulsion (comparative data from Ackland *et al.,* 2001; Carter & Ackland, 1994). ◇, male slalom; •, male sprint paddlers; ▲, male open rowers; ◆, male swimmers; ■, male water polo players; △, male lightweight rowers. Large solid circle = mean profile of male slalom.

non-athletes (52.2%: Norton & Olds, 1996). These data suggest that compared with other athletes, male slalom paddlers have neither relatively long nor relatively short trunks.

The mean sitting height/stature ratio for the female paddlers was 53.5% ($s = 1.06$). This was similar to that of slalom paddlers (53.2%) reported by Freeman *et al*. (1987) and the sprint paddlers (52.1%) reported by Carter (1982), the Polish kayakers (52.8%) reported by Sklad *et al*. 1994, and the paddlers from the Sydney Olympics(53.2%) reported by Ackland *et al*. (2003). These results place the female slalom paddlers towards the upper end of the range of athlete sitting height/stature ratios provided by Norton and Olds (1996), who reported values of <51% for basketball centres and forwards to >53% for divers, pentathletes, sprint swimmers, synchronized swimmers, and slalom canoeists. Interestingly, the mean value for the female slalom paddlers is not dissimilar to the mean of the reference population of non-athletes (52.9%) reported by Norton and Olds (1996). These data suggest that compared with other female athletes, female slalom paddlers have relatively longer trunks than many other athletes and longer even than their male counterparts.

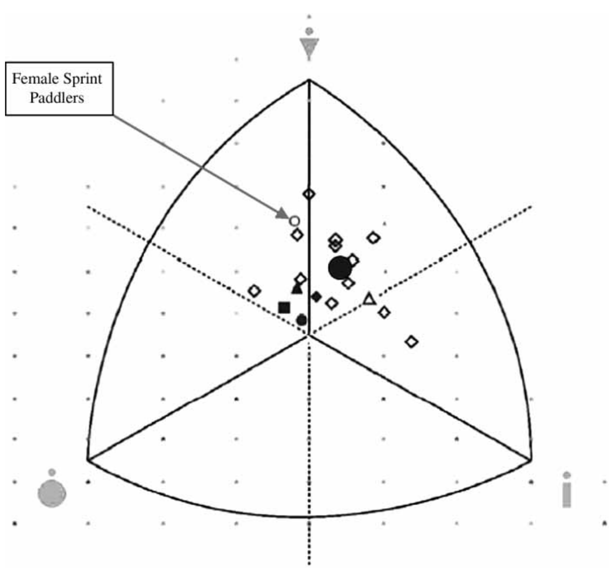

Figure 2. Somatoplots of female Olympic slalom paddlers and means for elite female athletes who use their upper extremities for propulsion (comparative data from Ackland *et al.,* 2001; Carter & Ackland, 1994). •, female synchronized swimmers; ◇, female slalom; ○, female sprint paddlers; ■, female water polo players; ▲, female open rowers; ◆, female swimmers; △, female lightweight rowers. Large solid circle = mean profile of female slalom.

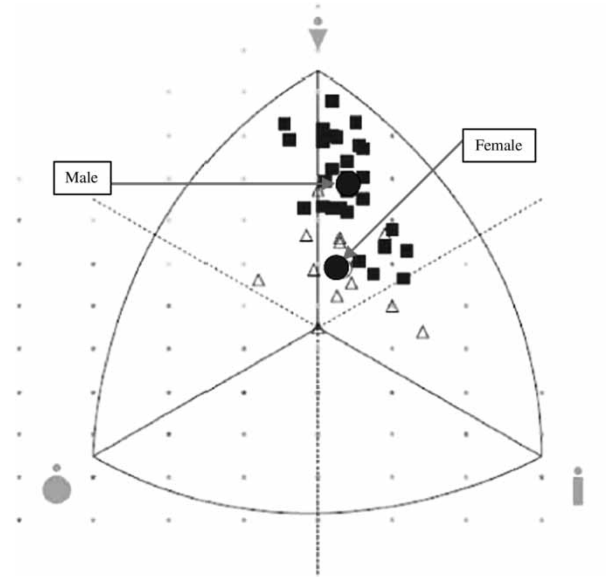

Figure 3. Somatoplots of male and female Olympic slalom paddlers. △, female slalom; ■, male slalom. Large solid circle = mean profile of each group.

Slalom canoeists have been shown to exhibit a high brachial index, which may provide a biomechanical advantage in catching the water (Norton & Olds, 1996) provided that the body has sufficient strength to capitalize on the potential advantage. The male slalom paddlers exhibited a mean brachial index of 76.7% ($s = 2.9$), which was similar to that of the male sprint paddlers at the Sydney Olympics (76.2, $s = 3.2$) reported by Ackland *et al*. (2003), higher than that of the male sprint Olympians (73.0) reported by Carter (1982) and the reference population of non-athletes (74.8) reported by Norton and Olds (1996), but lower than that of the kayak and canoe athletes (~79.5) reported by Norton and Olds (1996). The female slalom paddlers exhibited a mean brachial index of 76.0% ($s = 2.5$), which was higher than that of the female sprint paddlers at the

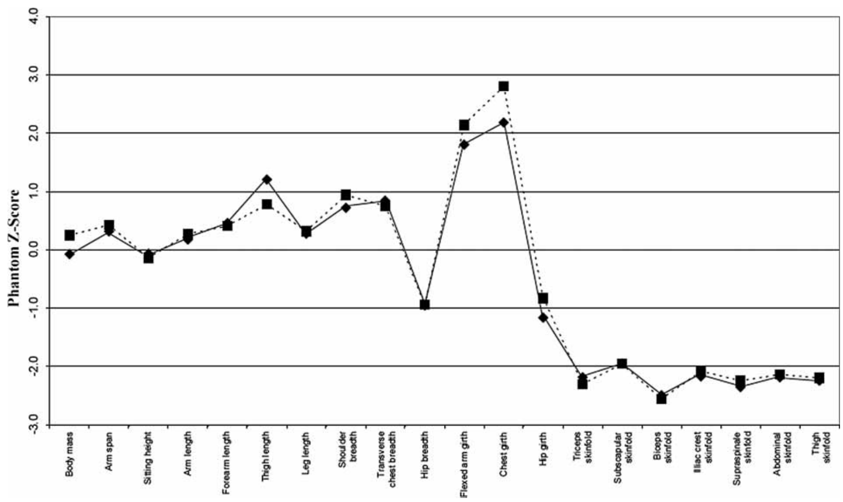

Figure 4. Relative body sizes of male Olympic sprint and slalom paddlers. ◆, slalom; ■, sprint (adapted from Ackland *et al.*, 2003).

Sydney Olympics (73.7, $s = 2.5$) (Ackland *et al.*, 2003), but similar to that of the slalom paddlers and the reference population of non-athletes reported by Norton and Olds (1996) with values approximating 75.5%. Clearly, elite slalom paddlers have quite a high brachial index, as do sprint paddlers. This is a genetic rather than physiological adaptation and so may be used as one indicator for talent identification purposes.

Best vs. Rest

A series of univariate analyses of variance was performed for each of the variables shown in Table I, comparing the Best male paddlers (those ranked in the top 10 of their event; $n = 15$) with the Rest ($n = 15$). The only significant difference in physical structure was observed for the ectomorphy variable ($p < 0.05$), where the Best male paddlers (mean 2.29) were more compact (less linear) than the Rest (mean 2.77). Short stature is an identifiable feature of slalom paddlers, as they are among the shortest of all athletes (Norton & Olds, 1996). The mean height of these athletes has been reported to be similar to the mean of a reference population of non-athletes (Norton & Olds, 1996). A short stature may be of considerable advantage to the slalom paddler, who is reliant on maintaining a low centre of gravity to increase stability in an ever-changing environment.

A second series of univariate analyses of variance was performed for the proportionality characteristics displayed in Figure 4. While the only significant difference in physical structure was observed for the variable Z-hip girth (means: Best $= -0.9601$ vs. Rest $= 1.3616$; $P < 0.021$), there were trends for both Z-hip breadth (means: Best $= -0.7645$ vs. Rest $= 1.1893$; $P < 0.052$) and Z-waist girth (means: Best $= 1.3656$ vs. Rest $= 0.9269$; $P < .058$). The Best male paddlers had smaller proportional hip girth and showed a tendency for smaller proportional hip breadth but larger proportional waist girth than the Rest. The small cell size prevented separate Best versus the Rest analysis for male kayak and canoe paddlers.

Kayak vs. canoe

A third series of univariate analyses of variance was performed for each of the variables shown in Table I, comparing the male kayak paddlers ($n = 12$) with the male canoe paddlers ($n = 19$). The canoe paddlers demonstrated a greater sum of 8 skinfolds (means: canoe = 57.1 mm vs. kayak = 45.8 mm) and a higher ranking in endomorphy (means: canoe = 1.8 vs. kayak = 1.4) than the kayak paddlers. These differences may be attributed to the nature of the on-water training regime, with kayak paddlers tending to place a significant emphasis on fitness consisting of loops and distance paddling, while that of the canoe paddlers is based mainly on technique and little distance work (M. Druce, personal communication, 22 November 2005). Moreover, the greater depth in the ability in the kayak class athletes (and less so in the canoe class) may also be a contributing factor.

There was also a trend for the canoe paddlers to have a greater thigh girth than the kayak paddlers (means: canoe = 54.02 vs. kayak = 52.58, $P < 0.054$). The canoe paddlers may require greater muscle bulk in this region due to the greater work demanded of the quadriceps and hamstring muscle groups when kneeling in this event. However, one cannot make a definitive statement in this regard, since canoe paddlers also possess a larger thigh skinfold thickness (mean = 10.1 mm) than kayak paddlers (mean = 7.7 mm). No significant differences were recorded for proportionality measures.

Conclusions

For those seeking talent identification guidelines for slalom kayaking and canoeing, we have little to offer. From a morphology perspective, present-day elite slalom paddlers are in some respects not different from a reference population of non-athletes. The resultant advantage is that there may be quite a large pool of potential paddlers to choose from.

When the Best male paddlers were compared with the Rest, the Best were shown to be more compact, less linear, and to have a smaller proportional hip girth than the Rest. A low centre of gravity may be advantageous for paddlers who are more compact and less linear. The brachial index is another variable that appears to provide an advantage in slalom paddling. However, it has a genetic basis and cannot be enhanced through training. For those lucky enough to have a high brachial index, sufficient strength will need to be developed if its potential advantage is to be realized.

Although we have begun to tease out potential differences between male slalom canoe and kayak paddlers, there is considerable scope to learn more about these athletes once a sizeable cohort is available. Furthermore, there were insufficient females to undertake any statistical analyses. We hope that this study forms the basis of a concerted effort to learn more about the morphological characteristics of both male and female slalom canoe and kayak paddlers.

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