Perceptual and Motor Skills, 2001, 93, 661-671.

PERCEIVED EXERTION SCALES ATTEST TO BOTH INTENSITY AND EXERCISE DURATION[1]

MURIELLE GARCIN AND VERONIQUE BILLAT

Faculté des Sciences du Sport et de l'Education Physique
Université de Lille 2

Summary.—The present purpose was to study the relationships between perceived exertion (RPE, ETL) and exercise duration for all-out runs eliciting $v\dot{V}O_2$ max. 12 endurance-trained men performed three exhausting exercises on an indoor track. The first test was an incremental exercise to measure their maximal oxygen uptake ($\dot{V}O_2$ max), the velocity associated with $\dot{V}O_2$ max ($v\dot{V}O_2$ max), the velocity of the lactate concentration threshold (vLT) and the velocity delta 50 (vΔ50: the velocity halfway between $v\dot{V}O_2$ max and vLT). The second and third tests were a constant load all-out run at $v\dot{V}O_2$ max and vΔ50 to measure the time to exhaustion at these intensities (tlim $v\dot{V}O_2$ max and tlimvΔ50, respectively). vΔ50 corresponded to 90.1 ± 2.5% $v\dot{V}O_2$ max; tlim $v\dot{V}O_2$ max and tlimvΔ50 were equal to 286 ± 71 sec. and 547 ± 157 sec., respectively. For a same given relative time (%tlim), athletes perceived exercise as harder and felt that they could endure less for $v\dot{V}O_2$ max than vΔ50. When subjects began to perceive exercise as "hard" (RPE = 15), they had run for only 36.4 ± 26.8%tlim at $v\dot{V}O_2$ max, whereas they had run for 46.1 ± 15.7 %tlim at vΔ50. These results indicate that RPE and ETL scales were a combined subjective estimation of both intensity and exercise duration for all-out runs at 90 and 100% $v\dot{V}O_2$ max. Therefore, this scale could be used to assess duration as well as intensity of exercise for the practical application in sport. Moreover, it could be suggested that exercise duration can be prescribed as a function of perceived exertion for healthy normal people. Consequently, perceived exertion could be an important tool to individualize the prescription of a training program.

Numerous studies have shown that the use of the Rating Scale of Perceived Exertion (RPE from 6 to 20), which was described by G. V. Borg in 1970, is a good indicator of physical stress and provides a psychological complement to physiological responses to exercise (Borg & Noble, 1974; Eston, Davies, & Williams, 1987; ACSM, 1990).

Borg (1970), Skinner, Hustler, Bergsteinova, and Buskirk (1973), and Borg and Noble (1974) showed that RPE is a linear function of physical work load for an incremental exercise, whereas there has been a great deal of controversy about exercise at constant load. Indeed, some studies observed a linear relationship between RPE and exercise duration (Noble, Metz, Pandolf, & Cafarelli, 1973; Horstman, Morgan, Cymerman, & Stokes, 1979; We-

[1]The authors gratefully acknowledge the Centre de Médecine du Sport C.C.A.S., 2 avenue Richerand, 75010 Paris, France. Address correspondence to Murielle Garcin, Laboratoire d'Etudes de la Motricité Humaine, Faculté des Sciences du Sport et de l'Education Physique, Université de Lille 2, 9 rue de l'Université, 59790 Ronchin, France or e-mail (mgarcin@mailsc.univ-lille2.fr).

nos, Wallace, Surburg, & Morris, 1996; Garcin, Vautier, Vandewalle, Wolff, & Monod, 1998), whereas other studies suggest that RPE reached near steady-state values during a constant exercise (Pandolf, Billing, Drolet, Pimenthal, & Sawka, 1984; Latzka, Muza, Levine, & Pandolf, 1989). However, these studies dealt with a medium intensity of exercise (30% to 86% of the velocity associated with the maximal oxygen uptake—$v\dot{V}O_2$ max) and exercise was not performed to exhaustion (the exercise duration was limited to 30 or 60 min. in most studies) (Noble, *et al.*, 1973; Horstman, *et al.*, 1979; Pandolf, *et al.*, 1984; Latzka, *et al.*, 1989; Wenos, *et al.*, 1996; Garcin, *et al.*, 1998).

There is a large variability in the RPE values for subjects performing the same relative constant workload, e.g., RPE = 14 ± 2.3 at 50% of exhaustion time for an exercise performed at 60% of maximal aerobic power (Garcin, *et al.*, 1998). At the fifth minute of constant load exercises till exhaustion, some subjects rate "hard" an exercise intensity that they were able to maintain for one hour, whereas the same rating corresponded to an exhaustion time equal to approximately 15 min. for other subjects (Vautier, 1994). Consequently, a second perceived exertion scale based on subjective estimation of exhaustion time (Estimated Time Limit, ETL) has also been used in addition to RPE during exercise to understand further how a subject is feeling (Garcin, Vandewalle, & Monod, 1999).

Most of the studies dealing with time perception have focused on subjective duration of noise, music, or light stimuli (Eisler, 1975, 1976; Eisler & Eisler, 1992). In these studies, subjects were asked to estimate and reproduce a time interval (Eisler, 1976; Vercruyssen, Hancock, & Mihaly, 1989). They indicated the beginning and the end of the variable interval verbally or by pressing a button, or kept a button pressed during the whole response duration (Eisler, 1976). Kirkcaldy (1984) observed the subjective time estimation. In his study, subjects were requested to produce as "accurate an estimate as possible" of what they considered to be a time period of 1 min. All these studies are related to elapsed time, but to our knowledge no study has dealt with expected time or subjective estimation of exhaustion time during constant load exercise.

Numerous studies showed RPE scale was an effective technique for prescribing (Smutok, Skrinar, & Pandolf, 1980; ACSM, 1990; Dishman, 1994; Dunbar, Goris, Michielli, & Kalinski, 1994) and monitoring exercise intensity (Eston, *et al.*, 1987; Ceci & Hassmen, 1991; Dunbar, Robertson, Baun, Blandin, Metz, Burdett, & Goss, 1992; Dishman, Farquhar, & Cureton, 1994). However, prescribing an adequate exercise stimulus involves proper adjustment of exercise frequency, intensity, and duration. Therefore, the purpose of the present investigation was to study the relationships among perceived exertion (RPE), estimated time limit (ETL), and exercise duration for all-out runs eliciting $v\dot{V}O_2$ max. The combined use of these scales would allow accurate prescription and regulation of training (intensity and exercise duration) for practical application in sport.

Method

Participants

Twelve endurance trained men (41.5 ± 6.5 yr., 70.2 ± 8.8 kg, 175.5 ± 5.9 cm) participated. The subjects were medically examined before they signed an informed consent form about the purpose and procedures of the experiment. The approval of the ethics committee was obtained for tests (University Lille 2).

Materials

Heart rate (HR) and oxygen uptake ($\dot{V}O_2$) were measured with a telemetric system (Cosmed®K4b², Italy). This material was validated by Hausswirth, Bigard, and Lechevalier (1997). Heartbeats and expired gases were collected and transmitted to the K4b² receiving unit. Before each exercise, the O_2 analysis system was calibrated using ambient air, which was assumed to contain 20.9% of O_2 (K4b² instructions manual). The calibration of the turbine flowmeter of the K4b² was performed using a 3-1 syringe (Quinton Instruments, Seattle). Blood lactate was determined by enzymatic oxidation analysis (Accu-Sport®, Boehringer, Germany).

The perception of exertion was expressed according to two scales: a French translation (Shephard, Vandewalle, Gil, Bouhlel, & Monod, 1992) of the Rating Scale of Perceived Exertion (RPE) (Borg, 1970) which consisted

TABLE 1
Rating of Perceived Exertion or RPE Scale (Borg, 1970)

How Hard Do You Feel This Exercise Is?	
6	
7	Very, very light
8	
9	Very light
10	
11	Fairly light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Very, very hard
20	

of 15 assessments between 6 ("very, very light") and 20 ("very, very hard") (Table 1), and a second scale based on subjective Estimation of Time Limit (ETL) Garcin, *et al.*, 1999) which consisted of 20 assessments between 1 ("more than 16 hours") and 20 ("2 minutes") (Table 2). This scale was designed as a function of the logarithm of the estimated exhaustion time (tlim) (ETL = 21 minus 2 n, with $n = \log_2$ (tlim) where tlim was expressed in minutes). A base 2 logarithm was chosen to have enough assessments for exhaustion times ranging from less than 2 minutes (anaerobic exercise) to many hours. For example, ETL was 19 for tlim equal to 2 minutes and 15 for tlim equal to 8 minutes (Table 2). To facilitate the use of this scale, ETL equal to 13 and 11 corresponded to 15 and 30 minutes instead of 16 and 32 minutes, respectively. Similarly, the values of ETL equal to or lower than 9 were expressed in multiples of one hour (Table 2).

TABLE 2
Estimated Time Limit Scale Based on Estimation of Exhaustion Time (Garcin, *et al.*, 1999)

How Long Would You Be Able to Perform an Exercise at This Intensity to Exhaustion?	
20	
19	2 minutes
18	
17	4 minutes
16	
15	8 minutes
14	
13	15 minutes
12	
11	30 minutes
10	
9	1 hour
8	
7	2 hours
6	
5	4 hours
4	
3	8 hours
2	
1	More than 16 hours

Procedure

Subjects performed an incremental exhausting exercise on an indoor track (400 m) in order to establish their maximal oxygen intake ($\dot{V}O_2$ max). According to the performances of these athletes, the initial speed was set at 12 $km \cdot h^{-1}$ and increased by 1 $km \cdot h^{-1}$ every 3 min. until 17 $km \cdot h^{-1}$ was attained. Each stage was separated by a 30-sec. rest. Then, after a 90-sec. rest, each incremental stage lasted 2 min. and the speed was increased by 1 $km \cdot h^{-1}$ until exhaustion, without resting time. Each subject was verbally encouraged to give maximum effort.

The criteria used for $\dot{V}O_2$ max were a plateau in $\dot{V}O_2$ despite an increase in running speed and heart rate (HR) over 90% of the predicted maximal heart rate (Taylor, Buskirk, & Henschel, 1955). The velocity associated with $\dot{V}O_2$ max ($v\dot{V}O_2$ max) was the lowest running speed which elicited a $\dot{V}O_2$ value equal to $\dot{V}O_2$ max (Billat & Koralzstein, 1996). The velocity of the lactate concentration threshold (vLT) was determined by the relationship between blood lactate concentrations and velocity and was defined as the velocity for which an increase in lactate concentration corresponding to 1 $mmol \cdot l^{-1}$ occurs between 3 and 5 $mmol \cdot l^{-1}$ (Aunola & Rusko, 1984). Velocity delta 50 ($v\Delta50$), which was the velocity halfway between $v\dot{V}O_2$ max and vLT, was calculated as $v\Delta50 = vLT + [(v\dot{V}O_2 \text{ max minus } vLT)/2]$.

Two and four days later, on the same track they performed a constant load exercise up to exhaustion at $v\dot{V}O_2$ max and $v\Delta50$ to establish the time to exhaustion at these intensities (tlim$v\dot{V}O_2$ max and tlim$v\Delta50$, respectively). Each subject was verbally encouraged to continue for as long as possible.

For the incremental and the constant load exercises, exhaustion was defined by the time at which the subject was unable to sustain the velocity, i.e., when the runner was more than 5 m behind the cyclist. These three exercises were carried out at the same time of day.

Speed was controlled during the incremental and the constant exercises by the experimenters. On the track, runners followed a pacing cyclist traveling at the required velocity. The cyclist received audio cues via a Walkman (Sony®), the cue rhythm determining the speed needed to cover 25 m. Visual marks were set at 25-m intervals along the track (inside the first lane) (Billat, Slawinski, Bocquet, Demarle, Lafitte, Chassaing, & Koralzstein, 2000). Moreover, experiments independently measured the time required to complete 25 m to check the pacer and runner speed.

During the exercise, heart rate and oxygen uptake were averaged every 15 sec. Fingertip blood samples were taken during the 30-sec. rest for the incremental exercise. The scales were explained before each exercise. These scales were written on a board fixed on the back of the experimenter who rode in front of the subject. The subjects were asked "How hard do you feel this exercise is?" and "How long would you be able to perform an exercise at this intensity to exhaustion?" For the incremental exercise, subjects had to give ratings corresponding to their sensations during the end of each stage. Up to 17 $km \cdot h^{-1}$, they had to point to a value on the perceived exertion scales, and the ratings were collected during the 30-sec. rest. Thereafter, subjects expressed the perceived exertion values with the fist (=10) or fingers (each=1) at the end of each step, i.e., during the last 15 sec. every stage of 2 min., to a second experimenter who rode next to the runner and collected the values. The procedure was the same for the constant load exercises but perceived exertion values were recorded every 2 min. up to the end of exercise. The order of RPE and ETL was the same during the three exercises for each subject but was randomized among the subjects.

Analysis

For each subject, for the exercises at $v\dot{V}O_2$ max and vΔ50, RPE and ETL values were calculated at 50% of the exhaustion time by linear interpolation of the %tlim-RPE relationship, and %tlim values were calculated for each subject for RPE=15 by linear interpolation of the RPE=%tlim relationship.

Results are presented as means and standard deviations. Statistical differences between means were tested with a Student t test for paired data. The relationships between pairs of variables were analyzed by a Pearson product-moment test (Sigma Stat®, Jandel, Germany). A covariance analysis (Hays, 1994) was carried out for the relationships between parameters in order to estimate the effect of running intensity on RPE or ETL for a given %tlim.

Results

Values of $\dot{V}O_2$ max, $v\dot{V}O_2$ max, vΔ50, and vLT were equal to 61.44 ± 6.39 $ml \cdot min.^{-1} \cdot kg^{-1}$, 17.17 ± 1.32, $km \cdot h^{-1}$, 15.77 ± 1.28 $km \cdot h^{-1}$, 14.38 ± 1.28 $km \cdot h^{-1}$, respectively.

vΔ50 corresponded to 90.1 ± 2.5 %$v\dot{V}O_2$ max; tlim$v\dot{V}O_2$ max and tlimvΔ50 were equal to 286 ± 71 sec. and 547 ± 157 sec., respectively. Exhaustion times between $v\dot{V}O_2$ max and vΔ50 were significantly different (t= –7.01, p<.001).

RPE and ETL were significantly correlated with exercise intensity expressed in percentage of $v\dot{V}O_2$ max (%$v\dot{V}O_2$ max) (p<.01; cf. Fig. 1, r=.91 and r=.86, respectively), and with exercise duration expressed in percentage of exhaustion time (%tlim) for $v\dot{V}O_2$ max and vΔ50 (p<.01; cf. Fig. 2a, r=.71 and r=.84, respectively, and cf. Fig. 2b, r=.68 and r=.58, respectively).

RPE at 50 %tlim was equal to 16 ± 1.3 for $v\dot{V}O_2$ max, i.e., an exercise intensity perceived as "almost very hard," and 15.3 ± 1.0 for vΔ50, i.e., an exercise intensity perceived as "hard." ETL at 50 %tlim was equal to 17.3 ± 1.5 and to 16.0 ± 2.1 for $v\dot{V}O_2$ max and vΔ50, respectively, i.e., an estimated exhaustion time approximately equal to 3 min. and 50 sec. for $v\dot{V}O_2$ max and to 6 min. and 10 sec. for vΔ50.

The exercise intensity induced a significant upward shift of the %tlim-

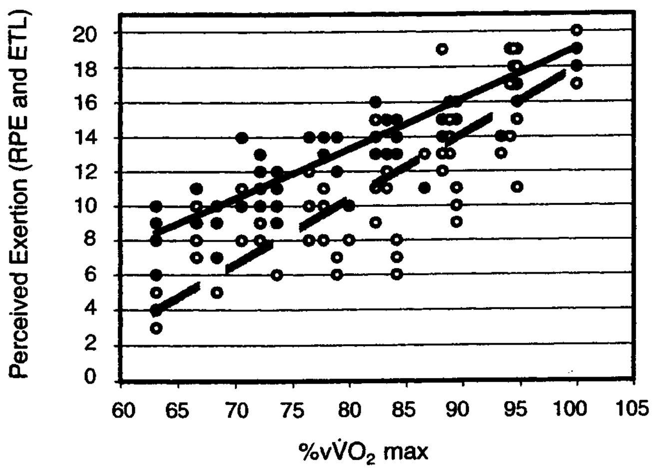

FIG. 1. Relationships between perceived exertion (RPE and ETL) and velocity expressed in percentage of the velocity associated with maximal oxygen uptake (%v$\dot{V}O_2$ max) during the incremental exhausting exercise [(●) and thick regression line, $r = .91$; (o) and dashed regression line, $r = .86$, respectively; $n = 12$]

RPE and %tlim-ETL regressions shown by the covariance analysis ($F_{1,93} = 7.71$, $F_{1,93} = 11.01$, $p < .01$; cf. Fig. 2a and 2b for RPE and ETL, respectively). This means that for a same given relative time (%tlim), athletes perceived exercise as harder and felt that they could endure less for v$\dot{V}O_2$ max than vΔ50.

For RPE = 15, i.e., exercise perceived as "hard," time being elapsed was equal to 36.4 ± 26.8 %tlim for v$\dot{V}O_2$ max (470 ± 340 m covered), and 46.1 ± 15.7 %tlim for vΔ50 (1060 ± 390 m covered).

DISCUSSION

This study clearly shows that RPE or ETL increase linearly with time to exhaustion for the two exercise intensities (90 and 100% v$\dot{V}O_2$ max) (Fig. 2a and 2b) in agreement with the results of Horstman, *et al.* (1979) and Garcin, *et al.* (1998).

Exhaustion time values to v$\dot{V}O_2$ max were similar to those of Billat, Faina, Sardella, Marini, Fanton, Lupo, Faccini, De Angelis, and Koralzstein (1996) (321 ± 84 sec.), Billat, Petit, and Koralzstein (1996) (258 ± 77 sec.), Billat, Binsse, Petit, and Koralzstein (1998) (321 ± 84 sec.), and to Billat, Flechet, Petit, Muriaux, and Koralzstein (1999) (283 ± 42 sec.), for high-level middle- and long-distance runners on treadmill tests.

For the same %tlim, RPE or ETL depended on running intensity (90 and 100% v$\dot{V}O_2$ max). Therefore, these results contradict the results of Garcin, *et al.* (1998) who found similar relationships between exercise dura-

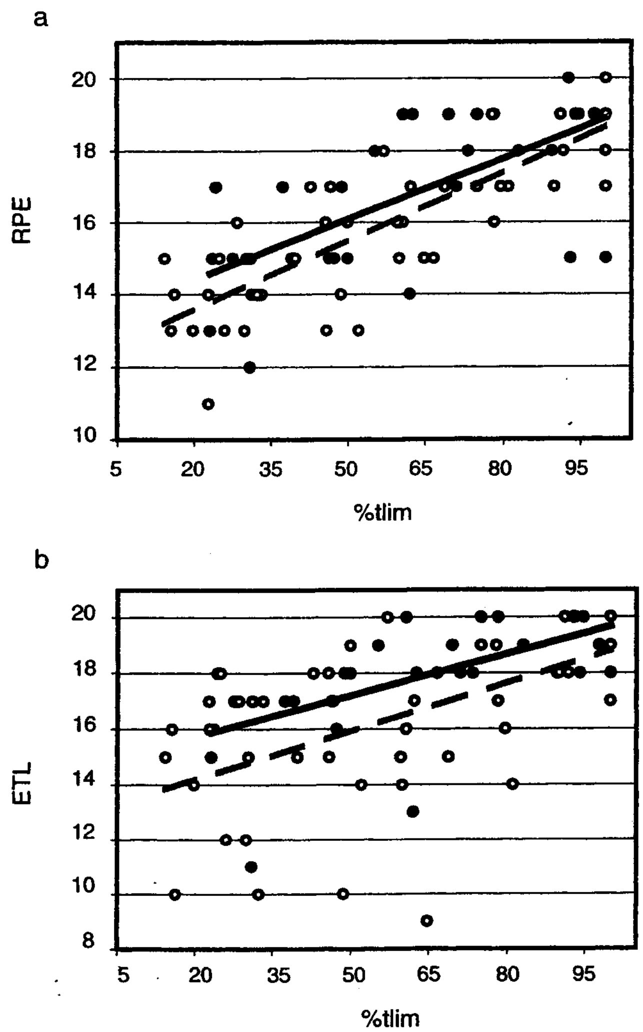

FIG. 2. (a) Relationships between perceived exertion (RPE) and time expressed in percentage of exhaustion time (%tlim) during the constant load exhausting exercise for the velocity associated with maximal oxygen uptake (v$\dot{V}O_2$ max) [(●) and thick regression line, $r = .71$] and the velocity delta 50 (the velocity halfway between v$\dot{V}O_2$ max and the velocity of the lactate concentration threshold –vΔ50) [(○) and thick regression line, $r = .84$; $n = 12$]. (b) Same relationships with the estimated time limit (ETL) for v$\dot{V}O_2$ max [(●) and thick regression line, $r = .68$] and vΔ50 [(○) and thick regression line, $r = .58$; $n = 12$].

tion and RPE for a cycle exercise at 60 and 73% of maximal power output. Contrary to Edwards, Melcher, Hesser, Wigertz, and Ekelund (1972), the time for which the work stimulus is applied is not a more important contributor to perceived exertion than the amount of work done. Therefore, we notice that the relationship between %tlim and RPE seems to be very similar for moderate exercise intensity whereas this relationship is different for intensities higher than the anaerobic threshold. It is likely that RPE was a subjective estimation of the exercise duration rather than exercise intensity when of a moderate nature, whereas RPE is a combined subjective estimation of both duration and exercise intensity for maximal exercise intensities. The same discussion is suitable for ETL results. These differences may also have been due to modality of exercise (running vs cycling) (Ekblom & Goldbarg, 1971; Thomas, Ziogas, Smith, Zhang, & Londeree, 1995). Therefore, this scale could be used to assess duration as well as intensity of exercise for practical application in sport.

Billat, Petit, and Koralzstein (1996; Billat, *et al.*, 1999) demonstrated that tlim at $v\dot{V}O_2$ max was useful to individualize the duration of interval training. In these studies athletes performed five repetitions of periods equal to 50% of tlim$v\dot{V}O_2$ max at velocity $v\dot{V}O_2$ max with the same durations of recovery at 60% of $v\dot{V}O_2$ max. Similarly, endurance-trained males performed an intermittent exercise (exercise periods were runs for 50% tlimvΔ50 at velocity vΔ50 with recovery periods equal to 25% tlimvΔ50 at one-half of velocity vΔ50) (Demarie, Koralzstein, & Billat, 2000). Therefore, it could be interesting to combine exercise duration and RPE to individualize the duration of interval training. Our results showed that, when subjects began to perceive exercise as "hard" (RPE = 15), they had run for only 36.4 ± 26.8 %tlim at $v\dot{V}O_2$ max, whereas they had run for 46.1 ± 15.7 %tlim at vΔ50. This 10% difference of tlim corresponded to distance or duration more than twice as long.

Consequently, it could be suggested that exercise duration can be prescribed in function of perceived exertion for healthy normal people. For example, subjects will perform repetitions of periods equal to 33% of tlim at $v\dot{V}O_2$ max and 50% of tlim at vΔ50. These values may vary depending on each subject's perceived exertion. Investigations regarding perceptions during constant load exercises to exhaustion could check that the optimum improvement in cardiorespiratory fitness occurs when training at these RPE, exercise intensity, and duration values.

Therefore, when the aim is to prescribe a training program, perceived exertion and estimated time limit values give us interesting information regarding healthy athletes' sensations during hard work until exhaustion. In particular, these values could help the coach to know the sensations of each athlete more precisely, if he can "push" the athlete or on the contrary slow up the athlete.

In conclusion, perceived exertion attests to both intensity and exercise duration for all-out runs at 90 and 100% $v\dot{V}O_2$ max and could be an important tool in the prescription of a training program, particularly for the exercise duration of the first repetition during an interval training session for healthy normal people.

REFERENCES

AMERICAN COLLEGE OF SPORTS MEDICINE. (1990) The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness in healthy adults. *Medicine and Science in Sports and Exercise*, 22, 265-274.

AUNOLA, S., & RUSKO, H. (1984) Reproducibility of aerobic and anaerobic thresholds in 20-50 year old men. *European Journal of Applied Physiology*, 53, 260-266.

BILLAT, V., BINSSE, V., PETIT, B., & KORALZSTEIN, J. P. (1998) High level runners are able to maintain a $\dot{V}O_2$ steady-state below $\dot{V}O_2$ max in an all-out run over their critical velocity. *Archives of Physiology and Biochemistry*, 106, 38-45.

BILLAT, V., FAINA, M., SARDELLA, F., MARINI, C., FANTON, F., LUPO, S., FACCINI, P. DE ANGELIS, M., & KORALZSTEIN, J. P. (1996) A comparison of time to exhaustion at $\dot{V}O_2$ max in elite cyclists, kayak paddlers, swimmers and runners. *Ergonomics*, 39, 267-277.

BILLAT, V., FLECHET, B., PETIT, B., MURIAUX, G., & KORALZSTEIN, J. P. (1999) Interval training at $\dot{V}O_2$ max: effects on aerobic performance and overtraining markers. *Medicine and Science in Sports and Exercise*, 31, 156-163.

BILLAT, V., & KORALZSTEIN, J. P. (1996) Significance of the velocity at $\dot{V}O_2$ max and time to exhaustion at this velocity. *Sports Medicine*, 22, 90-108.

BILLAT, V., PETIT, B., & KORALZSTEIN, J. P. (1996) Calibration de la durée des répétitions d'une séance d'interval training à la vitesse associée à $\dot{V}O_2$ max en référence au temps limte continu: effet sur les réponses physiologiques et la distance parcourue. *Science & Motricité*, 28, 13-20.

BILLAT, V., SLAWINSKI, J., BOCQUET, V., DEMARLE, A., LAFITTE, L., CHASSAING, P., & KORALZSTEIN, J. P. (2000) Intermittent runs at the velocity associated with maximal oxygen uptake enables subjects to remain at maximal oxygen uptake for a longer time than intense but submaximal runs. *European Journal of Applied Physiology*, 81, 188-196.

BORG, G. V. (1970) Perceived exertion as an indicator of somatic stress. *Scandinavian Journal of Rehabilitation Medicine*, 2, 92-98.

BORG, G. V., & NOBLE, B. (1974) Perceived exertion. In J. H. Wilmore (Ed.), *Exercise and sport sciences reviews*. New York: Academic Press. Pp. 131-153.

CECI, R., & HASSMEN, P. (1991) Self monitored exercise at three different RPE intensities in treadmill vs field running. *Medicine and Science in Sports and Exercise*, 23, 732-738.

DEMARIE, S., KORALZSTEIN, J. P., & BILLAT, V. (2000) Time limit and time at $\dot{V}O_2$ max, during a continuous and an intermittent run. *Journal of Sports Medicine and Physical Fitness*, 40, 96-102.

DISHMAN, R. K. (1994) Prescribing exercise intensity for healthy adults using perceived exertion. *Medicine and Science in Sports and Exercise*, 26, 1087-1094.

DISHMAN, R. K., FARQUHAR, R. P., & CURETON, K. J. (1994) Responses to preferred intensities of exertion in men differing in activity levels. *Medicine and Science in Sports and Exercise*, 26, 783-790.

DUNBAR, C. C., GORIS, C., MICHIELLI, D. W., & KALINSKI, M. I. (1994) Accuracy and reproducibility of an exercise prescription based on ratings of perceived exertion for treadmill and cycle ergometer exercise. *Perceptual and Motor Skills*, 78, 1335-1344.

DUNBAR, C. C., ROBERTSON, R. J., BAUN, R., BLANDIN, M. F., METZ, K., BURDETT, R., & GOSS, F. L. (1992) The validity of regulating exercise intensity by ratings of perceived exertion. *Medicine and Science in Sports and Exercise*, 24, 94-99.

EDWARDS, R. H., MELCHER, A., HESSER, C. M., WIGERTZ, O., & EKELUND, L. G. (1972) Physiological correlates of perceived exertion in continuous and intermittent exercise with the same average power output. *European Journal of Clinical Investigations*, 2, 108-114.

EISLER, H. (1975) Subjective duration and psychophysics. *Psychological Review*, 82, 429-450.

EISLER, H. (1976) Experiments on subjective duration 1868-1975: a collection of power function exponents. *Psychological Review*, 83, 1154-1171.

Eisler, H., & Eisler, A. D. (1992) Time perception: effects of sex and sound intensity on scales of subjective duration. *Scandinavian Journal of Psychology*, 33, 339-358.

Ekblom, B., & Goldbarg, A. N. (1971) The influence of physical training and other factors on the subjective rating of perceived exertion. *Acta Physiologica Scandinavica*, 83, 399-406.

Eston, R. G., Davies, B. L., & Williams, J. G. (1987) Use of perceived effort ratings to control exercise intensity in young healthy adults. *European Journal of Applied Physiology*, 56, 222-224.

Garcin, M., Vandewalle, H., & Monod, H. (1999) A new rating scale of perceived exertion based on subjective estimation of exhaustion time: a preliminary study. *International Journal of Sports Medicine*, 20, 40-43.

Garcin, M., Vautier, J. F., Vandewalle, H., Wolff, M., & Monod, H. (1998) Ratings of perceived exertion (RPE) during cycling exercises at constant power output. *Ergonomics*, 41, 1500-1509.

Hausswirth, C. A., Bigard, A. X., & Lechevalier, J. M. (1997) The Cosmed K4 Telemetry System as an accurate device for oxygen uptake measurements during exercise. *International Journal of Sports Medicine*, 18, 445-453.

Hays, W. L. (1994) *Statistics*. New York: Harcourt Brace College.

Horstman, D. H., Morgan, W. P., Cymerman, A., & Stokes, J. (1979) Perception of effort during constant work to self imposed exhaustion. *Perceptual and Motor Skills*, 48, 1111-1126.

Kirkcaldy, B. D. (1984) Individual differences in time estimation. *International Journal of Sport Psychology*, 15, 11-24.

Latzka, W. A., Muza, S. R., Levine, L., & Pandolf, K. B. (1989) Comparison of rated perceived exertion and constant effort during cycling exercise. In G. Ljunggren & S. Dornic (Eds.), *Psychophysics in action*. Berlin: Springer Verlag. Pp. 115-124.

Noble, B. J., Metz, K. F., Pandolf, K. B., & Cafarelli, E. (1973) Perceptual responses to exercise: a multiple regression study. *Medicine and Science in Sports*, 5, 104-109.

Pandolf, K. B., Billing, D. S., Drolet, L. L., Pimenthal, N. A., & Sawka, M. N. (1984) Differentiated ratings of PE and various physiological responses during prolonged upper and lower body exercise. *European Journal of Applied Physiology*, 53, 5-11.

Shephard, R. J., Vandewalle, H., Gil, V., Bouhlel, E., & Monod, H. (1992) Respiratory, muscular and overall perceptions of effort: the influence of hypoxia and muscle mass. *Medicine and Science in Sports and Exercise*, 24, 556-567.

Skinner, J. S., Hustler, R., Bergsteinova, V., & Buskirk, E. R. (1973) The validity and reliability of a rating scale of perceived exertion. *Medicine and Science in Sports*, 5, 94-96.

Smutok, M. A., Skrinar, G. S., & Pandolf, K. B. (1980) Exercise intensity: subjective regulation by perceived exertion. *Archives of Physical Medicine and Rehabilitation*, 61, 569-574.

Taylor, H. L., Buskirk, E., & Henschel, A. (1955) Maximal oxygen uptake as an objective measure of cardiorespiratory performance. *Journal of Applied Physiology*, 8, 73-80.

Thomas, T. R., Ziogas, G., Smith, T., Zhang, Q., & Londeree, B. R. (1995) Physiological and perceived exertion responses to six modes of submaximal exercise. *Research Quarterly for Exercise and Sport*, 66, 239-246.

Vautier, J. F. (1994) Puissance critique, indice d'endurance du travail dynamique. Paris, Thèse de Biomécanique et Physiologie du Mouvement de l'Université Paris XI Orsay.

Vercruyssen, M., Hancock, P. A., & Mihaly, T. (1989) Time estimation performance before, during, and following physical activity. *Journal of Human Ergonomy*, 18, 169-179.

Wenos, D. L., Wallace, J. P., Surburg, P. R., & Morris, H. H. (1996) Reliability and comparison of RPE during variable and constant exercise protocols performed by older women. *International Journal of Sports Medicine*, 17, 193-198.

Accepted October 17, 2001.