Validity of the heart rate deflection point as a predictor of lactate threshold during running

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Vachon, John A., David R. Bassett, Jr., and Stephen Clarke. Validity of the heart rate deflection point as a predictor of lactate threshold during running. J. Appl. Physiol. 87(1): 452–459, 1999.—During an incremental run test, some researchers consistently observe a heart rate (HR) deflection at higher speeds, but others do not. The present study was designed to investigate whether differences in test protocols could explain the discrepancy. Additionally, we sought to determine whether the HR deflection point accurately predicts lactate threshold (LT). Eight trained runners performed four tests each: 1) a treadmill test for maximal \( \dot{V}O_2 \) uptake, 2) a Conconi test on a 400-m track with speeds increasing \( \sim 0.5 \) km/h every 200 m, 3) a continuous treadmill run with speeds increasing 0.5 km/h every minute, and 4) a continuous LT treadmill test in which 3-min stages were used. All subjects demonstrated an HR deflection on the track, but only one-half of the subjects showed an HR deflection on the treadmill. On the track the shortening of stages with increasing speeds contributed to a loss of linearity in the speed-HR relationship. Additionally, the HR deflection point overestimated the LT when a continuous treadmill LT protocol was used. In conclusion, the HR deflection point was not an accurate predictor of LT in the present study.

Conconi test; exercise; endurance; performance; blood lactate

LACTATE THRESHOLD (LT) is an important variable in the field of physiology, because it closely predicts actual performance in endurance events such as distance running (2, 11, 17, 36). Conconi et al. (9) proposed a method for noninvasively determining LT in runners. Their results show the expected linear relationship between heart rate (HR) and running speed at submaximal speeds but a plateau in HR at high running speeds. These investigators report that the deflection point of the HR-running speed relationship occurs at the same speed as the LT (9). They report that this method is applicable to other endurance sports, including cycling, racewalking, rowing, skating, and swimming (4, 5, 8, 10, 15).

Conconi’s method (9) is controversial for two reasons. First, many physiologists report that there is a linear HR relationship during incremental, maximal exercise tests or that HR only reaches a plateau in a certain percentage of subjects (3, 20, 29, 31, 33). However, Conconi et al. (9) reported that HR leveled off in all 210 of the runners they initially tested and in all 65 of the runners tested in a subsequent study (4). A second problem is that numerous authors have reported that the HR deflection point overestimates the directly measured LT (23, 24, 27, 33), contrary to observations of Conconi and co-workers (4, 6–10, 15). Recently, Conconi et al. (10) acknowledged the controversy by listing a large number of studies that refute as well as support their hypotheses.

The present study was designed to assess the validity of Conconi’s method, which uses HR measurements to predict LT. The first aim of the study was to determine whether HR is linearly related to running speed or whether it reaches a plateau at higher running speeds (9). The second aim was to determine whether Conconi’s method results in an HR deflection point that accurately predicts LT during a continuous treadmill test.

METHODS

Subjects. Eight male distance runners, training 30–60 miles/wk, volunteered to participate in the study. Subjects were instructed not to perform hard physical training during the 48 h before each test. The clothing, shoes, and environmental conditions, as well as all equipment used, were consistent for each subject and were recorded to establish controlled experimental conditions. The ambient temperature and humidity were carefully monitored, since environmental conditions can influence HR and blood lactate levels (1, 18). Air temperatures for the track, treadmill, and LT tests were \( 21.8 \pm 6.2 \), \( 21.3 \pm 1.7 \), and \( 20.8 \pm 2.5 \) °C, respectively. Relative humidity values for track, treadmill, and LT tests were \( 57.4 \pm 12.6 \), \( 49.3 \pm 12.5 \), and \( 53.1 \pm 9.4 \)%, respectively. The sequence of tests was counterbalanced to minimize the influence of an order effect.

The nature of the study was explained to the subjects, and they were given an opportunity to ask questions about anything that was unclear. All subjects signed an informed consent form approved by the university’s Institutional Review Board. Anthropometric measurements were taken on each subject, including height, weight, and sum of skinfolds. The physical characteristics of the subjects are shown in Table 1.

Maximal exercise test. After a stretching and warm-up period, a graded maximal treadmill test was performed to determine the subject’s maximal \( \dot{V}O_2 \) uptake (\( \dot{V}O_2 \),max). Subjects ran at a comfortable speed (12–16 km/h) on the level for 1 min, and then the grade was increased by 1% at 1-min
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Table 1. Physical characteristics of the subjects

| Age, yr | 30.8 ± 5.9 |
| Height, cm | 177.4 ± 4.5 |
| Weight, kg | 71.4 ± 6.3 |
| VO_{2max}, ml·kg^{-1}·min^{-1} | 65.4 ± 5.6 |

Values are means ± SD. VO_{2max}, maximal O2 uptake.

intervals for as long as the subject could continue. A two-way breathing valve with a mouthpiece was used, and a noseclip was worn to prevent nasal breathing. Ventilation was measured at 1-min intervals with a calibrated airflow meter (RAM 9200, Rayfield Equipment, Waitsville, VT). Percentages of expired gases were measured with O2 and CO2 analyzers (Applied Electrochemistry, Sunnyvale, CA) connected to a computerized system. These analyzers were calibrated against known gases analyzed by the micro-Scholander technique (30). O2 uptake (VO2) and CO2 production were calculated using standard metabolic equations (28). Attainment of VO_{2max} was based on achieving two of the following three criteria: 1) a plateau in VO2 (<50% of the predicted increase in VO2) with increasing speeds, 2) respiratory exchange ratio >1.10, or 3) HR within 10 beats/min of age-predicted maximal HR (220 - age). HR was measured using a heart watch (Vantage XL, Polar Electro, Kempele, Finland).

Conconi's protocol. Subjects underwent a 10 min warm-up at 50% HR reserve. They then performed a continuous run of 8–12 laps around a 400-m track, starting at a speed of 10–14 km/h and finishing at a final speed of 18–22 km/h. The subjects were instructed to increase running speed at 0.5 km/h every 200 m until they could no longer continue. The investigators called out projected 200-m split times to the runners, and the actual running speeds were later computed from the 200-m split times stored in the stopwatch. HR was recorded continuously at 5-s intervals with use of the Polar heart watch (Vantage XL, Polar Electro, Kempele, Finland). The running speed was increased by 0.6 km/h.

RESULTS

In all subjects, the track protocol of Conconi et al. (9) resulted in an HR deflection at high running speeds. However, four of the eight subjects showed no signs of an HR deflection on the treadmill; subsequently, they will be referred to as group 1 (Fig. 1). The other four subjects demonstrated an HR deflection on the track and the treadmill tests; they will be referred to as group 2 (Fig. 2).

Figures 3 and 4 show the time course of the HR response in a typical runner from group 1 (subject 2) for the continuous treadmill run and the Conconi test, respectively. The maximal HR achieved on the Conconi test and the treadmill test was 180 beats/min. The maximal speed achieved was higher on the Conconi test (18.3 km/h) than on the treadmill (17.3 km/h).

Figures 5 and 6 show the time course of the HR response in a typical runner from group 2 (subject 5). The maximal HR achieved on the Conconi test was similar to that achieved on the treadmill test (186 and 185 beats/min, respectively). The maximal speed achieved was higher on the Conconi test (21.2 km/h) than on the treadmill (19.9 km/h).

LT in the subjects occurred at running speeds of 12.72–16.47 km/h. The HR deflection point occurred at 16.01–20.37 km/h (Table 2). LT and HR deflection data for subject 4 were not considered in the statistical analysis, because precise determination of LT was compromised by lack of a stable baseline. For the remaining subjects the difference in speeds represented by HR inflection and LT was statistically significant (P < 0.0008). The relationship between the speed at LT and HR deflection speed (r = 0.688) is depicted in Fig. 7.
Fig. 1. Blood lactate and heart rate (HR) responses to 3 continuous, incremental run tests. Subjects 1, 2, 3, and 4 (A, B, C, and D, respectively) showed an HR plateau on Conconi track protocol, in which 200-m stages were used, but not on a treadmill protocol, in which 60-s stages were used. HR deflection point (top arrow) occurred at higher speeds than lactate threshold (LT; bottom arrow).

Fig. 2. Blood lactate and HR responses to 3 continuous, incremental run tests. Subjects 5, 6, 7, and 8 (A, B, C, and D, respectively) showed an HR plateau on Conconi track protocol and treadmill protocol, in which 60-s stages were used. HR deflection point (top arrow) occurred at higher speeds than LT (bottom arrow).
DISCUSSION

One reason for the controversy surrounding Conconi's method (9) is that other researchers do not always find an HR deflection during an incremental exercise test (20, 29, 31, 33). One of the main features of Conconi's method is that as the test proceeds, the amount of time required to complete each stage decreases. With Conconi's track protocol, which results in a shortening of stage durations, all the runners demonstrated an HR deflection.

Using a treadmill protocol with constant 60-s stages, only one-half of the runners showed a noticeable HR deflection. These findings are consistent with the work of Astrand and Rodahl (3), Ekblom et al. (16), and...
Davies (13). These researchers noted a strong, linear relationship between work intensity and cardiac frequency at submaximal workloads. However, at near-maximal efforts, they found that some individuals demonstrated a slight deviation from linearity as HR began to plateau. In more recent studies, in which constant stage durations of 45–60 s were used, an HR deflection occurs in 45–71% of subjects (22, 23, 29). Thus it would appear that only about one-half of all individuals show an HR deflection with constant stage protocols, whereas virtually all subjects show an HR deflection with Conconi's protocol (4, 5, 8–10, 15, 21).

Fig. 5. Time course of HR response for subject 5 during each stage of a continuous treadmill run test (60-s stages). During last 3 stages, runner was unable to raise his HR above 185 beats/min. This subject showed an HR plateau on treadmill and Conconi protocol.

Fig. 6. Time course of HR response for subject 5 during each stage of a continuous Conconi test (200-m stages). Runner attained much faster speeds on Conconi test than on treadmill. However, his maximal HR still could not go much higher than 185 beats/min.
The unique feature of the present study is that it compared test protocols with constant and those with shortening stages in the same runners.

It has been hypothesized that the shortening of stages with Conconi's protocol may result in insufficient time for attainment of steady-state HR at high speeds. If this were true, it would explain the loss of linearity in the speed-HR relationship. However, Conconi et al. (9) argue against this hypothesis, noting that HR adapts to the speed-HR relationship. However, Conconi et al. (9) showed extremely close agreement between LT and HR deflection speed (r = 0.688). These observations agree with the findings of several other investigators during graded cycle ergometry (20, 23, 27) and running (24, 33). In contrast, Conconi et al. (9) showed extremely close agreement between LT and HR deflection (r = 0.99). The controversy surrounding this issue is difficult to resolve. However, we believe that the most likely explanation is that it is due to differences in the LT test protocol.

The second major finding in this study was that the HR deflection point (with Conconi's 1984 protocol) occurs at much higher speeds than the directly measured LT. In addition, there was only a modest correlation between the speed at LT and HR deflection speed (r = 0.688). The observations agree with the findings of several other investigators during graded cycle ergometry (20, 23, 27) and running (24, 33). In contrast, Conconi et al. (9) showed extremely close agreement between LT and HR deflection (r = 0.99). The controversy surrounding this issue is difficult to resolve. However, we believe that the most likely explanation is that it is due to differences in the LT test protocol.

Traditionally, LT is determined by one of two methods: 1) a continuous test with 1-, 3-, or 4-min stages (23, 26, 29, 32, 34, 35, 37) or 2) a discontinuous test where a series of three sets of 10-min runs (interspersed with 15 min of rest) are performed over several days (2, 12, 17, 19, 35). We used a continuous test with 3-min stages, which has been proven to yield LT values similar to a discontinuous test with 10-min stages (35). However, Conconi et al. (9) employed an unconventional LT test consisting of 1,200-m stages with 15 min of active recovery between stages. With Conconi's LT test, a runner would complete 1,200 m in ~4–6 min compared with the usual 10-min discontinuous stage. Because Conconi's stages are about one-half as long as a typical discontinuous stage, this may decrease the blood lactate accumulation, causing an artificial “shift” of the LT curve. This appears to be the reason that they report close agreement between HR deflection point and LT (7–10, 15, 25), whereas researchers using more conventional LT tests have found that the HR deflection overpredicts LT (23, 24, 27, 33).

We considered the effects of air resistance during the physiological testing. Our LT tests were conducted on a...
treadmill, whereas those of Conconi et al. (9) were conducted on an outdoor track. During treadmill running we used a fan to provide convective cooling; this created a head wind of 2.8 km/h. This meant that the runners faced a relative head wind that was 7–16 km/h greater than it would have during the track test. Differences in the LT test protocol, recovery mode and the individual anaerobic threshold (Abstract). Int. J. Sports Med. 9: 367, 1988.


