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Effect of long duration exercise on the ratings of perceived exertion and perceived difficulty of walking and running at the ventilatory threshold

F. GREGO [1], M. COLLARDEAU [1], J. M. VALLIER [1], D. DELIGNIERES [2], J. BRISSWALTER [1]

Aim. **The purpose of this study was to examine if the relationship between physiological changes classically observed with exercise duration and some subjective workload measures would be affected by the complexity of the locomotion mode (running *vs* racewalking).**
Methods. **The study was conducted on 24 well trained subjects (12 long distance runners and 12 racewalkers) divided in 3 groups (runners, racewalkers and control). Energy cost of locomotion (C), heart rate (HR), minute ventilation ($\dot{V}_E$), lactate concentration [La], ratings of perceived exertion (RPE 6-20 scale) and ratings of perceived difficulty (RPD 1-15 scale) were recorded during 2 10-min submaximal tests on a treadmill before and immediately after a 3 hour exercise (racewalking or running) conducted at the velocity ventilatory threshold (vVT).**
Results. **No significant variations in physiological parameters and perceived measures were observed in G_c. A significant increase ($p<0.05$) in energy cost of walking (mean: +9.4%) and running (mean: +7.5%) at the end of exercise was observed. A significant interaction of locomotion mode and exercise duration was found on perceived exertion and perceived difficulty. In racewalkers RPD significantly increased with duration whereas no significant effect was found for RPE. Conversely a significant increase in RPE was found after 3 hours in runners without any significant change in RPD.**
Conclusion. **This experiment suggests that, for a complex task, the classical relationship between RPE and metabolic load increase during prolonged exercise could be affected by changes in RPD. In this study, stability in RPE and increase in RPD observed in racewalkers may reflect an attentional focus dissociated from internal sensations and directed toward maintaining the required race walking gait.**

KEY WORDS: Exercise, physiology - Muscle, skeletal, physiology - Running - Walking.

[1]Laboratory of Sport Ergonomics and Performance University of Toulon-Var, La Garde, France
[2]Faculty of Sport and Physical Education University of Montpellier, Montpellier, France

Address reprint requests to: Prof. J. Brisswalter, Laboratoire Ergonomie Sportive et Performance, Université de Toulon-Var, Avenue de l'Université, BP 132, 83957 La Garde Cedex, France.
E-mail: brisswalter@univ-tln.fr

During long distance events, successful performance is dependent on various physiological and psychological factors. Among psychological factors, perceived workload represents an important determinant of performance.[1] A positive or a negative perception of workload could lead to either the continuation or the cessation of the competitive task. Several indicators of perceived workload have been used during the last decades. The most commonly used is perceived exertion that refers to a subjective estimate of physical work intensity.[2] Even if psychological factors can have some importance,[3] perceived exertion appears mainly related to the physiological cues [4] and environmental information associated with exercise.[5] Furthermore ratings of perceived exertion (RPE) have been classically suggested to be a useful additional measure to standard physiological responses associated with exercise constraints especially during long duration exercise leading to the appearance of fatigue

phenomenon.[6-8] Another indicator of perceived workload is perceived difficulty, that is defined in motor tasks as the assessment of the difficulty in performing the movement with accuracy, speed, or stability, according to the nature of the task.[9-12] Generally, perceived difficulty and perceived exertion have been studied separately. Experiments on perceived exertion have used tasks such as running or cycling, without any problem of motor coordination,[13] and conversely research on perceived difficulty has mainly focused on psychomotor tasks, without any significant energy expenditure.[9, 11, 12] Nevertheless Delignières *et al.*[10] have shown that subjects were able to clearly distinguish these 2 dimensions, and to assess them separately.

On the one hand, previous studies have indicated a significant effect of exercise duration on RPE scores in different stress situations.[14-16] Generally the origins of perceived exertion have been researched at the physiological level differentiating central and local factors.[4,17] The effects of exercise duration on physiological parameters are relatively well known. Studies conducted to identify the factors that influence performance during long duration exercise have observed an increase in the physiological constraints of the locomotion task such as: an increase in energy cost of locomotion and in ventilation,[18, 19] an increase in thermal stress,[20] and an impairment in mechanical efficiency or neuromuscular function.[21] On the other hand, to the best of our knowledge, no studies have analyzed the effect of fatigue induced by exercise on the subjective measure of difficulty. Furthermore all the studies analyzing RPE scores variability with exercise duration have used a freely chosen locomotion mode (running or walking) and no similar research has been conducted on a more complex locomotion mode. Within this framework, racewalking is a strictly controlled locomotion mode at once exhausting and difficult. Concerning difficulty, it must be noted that racewalking technique is determined by competition rules. Firstly, the "lifting" rule requires that the leading foot should make contact with the ground before the rear foot leaves it. The second rule called "creeping" requires an extension of the knee at the moment of vertical position during the support phase. Walkers must adhere to these rules or face disqualification. So the maintenance of walking coordination is a central problem in racewalking.[22, 23] Therefore the purpose of this study was to examine if the relationship between physiological changes classically observed with exercise duration and subjective measures would be affected by the locomotion mode complexity (*i.e.* running *vs* racewalking).

TABLE I.—*Subject characteristics.*

Parameters	Race walkers (n=12)	Runners (n=12)
Age (y)	24±4.2	22±2.6
Height (cm)	177±3.1	175.6±5.8
Mass (kg)	69.6±2.8	64.1±3.1
Body fat (%)	9.6±2.1	7.5±0.3

Values are expressed as means ± standard derivation.

Materials and methods

Subjects

The subjects were 12 racewalkers and 12 long distance runners regularly competing at a national level. All subjects were experienced treadmill runners or walkers. Subjects were divided into 3 groups: 8 racewalkers (G_w), 8 runners (G_r) and a control group (G_c, 4 runners and 4 walkers). Physical characteristics of the subjects are given in Table I. Before participating in this study, subjects were fully informed about protocol and written consent was obtained prior to all testing according to local ethical committee guidelines.

Experimental design

Each subject completed 2 testing sessions in the same week without any other training program (Figure 1). The 1st session was always a maximal protocol of determination of maximal oxygen uptake (VO_2 max) and ventilatory threshold (VT). For G_w and G_r the 2nd session was composed of 2 submaximal treadmill tests, before and after a 3 hour overground walk (G_w) or run (G_r). In order to test the reliability of equipment, and a possible effect of practice on dependant variables, subjects from G_c had to perform 2 submaximal tests before and after a 3 hour period without any exercise. All these submaximal tests used the accustomed locomotion mode of subjects and were conducted at the velocity eliciting the ventilatory threshold (vVT). The 2nd session was conducted 3 days after the maximal test.

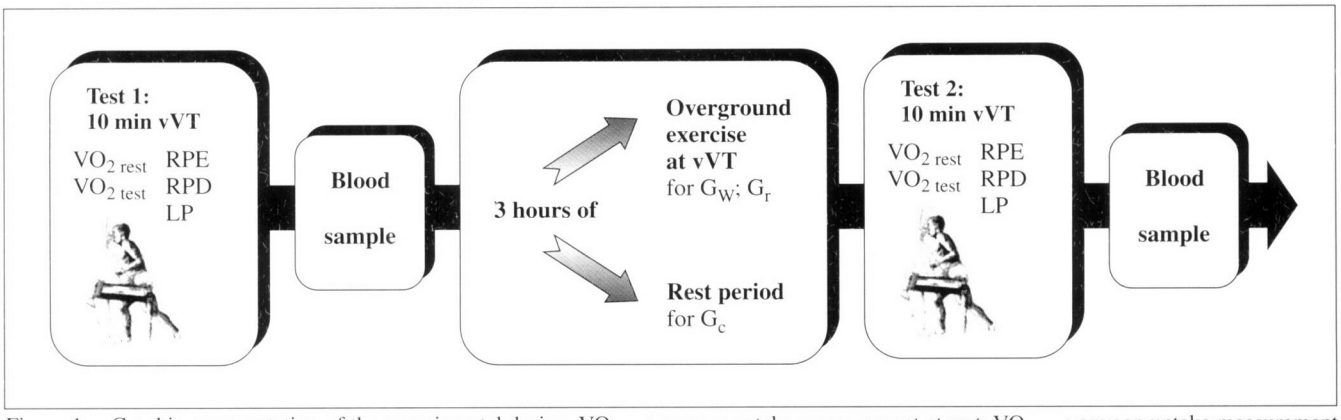

Figure 1.—Graphic representation of the experimental design. VO_{2rest}: oxygen uptake measurement at rest; VO_{2Test}: oxygen uptake measurement during test sessions; RPE: rating of perceived exertion; RPD: rating of perceived difficulty; LP: locomotor pattern analysis.

Data collection

Maximal oxygen uptake was determined in a 1st session during an incremental protocol on a treadmill. After a treadmill accommodation at 9 km.h^{-1} (walkers) or 11 km.h^{-1} (runners) and 3% grade, the velocity of locomotion was increased by 1 km.h^{-1} every 1 min until the subject reached volitional exhaustion. The criteria used for determination of VO_2 max were a plateau in VO_2, a maximum heart rate, and/or a respiratory exchange ratio above 1.1. During this test, VT was determined using the criteria of an increase in VE/VO_2 with no concomitant increase of VE/VCO_2.[24] During the 2nd session, an overground exercise (walk or run) was performed on a 400 m track very close to the laboratory (20 m). For each subject, and every 400 m the speed corresponding to vVT was controlled and regulated to be stable over 3 hours. Heart rate was recorded continuously (Vantage, Polar Electro Oy, Finland). Before and after this overground test each subject completed a submaximal test. Before the 1st submaximal test (Test 1), the subjects performed a 10-min treadmill accommodation bout at 10 km.h^{-1} (walkers) or 12 km.h^{-1} (runners). After a 4-min rest, the 1st submaximal test, 10-min in length and 0% in treadmill grade was carried out at vVT. The same test (Test 2) was performed immediately after the 3 hours. Exhaled gases were collected during the last 3-min and a blood sample was withdrawn from the earlobe at the end of each test to determine lactate concentration [La]. During the 2 tests, a pressure sensor was used to determine the occurrence of ground for each foot and therefore to analyze a possible change in the locomotor pattern (stride length and stride frequency). Furthermore the respect of racewalking stride rules was controlled using a video motion analysis system with a camera operating at a nominal rate of 50 frames.s^{-1}.

Physiological demand was assessed by calculating the energy cost of locomotion.[25] In order to calculate this parameter, expired gases were collected using a breath by breath system (CPX, Medical Graphics, St Paul, MN, USA). Analyzers were calibrated before and after each subject's session by using a 3-l syringe emptied to produce a flow rate similar to that found in exercise and with gases of known concentration (4.92% CO_2, 15.93% O_2). Energy cost (C), was calculated from the average of all the values recorded, according to the equation:[25]

$$C = [(VO_2 - VO_2\,rest)\,.\,v^{-1})]\,.60$$

C is expressed in ml.kg^{-1}.km^{-1}, VO_2 in ml.kg^{-1}.min^{-1} and v in km.h^{-1}.

Oxygen uptake at rest (VO_2 rest) was recorded during 4 minute before the 1st test, and only the last 2-minute values were used for analysis. Secondly, a capillary (fingertips) blood sample was collected from the subject in a 75 µl heparinised capillary tube for the determination of blood lactate concentration [La] using an electroenzymatic analyser (Accusport Boehringer Mannheim, Mannheim, Germany).

During this session, ratings of perceived exertion and perceived difficulty were collected in the last 2 minutes of each submaximal test. Ratings of perceived exertion were obtained by using the RPE scale.[9] This scale ranges in an ascending order from 6 ("very light")

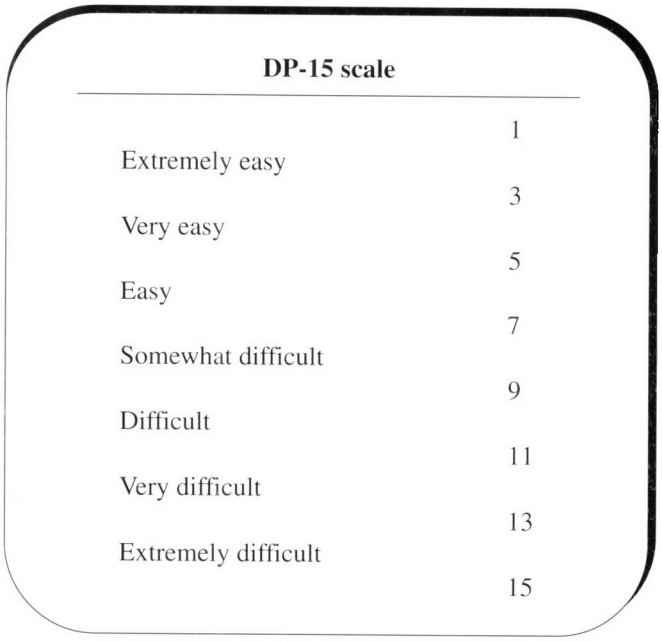

Figure 2.—The DP-15 scale.

to 20 ("very, very hard"). This RPE scale was preferred to more recent scales because of the good linearity between RPE and metabolic load reported for this scale.[26]

Perceived difficulty (RPD) was a 15-point category scale, with 7 labels, from "extremely easy" to "extremely difficult", symmetrically placed around a central label "somewhat difficult" (Figure 2). This scale was constructed on the principles of Borg's RPE scale.[27, 28] Previous validity and reliability tests have shown that in diverse perceptual motor tasks, the DP-15 scale was linearly related to objective difficulty, measured by the average amount of information to be processed, or by the average scores of performance.[10, 29] In this study, perceived difficulty was clearly defined to the subjects, as the subjective difficulty in maintaining the racewalking or running pattern with the same efficacy. Perceived exertion and perceived difficulty were estimated in a random order during the test.

Statistical analysis

All data are expressed as mean±SD. Analysis of variance (period x group) was performed using energy cost, heart rate, ventilation, lactate concentration, perceived exertion and perceived difficulty as the dependent variables. Newman-Keuls post-hoc tests were used to compare specific means. For all the statistical analyses, the level of significance was $p<0.05$.

Results

During the 1st session, the mean VO_2 of racewalkers and runners (64.5±2.6 and 68.2±3.8 $ml.kg^{-1}.min^{-1}$) were respectively attained at a locomotion speed of 15.4±1.2 $km.h^{-1}$ and 22±0.5 $km.h^{-1}$. Data for energy cost (C), minute ventilation (V_E), heart rate, (HR) perceived exertion (RPE), perceived difficulty (RPD), and lactate concentration [La] recorded during the 2nd session are shown in Table II. After the 3 hours exercise a significant increase in energy cost, ventilation and heart rate were found in both groups whereas no variations were observed for lactate concentration ($p>0.05$). No difference in heart rate recorded during the overground test was found between G_T and G_W. No significant variation in physiological parameters between Test 1 and Test 2 was observed in G_C. A significant interaction effect (duration *vs* locomotion mode) was found for perceived exertion and perceived difficulty. In G_W a significant increase in scores of perceived difficulty was observed with exercise duration ($p < 0.05$) leading the subjective evaluation of the task difficulty from "very easy" to "difficult". Conversely, no significant effect of exercise duration was found for perceived exertion. The mean score was 12.9±1.7 and corresponds to ratings of "moderately hard" on Borg's scale. On the contrary in G_T no changes in perceived difficulty were observed (around very easy) whereas a significant increase in perceived exertion was recorded after the 3 hours run (from "moderately hard" to "hard"). No significant differences in perceived measures were observed between Test 1 and Test 2 for G_C indicating that the changes in RPE and RPD could mainly be attributed to the 3 hours test.

Discussion and conclusions

The purpose of this study was to examine the relationships between perceived exertion, perceived difficulty and physiological changes with exercise duration between 2 different locomotion tasks. The main result of our study is the significant effect of locomotion mode on the perception of exercise workload. In race walkers, a significant increase in perceived

TABLE II.—*Physiological parameters, ratings of perceived exertion (RPE), ratings of perceived difficulty (RPD) recorded at the beginning (Test 1) and at the end (Test 2) of the 3 hours exercise in the runners group (G_r, n=8), racewalkers group (G_w n=8) and control group (G_c n=8).*

Parameters	Group	Test 1	Test 2
C ($ml O_2.kg^{-1}.km^{-1}$)	G_w	238.8±18.2	262.5±24.2*
	G_r	182.6±3.5#	196.8±5.7*#
	G_c	199.8±11.7	201.3±10.8
HR ($bt.min^{-1}$)	G_w	142.6±6.7	159.6±9.6*
	G_r	142.8±7.3	161.2±4.5*
	G_c	142.1±5.6	141.9±4.9
[La] ($mmol.l^{-1}$)	G_w	1.4±0.2	1.2±0.4
	G_r	2.1±1.1	1.8±0.8
	G_c	1.8±0.5	1.6±0.7
V_E ($l.min^{-1}$)	G_w	107.6±9.2	118±9.8*
	G_r	91.03±9.1#	117.4±7.1*
	G_c	97.6±10.1	95.4±8.8
RPE	G_w	12.7±0.8	12.9±1.7
	G_r	12.4±1.6	14.9±2.1*
	G_c	12.5±0.4	12.4±0.8
RPD	G_w	4.4±0.9	10.1±1.8*
	G_r	3.8±1.1	4.3±0.7
	G_c	4.2±0.6	3.9±0.4

Values are expressed as mean ± standard deviation. *When a significant difference was found between the 2 periods. # When a significant difference was found between runners and race walkers. $p<0.05$ for all comparisons.

difficulty was observed, but no increase in perceived exertion was found. On the contrary, in runners, an increase in perceived exertion was observed without any changes in perceived difficulty. Concerning RPE variability, the results found in runners are in agreement with previous studies indicating that perceived exertion increased linearly with the increase in metabolic load.[6, 14-16, 30] Within this framework, one unexpected result of this study was the stability in RPE in race walkers despite an increase in physiological constraints with exercise duration. Several non exclusive factors could be evoked to interpret these results.

Recent locomotion approaches have indicated that, in free walking or running, movement is a dynamic form that emerges from functional task constraints.[31] In this approach, running adaptation has been likened to a bouncing ball in which potential energy is stored in soft tissues and released as potential and kinetic energy. Thus when the subject can freely choose his running pattern, (*i.e.*, stride rate) this pattern emerges from physical principles and does not require attention.[31] In our study, we could therefore make the hypothesis that, during treadmill running, no attention is allocated to the efficacy of the running pattern and the subject focuses all his attention on body sensations. On the contrary in racewalking, technique is strictly determined by competition rules. Walkers must adhere to this definition or face disqualification. Our subjects were well trained racewalkers and therefore particularly used to complying with these rules. In our study, no failure to maintain contact was observed. This result was expected because the mean walking speed in this study (11.5±0.4 $km.h^{-1}$) was a habitual one for these walkers.[32] Furthermore, previous studies have shown that "lifting" was only observed in elite racewalkers from 13.5 $km.h^{-1}$.[23] In this study the method used for our kinematic analysis does not permit us to detect a significant alteration in locomotor pattern. This result is in agreement with a previous study conducted with elite racewalkers,[19] indicating that racewalkers are able to comply with the task constraints despite the effects of exercise duration. Within this framework, the increase in perceived difficulty could be related to the amount of mental effort invested to comply with walking task constraints.

Several investigations suggest that perceived difficulty is related neither to the objective difficulty of the task, nor to effective performance but to the amount of resources invested.[10, 12, 28] In our study, the increase in physiological constraints was linked with an increase in perceived difficulty whereas the objective difficulty of the walking task remained constant. The very low scores of perceived difficulty in Test 1 (around "very easy") clearly confirmed the overlearned nature of the

racewalking gait in our subjects. With exercise duration, perceived difficulty increased, showing that with fatigue the walking pattern required more mental effort for its maintenance. The mean rating was "difficult", indicating that fatigue induces a significant increase in the mental load to maintain race walking coordination. This result could be compared with those obtained by Dornic *et al.*,[11] showing that in noisy conditions subjects are able to maintain an equal level of performance in mental tasks as compared with quiet conditions. However, perceived difficulty was significantly higher in the former condition and particularly when noise was significant (*i.e.*, a conversation). According to the authors, this increase in perceived difficulty was related to the necessary increase in mental effort to sustain a given level of performance.

A surprising result of this study is the stability in perceived exertion observed during race walking with exercise duration despite an increase in physiological cues. Our results suggest that, in such complex locomotion mode, the increasing tendency in perceived exertion, due to the increase of physiological stress, is compensated by an inverse decreasing trend. Several works have shown the importance of psychological variables in the perception of exertion.[26] Among them, subjects could focus their attention on body sensations (association effect) or on the contrary could divert their attention away from body sensations during exercise (dissociation effect [3]). Some authors have evidenced the so-called "dissociation effect", when subjects while performing a bout of exercice are requested to hear music, or to realize mental calculations: in this case, perceived exertion appears to be systematically lower than in control condition.[3, 5, 33, 34] The explanation generally invoked is that subjects have to invest attention or mental effort in the secondary task, resulting in a distraction from their own fatigue. Therefore, in our study the stable RPE and increased RPD may reflect an attentionnal focus dissociated from internal sensations and directed toward maintaining the required race walking gait technique. Furthermore in this study, if the changes in C, HR or V_E are statistically significant after 3 hours, these alterations do not seem remarkable (respectively the rise in C for runners and race walkers represents: +7.5% and +9.4%). Therefore, the lack of change in RPE may also be due to the imprecision of the psychological scale to detect such physiological changes when a concomitant increase in perceived difficulty occurs.

From a practical standpoint, if we consider, as proposed by many authors [3] that perceived constraints represent an important determinant of performance, this experiment suggests, surprisingly, that in long-term racewalking perceived difficulty constitutes a more salient limitation than perceived exertion. This could allow a reconsideration of training and mental preparation strategies. On the other hand, according to the hypothesis proposed by Rejeski[3] when distinguishing between perception and focal awareness, the "dissociation" effect could lead to a stability in RPE despite an increase in physiological cues. Within this framework, it could be interesting during long duration running and race walking to manipulate the participant's cognitive strategies (associative *vs* dissociative) to examine whether the self-reported effort and difficulty varied as a function of known psychological strategies.

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