Objective and subjective analysis of the training content in young cyclists

Emmanuelle Delattre, Murielle Garcin, Laurence Mille-Hamard, and Véronique Billat

Abstract: The purpose of this study was to analyse the objective and subjective training for young cyclists that is prescribed by their coaches. Seven cyclists performed an incremental exercise to exhaustion before and after 14 weeks of training using an incremental test to determine their maximal oxygen uptake (VO₂ max), the velocity associated with VO₂ max (vVO₂ max), and the velocity associated with the ventilatory threshold (vVT). Cyclists completed a training record with the actual content and the perceived exertion of each training session during these 14 weeks. We have focused on the actual content of the training prescribed by the coaches. Analysis of the content of each session allowed us to calculate the objective training load (volume at different intensities) and to determine the subjective training load from perceived exertion ratings (training load, monotony, strain, and fitness-fatigue). The results showed that cyclists were training at a relatively low intensity and that training rating of perceived exhaustion was weak. Moreover, after 14 weeks of training, VO₂ max did not change whereas vVO₂ max and vVT increased significantly. Therefore, a discrepancy may exist between what is perceived during training and the effects of training. Consequently, objective and subjective indices collected from training books provided useful information supplementary to that recorded from the physiological indices alone.

Key words: training load, training book, perceived exertion, performance.

Résumé : Le but de cette étude était d’analyser le contenu objectif et subjectif d’un entraînement prescrit par les entraîneurs chez des jeunes cyclistes. Sept cyclistes ont effectué un test progressif maximal avant et après 14 semaines d’entraînement afin de déterminer leur consommation maximale d’oxygène (VO₂ max), la vitesse associée à VO₂ max (vVO₂ max) et la vitesse associée au seuil ventilatoire (vSV). Les cyclistes ont rempli un cahier d’entraînement avec le contenu et la perception de l’effort de chaque séance d’entraînement pendant ces quatorze semaines. Nous nous sommes intéressés au contenu réel de l’entraînement prescrit par les entraîneurs. L’analyse du contenu de chaque séance nous a permis de calculer la charge objective d’entraînement (volume à différentes intensités) et de déterminer la charge subjective d’entraînement à partir des valeurs de perception de l’effort (charge d’entraînement, monotone, contrainte, et fitness - fatigue). Les résultats ont montré que les cyclistes s’entraînaient à une intensité relativement faible et que l’entraînement était perçu comme léger. De plus, après 14 semaines d’entraînement, vVO₂ max et vSV ont augmenté significativement tandis que VO₂ max n’a pas changé. Un décalage peut donc exister entre ce qui est perçu et les effets de l’entraînement. Par conséquent, les indices objectif et subjectif recueillis dans les cahiers d’entraînement ont apporté des informations supplémentaires à celles fournies par les indices physiologiques seuls.


Introduction

Numerous authors have investigated the physiological approach to training in the sport of cycling (Hawley et al. 1997; Hoogeveen et al. 1999; Hoogeveen 2000; Norris and Petersen 1998). However, few have taken an interest in the psychological approach to training. Foster and de Koning (1999) and Foster et al. (2001a) have studied the subjective approach to training and developed a method that can be used to quantify the training load of a training session using a modification of Borg’s rating of perceived exertion (RPE) scale (Foster et al. 1996). Training was quantified by a modification of the method described by Banister and Calvert (1980) and Banister et al. (1986), which multiplies training intensity by duration to create a training impulse (TRIMP) score for each training session. Foster et al. (1996) used the RPE scale as a marker of training intensity within the TRIMP concept. This training quantification allows monitoring of each athlete’s training (verification of what is really done on the field and recording of the athlete’s subjective personal experience), an evaluation of the program during the training period, and, potentially, more effective programming of subsequent training (Foster et al. 2001a). To our knowledge, no investigation has focused on both the...
physiological and the psychological evaluation of training according to Foster’s method. Moreover, few authors have studied the objective approach to training, i.e., the real evaluation of the volume of work achieved at different levels of intensity (Billat et al. 2001, 2002, 2003). With this objective approach, training is prescribed by coaches rather than imposed by investigators (Hawley et al. 1997; Norris and Petersen 1998) and corresponds more to what takes place on the field. However, as Foster et al. (2001b) showed, there were significant differences between the training plan designed by the coaches and that executed by the athletes, and so it may be important to analyse the actual content of a training program performed by athletes because it is closer to reality. Moreover, training is performed on an outdoor track far from laboratory conditions.

Hence, the purpose of this study was to analyse the objective and the subjective load of the training program for young cyclists as prescribed by their coaches, and to assess the effects of that training on aerobic performance.

Materials and methods

Subjects
Seven young road cyclists (17.1 ± 0.4 years; 63.8 ± 4.1 kg; 176.5 ± 3.6 cm) who race at the regional (n = 5) and national (n = 2) levels and who attend the Van Der Mersche secondary school in Roubaix participated in the study at the beginning of the athletic season. The first test took place in November when cyclists started the new training season and the second at the end of February just before the first competition, which was a national level race. The cyclists had physical education lessons at their secondary school in Roubaix (2 h/week) where they belonged to the cycling unit, and students have been cycling for at least 3 years. They trained 5 times a week (13–15 h/week corresponding approximately to 12 000 km/year) in addition to physical education. In November and December, the cyclists trained twice a week by running and 3 times a week by road cycling. In January and February, they trained exclusively by road cycling (5 times a week). The subjects were medically examined before they provided informed consent. The approval of the Comité Consultatif de Protection des Personnes pour la Recherche Biomédicale de Lille was obtained for the research (CP 00/10).

Incremental exercise

In the first test, each cyclist performed incremental exercise to exhaustion on their own road racing bicycle on an outdoor cycle racing track (500 m) to determine their maximum oxygen uptake (VO2 max), the velocity associated with VO2 max (vVO2 max) and the velocity associated to their ventilatory threshold (vVT). The velocity associated with VO2 max was defined as the lowest speed which elicited a VO2 value equal to VO2 max (Billat et Koralisztein 1996).

Tests were performed in a climate of 6–14 °C without wind (<2 m·s−1, anemometer, Windwatch®, Alba, Silva, Sweden), 50%–75% relative humidity and 750–760 mmHg barometric pressure. The mass of the bicycles was 9.7 ± 0.4 kg. The diameter of the front and rear wheels was 0.7 m. Each subject selected his preferred gear ratio at each riding speed. All the subjects used clip-on pedal systems.

The power output developed by each cyclist for a given speed was estimated from the equation proposed by di Prampero et al. (1979):

\[
W = (4.5 \times 10^{-2})P + (4.1 \times 10^{-2}) \left( \frac{P_B}{T} \right) \text{SA} \cdot v^3
\]

in which 0.045 is the rolling resistance, \( P \) is the body mass of the cyclist plus the bicycle in kilograms, \( v \) is the speed in meters per second, 0.041 is the air resistance, \( P_B \) is the atmospheric pressure in millimetres of mercury, \( T \) is the air temperature in Kelvin, and \( \text{SA} \) is the cyclist’s body surface area.

According to the performance of these athletes, the initial load was set at 120 W, which corresponded to a different initial velocity for each cyclist. The load was increased by 30 W every minute without rest for all subjects that corresponded to different increments of velocity for each cyclist. The initial velocity and increments were calculated from di Prampero et al. (1979) inverse equation. Finally, the time needed to cover 125 m was calculated for each cyclist. The cyclist received audio cues via a whistle, the cue rhythm determining the speed needed to cover 125 m. Visual marks were set at 125 m intervals along the track. Exhaustion was defined as the point at which the subject was unable to sustain the velocity, i.e., when the cyclist was more than 5 m behind the mark at the audio cue. Each subject was verbally encouraged to give maximum effort.

Fourteen weeks later, the cyclists performed the same exercise test on the same track and under the same range of proposed conditions (i.e., 6–14 °C, 50–75% relative humidity, and 750–760 mmHg barometric pressure).

Cardio respiratory parameters

Heart rate (HR) and oxygen uptake (VO2) were measured with a telemetric system weighing 0.7 kg, which was worn on the back and abdomen (Cosmed® K4b2, Roma, Italy). This analyser has previously been validated for measuring oxygen uptake over a wide range of exercise intensities (McLaughlin et al. 2001). Moreover, the reliability of the VO2 measure has previously been attested (Hausswirth et al. 1997). Expired gas composition and heart rate (HR) were measured breath-by-breath and averaged every 5 s by the K4b2 receiving unit. Before each exercise session, the O2 analysis system was calibrated using ambient air, which was assumed to contain 20.9% of O2 and a gas of known CO2 concentration (5%) (K4b2 instructions manual). The calibration of the turbine flow meter of the K4b2 was performed using a 3 L syringe (Quinton Instruments®, Seattle) The criteria used for VO2 max were a plateau in VO2 (<150 mL·min−1) despite an increase in cycling speed, respiratory exchange ratio above 1.1, and HR over 90% of the predicted maximal HR (Astrand et Ryhming 1954; Lacour et al. 1991; Taylor et al. 1955). The maximal oxygen uptake was defined as the VO2 obtained averaging the 3 highest consecutive values during 15 s. Both Wasserman et al. (1973) and Beaver et al. (1986) methods were used to determine the ventilatory threshold by 3 separate investigators.

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Factors Cyclists (i.e., the difference between maximal HR, HRmax, and rest HR, HRrest (Karvonen and Vuorimaa 1988). Every subject kept a personal training record book. The type of training was classified according to the velocity achieved (1: Velocity < velocity at the ventilatory threshold (vVT). (2) Velocity included between the vVT and the velocity associated to the maximal oxygen uptake (vVO2 max). (3) Velocity associated to the maximal oxygen uptake. (4) Velocity > vVO2 max. Thirty minutes following the completion of a training session the athlete must describe the overall perception of effort during the session.

Table 1. Modified Borg scale used for rating perceived exertion (Foster et al. 1996).

<table>
<thead>
<tr>
<th>Rating</th>
<th>Verbal descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Rest</td>
</tr>
<tr>
<td>1</td>
<td>Really easy</td>
</tr>
<tr>
<td>2</td>
<td>Easy</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
</tr>
<tr>
<td>4</td>
<td>Somewhat hard</td>
</tr>
<tr>
<td>5</td>
<td>Hard</td>
</tr>
<tr>
<td>6</td>
<td>Really hard</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>Really, really hard</td>
</tr>
<tr>
<td>9</td>
<td>10 Maximal</td>
</tr>
</tbody>
</table>

Note: Thirty minutes following the completion of a training session the athlete must describe the overall perception of effort during the session.

Training

For 14 weeks, cyclists performed training sessions prescribed by their coach. Each cyclist was equipped with a HR monitor. The coach determined the intensity of the training session from a percentage of maximal HR reserve (MHRR), i.e., the difference between maximal HR, HRmax, and rest HR, HRrest (Karvonen and Vuorimaa 1988). Every subject kept a personal training record book. The type of training (continuous or interval), the training content (number of series, repetitions, HR in bpm, session duration, rest, distance), and the general perception of exertion during the training session were reported in the training record book using the RPE scale (Foster et al. 1996) (Table 1).

The 14-week training program was then analysed from the subjects’ training books. The content of the training sessions was classified according to the velocity achieved (1: v < vVT, 2: vVT ≤ v < vVO2 max, 3: v = vVO2 max and 4: v > vVO2 max). The relationship between % MHRR and velocity as demonstrated in the incremental test allowed the investigators to establish the relationship between the different levels of velocity achieved and the intensity of the training (% MHRR). The objective training load was determined by the total duration of training at each level of intensity. This was calculated by adding together the daily durations of training at each different intensity level over the full 14 weeks. The subjective training load was determined by the indices suggested by Foster (1998) and Foster and de Koning (1999), which includes RPE, training load, monotony, strain and, fitness-fatigue. The session RPE (intensity factor) was multiplied by the total duration of the training session in minutes (time factor) and yielded a measure of the session training load. The sum of all the training loads from all the sessions over the 14 weeks gave the total training load. The mean of the cycle training loads divided by standard deviation of the cycle training loads corresponded to the monotony (Foster and Lehmann 1997). These authors defined training strain as the product of total training load and monotony. According to Foster and de Koning (1999), the average training load of the previous 6 weeks was called fitness. The training load of the last week corresponded to fatigue. The difference between fitness and fatigue corresponding to the momentary performance level has been determined from a model developed by Banister et al. (1986) to evaluate the effects of a training session and uses the approximate time constants calculated by Banister for fitness and fatigue. When this sum is positive, the performance may be expected to be good and when it is negative the performance may be expected to be bad.

Statistical analysis

Results are presented as mean ± SD. A paired Student’s t test was used to compare test and retest (training effects) for VO2 max, vVO2 max, and vVT. All the calculations were made using SigmaStat® (Jandel, Germany). Significance was set at p < 0.05 for all statistical analyses.

Results

Objective analysis

Most of the cycling training (98.4%) was completed at v < vVT. Additionally, the portion of training attributed to high velocities (≥ vVO2 max) was low (0.4%) (Fig. 1).

Subjective analysis

The duration of the training session, RPE, total training load, monotony, strain, and fitness–fatigue values are presented in Table 2.
Training effects
Maximal and submaximal values of different variables measured at maximal intensity and at the ventilatory threshold for incremental exercise are presented in Table 3. Maximal oxygen uptake and VT expressed as % VO2max did not change, whereas VO2max and VT expressed as km·h⁻¹ increased significantly after 14 weeks of training (p < 0.05).

Discussion
The first aim of this study was to analyse the objective and subjective loads of a training program for young cyclists as prescribed by their coaches. Analysis of the objective training load showed that the amount of training at low intensity was very important (Fig. 1). Indeed, for the most part, the training of cyclists necessarily consists of low-intensity, longer duration work (Hawley et al. 1997; Hoogeveen 2000), which builds correct neural recruitment patterns and develops slow twitch muscle properties. Nevertheless, these authors also showed that work at high and (or) maximal intensities was necessary to improve VO2max. Therefore, it seems that the lack of work at these intensities prevented our cyclists from increasing their VO2max.

Analysis of the subjective training load confirmed this lack of training at high intensities. Either the RPE or the duration of the sessions (or both) proved low compared with Foster’s et al. (1996) and Foster’s (1998) values. Indeed, in the present study, RPE was equal to 2.7 ± 0.2 (corresponding to moderate effort) and was lower than Foster’s et al. RPE (1996) (RPE = 3.8 ± 0.1 corresponding to somewhat hard effort). The value of the cyclists’ weekly training load (1 967 units) was low but still within the range of those of Foster et al. (1996) and Foster (1998), who reported values between 1 386 (for athletes of average level) and 3 725 units per week (for serious competitive speed skaters). The large range of Foster’s values could be explained by the differences in age, practice level, sports activity, and stage in the season. Analysis of the training record books showed that coaches usually respected the fundamental principles of training, i.e., progressive increase, specificity, periodicity, individualisation, and succession of work and rest. The training load increased during the cycle, particularly from the seventh until the thirteenth week (Fig. 2). Nevertheless, we did not observe what we expected to see, i.e., a first part based on the endurance characterized by an increasing duration of the sessions and a relatively low RPE (November–December), followed by specific work that was more intense characterized by a decreasing duration and an increasing RPE (January–February), corresponding to the general work (in volume) then specific (more in intensity) usually recommended (Hawley et al. 1997; Laursen et al. 2002; Lindsay et al. 1996; Norris and Petersen 1998). The increase in the training load corresponded principally to an increasing duration (week 1: 51 ± 13 min vs. week 14: 106 ± 7 min) rather than an increasing intensity (week 1: RPE = 2.8 ± 0.8 vs. week 14: RPE = 3.5 ± 0.5). The training monotony level ranged between 0.7 and 1.3 through the 14 weeks. These values of monotony associated with a low training load brought about a low level of training strain (Foster and Lehmann 1997). This low variation of monotony (0.7–1.3) induced very close training load and strain values throughout the cycle. Bruin et al. (1994) demonstrated in an animal model that a given total training load is better tolerated when heavy training is alternated with light exercise, i.e., when training is not monotonous (value < 2; Foster 1998).

Because of a sharp increase in training during week 13, the fitness–fatigue index was less than 0 at the end of the study (1 week before the first competition), so the cyclists’ momentary performance level was reduced (Fig. 3). This was due to the fact that the training load in the last weeks was very high (approximately 4000 units for the 13th and 14th weeks). The coaches overloaded the cyclists’ training to produce an overcompensation with a view to the forthcoming competition. But there was no overcompensation because the cyclists did not have a sufficient period of rest (less than 1 week). Indeed, as suggested by Steinacker et al. (2000) and Halson and Jeukendrup (2004), overload is accompanied by overcompensation only after 1–2 weeks of recovery or tapering. However, as the cyclists’ coaches did not anticipate the necessary tapering between the end of the training and the competition (fatigue was higher than fitness in the 14th week), performance was relatively poor. Unfortunately, it has been difficult to compare our subjective results with optimal values because few studies have been done on this subject and we are the only investigators to have done these calculations on a training cycle of 14 weeks. Moreover, Foster’s investigations were performed principally with high level speed skaters.

The second aim of this study was to assess the effects of that training on aerobic performance. Again, our interest is based on what is observed in practice and not what was prescribed or planned in theory. Our results showed that VO2max increased significantly after 14 weeks of training. The VO2max improvement was probably due to the running (Tanaka 1994). Indeed, analysis of the training record books showed that 4.3% of the total duration of training done in running is at the beginning of the season. This training was made up of jogging at 60%–70% VO2max of interval training sessions (30/30, i.e., 30 s at 100% VO2max and 30 s at 60% VO2max for 10 to 15 min, and then increasing the

Table 3. Means and standard deviations of VO2max, vVO2max, vVT (expressed in km·h⁻¹ and %vVO2max) before and after 14 weeks of training (n = 7).

<table>
<thead>
<tr>
<th>Factors</th>
<th>Pre-training</th>
<th>Post-training</th>
<th>Paired t test</th>
</tr>
</thead>
<tbody>
<tr>
<td>VO2max (mL·min⁻¹·kg⁻¹)</td>
<td>63.8±7.6</td>
<td>64.4±5.1</td>
<td>t (6) = -0.380</td>
</tr>
<tr>
<td>vVO2max (km·h⁻¹)</td>
<td>41.9±1.3</td>
<td>43.1±0.7</td>
<td>t (6) = -3.141 *</td>
</tr>
<tr>
<td>VT (km·h⁻¹)</td>
<td>38.2±1.8</td>
<td>40.7±0.6</td>
<td>t (6) = -4.226 *</td>
</tr>
<tr>
<td>VT (% of VO2max)</td>
<td>91.2±4.7</td>
<td>94.4±1.7</td>
<td>t (6) = -2.071 *</td>
</tr>
</tbody>
</table>

Note: VO2max, maximal oxygen uptake; vVO2max, velocity associated with maximal oxygen uptake; vVT, velocity at the ventilatory threshold. Asterisk indicates p < 0.05.
intervals to 1 min) and of cross-country races. In running, 83.7% of the time training was completed at \( v < v_{VT} \); 11.3% at \( v_{VT} \leq v < v_{V\text{O}_2 \text{max}} \); 4.9% at \( v \geq v_{V\text{O}_2 \text{max}} \). Thus, according to Tanaka (1994), it seems there is a transfer of the training effects on \( V\text{O}_2 \text{max} \) from 1 form of activity to another. In fact, the nonspecific effects of the training are more obvious when running is used as the training mode. Loy et al. (1995) suggested that nonspecific effects of the training were lower than those produced by specific training. In our study, the amount of cycling training at 100% \( V\text{O}_2 \text{max} \) (0.4% of the total duration of the training) was not sufficient to allow cyclists to improve their \( v_{V\text{O}_2 \text{max}} \). However, our results indicate that \( v_{VT} \) increased significantly after 14 weeks of training. This improvement could be explained by cycling training sessions at an intensity close to \( v_{VT} \) (Fig. 1). Our findings are in agreement with those of Norris and Petersen (1998), who reported a significant increase of \( v_{VT} \) after 4 sessions per week training at an HR similar to that measured at VT for 8 weeks. In the same way, Londeree (1997) concluded in a meta-analysis that a training intensity higher than 80% \( VO_2 \text{max} \) was necessary to improve the VT in previously trained subjects. Unlike the previous factors, \( V\text{O}_2 \text{max} \) did not change after 14 weeks of training. This result may be linked to the lack of work at high intensity as explained previously (Hawley et al. 1997; Hoogeveen 2000; Laursen et al. 2002; and Norris and Petersen 1998). Furthermore, our
reported \( \text{VO}_2 \text{max} \) values were different from those of high level cyclists (Hawley et al. 1997; Hoogeveen 2000), but similar to those of Padilla et al. (1996) who measured young athletes at the same level. This could be explained by the age and the practice level of our cyclists. In agreement with the present results, Billat et al. (1999) reported in runners an absence of \( \text{VO}_2 \text{max} \) improvement despite the increase of \( \nu \text{VO}_2 \text{max} \). As suggested by these authors, the stability of \( \text{VO}_2 \text{max} \) and the improvement of \( \nu \text{VO}_2 \text{max} \) could be explained by an improved running efficiency. Finally, this disparity of results may be explained by the error measurement owing to the use of the Cosmed K4 and to the outdoor test on the cycle racing track. Consequently, although the amount of training at high intensity was very low and that RPE and fitness–fatigue indices were weak, we showed that training was efficient since \( \nu \text{VO}_2 \text{max} \), \( \nu \text{VT} \), and performance increased after the 14-week training program. Ultimately, our subjects were ranked between the 6th and the 20th place (out of 120–150 cyclists) in a national race and between the 13th and the 30th place (out of 120–150 cyclists) in an international race. Three of them participated in the “national challenge race” and finished 20th, 35th, and 38th. At the end of the season, cyclists made progress (4 “Junior” national level and 3 high level). For coaches, this would mean that they do not need to train young cyclists severely to obtain increases in performance. There is a discrepancy between what is perceived during training and the effects of training. We may hypothesize that training RPE values have been underestimated by cyclists because they perceived training very much lighter than the competition. This could be explained by the fact that cyclists trained at low and humdrum exercise intensities. Another explanation that could account for this underestimation was that the training exertion seemed negligible to them in relation to the exertion realised in competition.

Generally speaking, this study has allowed us to bring out the advantages and the disadvantages of Foster’s method. Indeed, this method was practical and easy to use, did not require expensive equipment, and allowed quantification of various activities and levels of intensity (Foster et al. 2001a). Subjective assessment with the RPE made it possible for variations in wind and gradient to be taken into account, in comparison with the objective training evaluation. Cycling, more than other activities, is dependent on such variations of climatic conditions, road surfaces or slope. However, the accuracy of the analysis depended heavily on the manner by which the training books were filled out. Unfortunately, it seemed that the index of fitness–fatigue was unsuited to our study for 2 reasons. In the first place, Foster and de Koning (1999) calculated this index on the basis of training cycles of 6 weeks that did not correspond to our training period of 14 weeks. We chose 14 weeks because this period is commonly used in France and corresponds to a training macrocycle. Secondly, the fitness–fatigue factor provides information only about the momentary performance level of the athlete. The index according to this method therefore depends on the moment in the training cycle at which the investigators or the coaches measured it. For our purposes, it must be measured at the end of the training cycle. In order for this method to be applicable, we may calculate the index of fitness–fatigue over a period of 14 weeks of training (fitness–fatigue = average of the weekly loads of the 14 weeks minus training load of the last week). Whether the calculations were made over 6 weeks or 14 weeks did not greatly change the fitness–fatigue values.

The objective method used may also be open to criticism. Indeed, with regard to training intensity, several authors have reported that HRrest and (or) HRmax were sensitive to biological variations such as fatigue, stress (Jeukendrup et al. 1992), and (or) environmental variations such as cold (Galloway and Maughan 1997), heat (Niess et al. 2003), wind (Brown and Banister 1985), and altitude (Levine and Stray-Gundersen 1992). For example, Brown and Banister (1985) compared cardiorespiratory responses in 7 trained cyclists who practised an outdoor cycling exercise (environmental conditions were simulated with fans) versus an equivalent cycle ergometer exercise in the laboratory (no wind conditions). These authors showed that during the outdoor test, the average HR was 7%–13% higher than under laboratory conditions. This suggested greater strain for a similar external work rate. Thus, the cyclist would not necessarily be in the same area of velocity intended by the coach with regard to the training HR. Furthermore, according to Neumann (1992), long-term muscular activity brings about an increase in body temperature as well as an increased HR. The HR increase becomes more and more significant with the appearance of muscular fatigue and dehydration, which limit heat loss. HR can also vary with the training state (Lehmann et al. 1993; Uusitalo et al. 2000). For an equivalent intensity of exercise, HRmax and HRrest decrease with training. They must therefore be regularly re-evaluated (Zavorsky 2000). In our study, the evolution of HRmax was not been taken into account in calculating the training HR as against HRrest Norris and Petersen (1998) and Billat et al. (1999) showed that it was necessary to revalue HRmax every 4 weeks so that training intensity could be more precisely monitored. This evolution could bring about a difference between prescribed and achieved intensity of the exercise. These disadvantages suggest the need for additional criteria in order to adequately prescribe and monitor intensity of training. It would be interesting to link the SRM® (Schorerer Rad Messtechnik) training system with a HR monitor to assess the intensity of exercise during the sessions. The SRM method would provide accurate values for the power output during exercise. The HR monitor would also allow a physiological index such as HR to be linked to that power output in order to estimate the level of intensity from a physiological point of view.

In conclusion, we feel that such a multidisciplinary approach is both original and interesting. Our study showed that a discrepancy may exist between what is perceived during training and the actual effects of training. Consequently, objective and subjective indices collected from training books provided useful information supplementary to that recorded from the physiological indices alone. Further research should be conducted to improve the tools used and to test them in other sporting situations and at different levels of performance.

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