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Development of aerobic and anaerobic power in adolescent rowers: a 5-year follow-up study

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We aimed to determine whether the physical and physiological superiority of early-maturing rowing athletes, observed at ages 12–13 years, over that of their late-maturing counterparts observed at the same ages, still persists at 17–18 years of age, when all adolescent athletes are expected to have completed pubertal development. We hypothesized that this superiority of early maturers would not be observed at reassessment, as late maturers would have likely "caught up" with their early-maturing peers. Twenty-one male rowers were assessed at age 12.8 ± 0.5 years and again at 17.5 ± 0.5 years (mean ± SD). They were divided into groups of early-maturing and late-maturing rowing athletes based on Tanner's sexual maturity ratings. A two-way repeated-measures MANOVA followed by a series of ANOVAs with one within-subject factor (time) and one between-subject factor (group) indicated significant ($P \leq 0.003$) within-subject and between-subjects main effects for lean body mass (LBM), maximal oxygen uptake ($\dot{V}O_{2max}$), and mean power (MP). The group × time interaction effects were significant for LBM ($P = 0.003$), $\dot{V}O_{2max}$ ($P = 0.004$), but not for MP ($P = 0.171$). Over 5 years, early-maturers' advantage dwindled in terms of LBM (+38% to +9%), $\dot{V}O_{2max}$ (+47% to +9%), and MP (+76% to +15%); however, these differences may still be considered practically relevant. The proposed hypothesis was not supported.

The total energy demands of a typical 2000 m rowing race are estimated to be 70–80% aerobic and 20–30% anaerobic (Secher, 2000; Maestu et al., 2005). In this strength-endurance sport, which is characterized by a very high energy expenditure rate, both energy pathways (i.e. aerobic and anaerobic) are stressed to their maximum potential (Steinacker et al., 1998). In recent years, several studies have aimed to establish performance predictors in competitive rowing (Womack et al., 1996; Russell et al., 1998; Cosgrove et al., 1999; Jurimae et al., 2000; Ingham et al., 2002; Riechman et al., 2002; Mikulic & Ruzic, 2008). Not surprisingly, all of these studies reported either indicators of aerobic power, in particular maximal oxygen uptake $\dot{V}O_{2max}$ (Womack et al., 1996; Russell et al., 1998; Cosgrove et al., 1999; Mikulic & Ruzic, 2008), or both $\dot{V}O_{2max}$ and indicators of anaerobic power, specifically mean power (MP) during short-term ergometer rowing (Jurimae et al., 2000; Ingham et al., 2002; Riechman et al., 2002) as strong correlates with rowing performance and important rowing-performance predictors.

Evidence shows that both maximal aerobic (Baxter-Jones et al., 1993; Armstrong & Welsman, 2001) and anaerobic (Armstrong et al., 2000, 2001; Van Praagh & Dore, 2002) performance in both trained and untrained individuals improve in males during childhood and adolescence as they age chronologically and mature physically. Data describing the physiological characteristics of rowers in their childhood and adolescent years are limited (Mikulic & Ruzic, 2008; Mikulic et al., 2009), and longitudinal studies that would document changes in rowers' physiological characteristics over childhood and adolescence do not exist. Longitudinal studies, as opposed to cross-sectional studies, are particularly valuable because they may provide much greater insights into the development of physiological variables in young athletes as they grow and mature.

Because selection for youth sport is based on chronological age, few late-maturing boys are successful during early adolescence, and by the age of 17–18 years many will have stopped participating in elite sport due to lack of success (Armstrong & Welsman, 2005). Indeed, data used for our previous studies (Mikulic & Ruzic, 2008; Mikulic et al., 2009) indicated that 12- and 13-year-old rowers in late puberty were superior in terms of body-size dimensions and both aerobic and anaerobic power variables when compared with their peers in the early stages of pubertal development. Encouraged by this observation, we invited rowers for a reassessment.

Just before 5 years after their initial visit, at a mean ± SD age of 17.5 ± 0.5 years, 21 of the participants in studies conducted by Mikulic and Ruzic (2008) and Mikulic et al. (2009) revisited the laboratory and were retested by the same researchers using the same procedures and equipment as in the original investigation.

The purpose of the current study was to examine the development of body size, aerobic and anaerobic power during adolescence in competitive male rowers. The primary aim of this study was to determine if the early-maturing rowers' superiority over the late-maturing rowers in terms of body size and of aerobic and anaerobic power persists at 17 and 18 years of age, when adolescent athletes are expected to have completed pubertal development. We hypothesized that the difference between the early- and late-maturing rowers observed during the initial assessment would not be observed during the reassessment due to the late maturers "catching up" with their early-maturing peers. If confirmed, this finding could potentially influence profiling procedures for talent identification and the development of young rowers. Specifically, it would yield a message to rowing coaches that they should try to encourage and retain late-maturing young rowers who are perhaps discouraged by perceived physical and physiological inferiority and lack of success and that coaches should consider giving these young athletes a chance to develop their physical and physiological potential before performing selection.

Methods

Participants

In 2005, 12- and 13-year-old male rowing athletes from four rowing clubs in Zagreb, Croatia, were invited to participate in the studies aiming to establish performance-predictive parameters in young rowers (Mikulic & Ruzic, 2008), to investigate the anaerobic power in young rowers with regard to physical maturity and body size (Mikulic et al., 2009), and to investigate changes in the parameters of body size, aerobic and anaerobic power over the course of adolescence (the aim of the current study). Sixty-eight athletes volunteered, met the eligibility criteria, and submitted written informed consent forms signed by both their parents or legal guardians and their coaches. The project received approval from the ethics committee of the School of Kinesiology at the University of Zagreb.

One disadvantage of longitudinal studies is inevitable attrition over the course of the study. Almost 5 years later, all four rowing clubs were again contacted, and 21 rowing athletes who had taken part in the initial assessment and were still active competitors agreed to revisit the laboratory. All of these athletes trained six to seven times (9–12 h) per week. Other participants who had been initially assessed were not available or were not invited for a reassessment due to one of the following: (1) they had shifted from competitive to recreational rowing, (2) they had forgone rowing training to participate in other sports, or (3) they were no longer active in sports. In an attempt to examine whether the retested subsample was representative of the entire initial sample of 68 rowers, we conducted independent sample *t*-tests on the rowers who were tested twice and on the rowers who were only initially tested. No significant differences were observed for chronological age ($P = 0.54$), stature ($P = 0.36$), body mass ($P = 0.52$), $\dot{V}O_{2max}$ ($P = 0.06$), or MP ($P = 0.12$) between the groups for the initial assessment.

Procedures

Age was computed from the date of birth to the dates of the examinations and rounded to the nearest decimal. Stature was measured using an anthropometer (GPM, Zurich, Switzerland), and body mass was determined using beam balance scale (Seca, Hamburg, Germany). Skinfold thickness over the triceps and calf regions was measured using a Harpenden caliper (British Indicators, West Sussex, UK), and the percentage of body fat was estimated using the method developed by Slaughter et al. (1988). Although the Slaughter method uses only two skinfold measurements to estimate body fat percentage, Heyward and Wagner (2004) have stated that it offers a satisfactory estimate of body fat percentage in active adolescent males with prediction error ranging from 3.6 to 3.8%.

Lean body mass (LBM) was estimated by subtracting the estimated body fat mass from the total body mass. All anthropometric measurements were taken according to standardized procedures (Weiner & Lourie, 1969). During the first laboratory visit, sexual maturity was visually assessed using the indices of pubic hair described by Tanner (1962). An experienced pediatrician performed the assessment for all participants. As the mean or median values when European male adolescents reach stage 5 of pubic hair development may range from 14.9 to 16.1 years (Malina et al., 2004), it was assumed that, for the second visit to the laboratory at the mean age of 17.5 ± 0.5 years, all athletes had reached stage 5 for pubic hair development, and hence the sexual maturity reassessment was not conducted.

We used a modified Wingate test on a rowing ergometer to assess anaerobic power in young rowers. Each participant was given 10 min to stretch and warm-up on the *Concept II* model C (Morrisville, New York, USA) rowing ergometer. The warm-up consisted of continuous rowing at an easy-to-moderate pace with three to four short sprints, in accordance with the participants' usual warm-up habits. After these warm-up exercises, participants were given a 2-min rest period while the ergometer was programmed for a 30-s trial at the maximum damper setting (10 on the resistance control dial, which corresponds to a drag factor of 158–160). The participants then performed an "all-out" 30-s effort with verbal encouragement from coaches and laboratory staff members. Power output was calculated and displayed by the *Concept II* computer and was recorded by the investigators. MP was the average individual stroke power over this 30-s trial. This methodology, used to conduct the modified Wingate test, has been described previously by Riechman et al. (2002), and we used this approach successfully in our earlier study (Mikulic et al., 2009).

Furthermore, we used an incremental continuous treadmill (Runrace Competition HC1200, Technogym, Italy) test to volitional exhaustion in order to obtain the parameters of aerobic power. This test was administered 30 min after the modified Wingate test to all the participants to ensure a full recovery. The test began with 3 min of walking at 3 km/h. The treadmill speed was increased by 1 km/h each minute (running started at 7 km/h) until the point of voluntary exhaustion. A constant inclination of 1.5° was used. The expired air was collected and analyzed using a *Quark* b^2 breath-by-breath gas

exchange system (Cosmed, Rome, Italy) equipped with *Quark b^2 6.0* PC software support (*Quark b^2* 8.2 for the final assessment). The heart rate of each participant was monitored using a short-range radio telemetry system (Polar Electro, Kempele, Finland). Cardio-respiratory parameters were calculated automatically and printed every 30 s. The highest values were calculated as arithmetic means of two consecutive highest 30-s values. The participants' rate of perceived exertion was monitored each minute using the Borg's rating of perceived exertion scale (Borg, 1973). We observed the following criteria to ensure that the young rowers had given their best effort: (1) the heart rate had reached a value within 5% of the age-predicted maximum, (2) the respiratory exchange ratio equaled 1.05 or higher, (3) achieved a plateau in oxygen uptake (an increase <2 mL/kg/min in two consecutive 30-s periods), and (4) rating of perceived exertion ≥ 18 on the Borg scale. We assumed that maximal effort had been given if at least three of the four criteria had been met. All participants satisfied these criteria on both occasions.

Statistical procedures

Descriptive statistics were calculated for all experimental data as mean ± SD. In order to test the hypothesis that the differences observed during the initial assessment between the two groups of rowers who differed in physical maturity would not be observed during the reassessment, we divided the participants into two sub-samples based on indicators of physical maturity obtained during the initial assessment. The indicators were as follows: group 1 – late maturers, i.e. rowing athletes classified in Tanner stages for pubic hair 1 and 2; and group 2 – early maturers, i.e. rowing athletes classified in Tanner stages for pubic hair 4 and 5. To obtain a clear distinction between early- and late-maturing rowing athletes, two young rowers classified in Tanner stage 3 for indices of pubic hair during the initial assessment were excluded from this part of analysis.

A two-way repeated-measures MANOVA with one within-subject factor (time) and one between-subject factor (group) was used in order to examine the effects of time and group on the variables representing body size (LBM), anaerobic power (MP), and aerobic power ($\dot{V}O_{2max}$). If a significant multivariate effect was detected, a series of two-way repeated-measures ANOVAs followed, again, with one within-subject factor (time) and one between-subject factor (group). Finally, in addition to the analyses of variables expressed in absolute units, identical statistical procedures, as described above, were used for $\dot{V}O_{2max}$ and MP normalized for LBM using the allometric exponent of 0.67, as predicted by the theory of geometric similarity (Nevill et al., 1992; Markovic & Jaric, 2005; Mikulic et al., 2009). The level of statistical significance was set to $P = 0.05$ for all statistics.

Results

The participants' age, degree of maturity, physical characteristics, and physiological characteristics on both assessment occasions are presented in Table 1.

Between the ages of 12.8 and 17.5 years, the rowers gained 16.3 cm in stature and 21.9 kg in body mass (Table 1). LBM increased by 21.1 kg, while body fat decreased by 4.6%. Maximal aerobic power, as assessed by $\dot{V}O_{2max}$, increased by 1.81 L/min (+62%). The corresponding increase in anaerobic power, as assessed using the MP value obtained during a modified Wingate test on a rowing ergometer, was even more dramatic: 334 W (+122%). Although the rowers classified in the group of early maturers were, as expected, chronologically older than their late-maturing counterparts (13.0 vs 12.6 years; early-maturing and late-maturing rowers, respectively, Table 1), the observed difference (i.e. ~ 4 months) was not significant (*t*-test: $P = 0.10$), which justifies further analysis and comparison between the groups.

A two-way repeated-measures MANOVA detected significant multivariate effects for group ($P<0.001$), time ($P<0.001$), and time × group interaction ($P = 0.005$). A subsequent series of two-way repeated-measures ANOVAs detected the significant main effects for the time factor for LBM ($P<0.001$), MP ($P<0.001$), and $\dot{V}O_{2max}$ ($P<0.001$). Further, significant between-subject effects (factor: group) were detected for LBM ($P = 0.003$), $\dot{V}O_{2max}$ ($P<0.001$) and MP ($P<0.001$). Finally, significant time × group interaction effects were detected for LBM ($P = 0.003$), $\dot{V}O_{2max}$ ($P = 0.004$), but not for MP ($P = 0.171$).

Table 1. Age, maturity status, physical, and physiological characteristics of young rowers on two assessment occasions

	Initial assessment			Final assessment		
	All rowers ($n = 21$)	Early-maturing rowers ($n = 10$)	Late-maturing rowers ($n = 9$)	All rowers ($n = 21$)	Early-maturing rowers ($n = 10$)	Late-maturing rowers ($n = 9$)
Age (years)	12.8 ± 0.5	13.0 ± 0.5	12.6 ± 0.5	17.5 ± 0.5	17.7 ± 0.5	17.3 ± 0.5
Tanner stage	2.9 ± 1.4	4.2 ± 0.4	1.4 ± 0.5	5.0 ± 0.0	5.0 ± 0.0	5.0 ± 0.0
Stature (cm)	165.1 ± 9.9	172.0 ± 7.8	157.6 ± 8.2	181.4 ± 5.3	182.0 ± 6.3	180.9 ± 4.5
Body mass (kg)	56.2 ± 11.4	62.4 ± 6.6	49.4 ± 12.7	78.1 ± 8.8	79.0 ± 8.0	76.9 ± 10.5
Skinfolds (mm)	24.6 ± 9.0	20.5 ± 6.4	28.9 ± 9.9	18.4 ± 7.3	15.6 ± 4.8	21.6 ± 7.8
Body fat (%)	19.1 ± 6.1	16.1 ± 4.7	22.3 ± 6.4	14.5 ± 5.1	12.5 ± 3.3	16.9 ± 6.1
Lean body mass (kg)	45.5 ± 9.9	52.1 ± 5.8	38.1 ± 8.6	66.6 ± 6.5	69.1 ± 6.7	63.5 ± 5.3
Maximal oxygen uptake (L/min)	2.91 ± 0.67	3.44 ± 0.44	2.34 ± 0.36	4.73 ± 0.39	4.92 ± 0.39	4.52 ± 0.29
Maximal oxygen uptake (mL/kg $LBM^{0.67}$/min)	225.7 ± 27.7	242.9 ± 22.2	206.5 ± 19.6	284.6 ± 16.7	288.4 ± 18.3	280.4 ± 14.6
Mean power (W)	273 ± 92	344 ± 70	195 ± 40	607 ± 76	647 ± 87	562 ± 31
Mean power (W/kg $LBM^{0.67}$)	20.9 ± 5.2	24.3 ± 4.7	17.1 ± 2.3	36.5 ± 3.3	37.8 ± 3.6	35.0 ± 2.3

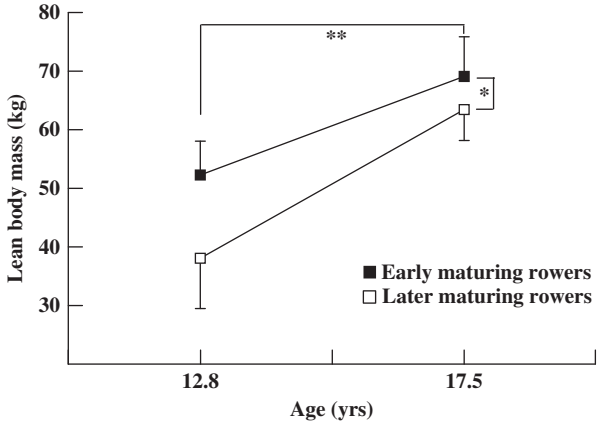

Fig. 1. Means for lean body mass for early- and late-maturing rowing athletes at two points in time of assessment; error bars represent SD; $*P = 0.003$ – significant main effect for group; $**P < 0.001$ – significant main effect for time.

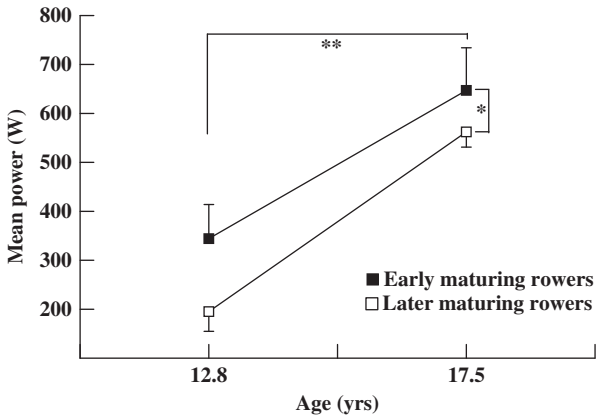

Fig. 2. Means for mean power for early- and late-maturing rowing athletes at two points in time of assessment; error bars represent SD; $*P < 0.001$ – significant main effect for group; $**P < 0.001$ – significant main effect for time.

To provide a better understanding of the maturity-related changes in the LBM, MP, and $\dot{V}O_{2max}$ among both groups of rowers assessed at two points in time, the means for both groups at both assessment points are presented graphically in Figs 1–3.

When $\dot{V}O_{2max}$ and MP values, after normalization for LBM, were used, a two-way repeated-measures MANOVA detected significant multivariate effects for group ($P < 0.001$) and time ($P < 0.001$), but not for time × group interaction ($P = 0.111$). Subsequent two-way repeated-measures ANOVAs detected the significant main effects for the time factor for MP ($P < 0.001$) and $\dot{V}O_{2max}$ ($P < 0.001$). Significant between-subject effects (factor: group) were detected for $\dot{V}O_{2max}$ ($P = 0.002$) and MP ($P < 0.001$).

Discussion

This research represents the first study to examine the changes in body size, aerobic power, and anaerobic power in competitive male rowers as they grow and

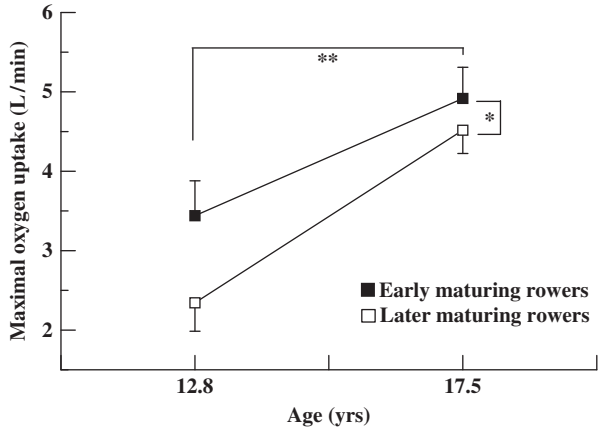

Fig. 3. Means for maximal oxygen uptake for early- and late-maturing rowing athletes at two points in time of assessment; error bars represent SD; $*P < 0.001$ – significant main effect for group; $**P < 0.001$ – significant main effect for time.

mature during adolescence. Our main findings indicate that between 12.8 and 17.5 years of age, late-maturing rowers do not completely "catch-up" with their early-maturing peers. Although the early-maturers' superiority in terms of stature and body mass diminished almost completely over the monitored period, the 5.6 kg (+9%) difference in LBM, in favor of early-maturing rowers, is still substantial. Moreover, the differences in both aerobic and anaerobic power observed at 12.8 years (+47% for $\dot{V}O_{2max}$ and +76% for MP in favor of early-maturing rowers) were drastically reduced at 17.5 years (+9% for $\dot{V}O_{2max}$ and +15% for MP in favor of early-maturing rowers). Despite such reductions over time, the observed differences at 17.5 years may still be considered practically relevant.

An analysis of values for $\dot{V}O_{2max}$ and MP normalized for body size, specifically for LBM, reveals a similar pattern of improvement over time and differences between groups, as observed for $\dot{V}O_{2max}$ and MP expressed in absolute units (Table 1). However, the LBM-normalized values for $\dot{V}O_{2max}$ and MP elicit differences between groups that are substantially smaller than when absolute values are used for rowers at age 12.8 years (+18% for $\dot{V}O_{2max}$ and +42% for MP in favor of early-maturing rowers) and 17.5 years (+3% for $\dot{V}O_{2max}$ and +8% for MP in favor of early-maturing rowers). These findings indicate that LBM, although not the sole contributing factor, appears to play a major role in establishing the physiological superiority of early-maturing rowers over their late-maturing counterparts. We intend to focus our further discussion on aerobic and anaerobic power values expressed in absolute units, because rowing is a weight-supported sport in which absolute units for $\dot{V}O_{2max}$ and MP have been found to correlate strongly with rowing performance and serve as key rowing-performance predictors (see introduction section).

The sample of national-level junior rowers in this study was 6 cm shorter and 4 kg lighter compared with elite male junior rowers competing at the World Junior Rowing Championships (Bourgois et al., 2000). Stature, body mass, and LBM have all been reported previously as strong correlates and/or important predictors of rowing performance (Russell et al., 1998; Cosgrove et al., 1999; Jurimae et al., 2000; Riechman et al., 2002; Mikulic, 2009). In our previous study designed to establish rowing performance predictors in 12- and 13-year-old rowers (Mikulic & Ruzic, 2008), we reported LBM as the strongest anthropometric correlate ($r = 0.82$) with 1000 m rowing-ergometer performance. The competitive advantage of early-maturing rowing athletes at 12–13 years is perhaps obvious as, for example, the muscle mass associated with adolescence, combined with the greater leverage of tall stature and longer arms and legs, benefits rowing performance. The important finding of the current study is that the differences in both stature and body mass observed at 12.8 years during the initial assessment (stature: 172.0 vs 157.6 cm; body mass: 62.4 vs 49.4 kg, early- and late-maturing rowers, respectively) have practically been eliminated at 17.5 years (stature: 182.0 vs 180.9 cm; body mass: 79.0 vs 76.9 kg, early- and late-maturing rowers, respectively). Nevertheless, the 5.6 kg (+9%) superiority of the early-maturing rowers in LBM, despite the decline over the monitored 5-year period is still practically relevant at 17.5 years. Moreover, greater LBM contributes to greater aerobic and anaerobic power, which early-maturing rowers have been found to maintain throughout adolescence.

The increase in anaerobic power throughout adolescence found in our sample of rowing athletes (+122%) was substantially more marked than the increase in aerobic power (+62%). This finding provides further evidence that the anaerobic-to-aerobic power ratio increases throughout the teen years in both athletes and non-athletes. Also, the results correspond to the findings of Armstrong and Welsman (2001) and Armstrong et al. (2001), who longitudinally followed non-trained boys from ages 12 to 17 years and reported similar increases in MP obtained using the Wingate test (+113%) and in $\dot{V}O_{2max}$ (+70%). Note that at both 12 and 17 years, the values for MP and $\dot{V}O_{2max}$ for our sample of trained athletes were, as expected, substantially greater than in non-athletes, as reported in Armstrong and Welsman (2001) and Armstrong et al. (2001).

Over the observed 5-year period, the $\dot{V}O_{2\,max}$ increased by 43% in early-maturing and by 93% in late-maturing rowing athletes. The difference between the groups declined from 47% in the initial assessment to 9% in the final assessment. The analysis of $\dot{V}O_{2max}$ values normalized for LBM indicates that higher aerobic power throughout adolescence in early maturers may at least be partially explained by higher LBM, an advantage they maintain over late maturers throughout adolescence. Indeed, it has been well documented that aerobic fitness ($\dot{V}O_{2max}$) benefits from such increases in LBM or, more specifically, increases in skeletal muscle mass (Armstrong et al., 1999; Armstrong & Welsman, 2001; Rowland, 2005). This superiority in $\dot{V}O_{2max}$ very likely benefits early-maturing rowers in terms of competitive performance. The importance of $\dot{V}O_{2max}$ in successful rowing performance has been well documented (see introduction section), and in our earlier study (Mikulic & Ruzic, 2008), we also reported $\dot{V}O_{2max}$ as the strongest overall correlate ($r = 0.87$) with rowing-ergometer performance in 12- and 13-year-old rowers.

At 12.8 ± 0.5 years, the difference in MP obtained using a modified Wingate test on a rowing ergometer between early- and late-maturing rowers was 76% in favor of early maturers (Table 1). Neuromuscular factors, hormonal factors, and improved motor coordination have all been suggested to explain the higher anaerobic power in adolescents compared with that of children (reviewed in Van Praagh & Dore, 2002). As the athletes progressed through adolescence, MP increased by 88% in early-maturing rowers and by 188% in late-maturing rowers. By the date of the final assessment, the difference between the groups was reduced to 15%. Note that the two-way repeated-measures ANOVA failed to detect a significant group × time interaction effect for MP (see "Results"), which indicates that the trend of MP development throughout adolescence is not significantly different between groups. We may thus surmise that greater LBM, and subsequently greater muscle mass, contributes to their superiority in anaerobic power, as is also the case with the observed superiority in aerobic power by early maturers. These findings are supported by the analysis of LBM-normalized values for $\dot{V}O_{2max}$ and MP. The energetic profile of a Wingate test may also partially account for the observed differences in MP. In particular, although the energy demands of a Wingate test rely primarily upon anaerobic energy pathways, it has been well documented (Hebestreit et al., 1993; Beneke et al., 2002) that the included aerobic component is substantial (i.e. ~ 20–35%). Therefore, higher aerobic power in early-maturing rowing athletes may contribute to their superiority in tests designed to indicate "anaerobic fitness."

In conclusion, this is the first study to quantify changes in the parameters of young rowers' body size and their aerobic and anaerobic power as they progress through adolescence. The observed differences in parameters of aerobic and anaerobic power between the early- and late-maturing rowing athletes had diminished by the final assessment; however, our proposed hypothesis that the differences observed

during the initial assessment between both groups of rowers would not be observed during the reassessment, due to the late maturers "catching up" with their early-maturing peers, was not supported. Although all rowers in the present study had completed their pubertal development before the reassessment, it is reasonable to assume that the process of physical growth and development had not ceased. Therefore, a subsequent examination after approximately 2 years would be warranted in order to supplement the findings of the present study. This approach, however, would pose a challenge for us, given the inevitable attrition in long-term longitudinal studies.

Perspectives

Biological clocks run at different rates in different young athletes, and rowers who mature early tend to be taller and heavier and to have larger LBM than those who mature when they are older. In 12- and 13-year-old rowing athletes, this difference is very much pronounced. The larger body size and greater aerobic and anaerobic power of early maturers provide them with an advantage over late maturers at the same chronological age. Talented children may be discouraged against or even denied the opportunity to advance through the selection process because they happen to be late maturers. Coaches who work with young rowers should be aware of the effect of growth and maturation on performance and should focus on providing opportunities that enable all young rowing athletes to participate in the sport and on nurturing individual talent regardless of the rate of each rower's biological clock.

Key words: rowing, adolescence, Wingate test, maximal oxygen uptake, body size.

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