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ORIGINAL INVESTIGATION

Determination of Submaximal and Maximal Training Zones From a 3-Stage, Variable-Duration, Perceptually Regulated Track Test

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Purpose: To validate a new perceptually regulated, self-paced maximal oxygen consumption field test (the Running Advisor Billat Training [RABIT] test) that can be used by recreational runners to define personalized training zones. ***Design:*** In a cross-sectional study, male and female recreational runners (N = 12; mean [SD] age = 43 [8] y) completed 3 maximal exercise tests (2 RABIT tests and a University of Montreal Track Test), with a 48-hour interval between tests. ***Methods:*** The University of Montreal Track Test was a continuous, incremental track test with a 0.5-km·h^{-1} increment every minute until exhaustion. The RABIT tests were conducted at intensities of 11, 14, and 17 on the rating of perceived exertion (RPE) scale for 10, 5, and 3 minutes, respectively, with a 1-minute rest between efforts. ***Results:*** The 2 RABIT tests and the University of Montreal Track Test gave similar mean (SD) maximal oxygen consumption values (53.9 [6.4], 56.4 [9.1], and 55.4 [7.6] mL·kg^{-1}·min^{-1}, respectively, $P = .722$). The cardiorespiratory and speed responses were reliable as a function of the running intensity (RPE: 11, 14, and 17) and the relative time point for each RPE stage. Indeed, the oxygen consumption, heart rate, ventilation, and speed values did not differ significantly when the running time was expressed as a relative duration of 30%, 60%, or 90% (ie, at 3, 6, and 9 min of a 10-min effort at RPE 11; $P = .997$). ***Conclusions:*** The results demonstrate that the RABIT test is a valid method for defining submaximal and maximal training zones in recreational runners.

Keywords: oxygen uptake, rating of perceived exertion, maximal aerobic capacity, field exercise, perceptual regulation

Every year, the New York, London, Berlin, and Paris marathons each attract around 30,000 to 50,000 adult runners of all levels. Most of these runners are recreational athletes. Many of them train alone and hope to progress by monitoring their heart rate (HR) and/or running speed rather than their perceived exertion. Recreational runners often define their training zones with reference to the estimated running speed associated with their maximal level of oxygen consumption (v$\dot{V}O_2$max) or their maximal heart rate (HR_{max}).[1,2] Some runners train with a coach who can measure the HR_{max} and v$\dot{V}O_2$max in an incremental protocol like the University of Montreal Track Test (UMTT)[3]—the current reference for calibrating high-intensity interval training or tempo training.[4] However, this form of training (based on 2 physiological parameters) does not consider psychological parameters that can be of value in defining training loads for marathon runners.[5] With regard to exercise testing and prescription, the psychological component of how "hard" or "easy" people perceive a physical effort to be was first emphasized by Borg[6] in the 1960s. Since then, a large body of literature data has demonstrated the reliability of perceptually regulated maximal oxygen consumption ($\dot{V}O_2$max) tests.[7] Furthermore, applications of Borg's rating of perceived exertion (RPE) scale have been included in mainstream guidelines for exercise testing and prescription.[8] Furthermore, Ceci and Hassmén[9] showed that runners were able to self-adjust their running intensity at 3 different RPE values, with an RPE of 11 ("light" on a 6–20 Borg scale) for 3 minutes, 13 ("somewhat hard") for 11 minutes, and 15 ("hard") for 5 minutes. However, effort duration has an effect on physiological responses and the RPE during self-paced interval training.[4] Finally, many runners (especially recreational runners and beginners) do not use the RPE scale to monitor their training zones. Thus, the development and evaluation of an easy-to-use, self-paced $\dot{V}O_2$max (SPV) field test would show that verbal communication is a novel means of defining training zones and thus producing a more precise, accurate training plan.[10] Hence, we decided to test the effect of exercise duration on the cardiorespiratory and speed responses in SPV protocols.

The primary objective of this study was to validate a new field-based SPV test (the Running Advisor Billat Training [RABIT] test) that recreational runners can easily use to reach their $\dot{V}O_2$max and thus define their training zones. The RABIT test was adapted from Ceci and Hassmén's[9] protocol, which requires the participant to perform 3 bouts of exercise only. To this end, we measured the reliability of cardiorespiratory and speed responses as a function of the running intensity (RPE: 11, 14, and 17) and duration (at 30%, 60%, and 90% of each stage).

Methods

Subjects

Twelve healthy adult recreational runners (8 men and 4 women; mean [SD]: age = 43 [8] y; weight = 69 [12] kg; height = 1.74 [0.9] m) familiar with $\dot{V}O_2$max testing volunteered to participate in the study. Participants performed each exercise test in random order, with a 48-hour interval between tests. The study's objectives and procedures were approved by an independent ethics committee (CPP Sud-Est V, Grenoble, France; reference: 2018-A01496-49). All participants were provided with the study information and gave their written consent to participation.

All participants completed a UMTT and 2 self-paced $\dot{V}O_2$max tests (RABIT1 and RABIT2) in a randomized, counterbalanced order 2 to 7 days apart. During the 48-hour recovery period

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between tests, participants were told to refrain from any training activities. Respiratory gases (oxygen uptake [$\dot{V}O_2$], ventilation [$\dot{V}E$], and the respiratory exchange ratio [RER]) were continuously measured using a portable breath-by-breath sampling system (K5; COSMED, Rome, Italy). A global positioning system watch (Garmin, Olathe, KS) was used to measure the HR and the pacing response (using 5-s data averages) throughout each exercise test. Participants were perceptually anchored to the Borg 6 to 20 RPE scale, that is, they were told that the numerical values equated to the feelings associated with the scale's corresponding written definitions (eg, RPE 20 equates to "maximal exertion"). During the UMTT, $\dot{V}O_2$max was confirmed by a visible plateau in $\dot{V}O_2$ ($\leq$2 mL·kg^{-1}·min^{-1}) with a standard increment in exercise intensity, and/or any indicative secondary criteria (visible signs of exhaustion; HR_{max} ±10 beats·min^{-1}; RER ≥ 1.15) around the point of volitional exhaustion.[8] The $\dot{V}O_2$max value determined in the UMTT (a graded exercise test) was checked using a verification stage.[11] Given the RABIT's design, the highest $\dot{V}O_2$max measurement was taken as the $\dot{V}O_2$max—independently of changes in running speed.[10]

The University of Montreal Track Test

The UMTT was conducted on a 400-m track with cones placed every 20 m. A prerecorded soundtrack indicated (using sound beeps) the moment when the subject had to pass near a cone to maintain the imposed speed. A longer sound marked a speed increment. The first step was set to 8.5 km·h^{-1}, with a subsequent increment of 0.5 km·h^{-1} every minute. When the subject was unable to maintain the imposed running pace and thus failed to reach the cone in time for the beep on 2 consecutive occasions, the test was over. The speed corresponding to the last completed step was recorded as the v$\dot{V}O_2$max (in kilometers per hour). The test's mean (SD) total duration in this study was 920 (220) seconds.

The RABIT Test

This 21-minute SPV test comprised 3 incremental exercise stages, adjusted to a prescribed RPE equating to "light" (RPE 11) for 10 minutes, "somewhat hard" (RPE 14) for 5 minutes, and "very hard" (RPE 17) for 3 minutes. Each step was followed by a 1-minute rest period. Participants were instructed to modify their running speed on a moment-to-moment basis in line with the prescribed RPE (rather than the endpoint of the task), so that their RPE (not their speed) remained constant for each stage. The test was conducted outdoors, on a hard dirt path. The RPE scale could be viewed by the participant at regular intervals (ie, every 100 m) because he/she was followed by the investigator on a bike. A verification test was performed to volitional exhaustion at a running intensity perceived to be higher than the peak speed attained during the last stage of the RABIT.[12] The verification criteria were a peak $\dot{V}O_2$ <2% higher in the verification phase than the incremental phase value and the peak HR.[13,14]

Statistical Analysis

All statistical analyses were performed using XLSTAT software (version 2019.1.1; Addinsoft, Paris, France). All the test variables ($\dot{V}O_2$, RER, HR, speed, and pace) were quoted as the mean (SD). Breath-by-breath data ($\dot{V}O_2$, $\dot{V}E$, and RER) and HR data from the 3 tests were averaged into 15-second bins prior to analysis. For each variable, the normality and homogeneity of the data distribution were examined in a Shapiro–Wilk test. A1-way analysis of variance (ANOVA) was applied to assess the validity and reproducibility of the maximal physiological responses ($\dot{V}O_2$, HR, RER, and $\dot{V}E$) and speed responses (peak, mean, and end speeds) within each RPE stage for the 2 RABIT tests and verifications phases. When significant differences were detected, a Holm–Sidak test was used to identify the source (ie, RABIT1 or RABIT2). A Bland and Altman's 95% limits of agreement analysis[15] was used to quantify the agreement (bias ± random error [1.96 × SD]) between the $\dot{V}O_2$max values measured in each test. Once the reproducibility of the data from the 2 RABIT tests had been confirmed, we compared the RABIT data with the UMTT in an ANOVA ($\dot{V}O_2$, HR, RER, and $\dot{V}E$) and in an ANOVA—a rank test (peak and mean speeds). Pearson coefficient (r) was used to qualify the correlation between the UMTT and the RABIT test as low (r = .30–.50), moderate (r = .50–.70), or high and very high (r = .70–1.00).

Then, we processed the data for testing the effect of the relative exercise duration on the cardiorespiratory and speed responses at each RPE stage. We normalized the duration of the stage on a relative scale (T1, T2, and T3) for comparing the time effect according to the RPE. A multivariate ANOVA was then used to gauge the reliability of the cardiorespiratory and speed responses as a function of the intensity (ie, RPE 11, RPE 14, RPE 17) and the relative duration (ie, 30%, 60%, and 90% of each stage duration). Based on the effect size (d_z = 0.88) and the mean (SD) $\dot{V}O_2$max,[16] we calculated that minimum sample size of N = 12 would be required to achieve a statistical power of 80% and alpha risk of .05.

Results

Concurrent Validity of the Maximal Values: UMTT Versus RABIT1 and RABIT2

The $\dot{V}O_2$max, maximal HR, and maximal RER measured during the 3-minute "hard" part of the 2 RABIT tests did not differ significantly from the corresponding values measured during the UMTT (Table 1). For the $\dot{V}O_2$max derived from the UMTT, RABIT1, and RABIT2 tests, the corresponding intraclass correlation coefficient and 95% limits of agreement were .87 and 1.5 (9.23) mL·kg^{-1}·min^{-1} (UMTT vs RABIT1) and .74 and 1.07 (14.89) mL·kg^{-1}·min^{-1} (UMTT vs RABIT2).

The Pearson correlation coefficients for the UMTT versus the RABIT tests for $\dot{V}O_2$max, $\dot{V}E$, HR_{max} and maximal running speed were, respectively, r = .79 (P = .002)/r = .60 (P = .039), r = .96 (P < .001)/r = .63 (P = .028), r = .88 (P < .001)/r = .87 (P < .001), and r = .83 (P < .001)/r = .90 (P < .001) (Figure 1).

In contrast, the $\dot{V}O_2$ in the verification phase for the 2 RABITs was significant lower than the $\dot{V}O_2$max for the 2 RABITs (51.5 [8.3] mL·kg^{-1}·min^{-1} vs 55.1 [7.8] mL·kg^{-1}·min^{-1}, respectively; P < .001). The speed in the verification phase was significantly greater (~115%) than the peak speed during the RPE 17 stage (19.5 [2.6] vs 16.7 [1.8], respectively; P < .001). The HR_{max} in the verification phase did not differ significantly from the corresponding values measured at RPE 17 in the 2 RABITs (173.5 [10.3] vs 174.2 [9.9], respectively; P = .821).

The RABIT Test: Reproducible for Cardiorespiratory and Pacing Responses According to the Intensity of Exertion

To assess the pacing response during the RABIT tests, an analysis of the breath-by-breath data ($\dot{V}O_2$, $\dot{V}E$, and RER), HR, and running

Table 1 Physiological, Perceptual, and Physical Responses Recorded After Completion of the UMTT and RABIT Tests

	UMTT	RABIT1	RABIT2	P
$\dot{V}O_2$max, mL·kg^{-1}·min^{-1}	55.4 (7.6)	53.9 (6.4)	56.4 (9.1)	.722
$\dot{V}E_{max}$, L·min^{-1}	126.3 (27.5)	124.1 (40.5)	117.4 (27.9)	.798
HR_{max}, beats·min^{-1}	175.2 (12.5)	174 (11.1)	174.4 (9.2)	.966
Maximal RER	1 (0.09)	0.99 (0.12)	0.98 (0.10)	.963
Peak speed, km·h^{-1}	15.3 (1.9)	16.7 (2.1)*	16.7 (1.6)*	.002
Average speed, km·h^{-1}	12.1 (1.1)	12.3 (1.7)	12.3 (1.5)	.597

Abbreviations: HR_{max}, maximal heart rate; RABIT, Running Advisor Billat Training; RER, respiratory exchange ratio; UMTT, University of Montreal Track Test; $\dot{V}E_{max}$, maximal ventilation; $\dot{V}O_2$max, maximal oxygen consumption. Note: The data are quoted as the mean (SD). RABIT is a self-paced $\dot{V}O_2$max field test.
*Significant difference ($P < .05$) between UMTT and RABIT.

speed (maximal, mean, and end running speed) data showed that there were no significant differences between RABIT1 and RABIT2 at any of the 3 RPE stages (RPE 11, RPE 14, and RPE 17; Table 2). In contrast, there were significant differences between each RPE (Table 2) in each RABIT test (except for RPE 14 vs RPE 17 in RABIT2 for the mean RER [$P = .068$]). Each of the perceptual intensities corresponded to 59% (RPE 11), 73% (RPE 14), and 89% (RPE 17) of the peak speed, and 66%–68% (RPE 11), 83%–85% (RPE 14), and 92% (RPE 17) of the $\dot{V}O_2$max observed from RABIT tests.

The RABIT Test: Reproducible for Cardiorespiratory and Pacing Responses According to the Duration of Exertion

In the submaximal stages (ie, RPE 11 and RPE 14), the participants maintained their speed in a steady-state manner between T1 and T3 while increasing their cardiorespiratory responses ($P = .099$ and $P = .799$; Figures 2 and 3). The RABIT test was robust for measuring cardiorespiratory responses as a function of the intensity and duration of exercise (Figure 2).

Discussion

The primary objective of this study was to assess the validity and reproducibility of a new SPV field test (namely the RABIT test) in recreational runners.

At first, we got the same maximal values in RABIT as in the UMTT—the track and field gold standard for determining $\dot{V}O_2$max in runners.[3] We obtain in the 3-minute RPE 17 of the RABIT protocol. This finding reinforces the pioneer work by Åstrand and Saltin[17] who recommended measuring $\dot{V}O_2$max during an all-out protocol of between 3 and 8 minutes. In the same way, Hanson et al[18] showed that a treadmill SPV test was as effective as the Bruce protocol proceeding with 3-minute stage duration, in eliciting an accurate $\dot{V}O_2$max easy applied on track and field. These findings suggest that the $\dot{V}O_2$max boundaries do not change—even when the test is self-paced and perceptually regulated.

We can point out that even if the RABIT did not require the participants to perceptually regulate their effort at RPE 20 (as required by many studies in the literature—especially Mauger et al[19]), we found the same maximal $\dot{V}O_2$ value in the RABIT as in the UMTT. Furthermore, the speed associated with $\dot{V}O_2$max was lower in the RABIT; even though the subjects started at a higher peak speed than in the UMTT, they rapidly slowed during the RPE 17 stage while maintaining their $\dot{V}O_2$max (as previously observed in studies with a decremental test[20,21]). Even though the requested RPE was 17, the subjects achieved $\dot{V}O_2$max as judged by the values in the UMTT and in the verification phase, where the difference in $\dot{V}O_2$ versus the RABIT was below the recommended 2%.[13] Moreover, according to the literature,[12,22,23] the HR_{max} during the verification phase did not differ by more than 2% with regard to the value in the RABIT, and the workload was well above 105% (115%, in fact) of the peak speed in the RABIT. In the study by Mauger and Sculthorpe,[16] the higher $\dot{V}O_2$max values achieved in the SPV test were attributed to a significant increase in power output in the final stage, followed by a significant drop at the end of the test. We also noted this phenomenon in the present study (see Figures 2 and 3). If we go deeper in the running strategy, we saw that all the runners adopted a fast-start strategy tending to achieve a supramaximal spike followed by a decline during the third part of the stage. Indeed, the workload corresponded to the value observed during the verification tests[24,25] was equivalent to about 110% of the maximum power in the UMTT.

Yet, it has been shown that a fast-start/all-out strategy to high-intensity exercise accelerates the change in O_2 levels and improves exercise performance[26,27] even if they decrease their speed after 1 minute, the $\dot{V}O_2$ was maintained at $\dot{V}O_2$max.[21] By consequence, even if we asked the runner to be at the intensity RPE 17, it seems that they have focused on the goal of running at a "hard" intensity for 3 minutes with a fast-start strategy, and the peak $\dot{V}O_2$ value would have been reached in the first minute of the last stage.[28] Moreover, the HR followed the same time course as $\dot{V}O_2$ because HR_{max} was reached. The results of the verification phase confirmed that the subjects had reached their maximal HR and $\dot{V}O_2$ in this 3-minute stage. This leads us to conclude that even when a "submaximal" (RPE 17) effort was requested in the RABIT test, the subject's habit of choosing their own pace during track or road running prompted them to choose a fast-start strategy—resulting in their achievement of $\dot{V}O_2$max at the RPE 17 stage. Similarly, Aisbett et al[29] found that a fast-start pacing strategy was associated with an elevated average $\dot{V}O_2$, when compared with even- or slow-starting conditions.

Second, our results show that a familiarization phase did not appear to be required for the RPE-based RABIT test given that the runners got the same physiological responses. Indeed, all the participants had the same maximal $\dot{V}O_2$, HR, $\dot{V}E$, and RER values in the 3-minute RABIT RPE 17 session. Indeed, after considering maximal values, we established that the RABIT test allowed our runners to produce reproducible submaximal cardiorespiratory and

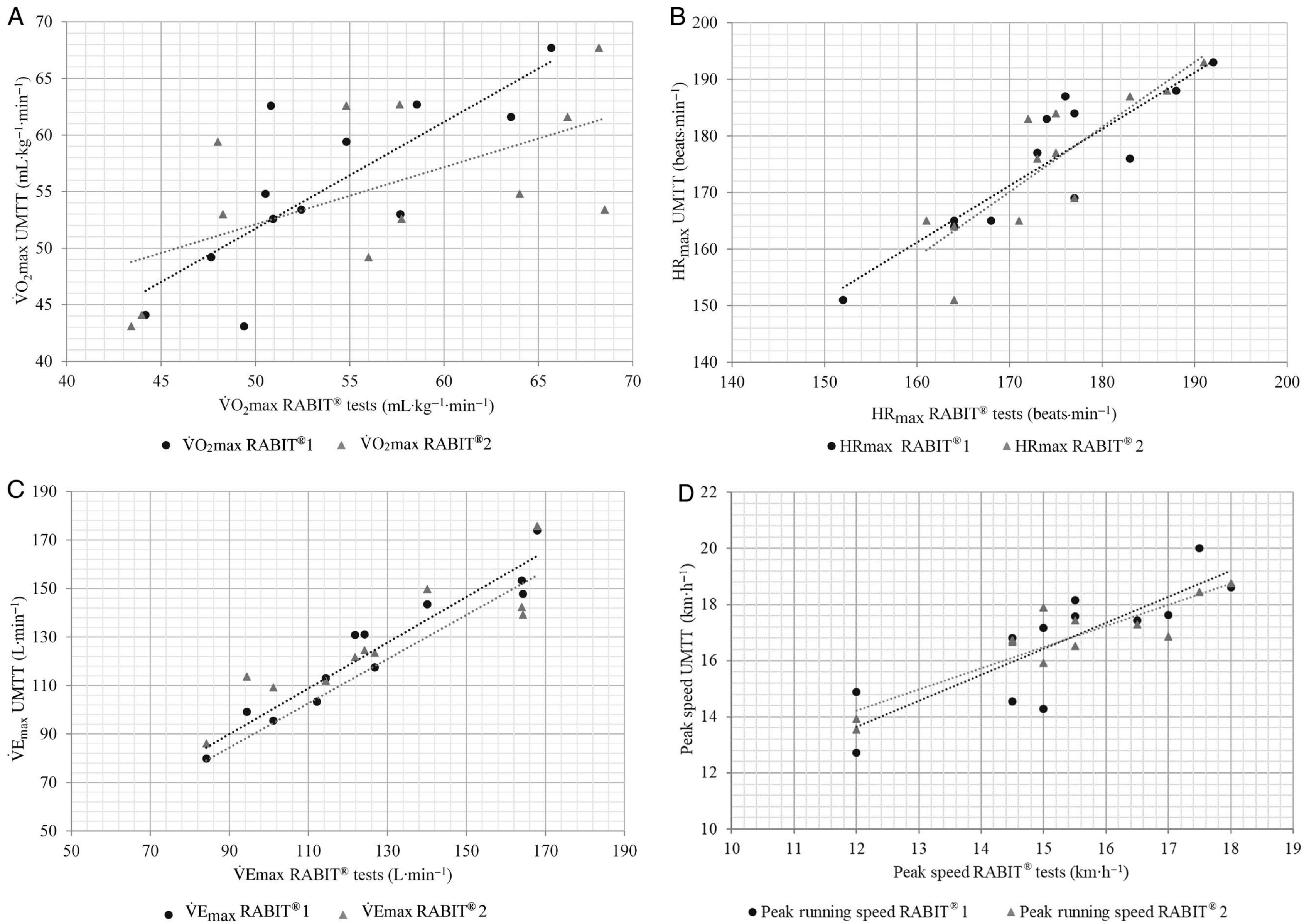

Figure 1 — Correlation between the University of Montreal Track Test (UMTT) and the RABIT field-based, self-paced maximal oxygen consumption test with regard to (A) $\dot{V}O_2max$, (B) HR_{max}, (C) $\dot{V}E_{max}$, and (D) peak running speed. HR_{max} indicates maximal heart rate; RABIT, Running Advisor Billat Training; UMTT, University of Montreal Track Test; $\dot{V}E_{max}$, maximal ventilation; $\dot{V}O_2max$, maximal oxygen consumption.

Table 2 Reproducibility of the Physiological and Speed Responses in the RABIT Tests

	RABIT1			RABIT2		
Test stage	**RPE 11**	**RPE 14**	**RPE 17**	**RPE 11**	**RPE 14**	**RPE 17**
$\dot{V}O_2$, mL·kg^{-1}·min^{-1}	36.6 (3.9)*,***	45.7 (4.4)***	49.9 (6.0)	37.3 (5.5)*,***	46.6 (7.0)***	51.9 (8.0)
$\dot{V}E$, L·min^{-1}	64.8 (12.1)*,***	94.1 (21.6)***	119.2 (27.2)	63.1 (9.5)*,***	93.1 (12.9)***	118.0 (21.3)
HR, beats·min^{-1}	132.3 (13.0)*,***	156.5 (12.8)***	167.8 (11.0)	131.4 (11.7)*,***	154.5 (14.6)***	167.1 (12.2)
RER	0.9 (0.1)*,***	0.9 (0.1)***	1.0 (0.1)	0.8 (0.1)*,***	0.9 (0.1)	1.0 (0.1)
Peak speed, km·h^{-1}	11.0 (1.3)*,***	13.7 (1.8)***	16.7 (2.1)	10.7 (1.5)*,***	13.6 (2.0)***	16.6 (1.7)
Average speed, km·h^{-1}	9.8 (1.2)*,***	12.3 (1.8)***	14.8 (2.3)	9.8 (1.7)*,***	12.3 (1.5)***	14.9 (1.7)
End speed, km·h^{-1}	9.4 (1.3)*,***	12.1 (1.6)***	14.5 (2.1)	9.5 (1.8)*,***	11.9 (2.0)***	14.4 (1.8)

Abbreviations: HR, heart rate; RABIT, Running Advisor Billat Training; RER, respiratory exchange ratio; RPE, rating of perceived exertion; $\dot{V}E$, ventilation; $\dot{V}O_2$, oxygen consumption. Note: The data are quoted as the mean (SD). RABIT is a self-paced $\dot{V}O_2$-maximum field test.
*Significant difference ($P < .05$) between RPE 11 and RPE 14. **Significant difference ($P < .05$) between RPE 11 and RPE 17. ***Significant difference ($P < .05$) between RPE 14 and RPE 17.

running speed responses as a function of the intensity and relative exercise duration by scaling the data to the first, second, and the last third of the test duration.[30,31] To the best of our knowledge, only one literature study has reported that mean submaximal cardiorespiratory and running speed responses are reproducible in an SPV test.[10] However, the latter study's 4 stages (RPE 11, RPE 13, RPE 15, and RPE 17) all had the same duration (2 min); this aspect of the study's design prevents a clear demonstration of reproducibility because effort duration is known to have an effect on physiological responses and the RPE. Importantly, our SPV field test took account of the variability in the RPE values for participants performing the same constant relative workload.[32] Furthermore, Garcin and Billat[33] showed that the RPE and the estimation of time limit increased linearly with time to exhaustion for exercise intensities at between 90% and 100% of $\dot{V}O_2$max. Furthermore, at a given relative time (percentage of the time limit), athletes perceived exercise as "hard" and felt that they could endure less exercise at v$\dot{V}O_2$max than at vΔ50 (an intermediate speed between the lactate threshold and $\dot{V}O_2$max). When participants began to perceive exercise as "hard" (ie, RPE 15), they had run for 36.4% of time limit at v$\dot{V}O_2$max and 46% of time limit at vΔ50. These results indicated that the RPE and the estimation of time limit reflect a mixture of exercise intensity and exercise duration (1) during all-out runs at 90% and 100% of v$\dot{V}O_2$max and even (2) when $\dot{V}O_2$max is reached at the end of a run at vΔ50. Thus, one strength of the RABIT test is its reproducibility for assessing cardiorespiratory and pacing responses as a function of both the intensity and duration of exercise.

Garcin and Billat[33] had already shown that a human athlete is able to estimate the time he/she can sustain for a given constant speed from 90% to 100% of v$\dot{V}O_2$max. In addition, this study shows for the first time that for a given RPE and without a learning step, the runner is able to reproduce both speed and $\dot{V}O_2$ at the same point in the step protocol (Figures 2 and 3). This suggests that RPE 17 was probably a supercritical intensity that enabled the $\dot{V}O_2$'s slow component to appear even during our 3-minute stage. This result was consistent with that of Burnley et al.[34] In Lim et al's[10] study, the subjects displayed the same $\dot{V}O_2$ peak at a lower maximum speed in SPV2 versus SPV1 and SPV3, and the speed strongly decreased during the RPE 20 stage in contrast to the RPE 17 stage. Consequently, the final speed in the 2-minute RPE 20 stage—it is difficult to hold maximum speed for 2 minutes, such as in an 800-m race—was almost the same as at RPE 17 (ie, about 14 km·h^{-1}, after a peak at 17 km·h^{-1}).

That is why the duration of each stage in our RABIT protocol differs (10 min at RPE 11, 5 min at RPE 14, and 3 min at RPE 17), so as to take account of effect of time on the $\dot{V}O_2$, the physiological response, and the estimated time limit that all the runners have in mind. The RPE might be a subjective estimation of (1) the duration of exercise (rather than the intensity) at a moderate exercise intensity and (2) both duration and intensity at maximal exercise intensities.[33] However, these studies were performed at a constant speed. Thus, it is still not known whether humans can reproduce the same physiological and running speed responses at 3 different RPEs (from moderate intensity to high intensity).[35] Eston and Williams[36] reported that the stated RPE after 4 minutes of cycling exercise at an RPE of 9, 13, and 17 was a reliable means of regulating of exercise intensity; however, the researchers focused on the difference between the field and the laboratory results, rather than the reproducibility of the cardiorespiratory response.[9] Furthermore, Bertuzzi et al[30] have shown that the relationships between perceived exertion, HR, and running velocity during a simulated 10-km race did not depend on the exercise duration.[30] In fact, the RPE is inversely and directly proportional to the remaining exercise duration.[31,37–39] Faulkner et al[31] showed that regardless of the distance, course elevation (gradient), and variations in pacing strategy, there were no differences in HR_{max} when the latter was expressed against the percentage of time or the percentage of distance.[40,41]

Teleoanticipation is another aspect to consider; it has been suggested that runners tend to adopt the same overall pacing strategy, even though several different strategies are available for events of different distances and durations. Hence, the most important factor in choosing a pacing strategy is knowledge of the endpoint of a particular event.[42] In line with this teleoanticipation hypothesis, the estimation of time limit corresponds to the perception of time when exercise at a constant power and a constant speed is performed until exhaustion.[41] However, the human self-paces his/her effort in real life, and notably in races from the 1500-m middle-distance event upward; we have used differential modeling of anaerobic and aerobic metabolism to show that runners continuously adjust their speed as a function of the remaining anaerobic capacity reserve.[43] The latter finding demonstrated that runners are able to adjust their effort by varying their running speed according to perceived effort. We recently found that recreational runners were able to adjust their acceleration every 4 seconds by asking them to do "soft," "medium," or "hard" accelerations.[44] In this study, the runners maintained their speed in a steady-state manner

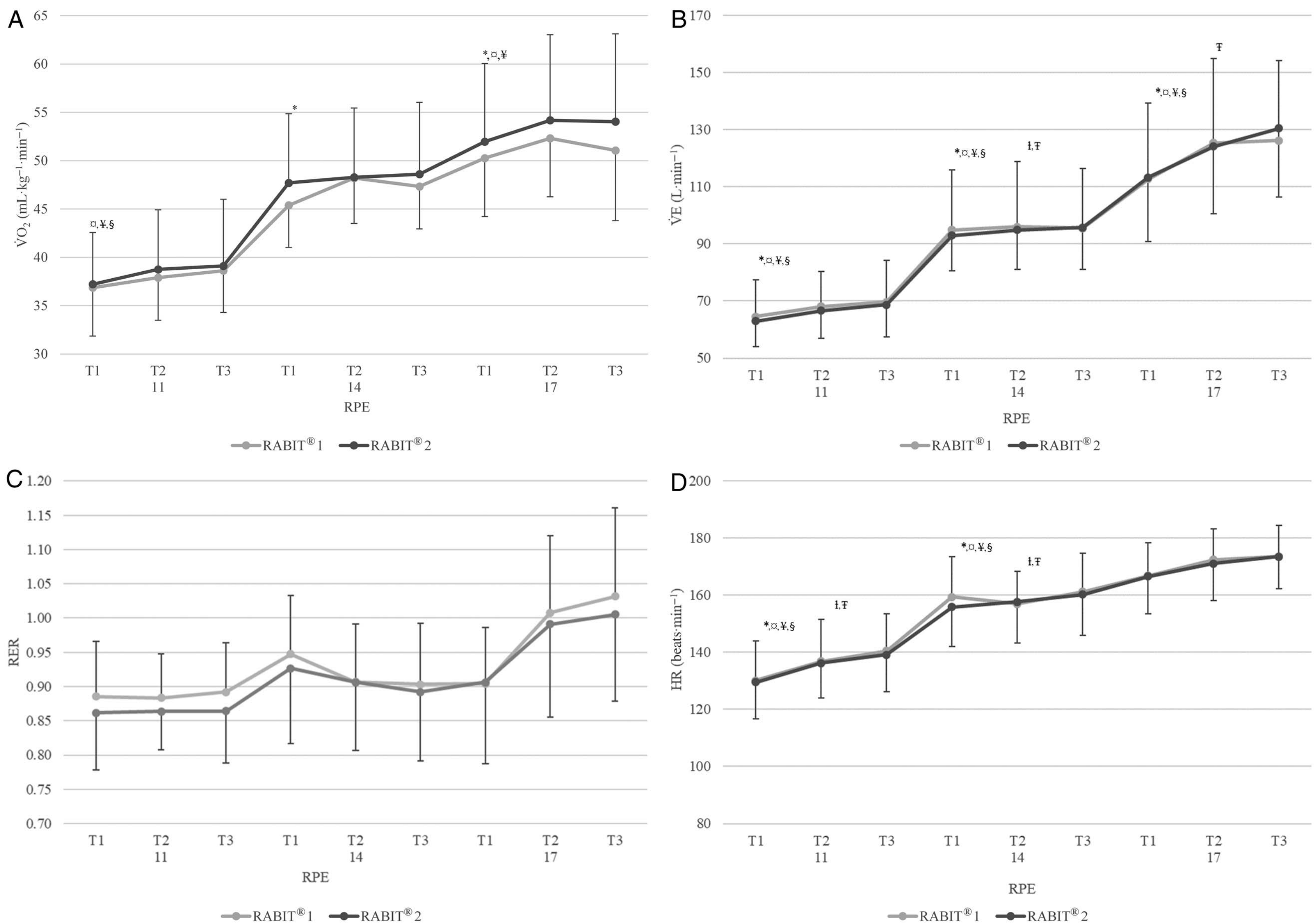

Figure 2 — Comparison of (A) $\dot{V}O_2$, (B) $\dot{V}E$, (C) RER, and (D) HR in 2 self-paced maximal oxygen consumption field-test (RABIT1 and RABIT2) for normalized durations (T1, T2, and T3) during the 3 RPE stages (RPE 11, 14, and 17). HR indicates heart rate; RABIT, Running Advisor Billat Training; RER, respiratory exchange ratio; RPE, rating of perceived exertion; $\dot{V}E$, ventilation; $\dot{V}O_2$, oxygen consumption. *Significant difference ($P < .05$) between T1 and T2 in RABIT1. §Significant difference ($P < .05$) between T1 and T3 in RABIT1. ƗSignificant difference ($P < .05$) between T2 and T3 in RABIT1. ¤Significant difference ($P < .05$) between T1 and T2 in RABIT2. ¥Significant difference ($P < .05$) between T1 and T3 in RABIT2. ŦSignificant difference ($P < .05$) between T2 and T3 in RABIT2.

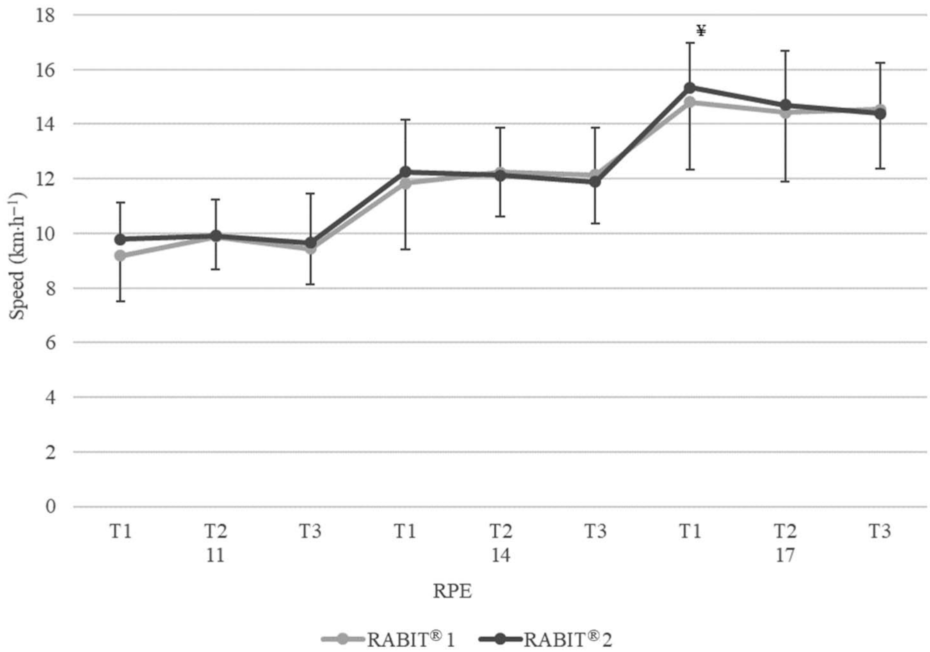

Figure 3 — Comparison of speed data in 2 field-based, self-paced maximal oxygen consumption tests (RABIT1 and RABIT2) for normalized durations (T1, T2 and T3) during the 3 RPE stages (RPE 11, 14, and 17). RABIT indicates Running Advisor Billat Training; RPE, rating of perceived exertion. ¥Significant difference ($P < .05$) between T1 and T3 in RABIT2.

during the submaximal stages (RPE 11 and RPE 14), while increasing the intensity of their cardiorespiratory responses as the run continues. In contrast, our recreational runners maintained their $\dot{V}O_2max$ during the maximal stage (RPE 17) by dropping their running speed. Thus, one can hypothesize that a runner uses the variation in speed (ie, acceleration) as a marker to preserve the power of running-specific muscles—even when the cardiorespiratory variables are rising.[44]

However, we still do not know how the runner associates a given RPE with a speed versus time. In perspective of the practical applications, the both major points show, for the first time, that recreational runners are able to self-pace in a reproducible way not only as a function of the intensity but also as a function of the relative exercise duration, their running speed, and cardiorespiratory responses.

Practical Applications

Most runners train by monitoring their HR and running speed, rather than the perceived effort. The runners or their coaches then define training zones with regard to $v\dot{V}O_2max$ or HR_{max}. The verbal communication used in the RABIT might constitute a novel tool for defining the different training zones and thus producing a training plan suited to the runner's ongoing physical condition. Moreover, the 3 intensities of the RABIT stages constitute practical markers that coaches can easily use to categorize their athletes' profiles.

In contrast to this study, a runner performing the RABIT test alone will probably monitor his/her HR (using a monitor) and running speed (using a global positioning system device). He/she will probably check the correspondence between the perceived intensity and that measured intensity objectively.

To better understand the mechanisms of self-paced control in an ecological setting (such as track tests and trail races), there is a need to perform additional studies in which speed, cardiorespiratory responses, and RPE responses are controlled in turn.

Conclusions

Our present results showed that also recreational runners were able to reproducibly adjust their effort as a function of the RPE (11, 14, and 17) and the duration of the RABIT test stages (10, 5, and 3 min). The running speed and cardiorespiratory responses were reproducible with regard to the RPE and to the proportion of each test stage (ie, 30%, 60%, and 90% of the stage's total duration). Thus, our results showed that the RABIT test is a reproducible, easy-to-use, field-based SPV test for recreational runners interested in defining their training zones without the need for expensive $\dot{V}O_2$ monitoring equipment.

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