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BRIEF REPORT

Physiological and Anthropometric Progression in an International Oarsman: A 15-Year Case Study

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Purpose: In this case study, a world-class rower was followed over a period of 15 y in which he evolved from junior to professional athlete. ***Methods:*** An incremental exercise test and a 2000-m ergometer test were performed each year in the peak period of the season starting at the age of 16 y. In addition, the training logs of 1 y each as a junior and a senior rower were recorded and analyzed. ***Results:*** Maximal oxygen uptake (VO_{2max}), maximal power output (P_{max}), and power output at 4 mmol/L blood lactate concentration increased until the age of 27 and then stabilized at 30 y at 6.0 ± 0.2 L/min, 536 ± 15 W, and 404 ± 22 W, respectively. At the age of 27–28 y the rower also had a career-best 2000-m ergometer test (5′58″) and on-water performance with a 4th place at the Olympic Games (2008) in Beijing and World Championships (2009). At the age of 23 y, the rower trained a total of 6091 km in 48 wk. Of the total training time, 15.4% consisted of general training practices, 23.4% resistance training, and 61.2% specific rowing training. ***Conclusion:*** The on-water performance in the World Championships and Olympic Games corresponded closely to the evolution in the rower's physiological profile and 2000-m ergometer performance. The long-term build-up program resulted in an increase in the physiological parameters up to the age of 27 y and resulted in a 4th position at the 2008 Olympic Games at a body mass of only 86 kg.

Keywords: elite rowing, single sculls, training history, physiological profile

Rowing is a strength-endurance sport lasting 6 to 8 minutes in which anthropometric parameters and both aerobic and anaerobic power have been identified as strong predictors of rowing performance.[1–5] Longitudinal studies in which elite athletes are followed over a multiyear period can provide important insights into the domain of talent identification and development of performance-related parameters. In the current study, a world-class single-sculls rower was followed over a 15-year period (age 16–30 y) between 1997 and 2012. To our knowledge this is the first study in which the development and training history of an elite athlete (ie, a world-class rower in single sculls) is reported from adolescence to the end of his professional career.

Methods

Participants

The participant provided informed consent to use the physiological and training data in this case presentation. The study was approved by the medical ethics committee of Ghent University Hospital (Belgium). The participant (born in 1982) had an international career spanning 1997–2012 with a sixth and fourth place at the Olympic Games in Athens (2004) and Beijing (2008), respectively, and a fourth place at the World Championships in 2009 as main achievements.

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Physiological Profile

The anthropometric measurements and incremental rowing test were performed once each year (except in 1998, 2000, and 2002) in the peak period of the year. Height (± 0.1 cm), body mass (± 0.1 kg; Seca-balance), and percentage body fat (based on skinfold thickness at 10 locations) of the participant were determined.[6]

The incremental rowing test was performed on a Concept II (model C, Morrisville, VT, USA) rowing ergometer. The test consisted of stages of 3 minutes, separated by rest periods of 30 seconds during which blood samples were taken from the finger for measurement of blood lactate concentration ([La]) using a lactate analyzer (1500 Sport, YSI Inc, Yellow Springs, OH, USA). The work rate of each stage was determined by setting out a directional time over 500 m that decreased with 5 seconds each step. When the [La] increased above 4 mmol/L the rower had to perform a final all-out stage, again for 3 minutes. Gas exchange was registered breath by breath by means of a metabolic measurement system (Jaeger Oxycon Pro, Hochenhausen, Germany) and averaged in 30-second intervals. VO_{2max} was set as the highest 30-second value obtained during the test. [La] was expressed as a function of work rate and VO_2, and the work rate (P_{La4}) and VO_2 (VO_{2La4}) at [La] of 4 mmol/L were determined by means of linear interpolation. VO_{2La4} was expressed relative to the VO_{2max}. The mean work rate during the final all-out step was considered maximal aerobic power (P_{max}).

A 2000-m ergometer test in which the rower had to perform a maximal 2000-m effort was conducted each year in February or March, 2 weeks before the start of the international rowing season.

Training History

During the athlete's development from junior to professional senior athlete, he followed the long-term build-up program developed in 1988 (and revised in 2001)[7] by the scientific committee of the

Flemish Rowing League. In the current study the training loads for the rower are estimated from the training logs during 1 year as a junior (ie, at 18 y) and 1 year as a senior rower (ie, at 23 y). The training data included number of sessions, duration of the sessions, distance covered on water and on the rowing ergometer, and training intensity. From the incremental rowing test, 4 intensity zones were defined—zone I, [La] < 2 mmol/L; zone II, [La] = 2 to 4 mmol/L; zone III, [La] = 4 to 8 mmol/L; and zone IV, [La] > 8 mmol/L—and the relative intensities of the specific rowing sessions were assessed by recordings of heart rate (HR) and [La] during training.

Results

Physiological Profile

The rower had a mean height of 1.84 m. His body mass increased progressively from 65.0 kg at the age of 16 years to 85.9 kg in 2009 (at the age of 28 y; Figure 1[a]). His mean percentage body fat was 10.6% ± 1.0% and ranged from 9.0% to 12.2%.

The rower's VO_{2max} (Figure 1[b]) increased considerably (1.24 L/min) from the age of 16 to 20 years. From 20 to 30 years his VO_{2max} continued to increase slightly (0.65 L/min) to stabilize at 6.0 ± 0.2 L/min (or 70.7 ± 2.4 mL · min^{-1} · kg^{-1}) at 27 to 30 years. P_{max} (Figure 1[c]) increased progressively from 330 W at 16 years to stabilize at 536 ± 15 W (6.32 ± 0.18 W/kg) at 25 to 30 years. P_{La4} (Figure 1[c]), on the other hand, continued to increase progressively to 404 W (4.75 W/kg) at 27 years and leveled off at a mean P_{La4} of 396 ± 22 W (4.64 ± 0.23 W/kg) between 27 and 30 years. The $\%VO_{2max}$ at [La] of 4 mmol/L reached the highest value of 94.2% at the age of 27 years (2012 Olympics) and decreased to a mean value of 92.2% ± 3.5% between June 2008 and July 2011. Maximal [La] ranged between 10.0 and 17.8 mmol/L. Maximal HR decreased from 203 beats/min at 16 years to 186 beats/min at 30 years.

The rower's 2000-m ergometer time decreased progressively from 6′51″ at the age of 16 years to 6′02″ at the age of 26 and stabilized in the following years (Figure 1[d]). His peak performance was 5′58″, in 2009.

Training Data

In Table 1 the training logs for the year as a junior and the year as a senior rower are presented. The contribution of the training volume in intensity zone I was maintained at 93% of total endurance-training duration. In the senior year the volumes in zones III and IV were higher, whereas in the junior year a higher contribution was spent in zone II.

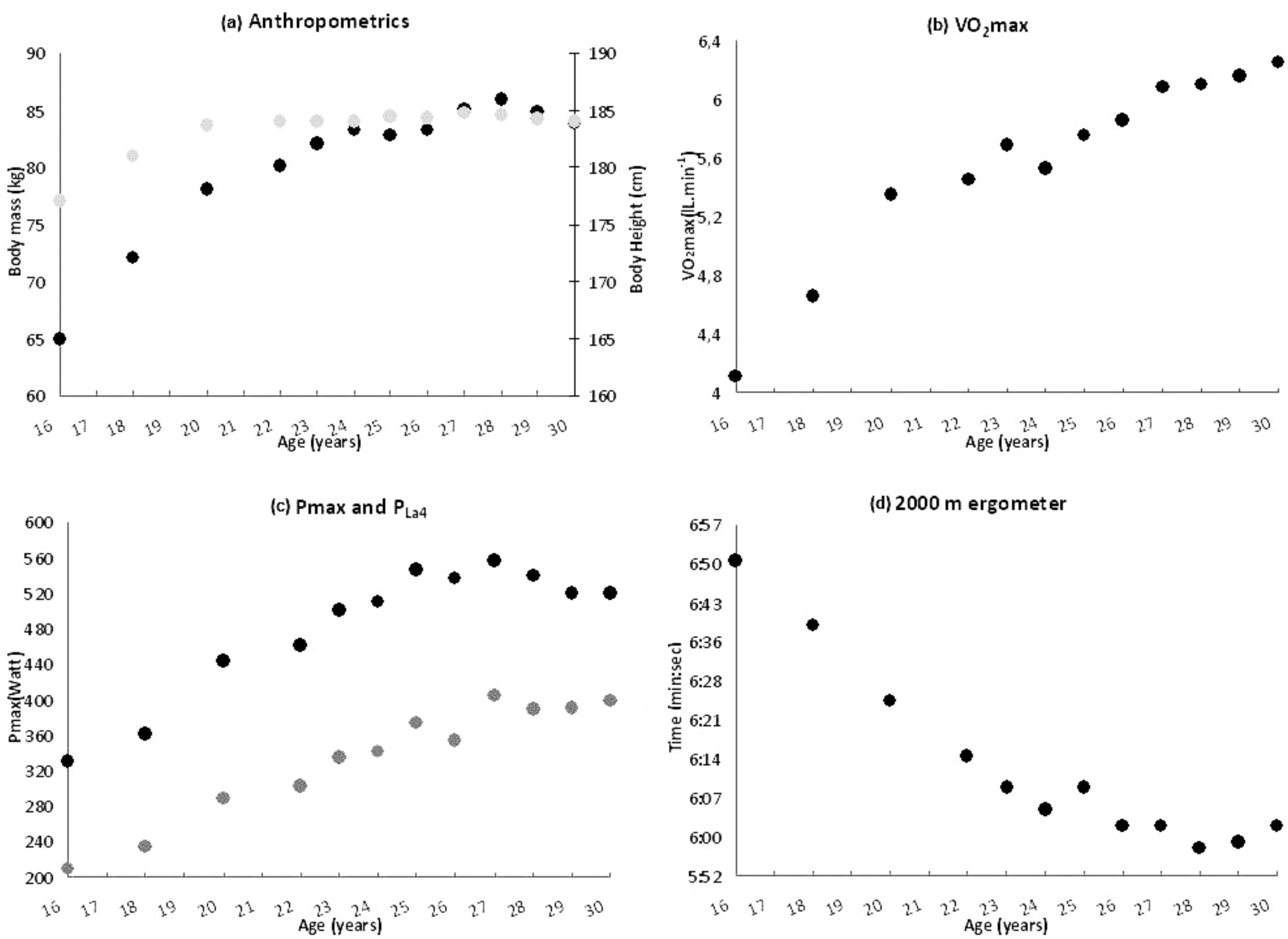

Figure 1 — Anthropometric and physiological progression of an international rower from age 16 to 30 years: (a) body height (gray dots) and mass (black dots), (b) VO_{2peak}, (c) maximal power output (P_{max}, black dots) and power output at blood lactate concentration of 4 mmol/L (P_{La4}, gray dots) obtained from the anthropometric measurements and incremental rowing exercise, and (d) 2000-m ergometer performance.

Table 1 Training Composition for an International Rower for a Period of 1 Year Each as a Junior and a Senior Rower

	Junior (1998–1999)	Senior (2003–2004)
Training wk (n)	45	48
Sessions/wk (n)	9	12.5
Volume/wk (h)	11.3	17.2
Duration/session (min)	75	82.5
General vs specific		
general conditioning (%)	9.1	15.4
resistance training (%)	25.5	23.4
specific rowing training (%)	65.4	61.2
Total rowing volume (km)	4371	6091
zone I (%)	92.8	93.1
zone II (%)	5.2	2.3
zone III (%)	1.0	1.7
zone IV (%)	1.0	2.9

Discussion and Practical Applications

Previous research on the anthropometric profile have shown that elite rowers generally have a height of 1.89 to 1.95 m and a body mass of 90 to 93 kg.[8–10] In comparison with the average of the other single-sculls rowers in the finals of the 2008 Olympics, the rower in the current study was 10 to 12 cm shorter and 10 kg lighter. Therefore, the performances of the rower in the current study in World Cups, World Championships, and Olympic Games can be qualified as being exceptional in relation to body dimensions and are probably related to excellent technical skills. The relatively small body dimensions made the rower more susceptible to weather conditions in competition. In conditions of heavy side or head wind, on-water competition performance becomes more dependent on the absolute power that can be produced. The results of the incremental rowing test and the 2000-m ergometer test should also be considered in the light of these anthropometric characteristics.

The VO_{2max} (6.0 L/min) in our rower is slightly lower compared with previous reported data on world-class rowers. An elite pair-oar rower (6.2 L/min),[8] the 2010 world champion in heavyweight quadruple sculls (6.6 L/min),[9] and a 2004 Olympic champion (6.8 L/min)[10] obtained higher VO_{2max} values than the rower in the current study. Although differences in test period and method might account in part for the lower VO_{2max}, the small body dimensions of our elite rower provide an important context for the observed differences. Surprisingly, the P_{max} of our rower was equal to or higher than that of the rowers studied by Lacour et al[8] (529 W), Godfrey et al[10] (546 W), and Mikulic[9] (481 W), despite his lower VO_{2max}. It should be noted, however, that in our study the laboratory tests were performed in the peak period (May to August), whereas in the other studies the tests were performed between December and March.

The rower in the current study performed best between 23 and 28 years of age, and, more specifically, at the ages of 27 (fourth place in the Olympics in 2008) and 28 years (fourth place at the world championships and two third places in World Cups). These highlights in performance in the main rowing championships can be related to the development of the rower's physiological profile, as obtained from the incremental rowing test. At the ages of 27 and 28 years his VO_{2max}, P_{max}, and $P_{[La]4}$ reached their peak values. These parameters have been identified as important predictors of 2000-m rowing-ergometer performance and on-water performance,[1–3] which also reached their peak at the age of 27 to 28 years. In contrast to the study of Mikulic,[9] in which VO_{2max} peaked at 20 years, the VO_{2peak} of the rower in the current study continued to increase progressively until the age of 27 years. In the study of Mikulic, P_{max} increased despite the leveling off in VO_2, whereas in the current study P_{max} leveled off before the peak in VO_{2max}. It should be noted, however, that Mikulic did not report the physiological profile of the elite rowing squad beyond the age of 22 years. In the study of Lacour et al,[8] both VO_{2max} and P_{max} increased slightly between the ages of 25 and 30 years. In the current study these parameters leveled off at this age. However, Lacour et al also reported that the VO_2 at [La] of 4 mmol/L reached its peak value (100% VO_{2max}) in the year in which the rower performed at his best and became world champion in pair-oar. Also in the current study, the VO_2 at [La] of 4 mmol/L increased to its highest value (95.4% VO_{2max}) at the Olympics in 2008. These results point out that the development of the 4-mmol/L threshold gains importance to perform optimally as VO_{2max} and P_{max} tend to level off. It should be noted that the submaximal results (P_{La4}) might be (slightly) underestimated compared with other studies due to methodological issues. In the current study the rowing pace was determined by setting out a directional time over 500 m that decreased by 5 seconds in each 3-minute stage. Since there is a cubic relationship between boat speed and power, this protocol will result in an exponentially increasing power pattern (ie, in contrast to the traditional linear increase in power).

The distribution of training volume in the intensity zones indicates the use of the polarized training model,[11] especially as the athlete moved into senior age. This model indicates that a large amount of training in zone I ([La] < 2 mmol/L) is an essential part of a competitive endurance-training program. It has been shown that successful endurance athletes spend little training time in zone II, that is, around the lactate threshold (ie, threshold model).[12] The rower in the current study trained according to the long-term build-up program until 2010.[7] From 2010 to the London Olympics in 2012, however, another coach used different training principles, and training did not correspond to the long-term build-up program. The total rowing distance at low intensities decreased and the focus shifted from maximal strength to strength-endurance training. We speculate that the relative decline in performance at the world championships and 2012 Olympics was a consequence of a relatively poor adaptive response to the change in training methods. These results suggest that continuity in training methods and techniques in a national rowing selection is essential to obtain world-class performance.

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References

1. Secher NH. Rowing. In: Shepard RJ, Astrand PO, eds. *Endurance in Sport*. Oxford, UK: Blackwell Science; 2000:836–843.
2. Maestu J, Jurimae J, Jurimae T. Monitoring of performance and training in rowing. *Sports Med*. 2005;35:597–617. PubMed doi:10.2165/00007256-200535070-00005

3. Jurimae J, Maestu J, Jurimae T, Pihl E. Prediction of rowing performance on single sculls from metabolic and anthropometric variables. *J Hum Mov Stud*. 2000;38:123–136.
4. Ingham SA, Whyte GP, Jones K, Nevill AM. Determinants of 2000 m rowing ergometer performance in elite rowers. *Eur J Appl Physiol*. 2002;88:243–246. PubMed doi:10.1007/s00421-002-0699-9
5. Riechman SE, Zoeller RF, Balasekaran G, Goss FL, Robertson RJ. Prediction of 2000 m indoor rowing performance using a 30s sprint and maximal oxygen uptake. *J Sports Sci*. 2002;20:681–687. PubMed doi:10.1080/026404102320219383
6. Parizkova J. *Body Fat and Physical Fitness*. The Hague, The Netherlands: Martinus Nijhoff BV; 1977.
7. Bourgois J, Vrijens J. Growth, maturation and development: consequences for a long-term build-up training programme in rowing. In: Fritsch W, ed. *Rudern—Entwicklung, Kooperieren, Vermitteln*. Sindelfingen, Germany): Sportverlag; 2001:71–83.
8. Lacour JR, Messonier L, Bourdin M. Physiological correlates of performance: case study of a world-class rower. *Eur J Appl Physiol*. 2009;106:407–413. PubMed doi:10.1007/s00421-009-1028-3
9. Mikulic P. Maturation to elite status: a six-year physiological case study of a world champion rowing crew. *Eur J Appl Physiol*. 2011;111:2363–2368. PubMed doi:10.1007/s00421-011-1870-y
10. Godfrey RJ, Ingham SA, Pedlar CR, Whyte GP. The detraining and retraining of an elite rower: a case study. *J Sci Med Sport*. 2005;8:314–320. PubMed doi:10.1016/S1440-2440(05)80042-8
11. Seiler KS, Kjerland GO. Quantifying training intensity distribution in elite endurance athletes: is there evidence for an “optimal” distribution. *Scand J Med Sci Sports*. 2006;16:49–56. PubMed doi:10.1111/j.1600-0838.2004.00418.x
12. Esteve-Lanao J, Rhea MR, Fleck SJ, Lucia A. Impact of training intensity distribution on performance in endurance athletes. *J Strength Cond Res*. 2007;21:943–949. PubMed