Rowing Performance and Estimated Training Load

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Abstract

We related the rowing performance and the associated physiological parameters to the training load as estimated by a questionnaire addressing the mean habitual weekly energy expenditure (MHWEE) of twenty-one international and national level oarsmen. The questionnaire also addressed the energy expenditure during training (EET) sessions classified as low- (EE1), moderate- (EE2), and high-intensity (EE3). To evaluate the physiological capability of the oarsmen, they performed incremental exercise to determine their maximal oxygen uptake ($\dot{V}O_{2max}$) and the $\dot{V}O_2$ relative to $\dot{V}O_{2max}$ corresponding to the 4 $mmol \cdot l^{-1}$ blood lactate concentration ($\dot{V}O_2 4\%$). The mean work rate sustained during a 2000-m all-out event on a rowing ergometer was considered as the rowing performance. On average, the rowers spent $16.4 \pm 1.0\ h \cdot wk^{-1}$ in training with $56 \pm 3\%$ of the time spent on the water. EET represented $43.5 \pm 1.7\%$ of MHWEE. Rowing performance and $\dot{V}O_{2max}$ were both related to MHWEE and EET. Also, rowing performance was related to EE1, EE2, and EE3. In contrast, $\dot{V}O_2 4\%$ was not related to the estimated energy expenditures. These results suggest that rowing performance and $\dot{V}O_{2max}$ are related to training load while $\dot{V}O_2 4\%$ was not in the present group of highly trained oarsmen.

Key words
Maximal oxygen uptake · lactate threshold · training intensity

Introduction

Besides high technical, tactical, and motivational capacities, excellence in rowing requires a high physiological ability [11,23, 25 – 27]. The high energy output during a race [8,12] stresses the organism to its maximum and implicates anaerobic and aerobic capacities to the fullest [11,12,23,24,28]. To improve their physiological ability, the high level rowers train almost twice a day [27]. The training volume has been considered on terms of the number of kilometres rowed or the time spent during training [11,16,20,23,27 – 29]. Steinacker [27] reported training volume for international level rowers about 6000 $km \cdot yr^{-1}$ or 1000 $h \cdot yr^{-1}$. The large panel of parameters associated with rowing performance leads to complex training schedules (including weight training, ergometer rowing, diversified practices like running and cross-country skiing) that makes accurate quantification of the training load difficult when only the number of kilometres rowed or the time spent during training are considered. To quantify the training load it may be an advantage to take into account not only the time spent during exercise but also its in-

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tensity. PAQAP is a physical activity questionnaire that furnishes an estimate of the energy expenditure related to each activity usually performed as the product of intensity times duration [5]. Also, PAQAP makes it possible to quantify the training load and its distribution among boat or ergometer rowing, running, muscle-developing exercises, diversified practices, and low-, moderate-, and high-intensity training.

Performance and training are linked by a dose-response relationship [1] also during rowing since success is reported to be related to training kilometres [28]. This dose-response relationship implies that the parameters of rowing performance i.e., $\dot{V}O_{2max}$ and anaerobic threshold [29], are related to the training load. $\dot{V}O_{2max}$ and anaerobic threshold increase concomitantly with training distance per year [27,29]. Equally, Secher et al. [24] observed a 4% increase in $\dot{V}O_{2max}$ in male and female rowers in response to a 6-month training period and Mahler et al. [20] reported that $\dot{V}O_{2max}$ and peak power production increased respectively by 14% and 18% in response to a 6-month period of training. However, if performance and associated physiological variables increase concomitantly with the training volume, Vermlust et al. [29] found no relationships between rowing performance, $\dot{V}O_{2max}$ or anaerobic threshold and daily training volume in minutes and kilometres rowed. These relationships deserve to be reinvestigated.

The specificity of the training intensity on rowing performance and associated physiological variable improvements remains controversial. While some prone high-intensity training especially during the competitive period [11], others suggest that endurance training is more effective than interval or tempo training for improving rowing performance and $\dot{V}O_{2max}$ [16,23,27]. Similarly, Hagerman [11] advocates training at or near the anaerobic threshold to shift the blood lactate versus percentage of $\dot{V}O_{2max}$ curve ($\dot{V}O_2 4\%$) to the right. This is not supported by the results of Mahler et al. [20] who reported a decrease of $\dot{V}O_2 4\%$ in response to three months of predominantly aerobic training, while the following three months of mainly anaerobic training induced an increase in $\dot{V}O_2 4\%$.

The aim of the present study was i) to propose a new tool to quantify the training load of rowers by considering an estimate of the energy expenditure related to each activity usually performed during training as the product of intensity times duration, ii) to relate rowing performance and associated physiological variables to the training load of the oarsmen, and iii) to investigate the specificity of the training intensity on these variables. A secondary aim of the present study was to compare the distribution of the training load of international and national level rowers.

Materials and Methods

Twenty-one oarsmen (13 heavy- and 8 lightweight) competing at an international and national level (IR= 9 and NR= 12, respectively) participated in the study. Prior to the experiments, height and body mass were measured, the balance giving the weight with an accuracy of 0.1 kg. Their age, height, and body mass were (mean ± SE) 22 ± 3 yr, 187 ± 8 cm, and 81 ± 9 kg, respectively. After being fully informed of the objective of the study performed in agreement with recommendations of the local Ethics Committee, the subjects gave their written consent.

Exercises were performed on wind resistance braked rowing ergometer (Concept II model C, Morrisville, VT, USA) with which the oarsmen were familiar. The computer display of the ergometer showed the stroke frequency, the duration of the event, the distance covered, and the work rate per stroke together with the average for the exercise duration.

Protocol

All measurements and questionnaires took place during the preparatory season. Each subject performed two exercise sessions separated by at least one week.

After a 5-min warm-up (heart rate ~ 130 beats · min^{-1}), the oarsmen performed incremental exercise to exhaustion. Each step of 3 min was followed by a 0.5-min rest. Starting at 150 or 200 W depending on the capacity of the athlete, the work rate was incremented by 50 W steps until exhaustion. During the rest periods a blood sample was collected for lactate determination. Expired gases were sampled during the last 30 s of each exercise period. Heart rate was recorded from an electrocardiogram. $\dot{V}O_{2max}$ and the $\dot{V}O_2$ corresponding to the 4 mmol · l^{-1} blood lactate concentration ($\dot{V}O_2 4$) were determined. $\dot{V}O_2 4$ was also expressed as a percentage of $\dot{V}O_{2max}$ ($\dot{V}O_2 4\%$).

During the second session, the oarsmen were asked to cover "2000 m" in an "all-out test". The time to cover the distance was recorded (min : s). Under these conditions, the oarsmen had to sustain their highest possible work rate. The rowers competed side by side to create emulation as part of the regular assessment of the rowers by the French Rowing Federation. The mean work rate (W) was taken as the performance (Perf).

Training load

The PAQAP questionnaire is the computerised version of the "questionnaire d'activités physiques Saint-Etienne" (QAPSE) which reports physical activities over one week and estimates the energy expenditure (EE) for each type of activity, including sports. The QAPSE has been validated in several populations of various age and physical fitness [4,5]. The questionnaire covers the different training sessions performed by the rowers. Therefore, the oarsmen had the possibility of giving their own training schedule for the period covering the experiments. The intensity of each activity is expressed as a multiple of the basal $\dot{V}O_2$ (3.5 ml · min^{-1} · kg^{-1}) according to the average heart rate during each training session. The training sessions were classified in three categories (T1, T2, and T3) according to the exercise intensity estimated from heart rates and blood lactate concentrations (Table **1**). T1 and T2 included low- and moderate-intensity rowing sessions in a boat, on the ergometer and running. T3 included high-intensity training sessions in a boat, on the ergometer, running and endurance-strength exercises (weight training). Multiplying the intensity of the activity by the duration provides an estimate of the mean habitual weekly energy expenditure (MHWEE), the energy expenditure during training (EET), and for each category of training intensity (EE1, EE2, and EE3 for T1, T2, and T3, respectively). Strength training (heavy load and small

Table **1** Classification of the types of training sessions performed by the rowers of the present study

	T1	*T2*	*T3*
Heart rate (beats·min⁻¹)	140–152	153–168	≈ 170
[Lactate] (mmol·l⁻¹)	≈ 2	≈ 3	≈ 4–5
Boat	21	21	2
Ergometer	21	21	1
Running	21	21	0
Muscle development: endurance-strength exercises			21

The training sessions were classified into categories T1, T2, and T3 corresponding to low-, moderate-, and high-intensity training sessions. T1 and T2 included rowing sessions in a boat, on the ergometer and running. T3 included training sessions in a boat, on the ergometer, running and weight training endurance-strength exercises (circuit training). Heart rate was recorded throughout the training sessions. Lactate concentrations are target values. In the lower part of the table is given the number of subjects for which values are available. Strength training (heavy load and small number of repetitions), stretching, and other diversified sport practices have not been classified separately but have been taken into account in EET

number of repetitions), stretching and diversified sport practices (e.g. bicycling) were taken into account in the EET. The extra-training energy expenditure that corresponds to that spent outside training, i.e. MHWEE minus EET, was also calculated. The questionnaire was completed under the supervision of the same interviewer within the month following the tests. All weeks during a training period do not hold the same intensity and volume since the programme incorporates periodisation. Therefore, the rowers were asked to provide data for a typical week of the training they performed during the two last months. This week had to be representative of the mean weekly training load over the two-month period that covered the experiment. The interviewer checked that the week described was in agreement with the training book record provided by the rower. The responses were not given to the coaches.

Measurements

$\dot{V}O_2$ was measured while the subjects breathed through a two-way mouthpiece (Hans Rudolph 2700, Kansas City, MO, USA) connected to a low-resistance, low dead space mixing chamber. The expired gas was analysed for O_2 and CO_2 by means of D-Fend Datex (Helsinki, Finland) and S3 A/I Ametek (Pittsburgh, PA, USA) analysers, respectively. The calibration was checked by using precision-analysed gas mixtures before and after each session. The expired gas was also collected in a Tissot spirometer for flow measurements. When $\dot{V}O_2$ reached a plateau while the work rate was increasing, $\dot{V}O_2$ was considered maximal ($\dot{V}O_{2max}$). When a plateau in $\dot{V}O_2$ was not observed, the following criteria were used: a respiratory exchange ratio greater than 1.1, an end-exercise lactate concentration higher than 9 mmol·l^{-1}, and a maximal heart rate of 220 minus age ± 10 beats·min^{-1}.

Micropunctures for 20 µl of blood were collected from the earlobe. Blood samples were diluted in a haemolysing solution and stored at 4 °C until analysis. Lactate concentration was determined enzymatically on whole blood [10] with an L.A. 640 Kontron lactate analyser (Roche Bio-electronics, Hoffman-La Roche, Basel, Switzerland).

Methodological considerations

According to Bergh et al. [2] a unit neutral to body dimensions should be applied to compare individuals who differ in body mass. For that purpose, a recent study recommended for rowers the use of body mass raised to the power 0.73 [17]. Since our population included 13 heavyweight and 8 lightweight (≤ 72.5 kg) oarsmen, the results might be influenced by interindividual variations of body mass (cv= 10.5 %). Therefore, the statistical analysis was repeated after the parameters were expressed relative to body mass raised to a power of 0.73.

Statistics

Data are expressed as means ± SE. The coefficient of variation (cv) was calculated as standard deviation/mean × 100. Relationships between two variables were studied by means of a linear (confirmed by the Pearson test) regression technique. The level of statistical significance was set at $p < 0.05$.

Results

Energy expenditure and training load

MHWEE was 157.92 ± 4.67 MJ·wk^{-1} (cv = 13.6 %, 162 and 155 MJ·wk^{-1} for IR and NR, respectively; NS). EET reached 69.39 ± 3.74 MJ·wk^{-1} (78.7 ± 3.7 vs. 62.4 ± 5.1 for IR and NR, respectively; $p < 0.05$), corresponding to 43.5 ± 1.7 % of MHWEE and 10 % of the time (48.7 ± 1.6 % and 11.6 ± 0.5 % vs. 39.7 ± 2.1 % and 8.4 ± 0.7 % for IR vs. NR, respectively; $p < 0.01$). While EET was related closely to MHWEE ($r = 0.80$, $p < 0.001$), there was no relationship between EET and the extra training energy expenditure ($r = 0.003$, $p = 0.99$). Similar results were obtained among the IR and the NR.

The rowers spent 16.4 ± 1.0 h·wk^{-1} in training (19.5 ± 0.8 and 14.0 ± 1.2 h·wk^{-1} for IR and NR, respectively; $p < 0.01$). This represented 7 to 13 (range) training sessions per week, depending on the performance level of the rower. On-water training represented 9.3 ± 0.8 h·wk^{-1} (12.2 ± 0.8 and 7.1 ± 0.8 h·wk^{-1} for IR and NR, respectively; $p < 0.01$), i.e. 56.3 ± 3.3 % of the training time (66.9 ± 3.1 % and 54.1 ± 4.4 % for IR and NR, respectively; $p < 0.05$).

The time spent for each category of training intensity represented 8.4 ± 0.6, 2.6 ± 0.3 and 2.7 ± 0.2 h·wk^{-1} for T1, T2, and T3, respectively, i.e. 52.1 ± 2.8 %, 15.7 ± 1.4 %, and 17.2 ± 1.1 % of the total time spent for training. International level rowers displayed higher EE1, EE2, and EE3 compared to their national level counterparts (Table **2**), but EE1 %, EE2 %, and EE3 % were not significantly different between the two categories of rowers (Table **2**).

Performance and physiological characteristics

The $\dot{V}O_{2max}$ values were 5.34 ± 0.08 l·min^{-1} (5.32 ± 0.14 and 5.35 ± 0.09 l·min^{-1} for IR and NR, respectively; NS) and 217 ± 3 ml·min^{-1}·kg$^{-0.73}$ (226 ± 3 and 210 ± 3 ml·min^{-1}·kg$^{-0.73}$ for IR and NR, respectively; $p < 0.01$). $\dot{V}O_2 4$ values was 4.63 ± 0.10 l·min^{-1} (4.71 ± 0.16 and 4.57 ± 0.13 l·min^{-1} for IR and NR, respectively; NS), respectively. $\dot{V}O_2 4\%$ corresponds to 86.6 ± 1.1 % of $\dot{V}O_{2max}$ (88.3 ± 1.0 % and 85.3 ± 1.6 % for IR and NR, Table **2** Energy expenditure for each category of training intensity (EE1, EE2, and EE3 for T1, T2, and T3, respectively) and their proportion (EE1 %, EE2 %, and EE3 %, respectively) of the total energy expenditure during training (EET)

Level	*EE1*	*EE2*	*EE3*	*EE1 %*	*EE2 %*	*EE3 %*
International (n = 9)	45.35 ± 3.05	15.85 ± 1.07	14.45 ± 1.23	57.4 ± 2.3	20.6 ± 1.8	18.2 ± 1.2
National (n = 12)	32.77 ± 3.71	10.31 ± 1.75	13.56 ± 1.09	52.3 ± 4.2	16.2 ± 2.4	22.4 ± 1.7
Statistical difference	***	**	*	NS	NS	NS

Values are mean ± SE, EE1, EE2, and EE3 are expressed in $MJ \cdot wk^{-1}$. EE1 %, EE2 %, and EE3 % are expressed as percentage of EET. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; NS: not significant

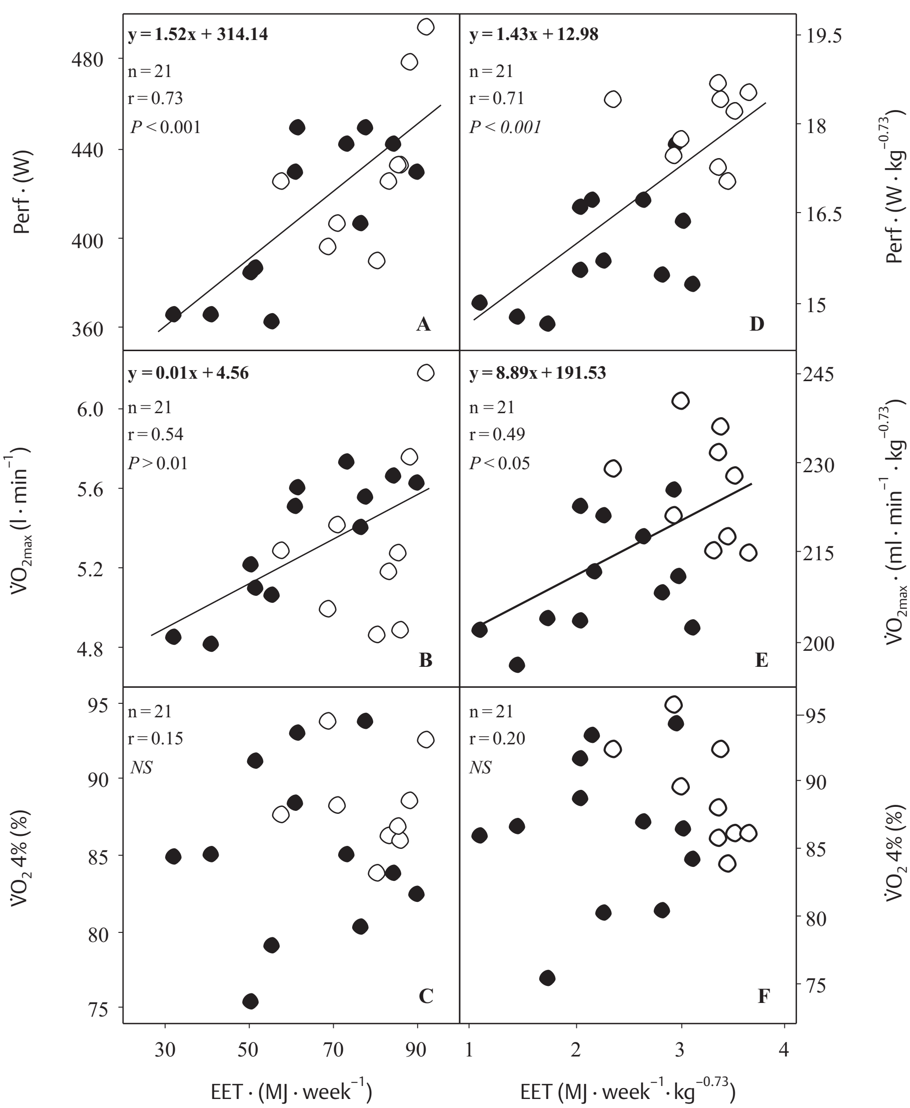

Fig. **1 A** to **F** Relationships between the 2000-m performance (Perf) on a rowing ergometer, maximal oxygen uptake ($\dot{V}O_{2max}$), and oxygen uptake corresponding to the 4 $mmol \cdot l^{-1}$ blood lactate concentration expressed as percentage of $\dot{V}O_{2max}$ ($\dot{V}O_2 4\%$) and the total energy expenditure estimated during training (EET). The left and right panels respectively illustrate the results obtained for international (open circles) and national (closed circles) level rowers when the parameters are expressed in absolute terms and as a function of body mass to the power 0.73 (see the text for details).

respectively; NS). On the average, the oarsmen performed the 2000-m all-out performance in 6 : 17 ± 0 : 02 min : s (6 : 13 ± 0 : 03 and 6 : 20 ± 0 : 03 min : s for IR and NR, respectively; NS), i.e. they were able to sustain a work rate of 419 ± 8 W (432 ± 12 and 410 ± 10 W for IR and NR, respectively; NS).

Rowing performance was related to $\dot{V}O_{2max}$, $\dot{V}O_2 4$, and to $\dot{V}O_2 4\%$ ($r = 0.84$, $p < 0.001$; $r = 0.85$, $p < 0.001$, and $r = 0.48$, $p < 0.05$, respectively).

Rowing performance was also related to MHWEE, EET, EE1, EE2, and EE3 (Fig. **1**, Table **3**). $\dot{V}O_{2max}$ was related to MHWEE and EET (Fig. **1**, Table **3**). $\dot{V}O_2 4\%$ was not related to MHWEE, EET, EE1, EE2, EE3, EE1 %, EE2 %, and EE3 % (Fig. **1**, Table **3**).

No relationship between age and rowing performance, $\dot{V}O_{2max}$, MHWEE or EET was found. $\dot{V}O_2 4\%$ was related to age in the subgroup of international level rowers ($n = 9$, $r = 0.80$, $p < 0.01$).

Table 3 Correlations between energy expenditure parameters and rowing performance and physiological factors associated with rowing performance

	Perf (W)	$\dot{V}O_{2max}$ (l·min^{-1})	$\dot{V}O_2$4% (%)
MHWEE (MJ·wk^{-1})	r = 0.79***	r = 0.78***	r = 0.11 NS
EET (MJ·wk^{-1})	r = 0.73***	r = 0.54**	r = 0.17 NS
EE1 (MJ·wk^{-1})	r = 0.58**	r = 0.38 NS	r = 0.03 NS
EE2 (MJ·wk^{-1})	r = 0.44*	r = 0.21 NS	r = 0.17 NS
EE3 (MJ·wk^{-1})	r = 0.54**	r = 0.48*	r = 0.20 NS
	Perf (W·kg$^{-0.73}$)	$\dot{V}O_{2max}$ (ml·min^{-1}·kg$^{-0.73}$)	$\dot{V}O_2$4% (%)
MHWEE (MJ·kg$^{-0.73}$·wk^{-1})	r = 0.76***	r = 0.70***	r = 0.18 NS
EET (MJ·kg$^{-0.73}$·wk^{-1})	r = 0.71 ***	r = 0.50 *	r = 0.13 NS
EE1 (MJ·kg$^{-0.73}$·wk^{-1})	r = 0.58**	r = 0.37 NS	r = 0.01 NS
EE2 (MJ·kg$^{-0.73}$·wk^{-1})	r = 0.62**	r = 0.46**	r = 0.21 NS
EE3 (MJ·kg$^{-0.73}$·wk^{-1})	r = 0.38 NS	r = 0.25 NS	r = 0.08 NS

Values are correlation coefficients and the asterisks represent the statistical significance with * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ and NS: not significant. MHWEE is the mean habitual weekly energy expenditure. EET is the habitual energy expenditure related to rowing training. Perf is rowing performance. $\dot{V}O_{2max}$: maximal oxygen uptake; $\dot{V}O_2$4%: oxygen uptake corresponding to the 4 mmol·l^{-1} blood lactate concentration expressed as percentage of $\dot{V}O_{2max}$. EE1, EE2, and EE3 are the energy expenditures relative to low-, moderate- and high-intensity training sessions, respectively

Influence of body mass

Rowing performance (W·kg$^{-0.73}$) was related to $\dot{V}O_{2max}$ (ml·min^{-1}·kg$^{-0.73}$), $\dot{V}O_2$4 (ml·min^{-1}·kg$^{-0.73}$), and $\dot{V}O_2$4% ($r = 0.82$, $p < 0.001$; $r = 0.82$, $p < 0.001$ and $r = 0.55$, $p < 0.01$; respectively).

Rowing performance (W·kg$^{-0.73}$) and $\dot{V}O_{2max}$ (ml·min^{-1}·kg$^{-0.73}$) were significantly related to MHWEE and EET (MJ·kg$^{-0.73}$·wk^{-1}) but not $\dot{V}O_2$4% (Table **3**). The correlations between EE1, EE2, and EE3 (MJ·kg$^{-0.73}$·wk^{-1}) and rowing performance or associated physiological variables are given in Table **3**.

Discussion

While previous studies estimated training volume by the number of kilometres rowed or the training time [16,27–29], the present work quantified the training load estimating energy expenditure of all the exercises performed during training. The main interest of using the questionnaires is that the method is applicable in all the situations met in rowing. It allows quantifying almost instantaneously the training load taking into account the volume and intensity of any rower (lightweight or heavyweight, international or national) for all the training sessions completed in rowing (boat and land training) at any time during the year (account taken of periodisation). The most important findings are the relationships obtained between rowing performance or $\dot{V}O_{2max}$ and the energy expenditure during training.

Energy expenditure and training load

As a first element of comparison, MHWEE estimated by the questionnaire is close to that reported previously (175–203 MJ·wk^{-1}) for competitive rowers [18]. Furthermore, EET represented 43.5 ± 1.7% of the total habitual EE over a week while training time represented on average 10% of the time. These proportions were significantly higher for IR than for NR.

The international level rowers trained almost twice a day (11–13 training sessions per week). This represented 19.5 ± 0.8 h·wk^{-1} in training while the national rowers spent 14.0 ± 0.3 h·wk^{-1} training. The extra-training energy expenditure was not negatively related to EET but tended to be lower in the international than in the national level rowers (83.44 MJ·wk^{-1} vs. 92.31 MJ·wk^{-1}, $p = 0.055$).

The training sessions differed by their intensity, duration, and mode (Table **1**). While the results reported in Table **2** indicated that the international rowers trained more than their national counterparts, the partition of the training load in terms of intensity did not appear different from one group to the other. However, the partition of training between the practices was different. International level rowers attached more importance to on-water training (66.9 ± 3.1% of EET) than the national oarsmen (54.1 ± 4.4% of EET, $p < 0.05$).

Performance or physiological associated variables and training load

The energy expenditure during training could be a major determinant of the performance of the group of oarsmen studied. This observation is supported by the positive relationship obtained between rowing performance and EET (Fig. **1A**) and by the lack of a relationship between rowing performance and the extra-training energy expenditure. The results show also relationships between $\dot{V}O_{2max}$ and EET (Fig. **1B**) or MHWEE. These correlations would argue for a dose-response relationship between $\dot{V}O_{2max}$ and energy expenditure. An alternative explanation would be that both $\dot{V}O_{2max}$ and the ability to sustain higher training loads are the results of the rowers' training history. The present results contrast with the lack of relationships reported previously between rowing performance or $\dot{V}O_{2max}$ and daily training volume in minutes and kilometres [29]. The discrepancy between the studies might be explained by the different methods used for quantifying the training load.

A high $\dot{V}O_{2max}$ appears to be a necessary but not sufficient condition to excel in rowing. According to Hagerman [11], one objective of rowing training is to improve a rower's ability to compete at a greater percentage of $\dot{V}O_{2max}$ without producing significant lactate accumulation. A relationship between $\dot{V}O_24\%$ and the fraction of $\dot{V}O_{2max}$ sustained during a 2000-m all-out performance test on a rowing ergometer was reported [21]. However, $\dot{V}O_24\%$ was not related to MHWEE or to EET (Table **3**). This contrasts consistently with the relationships reported in the present study between EET and performance or $\dot{V}O_{2max}$. Furthermore, the effects of training on $\dot{V}O_24\%$ are well-documented [3,7,13–15,19,22]. A first hypothesis accounting for this lack of relationship would be that $\dot{V}O_24\%$ is for a large part genetically determined. A genetic contribution to the response of the ventilatory threshold to aerobic training was reported by Gaskill et al. [9]. Another hypothesis would be that the methodology employed using only one representative week of training does not allow to put in evidence a relationship maybe more complex than those found for performance and $\dot{V}O_{2max}$. $\dot{V}O_24\%$ increased when $\dot{V}O_{2max}$ levelled off after 24 years of age in high-level oarsmen [21]. Therefore, a possible explanation could be that $\dot{V}O_24\%$ is determined by long-term training (in terms of years) in already well-trained athletes. The relationship between age and $\dot{V}O_24\%$ obtained for the international rowers (a homogeneous group of athletes with similar investment in rowing training) supports this hypothesis. We emphasise that this rationale specifically concerns trained athletes and cannot be applied to recreational or young athletes who respond to training by an increase in both $\dot{V}O_{2max}$ and $\dot{V}O_24\%$ [6].

Performance or physiological associated variables and intensity of training

The relationships between rowing performance and EE1, EE2, and EE3 (Table **3**) suggest that training at any intensity would contribute to improvement of performance. On the other hand, the lack of correlation between EE1, EE2, or EE3 and $\dot{V}O_{2max}$ or $\dot{V}O_24\%$ leaves open the question of whether one training intensity is better than some other for improving $\dot{V}O_{2max}$ or $\dot{V}O_24\%$. While Hagerman [11] advocates training at or near to the anaerobic threshold to improve $\dot{V}O_24\%$, Mahler et al. [20] reported a decrease in $\dot{V}O_24\%$ in response to three months of predominantly aerobic training while the following three months of training performed mainly at the anaerobic threshold induced an increase in $\dot{V}O_24\%$. Later, Steinacker [27] promoted training intensities below the anaerobic threshold. The lack of a greater effectiveness of one training intensity over another do not support these recommendations.

Influence of body mass

Since our population included heavyweight and lightweight oarsmen, we have also sought for relationships between variables where the body mass has been raised to the power 0.73. The results obtained are in agreement with those found without the use of a fractional exponent and lead to the same interpretations (Table **3**, Fig. **1D–F**).

Conclusions

The training load estimated by the questionnaire makes it possible to characterise the activity of an oarsmen and to estimate accurately its training load. The international level rowers expended more energy during training than the national level rowers. Although the relative distribution among the different categories of training intensity was not different for the two groups, the international level rowers spent proportionally more time in on-water training than their national counterparts. Rowing performance and $\dot{V}O_{2max}$ were related to the estimated energy expenditure in training. We did not find any relationship between $\dot{V}O_24\%$ and training load parameters, but $\dot{V}O_24\%$ was closely related to age in the international level rowers.

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