THE COMPARISON BETWEEN RPE AND PHYSIOLOGICAL PARAMETERS AS A PREDICTOR OF 5000m ENDURANCE RUNNING PERFORMANCE

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Abstract

Introduction: The purpose of this study was to compare weather the perceptual or physiological determinants of endurance running performance is better predictor in an elite and active individual.

Methods: Eleven long distance male runners were recruited to take part in the study. Each participant completed an incremental exercise test to exhaustion to identify V̇O2max and maximal minute power output, a submaximal test to assess lactate threshold and running economy, a fixed power output equivalent to 75% V̇O2max the slope of the increase in perception of effort over time, termed ‘perceptual efficiency, and a 5000m running performance. Pearson bivariate 2-tailed correlation tests were used to determine correlations between variables, and single linear regression tests were performed to determine standard error of the estimate (SEE), and 95% confidence interval (CI).

Results: The best predictor of laboratory 5000m running performance were RPE slope ($r = 0.86$, $p < 0.01$ SEE= 15.3%). Standard error of the estimate was 16.0 %, and the V̇O2max was also strongly correlated with running performance ($r = 0.84$, $p < 0.01$; SEE = 18.5%). Finally, the Blood lactate at 2 $mM.L^{-1}$ (W) ($r = 0.63$, $p < 0.05$, SEE = 33.42%). However, blood lactate at 4 $mM.L^{-1}$ (W) ($r = 0.51$, $p > 0.05$, SEE = 39.42%), and also Running Economy at speed 10km V̇O2 ($ml.kg^{-1}.min^{-1}$) ($r = 0.32$, $p > 0.05$, SEE = 38.06%) were not correlate with 5000m running performance.

Discussion: The results showed that RPE and V̇O2max were the strongest predictors of laboratory 5000m running performance. Even though other measures of participant mass, running performance at a blood lactate of 2mmol/L were significantly related to 5000m running performance, linear regression analysis identified that the best predictor of 5000m running performance were RPE and V̇O2max.

Introduction

The determinants of endurance exercise performance have been studied for decades from simple measures such as heart rate, to whole body measures including the maximal oxygen consumption (V̇O2max), and more recently via microscopic molecular and genetic markers. The physiology underpinning endurance exercise performance was being investigated as early as 1910 when August Krogh developed a cycle ergometer to accurately determine oxygen consumption and energy expenditure. In the 1920s A.V. Hill presented the concept of V̇O2max, and along with Henry Taylor, Per-Olof Åstrand and Bengt Saltin 1950s and 1960s developed some of the seminal methodological approaches to measuring physiological parameters associated with endurance exercise performance. Indeed, Åstrand and Saltin's work from the 1960s was the first to present a clear relationship between V̇O2max and endurance exercise performance across a range of sports. However, it was also acknowledged that endurance exercise performance was not solely governed by an athlete's V̇O2max and that other submaximal physiological parameters were also important. Thus, in the 1970s and early 80s researchers also began to investigate the relationships between the lactate and/or ventilatory thresholds and endurance exercise performance as a way of determining the percentage of V̇O2max that could be sustainable for a given period of time. In this regard, Costill (1970) demonstrated a strong relationship between the curvilinear blood lactate response during an incremental exercise test, and marathon running performance. More recent research has established the concept of the lactate threshold within an incremental exercise test, and attempted to link it to endurance exercise performance by suggesting it interacts with V̇O2max to determine the exercise intensity that can be sustained for a given period of time during endurance exercise, also termed the "performance V̇O2" (Holloszy and Coyle., 1984; Holloszy et al., 1977; Robergs et al., 2004), maximal oxygen uptake (VO2max) sets the upper limit for the endurance performance. In those studies, in which the subjects had similar VO2max values, sub-maximal endurance (e.g. Costill et al. 1973; Farrell et al. 1979) and running economy (e.g. Conley and Krahenbuhl 1980; Morgan et al. 1989) have been shown to be related to endurance performance. Di Prampero (2003) and Bassett and Howley (1997, 2000) summarized that VO2max, fractional utilization of VO2max, and running economy are the major variables determining the velocity that can be maintained in distance races. Although success in endurance sports requires high VO2max, it cannot fully explain all the measured differences in endurance performance. Simultaneous strength and endurance training have been shown to improve muscle strength, running economy, and distance running performance without any changes in VO2max (Johnston et al. 1997; Paavolainen et al.

1999a) suggesting that neuromuscular factors may also be important determinants of endurance running performance. This is supported by the study of Paavolainen et al. (1999) indicating that better performance in the 10 km time trial is related to higher pre-activation of the working muscles accompanied with shorter contact times (CT) throughout the run. They presented a hypothetical model of the variables related to distance running performance. In the new model, the traditional model of endurance performance (Di Prampero 1986; Bassett and Howley 1997) was supplemented with the inclusion of factors relating to the neuromuscular capacity to produce power. Paavolainen et al. (1999a) also observed a significant relationship between the improvements in force and velocity tests, maximal anaerobic running test (Rusko et al. 1993), and running economy suggesting that that the maximal velocity of the MART (VMART) can be used as an indicator of neuromuscular power in endurance athletes. The VMART positively correlates with the times for running distances from 400 to 5,000 m and with cross-country skiing performance (Paavolainen et al. 1999a). An alternative explanation for the limitation of endurance performance postulates that a central nervous system integrates input from various sources during physical activity and prevents the recruitment of skeletal muscles beyond levels of intensity and duration where potential damage could occur to the heart and other vital organs (Lambert et al. 2005; Noakes 2000; Noakes et al. 2001). In accordance with this explanation, the changes in the number of skeletal muscle motor units recruited during exercise provide a more complete explanation for the impaired performance that develops during exercise and for differences in athletic performance (St Clair Gibson and Noakes, 2006). On the other hand, a strong link between Borg's rating of perceived exertion (RPE) and physiological parameters associated with endurance exercise performance (heart rate and blood lactate concentration) in 2,560 participants. Scherr et al. (2012) demonstrated a strong relationship between RPE (Borg scale 6-20), heart rate ($r = 0.74$, $P<0.001$) and blood lactate concentration ($r = 0.83$, $P<0.001$) during submaximal exercise performance. Moreover, a fixed blood lactate level of 3 or 4 $mM.L^{-1}$was seen to correlate with RPE values of 10.8 and 13.6 respectively. Scherr's study suggests that perception of effort could be an alternative method to consider endurance performance determinants compared to more "traditional" physiological parameters. Indeed, Marcora and Staiano (2010) have demonstrated that the perception of effort can been seen to determine endurance exercise performance independently of alterations in cardiorespiratory, metabolic and neuromuscular parameters. Therefore, it is possible that perception of effort could play a major role in determining endurance performance. However, Marcora and Staiano's study was conducted using a time to exhaustion test, and therefore does not permit the self-regulation of speed/power output experienced during endurance exercise performance (i.e. pacing strategy). Therefore, the degree to which perception of effort can account for variation in a self-paced running endurance performance, and how this compares to "traditional" physiological parameters is unknown. As a consequence, the hypothesis of this study was that the perception of effort would be a stronger predictor of 5000m running performance than V̇O2max, LT, and running economy.

Methods

Eleven long distance male runners were recruited to take part in the study. The experimental protocol and procedures were approved by the Ethics and Research Committee of the University of Sulaimanyiah (sport science and physical education collage). All participants provided written informed consent and completed a health questionnaire prior to participation.

Experimental Design:

All participants completed four test visits, the first being an incremental exercise test to volitional exhaustion to identify V̇O2max, the second to assess running economy and lactate threshold, the third to identify the rate of increase in the perception of effort at a fixed work rate, and the final visit to assess 5000m running performance.

At visit 1, participants completed an incremental exercise test to exhaustion on a treadmill (Ergo-runs premium8/8a24). Participants performs their individual warm-up regimen which might include 10–15 min jogging and some stretching. Athletes should be fitted with a telemetric heart rate monitor, participants performes the incremental running test until volitional exhaustion starting from 12 km/h, each stage is 3 min in duration and treadmill belt speed is increased by 1.0 km/h at the end of each stage. Subjects should complete a minimum of five stages and a maximum of nine stages. Pulmonary gas exchange was measured using (FitMate™, Cosmed, Rome, Italy) throughout the test. Heart rate was continuous measured throughout the test (S810i, Polar, Kempele, Finland), and the perception of effort, recorded as a rating of perceived exertion (Borg 6-20 scale; Borg, 1998) will be taken at the end of each minute. V̇O2max was calculated as the highest V̇O2 attained during a 60 s period in the test.

At visit 2, participants completed a submaximal exercise test to assess their lactate threshold and running economy. Initially, a capillary blood sample have taken before participant starts a warm up on a treadmill (Ergo-runs premium8/8a24, Flugplatzstr, Germany) for 10–15 min jogging and some stretching. The exercise test commenced at 14 km/h and consisted of between 6-8 subsequent stages, each stage 3 minutes in duration. Work rate was increased by 1.0 km/h at the end of each stage, the participant should place his hands on the guard-rails at the side of the treadmill, and lift their legs so that they are astride the moving treadmill belt. A fingertip blood sample should then be taken as quickly as possible using standardized procedures (i.e. alcohol swab, wipe with tissue, puncture, wipe away first drops of blood with tissue, and collect into capillary tube). The blood collection procedure should take ~15–30 s. When the blood has been collected, the athlete should take their weight on their hands, match their cadence to treadmill belt speed and resume running. Expired air was collected during the last minute of each stage using Douglas bags (Hans Rudolph, USA). After the test, the collected air was analysed for the fraction of expired oxygen and carbon dioxide using a Servomex 4100 service manual analyser (Servomex, Crowborough, East Sussex). Blood samples to assess for the level of lactate accumulation will be taken at the end of each stage using (lactate plus, Nova Biomedical, USA). The test terminated once the participant's measured blood lactate exceeded 4 $mM.L^{-1}$. Running economy was subsequently calculated as the oxygen cost of running for a given speed in W per liter of oxygen consumed.

During visit 3, participants cycled continuously for 15 minutes at a power output equivalent to 75% V̇O2max (established at visit 1) on a treadmill (Ergo-runs premium8/8a24, Flugplatzstr, Germany). The test required participants to complete 15 minutes of running 75%MMP, or until their they are no able to continue. The Borg 6-20 RPE scale (Borg, 1998) was used to assess perceived exertion at each minute throughout the test. The slope of the increase in perception of effort over time was subsequently calculated to provide a single value for RPE (Angius et al., 2016). Participants then rested for 15 minutes after which they undertook a familiarization of the performance time trial to be conducted during visit 4.

Finally at visit 4, participants performed a5000m running performance time trial. A capillary blood sample have taken before participant starts a warm up on a treadmill (Ergo-runs premium8/8a24, Flugplatzstr, Germany) for 10–15 min jogging and some stretching, participants will be completed a time trial in which they were asked to complete as fast as possible. During the performance time trial participants will run on a treadmill (Ergo-runs premium8/8a24, Flugplatzstr, Germany). Expired gases analyzed by (FitMate™,Cosmed, Rome, Italy) and RPE was monitored every minute during the test. Running speed, and heart rate were continuously monitored throughout. Blood samples were taken pre, every 1000m during and at the end of the test to assess and test blood lactate concentration.

Statistical Analysis:

Data were initially assessed for normality of distribution using a Shaprio-Wilk test. Pearson bivariate 2-tailed correlation tests were used to determine correlations between physiological variables, and RPE slope with cycling time trial performance. Moreover, a single regression analysis was used to determine standard error of the estimate (SEE), and 95% confidence interval (CI), and F values. Multiple regressions were not used because of the low number of subjects (n = 11). Data are presented as mean ± standard deviation unless otherwise stated. Statistical analyses were performed using the software program SPSS, version 20.0 (Statistical Package for Social Science, Chicago, Illinois, USA). Statistical significance was accepted at an alpha value of $P < 0.05$.

Results

All participants completed each of the 4 laboratory visits. The mean ± SD of data for each of the laboratory tests is presented in Table 1 below.

Table 1: Results from laboratory tests (n = 14).

	Mean	±	SD
Incremental Exercise Test			
V̇O2max ($ml.kg^{-1}.min^{-1}$)	62.11	±	5.27
Lactate Threshold and Economy Test			
Power at 2 $mM.L^{-1}$ (W)	247.33	±	20.38
Power at 4 $mM.L^{-1}$ (W)	280.33	±	16.83
Economy at speed 10km V̇O2 ($ml.kg^{-1}.min^{-1}$)	38.66	±	3.27
Economy at speed 11km V̇O2 ($ml.kg^{-1}.min^{-1}$)	43.22	±	3.03
Economy at speed 12km V̇O2 ($ml.kg^{-1}.min^{-1}$)	47.88	±	3.55
Economy at speed 13km V̇O2 ($ml.kg^{-1}.min^{-1}$)	51.88	±	3.44
Economy at speed 14km V̇O2 ($ml.kg^{-1}.min^{-1}$)	55.33	±	3.27
75% MMP Test			
RPE Slope (A.U.)	0.54	±	0.04
5000m Running performance			

Mean Power (W)	328.6	±	40.32
Mean V̇O2 ($ml.kg^{-1}.min^{-1}$)	46.28	±	4.5
% V̇O2max	76.13	±	14.62
Work done (kJ)	206.24	±	6.40

Results from laboratory tests (n = 11).for physiological parameters of 5000 m running performance and RPE slope.

V̇O2max vs. 5000m running Peformance:

One of two correlated variable with 5000m running performance was absolute V̇O2max (r = 0.84, $p < 0.01$; SEE = 18.5%). However, V̇O2max per kilogram body mass was not found to correlate with 5000m running performance (r = 0.62; SEE=32.6% $P < 0.05$; 95%).

RPE vs. 5000m running Performance

On the same hand, RPEslope was also correlated strongly with cycling time trial performance (r = 0.86, $p < 0.01$ SEE= 15.3%).

Lactate threshold vs. 5000m running Peformance

Cycling power output at 2 $mM.L^{-1}$ blood lactate was correlate with cycling time trial performance (r = 0.63, $p < 0.05$, SEE = 33.42%). However, cycling power output at 4 $mM.L^{-1}$ blood lactate was not correlated to time trial performance (r = 0.51, $p > 0.05$, SEE = 39.42%)>

Running economy vs. 5000m running Peformance

There were no significant correlations were found between Running Economy at speed 10km V̇O2 ($ml.kg^{-1}.min^{-1}$) (r = 0.22; SEE = 43.3%), Running Economy at speed 11km V̇O2 ($ml.kg^{-1}.min^{-1}$) (r = 0.23; SEE = 39.6%), Running Economy at speed 12km V̇O2 ($ml.kg^{-1}.min^{-1}$) (r = 0.31; SEE = 32.5%). Running Economy at speed 13km V̇O2 ($ml.kg^{-1}.min^{-1}$) (r = 0.28; SEE = 34.9%), Running Economy at speed 14km V̇O2 ($ml.kg^{-1}.min^{-1}$) (r = 0.32, $p > 0.05$, SEE = 38.06%)), and running Peformance (all $P > 0.05$).

Discussion

The primary aim of the current study was to investigate the relationship between running performance and physiological (V̇O2max, LT, running economy) and psychobiological (RPE) parameters. Results from the current study demonstrated that absolute V̇O2max ($L.min^{-1}$), and maximal minute power, body mass, power output at 2 $mM.L^{-1}$ blood lactate, and RPE were correlated with running performance. However, the two best variable correlating with running performance were RPE ($r = 0.86$, $p < 0.01$) and absolute V̇O2max (($r = 0.84$, $p < 0.01$). In support of this finding, previous research has suggested that endurance performance can be predicted by V̇O2max, as both V̇O2max and exercise performance are determined by the integrative capacity of the heart to produce a high cardiac output, whole body haemoglobin, muscle oxygen extraction and high muscle blood flow, and the ability of the lungs to oxygenate the blood (Bassett and Howley, 2000; Kanstrup and Ekblom, 1984; Rowell, 1986; Saltin and Strange, 1992). However, RPE and V̇O2max have been shown to be a poor predictor of performance within elite athletes due to large differences in performance, but relatively similar V̇O2max values (Storen et al., 2013). This is contrary to the findings of the current research, although it is highly likely that this is the result of the relatively "untrained" study population. This study recruited elite and trained participants with a narrow range of aerobic fitness, and thus performance potential. It is therefore unsurprising that a strong correlation was established between RPE, V̇O2max and running performance.

Whilst it is acknowledged that endurance performance is predominantly determined by physiological parameters (Joyner and Coyle, 2008), there is an ever-increasing acknowledgement that the perceptual response to exercise also forms an important part of the jigsaw. Indeed, an interesting and novel finding from the current study was that the perception of effort was a significant correlate of laboratory-based running performance ($r = 0.86$, $p < 0.01$). Using a novel test design, the increase in a participant's RPE was observed as a linear function time during a bout of high intensity running at a fixed power output of 75% MMP. The slope of the increase in RPE over the 15 min period of exercise was used as an indicator of what we have termed "perceptual efficiency". Thus, at the same relative exercise intensity, individuals who demonstrate a steeper slope of increase in RPE are assumed to have a lower "perceptual efficiency" than individuals with a shallower slope over the same time period. The results of the current study demonstrate a relationship between RPE slope and 5000m running performance. Indeed, several models report that the RPE is of critical importance in determining endurance exercise performance (Amann and Dempsey, 2016; Noakes, 2004; Marcora and Staiano, 2010; Tucker and Noakes, 2009).

The afferent feedback model suggests that following the onset of exercise, thermal, mechanical and chemical stimuli alter intramuscular receptor activity, which affects the firing rate of small-diameter group III/IV afferent fibres (Amann and Dempsey, 2016). Thus, it is likely that this neural feedback was increased during the constant running performance at 75% MMP as peripheral muscle fatigue developed due to the accumulation of muscle metabolic by-products. This heightened afferent feedback is thought to cause reflex inhibition of alpha motor neurons at both the muscle and supraspinal levels (Gandevia, 2001), and be a major factor involved in the development of central fatigue (Amann and Dempsey, 2008). The afferent feedback model of endurance exercise performance suggests that this feedback from peripheral muscle fatigue inhibits central motor drive, limiting endurance exercise performance, and resulting in an increased perception of effort (Amann et al., 2013; Wright et al., 2008).

Scherr et al. (2012) established a strong relationship between RPE and the blood lactate response in a group of 2,560 individuals ($r = 0.83$; $p < 0.001$). Specifically, the lactate threshold and the individual anaerobic threshold were strongly correlated with RPE values of 10.8 and 13.6. Moreover, fixed lactate thresholds of 3 and 4 $mM.L^{-1}$ were correlated with RPEs of 12.8 and 14.1 respectively. Thus, in line with the afferent feedback model, the increased level of sensory feedback from the accumulation of metabolic by-products could have resulted in the generation of the greater RPEs in Scherr's study. Indeed, afferent feedback from lactate production has been suggested to be a key factor in the generation of the perception of effort during cycling time trial performance (Wright et al., 2008).

An alternative hypothesis is provided by Marcora and colleagues (2008, 2009 and 2010) whose psychobiological model suggests that the perception of effort may regulate endurance performance as a consequence of the interaction between potential motivation and effort-based decision-making. According to the psychobiological model of endurance performance, the self-regulation of power/speed output during endurance exercise performance (pacing) is induced mainly by five different motivational/cognitive aspects: (1) perception of effort; (2) potential motivation; (3) knowledge of the distance/time to cover; (4)

previous experience/memory of perceived exertion during exercise of varying intensity and duration, and (5) knowledge of the distance/time remaining. However, the psychobiological model is somewhat limited in that it states that the perception of effort is the sole determinant of endurance performance. Results from the current study suggest that even through “perceptual efficiency” is a significant correlate for endurance exercise performance, it does not have as much predictive power as the V̇O2max.

Several previous studies have documented significant relationships between physiological parameters (e.g. V̇O2max, maximal minute power output, lactate threshold, power output at lactate threshold, efficiency), and endurance performance (Balmer et al., 2000; Hoogeveen and Hoogsteen, 1999). The findings of the current study are largely supportive of the previously published literature. The current study found that LT at 2 $mM.L^{-1}$ was correlated with time trial performance ($r = 0.63$, $p < 0.05$). This is not an unexpected finding as power output at LT at 2 $mM.L^{-1}$ has been suggested to be influenced by V̇O2max and cycling economy (Conley and Krahenbuhl, 1980). Indeed, work by Coyle et al. (1988) demonstrated that during a prolonged period of running at 88% V̇O2max, participants with a lactate threshold that occurred at a higher percentage of their V̇O2max were able to cycling for longer than those who had a LT occurring at a lower % V̇O2max.

Participants in the present study were all recreationally active male and female representing a rather heterogeneous performance group. The large range of V̇O2max difference values recorded from the participants may serve as a limitation to the interpretation of the study findings. As V̇O2max sets the upper limit for endurance performance, and aerobic metabolism is the key energy system for the time trial used within this research study, it is no surprise that with an elite and trained cohort.

Conclusion

Endurance exercise performance is determined by several physiological, mechanical and psychological/perceptual variables. Ultimately, the ability of an individual to tolerate or sustain a high-power output during endurance exercise performance is limited by their capability to resist fatigue. This study demonstrates that absolute V̇O2max ($L.min^{-1}$) and RPE were best predictor of 5000m running performance in a group of elite and well-trained individuals. In comparison to the traditional physiological parameters, the perception of effort has received limited research attention, but as demonstrated by this study, it is an important predictor of endurance performance.

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Tables

Results from laboratory tests (n = 11). for physiological parameters of 5000 m running performance and RPE slope.