Research Article

Relationship between perceived exertion and blood lactate concentrations during incremental running test in young females

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Abstract

**Background:** To investigate more practical handling of Borg’s ratings of perceived exertion (RPE) and category-ratio scale of RPE (CR-10), we evaluated interrelationships between RPE, CR-10, and blood lactate concentrations ((Lȧ)b) during incremental treadmill running tests for young females with different aerobic fitness levels.

**Methods:** Oxygen consumption, heart rate, (Lȧ)b, RPE, and CR-10 were measured from distance runners (DR; n = 15), race walkers (RW; n = 6), and untrained females (UT; n = 11). These variables corresponding to the lactate threshold (LT) and onset of blood lactate accumulation (OBLA) were compared among these groups.

**Results:** The UT had significantly lower RPE at LT than DR and RW, although the CR-10 at LT was not significantly different among these groups. The CR-10 at OBLA was significantly lower for the UT than DR. The relationship between (Lȧ)b and CR-10 was approximated well by two linear regression lines, meaning that an intersection was observed between (Lȧ)b and CR-10. The CR-10 at the intersections ranged from 3.1 to 3.2 without any significant group differences, and those scores were not significantly different from those obtained at the intersections.

**Conclusion:** These data proposed that “CR-10 ≈ 3” would be a non-invasive criterion for evaluating exercise intensity corresponding to the LT for young females regardless of their aerobic fitness levels.

**Keywords:** Physical fitness, CR-10, OBLA, Training, RPE, LT
Background

The blood lactate concentrations ((La^-)b) have been used to monitor exercise intensity during both resistance and dynamic exercises [1,2]. In particular, Seiler and Kjerland [3] showed that more than 75% of an entire training program was set at an exercise intensity corresponding to or under the individual lactate threshold (LT), even for elite rowers [4], junior national-level cross-country skiers [3], world-class cyclists [5], highly trained long distance runners [6,7], and race walkers [7]. However, several invasive blood samplings are required to determine the exercise intensity corresponding to the individual LT or onset of blood lactate accumulation (OBLA). Thus, these indices are not always applied when coaching endurance athletes.

Indeed, (La^-)b does not necessarily increase linearly during incremental exercise [8-11]. In contrast, heart rate (HR) or ratings of perceived exertion (RPE) increase linearly associated with an increase in exercise intensity [12-14]. These previous findings suggested that the HR or RPE appeared to be practical for monitoring training intensities during training sessions.

The RPE was originally proposed for ergonomic purposes to evaluate “overall” perceived exertion, physical stress, and exhaustion during physical effort [15,16]. Borg et al. [17] further found a significant relationship between RPE and HR or (La^-)b during arm and leg exercises.

A modified RPE, so-called category-ratio scale of RPE (CR-10), was proposed as a unique method to evaluate various clinical perceptions, including localized pain, fatigue, and perceived exertion during physical effort [18]. It is important to note that this unique index is closely correlated with the physiological variables, such as HR and (La^-)b, during submaximal “dynamic” exercise [18]. However, both RPE and CR-10 are still subjective when monitoring the individual exercise intensities. Indeed, a considerable variability exists in the RPE scores corresponding to the ‘ventilatory threshold (VT)’ or LT, ranging from 10.2 to 16.5. [14,19-23].
Such a variety of RPE scores should be derived from mixed effects of gender, age, training status, or muscle fatigue. This implies that comparing the data for RPE or CR-10 might be limited to homogeneous groups based on aerobic fitness levels [21,23-26], training status [3,13,25,27,28], or healthy aged people [29,30].

As described previously, $(La^-)b$ exhibits a gradual increase at light and moderate exercise intensities and a sharp increase at a heavy exercise intensity [8-11]. The CR-10 also shows a linear increase in association with exercise intensity during dynamic exercise [12,13]. Based on these observations, there exists a possibility of an intersection if the CR-10 is expressed as a function of $(La^-)b$. Thus, we hypothesized that the relationship between CR-10 and $(La^-)b$ could be approximated by two regression lines using a non-linear least squares method, and that an intersection would appear around LT for young females with various aerobic fitness levels. Our second hypothesis was that a possible intersection between CR-10 and $(La^-)b$ would be explained by a particular CR-10 score in those participants, because perceptual effort expressed by CR-10 shows a linear increase in association with exercise intensity [12,13]. To test these hypothesis, the purpose of this study was to evaluate the interrelationships between $(La^-)b$, HR, RPE, and CR-10 among groups of young females with different aerobic fitness levels.

Methods

Subjects

This study included fifteen female distance runners (DR group), six female race walkers (RW group), and eleven untrained females as a control (UT group). It was quite difficult to recruit ‘pure’ race walkers, because some of Japanese race walkers often train as ‘Ekiden’
(long-distance road relay) runners. Thus, the sample size for the RW was smaller than other
groups. Instead, the RW involved ‘pure’ race walkers only. The UT was recruited from
untrained female senior and graduate students, so that a significant age difference appeared
(Table 1). The physical characteristics of these three groups are summarized in Table 1. All
participants had no history of cardiovascular or metabolic disease. Each participant had a
normal menstrual cycle as defined by regular periodicity and was not taking oral
contraceptives. Testing during the follicular phase was completed on days 3-6 (day 1 = first
day of menstrual flow). After providing detailed explanations of all procedures as well as
possible risks and benefits of participation, all participants signed informed consent. This
study conformed to the Declaration of Helsinki, and all procedures were approved by the local
ethics committee of Kyushu Sangyo University (H240324).

Exercise protocols and measurements
An incremental running test was administered using a motor-driven treadmill at 0% grade
(Nishikawa Iron, Ltd., Japan). The initial treadmill velocity was set at 180 m-min\(^{-1}\) for 5-min
for the DR and 80 m-min\(^{-1}\) for 5-min for the RW and UT. The treadmill velocity was then
increased by 20 m-min\(^{-1}\) every 5-min until volitional exhaustion. It was obvious that the UT
and RW walked on the treadmill at the initial stage, however, they were instructed to run at
more than 100 m-min\(^{-1}\) for the purpose of this study. These different initial treadmill velocities
and our instruction for running at more than 100 m-min\(^{-1}\) would not influence perceived
exertion at LT, because Ekkekakis et al. [20] showed that a difference of the incremental
protocol did not influence the perceived exertion at LT.
Oxygen consumption (\(\dot{V}O_2\)), carbon dioxide output (\(\dot{V}CO_2\)), and minute ventilation were
analyzed using a computerized breath-by-breath measurement system (AE-310S, Minato Medical Science Co. Ltd., Osaka), which were calibrated before each measurement with room air and reference gas of known concentrations (O₂ 15.22%, CO₂ 5.17%, and N₂ 79.61%). The average VO₂ during the final 1-min of each stage was regarded as the VO₂ for that stage. The ratio of the VCO₂ to VO₂ was used to calculate the respiratory exchange ratio (RER; VCO₂/VO₂). During the incremental running test, the HR was continuously monitored by an electrocardiogram, and the average HR value during the final 1-min of each stage was regarded as the HR for that stage. Scores for RPE and CR-10 were selected at the end of each stage from a scale (Table 2). When given criteria were met (e.g., a plateau or a drop in VO₂, HR > 95% of age-predicted maximum [31], or RER > 1.1), the highest average value of 1-min VO₂ was regarded as the individual maximal oxygen uptake (VO₂max) [32,33]. In this matter, a plateau or a drop in VO₂ was the primary criterion for determining the VO₂max, but if not, HR over 95% of age-predicted maximum [31] or RER > 1.1 was used to interpret the attainment of the volitional exhaustion.

After selecting RPE and CR-10 scores, the participants put their right hand on a small table located beside the treadmill, and 20 µL blood samples were obtained from the right index finger. After blood sampling, (La−)b was analyzed by a lactate analyzer (Diagluca, HEK-30L, Toyobo, Japan) using an enzyme electrode method. The individual LT was systematically determined on a basis of the log-log transformation for the relationship between (La−)b and VO₂ [7,9,34,35]. This procedure was used to determine the value of each independent variable corresponding to the individual LT. VO₂, %VO₂max, HR, RER, RPE, (La−)b, and CR-10 corresponding to the individual LT were evaluated for each participant.

The onset of blood lactate accumulation (OBLA), defined as the exercise intensity
corresponding to 4 mM (La\(^{\prime}\))b, was also determined on a basis of a method described by Abe et al. [8]. For instance, all variables obtained from the incremental test was plotted as a function of (La\(^{\prime}\))b. An exponential interpolation was applied for the relationship between (La\(^{\prime}\))b and each variable to determine the value of each variable corresponding to OBLA.

**Statistical analysis**

Data are given as means ± standard deviations (SD). A regression analysis using an exponential function was used to determine the relationships between (La\(^{\prime}\))b and RPE. Non-linear least squares analysis was also used to determine the relationship between CR-10 and (La\(^{\prime}\))b. This procedure gives an intersection between CR-10 and (La\(^{\prime}\))b, and the individual CR-10 corresponding to the intersection were compared to those obtained at LT. A one-way repeated measures analysis of variance (ANOVA) within participants was used to compare physical and physiological indices among three groups. A two-way repeated measures of ANOVA within participants (3 groups × 2 CR-10 scores at LT and intersections) was applied to compare the CR-10 at LT and at the intersections between CR-10 and (La\(^{\prime}\))b. The values for (La\(^{\prime}\))b obtained at LT and at the intersections were also compared using a two-way repeated measures of ANOVA within participants. If a significant $F$ value was obtained, then Tukey’s multiple comparison was used as a post hoc test for the appropriate data sets. Statistical significance was set at the 0.05 probability level.

**Results**

The average $\dot{V}O_{2\text{max}}$ for each group are summarized in Table 1. A significant difference was found in the $\dot{V}O_{2\text{max}}$ among three groups (DR > RW > UT, $p < 0.01$). These significant
differences in the \( \dot{\text{VO}}_{2\text{max}} \) reflected differences in the \%\( \dot{\text{VO}}_{2\text{max}} \) at LT and OBLA \((p < 0.01 \text{ at LT, } p < 0.05 \text{ at OBLA, Table 3})\). Physical characteristics, such as body height and weight, were not significantly different among these groups (Table 1), however, the UT was significantly older than RW and DR \((p < 0.01 \text{ for both DR and RW})\).

The HR responses during incremental test are shown in Figure 1A. The HR increased linearly as a function of \%\( \dot{\text{VO}}_{2\text{max}} \) (Figure 1A). Table 3 shows that the average HR at LT was significantly lower for the UT than for the DR and RW \((p < 0.01 \text{ for both DR and RW, Table 3})\), whereas the average HR at OBLA was not significantly different among these groups \((p > 0.13, \text{ Table 3})\).

During the incremental test, the RPE and CR-10 increased linearly as a function of HR for all groups (Figure 2). As shown in Table 3, the UT showed a significantly lower RPE at LT than the DR \((p < 0.05)\) and RW \((p < 0.01)\), whereas there were no significant differences in the CR-10 at LT and at the intersections \((p > 0.12, \text{ Figure 4})\). In contrast, a significantly higher CR-10 at OBLA was found for the DR than for the UT \((p < 0.05, \text{ Table 3})\), although there were no significant differences in the RPE at OBLA among these groups \((p > 0.06, \text{ Table 3})\).

The \((\text{La}^{\prime})b\) expressed as a function of \%\( \dot{\text{VO}}_{2\text{max}} \) exhibited a curvilinear relationship during the incremental test for all groups (Figure 1B). The left panel of Figure 3 shows the curvilinear relationships between RPE and \((\text{La}^{\prime})b\) for all groups. The relationships between CR-10 and \((\text{La}^{\prime})b\) exhibited two regression lines with an intersection during the incremental test for all groups (Figure 3 right panel). Its determining variables \((r^2 \text{ values for two regression lines})\) constituted a coefficient more than 92%.

Figure 4 shows scattered CR-10 scores at LT and intersections. A two-way ANOVA for 3 groups \(\times 2\) CR-10 scores revealed that no significant differences were found for the CR-10
scores at LT and intersections (score effect $p = 0.97$, group effect $p = 0.87$, groups × score interaction $p = 0.75$). Instead of the CR-10, the (La$^{\text{a}}$)$_b$ at the intersections were significantly different among three groups (DR = 1.2 ± 0.4 mM, RW = 0.9 ± 0.3 mM, and UT = 1.9 ± 0.3 mM, respectively. $p < 0.01$ for each group comparison). The (La$^{\text{a}}$)$_b$ only for the RW at the intersection was significantly lower than that obtained at LT ($p < 0.05$, Table 3).

**Discussion**

**Overview**

We investigated the interrelationships among HR, RPE, CR-10, and (La$^{\text{a}}$)$_b$ for young females with different aerobic fitness levels. Major findings of this study were summarized as follows.

1. For all groups, the relationship between (La$^{\text{a}}$)$_b$ and CR-10 was approximated well by two linear regression lines, indicating that an intersection was obtained for this relationship (Figure 3 right panel).

2. The average (La$^{\text{a}}$)$_b$ values at the CR-10 intersections, ranging from 0.9 to 1.9 mM, were significantly different among groups (Figure 3 right panel), and the (La$^{\text{a}}$)$_b$ at the intersection for the RW was significantly lower than that obtained at LT (Table 3).

3. Any significant differences were not observed in the CR-10 scores obtained at LT and intersections (Figure 4).

4. The HR and RPE at OBLA were not significantly different among three groups, whereas the HR and RPE at LT were significantly lower for the UT than both endurance groups (Table 3).
**Interrelationship among physiological and perceptual variables at LT**

In support of our first hypothesis, a considerable finding of the present study was that the relationship between \((\text{La}^-)\text{b}\) and CR-10 was approximated well by two linear regression lines, indicating that an intersection could be identified for this relationship for each group (Figure 3 right panel). It was interesting to note that the average CR-10 at these intersections ranged from 3.1 to 3.2 without any group differences (Figure 3 right panel and Figure 4). With regard to the CR-10 at the intersection, our second hypothesis was also supported.

Table 3 showed that there were no statistically significant differences in the average \((\text{La}^-)\text{b}\) at LT, which were equivalent to those obtained in a series of our previous studies [7,34,35]. The \((\text{La}^-)\text{b}\) at the intersection corresponded to 0.9-1.9 mM with significant group differences, and the \((\text{La}^-)\text{b}\) for the RW were significantly lower than that obtained at LT. Thus, our first hypothesis with regard to the \((\text{La}^-)\text{b}\) values at the intersections were not supported. However, it was worth noting that the CR-10 at LT and intersections were not significantly different among three groups (Figure 4), suggesting that “CR-10 \(\approx 3\)” might be a non-invasive criterion for evaluating the individual LT for young females regardless of their aerobic fitness levels.

Indeed, “CR-10 \(\approx 3\)” was further supported by previous studies in healthy older people [29] and junior national-level cross-country skiers [3], although the ages and aerobic fitness levels of the participants widely ranged in those studies. A subjective variable (CR-10) in association with a physiological variable ([La^-]b) would make us more confident for predicting exercise intensity corresponding to the individual LT, because it was independent of the aerobic fitness levels among young females (Figure 3, Figure 4, and Table 3).

Figure 2 showed that RPE (upper) and CR-10 (lower) in association with HR increased linearly during the incremental test for all groups. These linear responses for RPE and CR-10...
during the incremental test were supported by the results of previous studies [12,13,17]. The average CR-10 at LT ranged from 3.2 to 3.8 without any significant differences among these groups (Figure 4 and Table 3). Thus, these results indicated that the CR-10 could be useful to monitor the exercise intensity corresponding to the individual LT regardless of the aerobic fitness levels in young females. The perceptual efforts expressed by CR-10 at LT corresponded to “somewhat strong” in this study (Table 2). The CR-10 at LT seemed to be somewhat lower than that of some previous studies [24-26], but it was equivalent to that observed in other studies [3,13,29,33]. These inconsistent results with regard to CR-10 at LT could be due to differences in participants’ health status for elderly COPD patients [24] or the type of exercise [25,26].

We also found that RPE at LT were significantly lower for the UT than for two endurance groups. The perceptual efforts expressed by RPE at LT ranged from “fairly light” to “somewhat hard” (Table 2). However, no significant differences were found in the RPE and HR at LT between RW and DR, so that the data for RPE and HR could be also useful to predict the exercising intensity corresponding to the individual LT for female endurance athletes.

CR-10 and RPE at OBLA

There is little information for CR-10 corresponding to the individual OBLA during dynamic exercise, particularly for females. As shown in Figure 1A, the HR increased linearly at submaximal exercise intensities for all groups. Table 3 showed that the HR at OBLA corresponded to around 180 beats·min\(^{-1}\) without any significant differences among three groups. There were no significant differences in the RPE at OBLA among three groups. These
results indicated that a combination of HR and RPE could be useful to predict the exercise intensity corresponding to the individual OBLA regardless of aerobic fitness levels. In fact, Borg et al. [17] suggested that a combination of HR and (La')b could predict RPE more accurately than either variable alone when these variables were applied to moderately or highly fit males.

The CR-10 at OBLA was significantly higher for the DR than that for the UT, but it was not significantly different from that for the RW (Table 3). Thus, this combination could be particularly valuable for female endurance athletes when using CR-10 at OBLA. Fabre et al. [31] used a different method to determine individual exercise intensity at OBLA for highly fit professional soccer players. It is important to note that two previous studies [17,31] had something in common as both involved trained athletes. Recent clinical investigations also revealed that a high-intensity interval training, which should be above OBLA, improved not only cardiorespiratory functions [36] but also locomotor functions [37] even in clinical patients. Thus, the determination of the individual exercise intensity at OBLA could be necessary not only for trained athletes but also for untrained or clinical patients.

Practical applications and limitations

As previously described, endurance training models at LT or OBLA have been used in a number of studies and demonstrated significant improvements in the aerobic fitness level or performances not only for healthy older sedentary populations [29,30] but also for different groups of endurance athletes [3,7,28,38]. These previous studies indicated that programming LT training would be particularly important, and monitoring the training intensity corresponding to the individual LT would be necessary to lead potential athletes toward
success in each endurance event.

The results of the present study will contribute to a practical handling of RPE and CR-10 for daily training not only for female endurance athletes but also for untrained females regardless of their aerobic fitness levels. However, some considerations are still necessary. Patients with cardiorespiratory disorders showed relatively greater RPE at LT than healthy populations [14,24]. The RPE corresponding to the LT or VT seems to be different between males and females regardless of their fitness levels [14,19,21]. Unfortunately, our present study did not involve male participants, however, we showed a narrow range of CR-10 scores (3.1-3.2) at LT with a small deviation (coefficient of variance < 10%), being independent of their aerobic fitness levels in young females. The use of perceived exertion in association with HR and/or (La')b will be useful for avoiding a risk of overtraining and a lack of necessary training intensity, at least, for females.

Conclusions

The relationship between (La')b and CR-10 was approximated well by two linear regression lines, indicating that an intersection was observed for this relationship among females regardless of their aerobic fitness levels. The CR-10 scores at the intersections were within a narrow range of 3.1-3.2. The CR-10 scores at LT and intersections were not significantly different among three groups. These data suggested that “CR-10 ≈ 3” would be a non-invasive criterion for evaluating exercise intensity corresponding to the LT for young females regardless of their aerobic fitness levels.

The HR at OBLA was not significantly different among three groups, whereas CR-10 at OBLA was significantly lower for the UT than for the endurance athletes. These results further
suggested that the CR-10 in association with HR responses could be also available to predict
the exercising intensity corresponding to the individual OBLA for female endurance athlete.
Competing interests

There are no conflicts of interest with any company or product used in the data collection of this study. We also declare that the results of this study do not constitute endorsement of the product by the authors or any companies.

Authors’ contributions

DA, YF, and TY participated in the study design. HU and YF participated in the data collection. DA and TY drafted the first manuscript. KS and YF gave critical comments on the first manuscript. DA drafted the final version of the manuscript. All authors checked the final version before submission.

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Japan.  

Faculty of Health and Sports Science, Doshisha University, Japan
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Figure Legends

Figure 1. Heart rate (HR) (panel-A) and blood lactate concentrations [(La\textsuperscript{-})b] (panel-B) expressed as a function of \%VO\textsubscript{2max}. Distance runners (○), race walkers (●), and untrained individuals (□). Values are means ± SD.

Figure 2. RPE (upper) and CR-10 (lower) expressed as a function of HR. Each plot was same as Figure 1. Values are means ± SD.

Figure 3. RPE (left) and CR-10 (right) expressed as a function of (La\textsuperscript{-})b among three groups. The curvilinear model between (La\textsuperscript{-})b and the RPE and double regression lines between (La\textsuperscript{-})b and the CR-10 could be applied. Each plot was same as Figure 1. Values are means ± SD.

Figure 4. A scattered graph of CR-10 scores obtained at LT and intersections between CR-10 and (La\textsuperscript{-})b. Each plot was same as Figure 1. Solid, dashed, and dotted crossbars were the mean values for each group.
Table 1. Physical Characteristics and maximal oxygen uptake in all groups.

<table>
<thead>
<tr>
<th>groups</th>
<th>n</th>
<th>Age (year)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>VO_2max (ml/kg/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UT</td>
<td>11</td>
<td>23.3 ± 2.9</td>
<td>158.0 ± 3.4</td>
<td>51.1 ± 3.2</td>
<td>35.2 ± 2.3</td>
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<tr>
<td>DR</td>
<td>15</td>
<td>19.1 ± 1.0</td>
<td>160.3 ± 4.5</td>
<td>50.1 ± 6.3</td>
<td>56.5 ± 4.4</td>
</tr>
<tr>
<td>RW</td>
<td>6</td>
<td>19.2 ± 1.1</td>
<td>158.4 ± 5.7</td>
<td>50.3 ± 2.8</td>
<td>49.1 ± 3.4</td>
</tr>
</tbody>
</table>

Data are mean ± SD. UT: untrained control, DR: distance runners, RW: race walkers. * vs. UT (p < 0.01), † vs. DR (p < 0.01).

Table 2. Category-ratio scale of perceived exertion (CR-10) and original RPE.

<table>
<thead>
<tr>
<th>CR-10 scale</th>
<th>RPE scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>0.5</td>
<td>7</td>
</tr>
<tr>
<td>1</td>
<td>Very, very light</td>
</tr>
<tr>
<td>2</td>
<td>Very light</td>
</tr>
<tr>
<td>3</td>
<td>Fairly light</td>
</tr>
<tr>
<td>4</td>
<td>Somewhat hard</td>
</tr>
<tr>
<td>5</td>
<td>Hard</td>
</tr>
<tr>
<td>6</td>
<td>Very hard</td>
</tr>
<tr>
<td>7</td>
<td>Very, very strong</td>
</tr>
<tr>
<td>8</td>
<td>17</td>
</tr>
<tr>
<td>9</td>
<td>18</td>
</tr>
<tr>
<td>10</td>
<td>19</td>
</tr>
<tr>
<td>*</td>
<td>Maximal</td>
</tr>
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</table>
Table 3. Physiological and perceptual data obtained at lactate threshold (LT) and onset of blood lactate accumulation (OBLA).

<table>
<thead>
<tr>
<th>Variables</th>
<th>UT</th>
<th>DR</th>
<th>RW</th>
</tr>
</thead>
<tbody>
<tr>
<td>at LT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{O_2}$ (ml·kg$^{-1}$·min$^{-1}$)</td>
<td>19.5 ± 3.1</td>
<td>43.6 ± 4.0$^{**}$</td>
<td>34.8 ± 3.3$^{***}$</td>
</tr>
<tr>
<td>$%V_{O_2}\text{max}$ (%)</td>
<td>55.3 ± 6.0</td>
<td>77.0 ± 3.6$^{**}$</td>
<td>70.8 ± 2.3$^{***}$</td>
</tr>
<tr>
<td>HR (beats·min$^{-1}$)</td>
<td>137 ± 14.1</td>
<td>162 ± 12.3$^{**}$</td>
<td>159 ± 9.7$^{**}$</td>
</tr>
<tr>
<td>RER</td>
<td>0.95 ± 0.04</td>
<td>0.91 ± 0.02$^{**}$</td>
<td>0.89 ± 0.02$^{**}$</td>
</tr>
<tr>
<td>(La±b) (mM)</td>
<td>1.7 ± 0.6</td>
<td>1.4 ± 0.4</td>
<td>1.5 ± 0.3</td>
</tr>
<tr>
<td>RPE</td>
<td>11.2 ± 1.5</td>
<td>12.3 ± 1.6$^{*}$</td>
<td>13.0 ± 1.6$^{**}$</td>
</tr>
<tr>
<td>CR-10</td>
<td>3.2 ± 0.9</td>
<td>3.4 ± 0.8</td>
<td>3.8 ± 1.1</td>
</tr>
<tr>
<td>at OBLA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{O_2}$ (ml·kg$^{-1}$·min$^{-1}$)</td>
<td>30.6 ± 3.2</td>
<td>53.0 ± 4.0$^{**}$</td>
<td>47.5 ± 3.8$^{**}$</td>
</tr>
<tr>
<td>$%V_{O_2}\text{max}$ (%)</td>
<td>87.4 ± 8.6</td>
<td>93.7 ± 3.0$^{**}$</td>
<td>96.7 ± 4.1$^{*}$</td>
</tr>
<tr>
<td>HR (beats·min$^{-1}$)</td>
<td>180 ± 9.4</td>
<td>180 ± 3.0</td>
<td>185 ± 7.4</td>
</tr>
<tr>
<td>RER</td>
<td>1.04 ± 0.02</td>
<td>0.99 ± 0.02$^{*}$</td>
<td>0.98 ± 0.01$^{*}$</td>
</tr>
<tr>
<td>RPE</td>
<td>15.6 ± 2.1</td>
<td>16.7 ± 1.8</td>
<td>16.9 ± 1.8</td>
</tr>
<tr>
<td>CR-10</td>
<td>5.8 ± 1.5</td>
<td>7.0 ± 1.3$^{*}$</td>
<td>6.8 ± 1.6</td>
</tr>
</tbody>
</table>

Data are mean ± SD. UT: untrained control, DR: distance runners, RW: race walkers; $V_{O_2}$: oxygen uptake, HR: heart rate, RER: respiratory exchange ratio, (La±b): blood lactate concentration, CR-10: category-ratio scale of RPE, and RPE; ratings of perceived exertion. $^{*}$ vs. UT ($p < 0.05$ and $p < 0.01$), and $^{*}$ vs. DR ($p < 0.01$), respectively.
Figure 1
Figure 2
Race Walkers (RW)
Distance Runners (DR)
Untrained (UT)

![Graphs showing data for Race Walkers (RW), Distance Runners (DR), and Untrained (UT).](image)

- **RPE (Score)**
  - DR: \( y = 0.14 e^{0.19x}, r^2 = 0.99 \)
  - RW: \( y = 0.13 e^{0.19x}, r^2 = 0.97 \)
  - UT: \( y = 0.38 e^{0.15x}, r^2 = 0.97 \)

- **CR-10 (Score)**
  - DR: \( y = 0.20x + 0.55, y = 0.82x - 1.49, r^2 = 0.99 \)
  - RW: \( y = 0.10x + 0.58, y = 0.71x - 1.38, r^2 = 0.99 \)
  - UT: \( y = 0.25x + 1.09, y = 0.74x - 0.42, r^2 = 0.92 \)

**Figure 3**
Figure 4