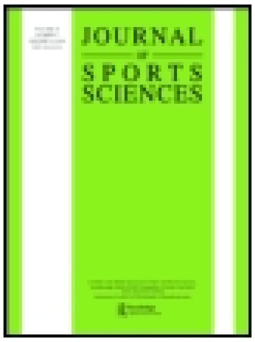

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Sprint kayaking and canoeing performance prediction based on the relationship between maturity status, anthropometry and physical fitness in young elite paddlers

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ABSTRACT

This study aimed to identify the maturity-related differences and its influence on the physical fitness, morphological and performance characteristics of young elite paddlers. In total, 89 kayakers and 82 canoeists, aged 13.69 ± 0.57 years (mean ± s), were allocated in three groups depending on their age relative to the age at peak height velocity (pre-APHV, circum-APHV and post-APHV) and discipline (kayak and canoe). Nine anthropometric variables, a battery of four physical fitness tests (overhead medicine ball throw, countermovement jump, sit-and-reach test and 20 m multistage shuttle run test) and three specific performance tests (1000, 500 and 200 m) were assessed. Both disciplines presented significant maturity-based differences in all anthropometric parameters (except for fat and muscle mass percentage), overhead medicine ball throw and all performance times (pre > circum > post; $P < 0.05$). Negative and significant correlations ($P < 0.01$) were detected between performance times, chronological age and anthropometry (body mass, height, sitting height and maturity status), overhead medicine ball throw and sit and reach for all distances. These findings confirm the importance of maturity status in sprint kayaking and canoeing since the more mature paddlers were also those who revealed largest body size, physical fitness level and best paddling performance. Additionally, the most important variables predicting performance times in kayaking and canoeing were maturity status and chronological age, respectively.

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KEYWORDS
Maturity; fitness level; morphology; kayaking; canoeing

Introduction

During childhood and adolescence, several physical and physiological changes occur as a result of maturation and pubertal growth (Mendez-Villanueva et al., 2011; Mirwald, Baxter-Jones, Bailey, & Beunen, 2002; Philippaerts et al., 2006; Sherar, Esliger, Baxter-Jones, & Tremblay, 2007). However, the tempo and timing of those changes vary depending on each individual between the ages of 8 and 16 years (Welsman & Armstrong, 2000). At the same chronological age, critical differences can be observed between young athletes in body size as during the growth phase body weight typically increases by approximately 160% and height by 40% (Vaeyens, Lenoir, Williams, & Philippaerts, 2008; Welsman & Armstrong, 2000). Along this morphological development, physical attributes such as strength or aerobic power also improve around 150% as a consequence of maturation (Falk & Bar-Or, 1993; Mirwald et al., 2002) and become determining factors in success in certain sports. Especially during pubertal years, significant associations have been observed between performance and body size with correlations coefficients exceeding $r = 0.7$ in several sports such as cycling and running (Armstrong & Welsman, 1997; Welsman & Armstrong, 2000). Current talent identification programmes only search for young athletes with the best performance results and the superior physical attributes that typically characterise professional athletes. Usually those attributes are identified in older athletes and their presence in young athletes does not automatically translate into exceptional performance in adulthood. In addition, the development of physical and anthropometric factors during puberty is influenced by maturation and many young athletes with optimal attributes are not able to retain them throughout the process (Vaeyens et al., 2008). Nevertheless, to date the main criterion to establish categories in youth sports has been the chronological age, not taking into consideration maturity status that could be easily determined by the age at peak height velocity (APHV) (Mirwald et al., 2002).

Traditionally, kayak research has focused on determining the physiological level and anthropometric characteristics of international kayakers in an attempt to identify the determinants of optimal performance (Ackland, Ong, Kerr, & Ridge, 2003; Tesch, 1983; van Someren & Howatson, 2008). Most successful paddlers have shown larger anthropometric parameters resulting in a more robust and compact morphology (Fry & Morton, 1991; van Someren & Palmer, 2003). In addition, the impact of anthropometry on performance has been largely confirmed as several variables such as muscle mass, height,

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body fat and length of the limbs have been identified as contributing factors to peak performance in senior and junior paddlers (Alacid, Marfell-Jones, Lopez-Minarro, Martinez, & Muyor, 2011; Fry & Morton, 1991; Ridge, Broad, Kerr, & Ackland, 2007; Shephard, 1987; Sklad, Krawczyk, & Majle, 1994; van Someren & Palmer, 2003). Similarly, strong correlations between fitness level and performance have consistently been reported in many sports (Gabbett & Georgieff, 2007; Pyne, Gardner, Sheehan, & Hopkins, 2006; van Someren & Howatson, 2008). Early studies in sprint kayaking only used VO_{2max} test to evaluate the physiological capacity of elite kayakers (Pendergast, Cerretelli, & Rennie, 1979; Tesch, 1983). Nevertheless, recent research by van Someren and Howatson (2008) used predictive equations to identify the contribution of anthropometric and physiological variables to performance and then predict race times in flatwater kayaking in senior paddlers. However, in sprint kayaking and canoeing the use of specific field tests has been limited to typically determine aerobic power and isokinetic strength in order to identify paddler's overall status (Fry & Morton, 1991; Hamano et al., 2015; van Someren & Howatson, 2008).

To date, sprint kayaking and canoeing research has tried to identify performance determinants exclusively from senior elite paddlers. Moreover, the limited number of investigations conducted with young paddlers did not take into account maturational factors such as skeletal age or APHV in the determination of paddler profiles and in the identification of future talents. Therefore, the main purpose of this study was to investigate the possible influence of maturation on the physical characteristics and performance of highly trained young kayakers and canoeists. Specifically the aims of this investigation were (1) to compare the maturity-related differences in anthropometry, physical fitness and performance times between three maturity groups; and (2) to determine the relationship and the relative importance of anthropometric and physical fitness attributes and their ability to predict performance times over 1000, 500 and 200 m.

Method

Participants

A total of 171 young male paddlers (89 kayakers and 82 canoeists), aged 13.69 ± 0.57 years (mean ± s), were recruited for this study. All participants were training on a regular basis (at least 2 h per day between 4 and 6 days per week) and were selected by the Royal Spanish Canoeing Federation to participate in National Development Camps based on their age group-level results. The experimental procedures were approved by the Institutional Ethical Committee and written parental or guardian informed consent was obtained before the beginning of the study. Participants were excluded from assessment if they presented signs of disease or who were under pharmacological treatment during the testing period.

Procedures

During the National Development Camps, a series of physical and anthropometric assessments were performed over 4 days. All participants were instructed to avoid strenuous exercise and caffeine ingestion and to maintain their regular pre-training diet at least 48 h before the tests. Clear instructions of each physical test procedure were provided prior to the general warm-up consisting of 6–8 min of multidirectional running activity and 5 min of upper and lower limbs general dynamic stretching delivered and supervised by a strength and conditioning coach. The specific warm-up involved 5 min of familiarisation time with the materials and procedures used shortly before the beginning of each test. In the assessment of physical fitness, only the best of three attempts in each test was considered for analysis, giving at least 3 min rest between attempts, except for 20 m multistage shuttle run test which was performed only once. To prevent any potential body composition changes, anthropometric assessments were performed early in the morning (Gabbett & Georgieff, 2007), followed by field-based physical tests. After a minimum of 4 h rest, participants concluded each testing session with one specific performance test on water.

Anthropometry

All measurements were taken by a fully certified level 2 anthropometrist following the procedures described by the International Society for the Advancement of Kinanthropometry. Body mass (kg) was determined using a SECA 862 (Digital scale, SECA, Germany); height (cm) and direct lengths (cm) with a GPM anthropometer (Siber-Hegner, Switzerland); girths (cm) with a metallic non-extensible tape Lufkin W606PM (Lufkin, USA) and skinfold thickness (mm) was measured at six sites (triceps, subscapular, supraspinale, abdominal, front thigh and medial calf) with a Harpenden skinfold calliper (British Indicators, UK). The equation body mass (kg)/height^2 (m) was used for body mass index (BMI) calculations. Muscular mass percentage was determined by the anthropometric formula described by Poortmans, Boisseau, Moraine, Moreno-Reyes, and Goldman (2005), whereas fat mass percentage was estimated using triceps and subscapular skinfolds according to the equation defined by Slaughter et al. (1988). To avoid measurement errors, all instruments were calibrated before the beginning of each testing session. The variables were taken twice, or three times, if the difference between the first two measurements was greater than 5% for the skinfolds and 1% for the rest of the dimensions, with the mean values (or median in the last case) used for data analysis. The intra-rater technical error of measurement for skinfold thickness was 3.05% and for the rest of the variables 0.69%.

Maturity status

Maturity status was defined as the current age of the athlete relative to his APHV. The APHV was estimated using the procedures described by Mirwald et al. (2002) and was considered a maturational benchmark (0 value) representing the time of maximum growth in stature. Each measurement was described as years from/to peak height velocity (PHV) assuming the difference in years as a value of maturity offset. Thus, negative values indicated the years remaining until APHV, whereas positive values indicated the years past from APHV. On this basis, all participants were distributed into three groups depending on their maturity status (Mendez-Villanueva et al., 2010) at the time of the assessment: pre-APHV (<–0.5 years to PHV), circum-APHV (>–0.5 years to PHV to <0.5 years to PHV) and post-APHV (>0.5 years to PHV).

Physical fitness assessment

The overhead medicine ball throw test was selected to evaluate upper body muscular power (Gabbett & Georgieff, 2007). Participants were required to throw a 3 kg medicine ball as far forward as possible from a standing and arm-relaxed position. As long as the feet were not moved during the test, counter-movements were allowed.

Lower body power was determined using the counter-movement jump test (CMJ) following the recommendations described by Temfemo, Hugues, Chardon, Mandengue, and Ahmaidi (2009). A countermovement until approximately 90º of knee flexion was allowed prior to the jump on a Bosco platform (Bosco System, Barcelona, Spain) which recorded athlete's contact time (s) and jump height (m).

The sit-and-reach test was used to determine hamstring flexibility (Lopez-Miñarro et al., 2013). From a seated position with no shoes, participants were instructed to keep their legs together and knees extended whilst their heels were flat against the bottom of a testing board (Richflex System, Sportime, USA). The objective was to slowly reach as far forward as possible by sliding the hands together one over the other along the testing board and to hold the resulting position for at least 2 s. The distance reached was then registered to the nearest centimetre by means of a tape measure placed on the top of the board with the zero mark representing the plantar surface. Therefore, positive values were considered once participants had reached beyond the toes.

The multistage shuttle run test (mp3 version, Coachwise, UK) was used to estimate the maximal aerobic capacity (VO_{2max}) according to the procedures described by Lager and Lambert (1982). Paddlers were required to run a 20 m shuttle progressively increasing in speed, being timed with an audible "beep" until reaching volitional exhaustion. When two consecutive shuttles were completed out of time, it was considered the end of the test, registering the last successful repetition made for subsequent $VO2_{max}$ estimation using the regression equation defined by Ramsbottom, Brewer, and Williams (1988).

Performance parameters

On three separate days, participants were required to complete three trials of 1000, 500 and 200 m at maximum effort (one per day). All tests were performed under race conditions on a measured flatwater course and were laterally recorded by a JVC Everio MG-135 (Victor Company, Japan) at 30 frames per second. For that purpose, a motorboat followed the navigation trajectory of the paddler, leaving at least 5 m separation between crafts to avoid water influence. To determine performance time, the frames from the first traction movement to the finish line were calculated by the Virtualdub software 1.8.8 (Avery Lee). Performance tests were postponed when wind velocity was above $2 \text{ m} \cdot \text{s}^{-1}$ to avoid its influence on race time.

Statistical analyses

Measures of homogeneity and spread are reported as mean and standard deviation (s). The hypotheses of normality of the distribution and homogeneity of variance were investigated using the Kolmogorov–Smirnov test and Levene's test, respectively. The comparisons of maturation group means were performed using one-way analysis of variance (ANOVA) test with three levels (pre, circum, post) when statistical tests revealed no violations of the assumptions of normality and homogeneity. If one-way ANOVA analysis revealed significant differences, *post hoc* Bonferroni tests were conducted to allocate the differences between groups. Kruskal–Wallis test was used when normality supposition of data was rejected and *post hoc* Mann–Whitney tests with Bonferroni corrections (0.05/3) were performed if any significant difference was detected. The level of significance was set as $P < 0.05$. Pearson's correlation coefficient (r) was used to determine the interrelationships between performance times and anthropometry and between performance times and physical fitness. When the assumptions of normality were violated, Spearman's correlation coefficient (r_s) was used. In addition, stepwise multiple linear regression analysis was conducted to determine which anthropometric and physical fitness attributes could predict performance times. All non-significant variables in the linear correlation were excluded from the stepwise regression analysis. Collinearity was investigated using the variance inflation factor and the collinearity tolerance statistics. Predictor variables with variance inflation factor values greater than 10 and/or tolerance level of less than 0.1 were not included in the model. All statistical analyses were conducted using SPSS v22.0 (SPSS Inc., Chicago IL, USA).

Results

The anthropometric and physical fitness characteristics and performance times of both kayakers and canoeists are presented in Table 1 according to maturity groups. In kayakers, significant differences ($P < 0.05$) were observed in all anthropometric characteristics between pre and post, and circum and post groups apart from sum of six skinfolds, fat mass percentage, muscle mass percentage and BMI. Circum kayakers only presented significantly higher values than pre kayakers in body mass, height, sitting height and maturity status. Similarly, post canoeists revealed significant greater values than pre in all anthropometric variables ($P < 0.05$) including maturity status while circum canoeists showed significantly different values than pre and post canoeists except for sum of six skinfolds, fat mass percentage and muscle mass percentage. Results from physical fitness tests showed significantly higher overhead medicine ball throw values in both post kayakers and canoeists when compared with their other two maturity groups ($P < 0.05$), whereas no significant differences were observed in estimated VO_{2max}. Significantly greater CMJ values were detected in post than in circum kayakers (0.38 ± 0.07 and 0.34 ± 0.08 m, respectively; $P < 0.05$). For canoeists, higher sit-and-reach values were observed for post compared with the pre group (5.69 ± 8.24 and 0.52 ± 7.45 cm, respectively; $P < 0.05$). In both kayakers and canoeists, all performance times were significantly different between the groups ($P < 0.05$) with the exception of the 1000 m kayak between circum and pre groups.

Table 1. Anthropometric, physical fitness and performance parameters for the three maturity levels in kayakers and canoeists (mean ± s).

	Kayak			Canoe		
	Pre (n = 9)	Circum (n = 36)	Post (n = 44)	Pre (n = 22)	Circum (n = 30)	Post (n = 30)
Chronological age (years)	13.08 ± 0.28	13.35 ± 0.41	14.07 ± 0.38†§	13.22 ± 0.46	13.61 ± 0.53*	14.15 ± 0.42†§
Anthropometry						
Body mass (kg)	48.40 ± 6.27	56.35 ± 6.80*	64.78 ± 8.66†§	42.97 ± 6.55	54.36 ± 9.67*	64.82 ± 8.60†§
Height (cm)	158.30 ± 5.21	165.70 ± 4.65*	172.94 ± 4.75†§	153.13 ± 7.69	162.30 ± 7.17*	170.73 ± 5.56†§
Sitting height (cm)	82.07 ± 2.83	86.89 ± 2.19*	92.91 ± 2.64†§	79.60 ± 3.42	85.77 ± 2.30*	91.17 ± 2.90†§
BMI (kg · m^{-2})	19.27 ± 1.79	20.49 ± 1.98	21.63 ± 2.49†	18.25 ± 1.68	20.55 ± 2.76*	22.22 ± 2.69†§
Sum of six skinfolds(mm)	62.10 ± 27.02	63.12 ± 20.43	66.16 ± 26.64	48.70 ± 19.75	63.79 ± 34.46	73.34 ± 39.49†
FM percentage (%)	15.11 ± 6.05	15.47 ± 4.64	16.39 ± 6.39	12.30 ± 4.45	15.43 ± 7.36	18.16 ± 9.00†
MM percentage (%)	46.85 ± 1.80	46.34 ± 2.06	46.93 ± 2.15	47.44 ± 3.15	46.14 ± 3.11	45.84 ± 2.70
Maturity status (years from/to APHV)	−0.76 ± 0.32	0.02 ± 0.30*	1.11 ± 0.40†§	−1.03 ± 0.46	−0.01 ± 0.32*	1.03 ± 0.37†§
Physical fitness						
OMBT (m)	5.20 ± 0.65	5.85 ± 1.00	6.64 ± 1.12†§	4.61 ± 0.81	5.36 ± 0.89*	6.48 ± 1.11†§
CMJ (m)	0.34 ± 0.08	0.34 ± 0.06	0.38 ± 0.07§	0.32 ± 0.06	0.33 ± 0.07	0.35 ± 0.08
SR (cm)	7.78 ± 5.52	7.84 ± 6.34	9.19 ± 6.43	0.52 ± 7.45	3.17 ± 7.84	5.69 ± 8.24†
VO_{2max} (ml · kg^{-1} · min^{-1})	49.71 ± 6.03	49.62 ± 4.03	51.2 ± 4.83	48.32 ± 3.63	47.73 ± 4.44	47.95 ± 5.93
Performance						
1000 m time (s)	287.53 ± 17.09	279.69 ± 14.76	262.40 ± 11.50†§	351.01 ± 21.39	332.58 ± 19.35*	312.58 ± 20.04†§
500 m time (s)	147.18 ± 12.58	139.14 ± 7.08*	129.93 ± 7.29†§	184.71 ± 18.82	169.78 ± 16.97*	159.80 ± 17.20†§
200 m time (s)	53.59 ± 4.20	50.44 ± 2.89*	46.41 ± 2.63†§	68.11 ± 6.00	61.91 ± 5.16*	58.11 ± 5.16†§

APHV, age at peak height velocity; BMI, body mass index; CMJ, countermovement jump; FM, fat mass; MM, muscle mass; OMBT, overhead medicine ball throw; SR, sit and reach.
*Significant difference (P < 0.05) between circum and pre paddlers.
†Significant difference (P < 0.05) between post and pre paddlers.
§Significant difference (P < 0.05) between post and circum paddlers.

Table 2. Correlation between anthropometric and physical fitness characteristics and performance in kayakers and canoeists (r).

	Kayak			Canoe		
	1000 m	500 m	200 m	1000 m	500 m	200 m
Chronological age (years)	−0.720**	−0.600**	−0.712**	−0.670**	−0.688	−0.654**
Anthropometry						
Body mass (kg)	−0.441**	−0.325**	−0.423**	−0.376**	−0.301**	−0.347**
Height (cm)	−0.495**	−0.433**	−0.510**	−0.479**	−0.368**	−0.403**
Sitting height (cm)	−0.514**	−0.622**	−0.643**	−0.531**	−0.397**	−0.530**
BMI (kg · m^{-2})	−0.280**	−0.183	−0.273**	−0.298**	−0.220	−0.245*
Sum of six skinfolds (mm)	0.061	0.145	0.103	−0.027	0.087	0.048
FM percentage (%)	0.027	0.118	0.094	−0.053	0.039	0.023
MM percentage (%)	−0.091	−0.240*	−0.203	−0.133	−0.172	−0.151
Maturity status (years from/to APHV)	−0.628**	−0.674**	−0.731**	−0.653**	−0.546**	−0.632**
Physical fitness						
OMBT (m)	−0.514**	−0.436**	−0.513**	−0.612**	−0.483**	−0.618**
CMJ (m)	−0.229*	−0.390**	−0.231*	−0.341**	−0.364**	−0.267*
SR (cm)	−0.293**	−0.460**	−0.518**	−0.376**	−0.375**	−0.452**
VO_{2max} (ml · kg^{-1} · min^{-1})	−0.166	−0.218*	−0.188	−0.326**	−0.286*	−0.334**

APHV, age at peak height velocity; BMI, body mass index; CMJ, countermovement jump; FM, fat mass; MM, muscle mass; OMBT, overhead medicine ball throw; SR, sit and reach.
*Significant differences (P < 0.05).
** Significant differences (P < 0.01).

Table 2 summarises the relationship between anthropometric and physical fitness variables with performance times according to discipline. Chronological age, body mass, height, sitting height and maturity status were negatively associated with performance time (P < 0.01) over 1000, 500 and 200 m in both kayakers and canoeists. The negative relationship between BMI and performance time was only significant in 1000 and 200 m (P < 0.01), whereas sum of six skinfold, fat mass percentage and muscle mass percentage presented no significant correlation with any distance either in kayak or canoe apart from muscle mass percentage with 500 m kayaking (P < 0.05). Analysis of physical fitness parameters revealed significant negative association of overhead medicine ball throw and sit and reach with performance time (P < 0.01) over the three distances and also of CMJ with 1000, 500 (P < 0.01) and 200 m performance times (P < 0.05) in both disciplines. Only significant correlations were observed between estimated VO_{2max} and performance time in 500 m kayaking and canoeing (P < 0.05) and 1000 and 200 m kayaking (P < 0.01).

The stepwise linear regression equations that identify determining factors that predict performance times are presented in Tables 3 and 4 for kayakers and canoeists, respectively. In kayakers, chronological age, maturity status and overhead medicine ball throw significantly contributed to predict 1000 m performance time (P < 0.01); maturity status, height, sit and reach and CMJ to predict 500 m performance time (P < 0.01); and maturity status, CMJ, height and overhead medicine ball throw to predict 200 m performance time (P < 0.01). Similarly, for canoeists 1000 m time was significantly

Table 3. Regression equations for kayakers to predict performance over 1000, 500 and 200 m.

Distance (m)		r^2	SEE (s)
1000	1000 m time = 405.319 − (8.101 × chronological age) − (3.225 × OMBT) − (6.108 × maturity status)**	0.45	11.8
500	500 m time = 51.704 − (11.049 × maturity status) − (0.406 × SR) + (0.599 × height) − (24.324 × CMJ)**	0.61	5.78
200	200 m time = 20.380 − (4.305 × maturity status) − (11.781 × CMJ) + (0.227 × height) − (.558 x OMBT)**	0.67	2.02

CMJ, countermovement jump; OMBT, overhead medicine ball throw; SEE, standard error of estimate; SR, sit and reach.
**Significant contribution (P < 0.01) to the predictive model.

Table 4. Regression equations for canoeists to predict performance over 1000, 500 and 200 m.

Distance (m)		r^2	SEE (s)
1000	1000 m time = 759.974 − (20.233 × chronological age) − (4.826 × OMBT) − (1.004 × VO_{2max}) − (.900 × sitting height)**	0.62	15.80
500	500 m time = 465.723 − (21.411 × chronological age) − (0.586 × SR)**	0.52	13.91
200	200 m time = 164.883 − (4.187 × chronological age) − (1.335 × OMBT) − (0.320 × VO_{2max}) − (0.254 × sitting height) − (0.138 × SR)**	0.60	4.34

OMBT, overhead medicine ball throw; SEE, standard error of estimate; SR, sit and reach.
**Significant contribution (P < 0.01) to the predictive model.

predicted by chronological age, overhead medicine ball throw, estimated VO_{2max} and sitting height (P < 0.01); 500 m by chronological age and sit and reach (P < 0.01); and 200 m by chronological age, overhead medicine ball throw, estimated $VO2_{max}$, sitting height and sit and reach (P < 0.01). Additionally, the linear relationship between maturity status and performance times and between chronological age and performance times is shown in Figures 1 and 2 for kayakers and canoeists, respectively. Kayakers revealed significant r^2 values from 0.40 to 0.54 in the relationship between maturity status and performance time for all distances, whereas better associations were identified for canoeists between

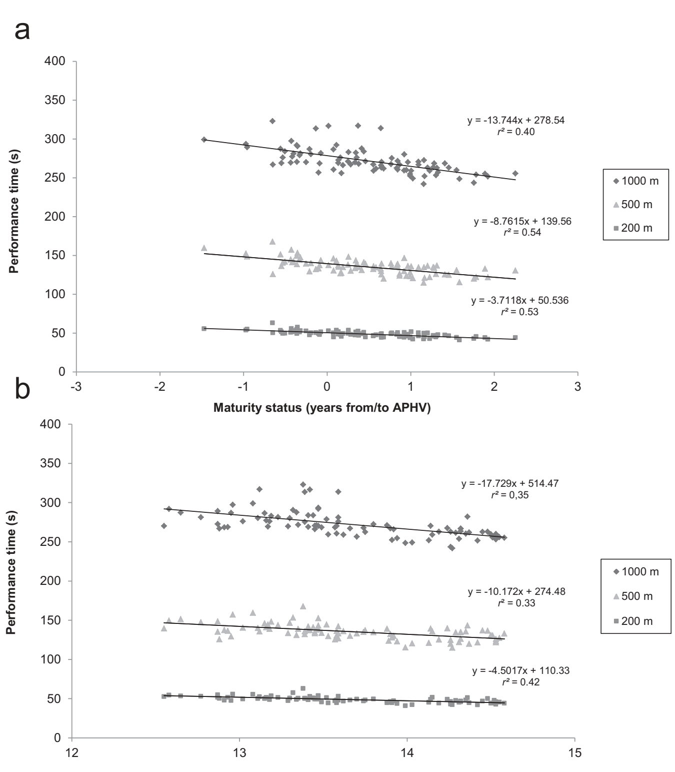

Figure 1. Linear relationship between (a) performance time and maturity status and between (b) performance time and chronological age in kayakers.

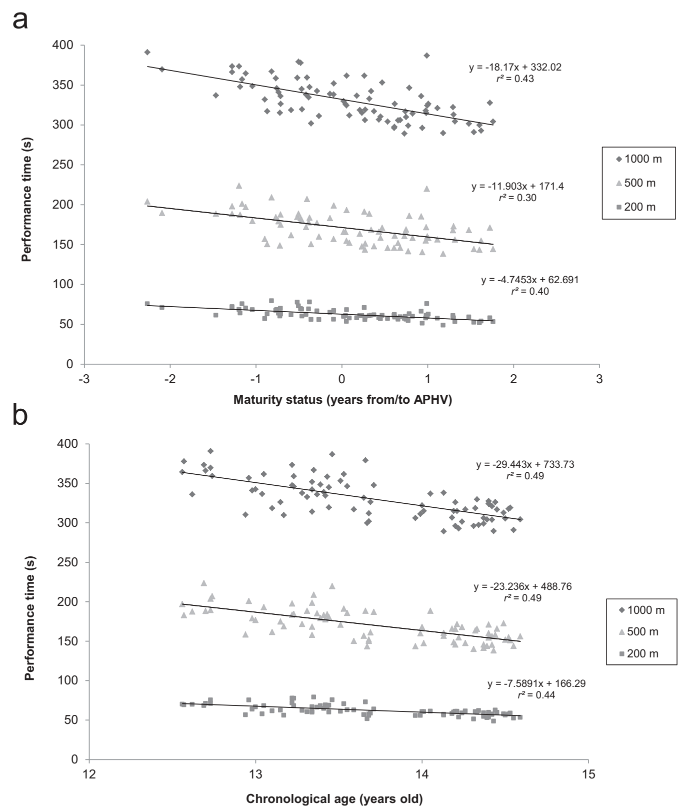

Figure 2. Linear relationship between (a) performance times and maturity status and between (b) performance time and chronological age in canoeists.

chronological age and performance times, observing values from 0.44 to 0.49.

Discussion

The main finding of our research was the significantly superior fitness and anthropometric attributes as well as better race times observed by the paddlers with greater maturity status. In addition, performances in all distances were mainly associated with basic anthropometric parameters and explosive strength tests. Maturity status was identified as the greatest predictor of performance times in kayaking, whereas chronological age was the parameter that better predicted canoeing performance times. These results provide normative data about the relative importance of physical attributes and maturity status in the determination of performance on sprint kayaking and canoeing.

In open water sports such as rowing and canoeing, common anthropometric characteristics have been observed according to the level of performance (Fry & Morton, 1991; Hamano et al., 2015; Sklad et al., 1994) and have been used as determinants of top athletes (Ackland et al., 2003). Present results revealed positive tendencies for the majority of the basic anthropometric attributes in the transition from pre to post, when the maturity status increased, but only significant differences between the three groups were observed in body mass, height and sitting height. The tallest and heaviest kayakers and canoeists were also those who presented the more advanced maturity status, suggesting the greater the maturity the more athletic morphology. These findings support previous research with young competitive and non-competitive athletes in the analysis of basic anthropometric parameters and maturity status at different stages (Falk & Bar-Or, 1993; Mendez-Villanueva et al., 2010; Mirwald et al., 2002). Regarding kayak research, Alacid, Muyor, Vaquero-Cristobal, and Lopez-Minarro (2012) compared young white water with sprint kayaking women at the same chronological age. Similarly, they found that sprint kayakers presented larger maturity status and also exhibited superior anthropometric values in stature, height and sum of six skinfolds (Alacid et al., 2012).

Although no significant differences were detected in fat mass percentage between maturity groups, a positive tendency was observed from pre to post groups, especially in canoeists, with adiposity values ranging from 12% to 18%. Changes in adiposity levels have been associated with maturity status and chronological age growth in the few kayak studies where young paddlers have been analysed (Alacid et al., 2012; Sidney & Shephard, 1973). Despite the fact that muscle mass percentage remains stable in the transition to a greater maturity status, these results confirm that both young kayakers and canoeists significantly tended to develop a larger and more athletic morphological profile as maturity status increases.

In the present study, only sit and reach in canoeists and overhead medicine ball throw in both disciplines revealed significant differences in the transition from pre to post maturity groups. Nevertheless, the majority of the physical parameters analysed presented positive tendencies. The parallel increases of overhead medicine ball throw and CMJ tests with maturity status might confirm the findings from previous studies about peak strength development around PHV (Armstrong & Welsman, 1997; Mirwald et al., 2002) since strength components have been associated with these power tests (Gabbett & Georgieff, 2007; Temfemo et al., 2009). According to other maturity-based analyses in sports science, changes in performance and physical attributes are particularly evident just before and during peak height PHV, with lower rates of change after that point (Mirwald et al., 2002; Welsman & Armstrong, 2000). In contrast, Philippaerts et al. (2006) determined that flexibility exhibited peak development during the years after PHV. The current results in sit and reach only demonstrated positive tendencies as maturity status increases in kayaking and canoeing but significant increases in sit-and-reach values when comparing pre and post groups of canoeing. A possible explanation may be the paddling position adopted by canoeists where a major degree of flexibility is required in the front leg (Lopez-Miñarro et al., 2013). Regarding estimated VO_{2max}, slight increases paralleled maturity development in kayakers, while canoeists' level of aerobic power tended to stabilise along puberty. Likewise, prior studies determined that peak aerobic power remains stable during several stages of pubertal growth when expressed relative to weight (Falk & Bar-Or, 1993), whereas absolute VO_{2max} seems to increase along with biological growth (Falk & Bar-Or, 1993; Krahenbuhl, Skinner, & Kohrt, 1985).

The influence of biological maturation on paddling performance was demonstrated since significant race time improvements were observed parallel to maturity status in both paddling disciplines. The fact that significant differences were observed between all maturity groups in the three distances revealed the great importance of maturity status at similar chronological age, suggesting that maturity status is a predictor of race performance. Additionally, due to the relatively low variation of the estimated VO_{2max} in the transition from pre to post maturity groups, performance progressions seem to come from anaerobic power that especially improves after PHV (Falk & Bar-Or, 1993).

Previous research in the last decade has focused on anthropometric factors in young paddlers but its association with race performance remains unexplored. The finding from the present investigation that body dimensions (weight, height, sitting height and BMI) were significantly correlated with performance times ($P < 0.01$) were consistent with previous investigations in senior elite paddlers since larger paddlers tend to show improved race times (Ackland et al., 2003; Hamano et al., 2015; van Someren & Palmer, 2003). Even though weight increments result in larger hull friction drag that negatively affects boat speed (Jackson, 1995), it appears that larger paddlers have the ability to generate greater power relative to body mass, making it possible to improve performance and increase weight simultaneously (van Someren & Howatson, 2008). When analysing body mass composition, no correlation was determined between fat mass percentage and muscle mass percentage with performance at any distance. These findings might suggest that weight increments associated with better performances are explained by general biological growth of all attributes rather than body mass percentage changes along puberty. In senior paddlers, previous research (van Someren & Howatson, 2008; van Someren & Palmer, 2003) identified no correlation between somatotypes and performance times in 1000, 500 and 200 m while in 200 m fat mass and sum of skinfolds were inversely related to race time ($r = -0.76$, $P < 0.01$; $r = -0.72$, $P < 0.01$, respectively). In contrast, Fry and Morton (1991) detected poorer performances associated with large adiposity levels at longer distances (500 and 1000 m). Apparently, the nature of the event and the maturity status seem to be determinants of body composition in adult kayakers (Fry & Morton, 1991; van

Someren & Palmer, 2003). In any case, previous research suggests that a robust and compact somatotype is common among top paddlers and its development might be beneficial to performance in young paddlers as well (Alacid et al., 2011; Ackland et al., 2003; van Someren & Palmer, 2003). As for maturity status in the current investigation, it is worth mentioning that a high negative correlation with performance times were observed ($P < 0.01$) across all distances and disciplines, with r values higher than −0.54.

Physical fitness tests have been occasionally used by coaches not only for monitoring individual fitness level but also as criteria for recruiting best athletes (Gabbett & Georgieff, 2007; Leone, Lariviere, & Comtois, 2002). Power test results, particularly those from upper limbs (overhead medicine ball throw), demonstrated the importance of power and strength in the achievement of fast race times especially by canoeists at 200 and 1000 m. Although these results might seem contradictory due to the different nature of both events, similar findings can be observed in prior research. Using an isokinetic dynamometer, Fry and Morton (1991) revealed that larger distances presented greater correlation with muscular power than sprint events, while van Someren and Howatson (2008), on the other hand, identified greater associations with shortest distances. However, comparisons with the current results must be treated with caution since different methodology was used for determining muscular power and strength. Regarding sit and reach, a negative association with performance time was identified in canoeists, observing an increasing tendency when distance decreased. It could mean that short events demand a greater flexibility degree perhaps as a consequence of the use of larger and more forward attacks by sprinters.

Traditionally, VO_{2max} has been associated with optimal performance (Pendergast et al., 1979; Shephard, 1987; Tesch, 1983), especially in the longest sprint distance of 1000 m (Fry & Morton, 1991). Nevertheless, the present study only found correlations between these two parameters in all distances in canoeing and 500 m kayaking, observing even better VO_{2max} associations with 200 m than with 1000 m in both disciplines. Similarly, the secondary role of aerobic power in pubertal athletes' performance has been previously reported by Bar-Or (1987), likely as a result of the metabolic specialisation into aerobic or anaerobic that occurs after PHV (Falk & Bar-Or, 1993). Taking into consideration this late metabolic specialisation, it was unsurprising that the best paddlers performed equally well across the three Olympic distances. In addition, contradictory results have also been observed in the latest kayak investigations with adults. No correlation between peak VO_2 and 1000, 500 and 200 m race times was determined, whereas the VO_2 at threshold was positively correlated with 1000 m performance (van Someren, Backx, & Palmer, 2001; van Someren & Howatson, 2008). Similarly, Bishop, Bonetti, and Dawson (2002) only identified significance differences in total VO_2 but not in peak VO_2 when paddling at different pacing strategies. These latest findings might suggest the importance of the maintenance of submaximal and supramaximal intensities rather than the achievement of greater peak VO_2 momentarily.

During puberty, several changes, mainly affected by physical and physiological development, make talent identification difficult from only specific performance data. Particularly in kayaking, maturity status highly contributes to performance since it explains a large variance in the regression equations of all three distances in the prediction of performance time. Maturity status seems to be especially important in the shorter distances as r^2 values increased when distance decreased. Moreover, the presence of CMJ, overhead medicine ball throw and sit and reach in the prediction equations might indicate the importance of muscular power and flexibility to predict kayak performance. As for canoeing, chronological age, sitting height and physical fitness were identified as the best determinants to predict performance times. No remarkable differences were detected between distances perhaps as a result of the lack of distance specialisation at early ages. These findings confirmed the greater importance of maturity status and physical fitness in kayakers in comparison with canoeists. Apparently, to achieve optimal performance kayaking demands an early high physical development whilst canoeing involves more technical ability (Alacid, Marfell-Jones, Muyor, López-Miñarro, & Martínez, 2015).

Conclusions

The results of the current investigation demonstrated the maturity-related differences of young highly trained kayakers and canoeists, confirming that the more biologically mature paddlers were also those who revealed the largest and most robust profiles, greatest physical fitness level and best paddling times. In agreement with prior research (Fry & Morton, 1991; van Someren & Howatson, 2008), superior physical fitness and body size were associated with greater performance and were identified along with maturity status and chronological age as the best predictors of kayaking and canoeing performance times, respectively. Therefore, these findings provide valuable information about the determinants of kayak and canoe performance and indicate that traditional methods for determining and recruiting young talents typically based on performance and chronological age seem to be outdated. The inclusion of maturity status into talent identification programmes is highly recommended as a more accurate index of performance potential, especially in kayakers. In addition to maturity–performance relationship, physical fitness and anthropometry should be taken into consideration as determinants of athlete's overall status and to also identify potential talented athletes among non-practitioners and late maturing paddlers that otherwise would be overlooked.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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