Differential Perceived Exertion Measured Using a New Visual Analogue Scale during Pedaling and Running

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Abstract The purpose of this study was to evaluate the differential perceived exertion measured using a new set of Visual Analogue Scales (VAS) during pedaling and running. The subjects were eleven healthy males. They performed an incremental maximal test and then three 4-min stages of exercise, for both pedaling and running. During the tests, \( \dot{V}_O_2 \), \( \dot{V}_{CO_2} \), \( \dot{V}_E \), \( f \), and HR were monitored continuously. Bla and perceptual variables including VAS consisting of four scales (VAS 1–VAS 4) and Borg’s RPE were measured at the end of each stage. Although the \( \dot{V}_O_2 \) (\%\( \dot{V}_O_{2,max} \)) and HR for both pedaling and running were not significantly different, Bla in pedaling was significantly higher than that in running. A significant interaction (mode, stage) was also obtained. The VAS 1 of pedaling was significantly higher than that of running. A significant interaction in VAS 1 (mode, stage) was obtained. The VAS 2 of pedaling was significantly higher than that of running. The subjects indicated that local pain became stronger than central pain in pedaling, but they were almost equal in running. In both pedaling and running, leg pain became stronger than arm pain (VAS 3). VAS 4 showed that during running, breathing difficulty and heart pain were almost equal in perceived intensity. However, during pedaling, breathing difficulty became greater than heart pain. Thus, a new four-part visual analogue scale was found to be useful for monitoring exercise intensity. In addition, the new VAS gave us more information in relation to the differential perceived exertion reflected in the different physiological responses obtained by different exercise modes. J Physiol Anthropol 25(2): 171–177, 2006 http://www.jstage.jst.go.jp/browse/jpa2 [DOI: 10.2114/jpa2.25.171]

Keywords: ratings of perceived exertion, visual analogue scales, borg scale, exercise mode, exercise intensity

Introduction

In most situations of sports and/or physical education in Japan, one sports instructor or teacher generally teaches many students at the same time. In their management of the class, instructors should pay attention to controlling the exercise intensity in order to get a higher effect physiologically but with a low risk of accidents such as sudden death. From this point of view, it is better to monitor the physiological responses of all students during the exercise.

Borg’s Ratings of Perceived Exertion (RPE) has provided a gauge of impending fatigue during exercise testing (ACSM, 2000; Borg, 1982; Ekblom and Goldbarg, 1971) and it has been thought that RPE is useful for regulating exercise intensity (Ceci and Hassmen, 1991; Dunbar et al., 1992; Eston et al., 1987; Glass et al., 1992; Herman et al., 2003; Kurokawa and Ueda, 1992). RPE may reflect overall feelings of exertion (RPE-O), integrated cardio-respiratory effort (RPE-C) and local muscular fatigue (RPE-L/RPE-Legs/RPE-Arms) (Ekblom and Goldbarg, 1971; Robertson and Noble, 1997; Ueda et al., 1993). Although differentiated exertional signals are measured by RPE-L, RPE-A, and RPE-C, Green et al. (2003), Hetzler et al. (1991) and Mahon et al. (1998) found that RPE-L and RPE-O were significantly greater than RPE-C around the anaerobic threshold (AT) during pedaling. Conversely, for treadmill running, Hetzler et al. (1991) and Seip et al. (1991) found no significant differences between RPE-O and differentiated RPE at 2.0, 2.5, 4.0 mmol/l blood lactate concentration (Bla) and the lactate threshold (LT). In principle, it was thought that the local factors (ratings) provide dominant sensory signals, and central factors (ratings) act as amplifiers or gain modifiers RPE-O (Caffarelli, 1982; Robertson, 1982). The difference among previous studies was thought to be the use of Borg’s RPE scale in order to evaluate the differentiated RPE, namely the differentiated RPE values obtained in each study was so close that it was difficult to understand the relations of inter-differentiated perceived exertion. Thus, it was desired that the scale for differential perceived exertion clarified the relations...
of inter-differential perceived exertion and reflected the changes of physiological responses. To overcome this problem, we made a new visual analogue scale (VAS) for use in this study. This scale used a 20 cm line with labels for the extremes at either end and tried to quantify the relative size of effort and/or pain of the bipolar perceived exertion, but not the absolute size of effort and/or pain. VAS might be originally more useful than Borg’s RPE that was constructed to be a linear relationship with exercise intensity, as the psychophysical functions were described by power functions (Borg, 1998). Thus, VAS has often been used in clinical and applied settings to find perceived exertion and is useful for investigating the relative contribution of each aspect of differentiated perceived exertion in order to decide the overall perceived exertion. The purpose of this study was to evaluate the differential perceived exertion using this new VAS during pedaling and running. Another purpose was to evaluate whether or not it was possible to obtain the relative contributions of differentiated perceived exertion correspond to the exercise modes and exercise intensities.

**Methods**

**Subjects**

Eleven healthy males volunteered to participate in this study. Written informed consent was obtained from all the subjects. The subjects performed two different tests. In test 1, the subjects performed an incremental maximal test on a cycle ergometer and on a treadmill to determine their $V_{O2\text{ max}}$ in both pedaling and running. The two maximal exercise tests were administered about one week apart. The order of the two tests was randomly assigned to the subjects. Table 1 shows the means of their ages, heights, weights and $V_{O2\text{ max}}$ in both pedaling and running.

<table>
<thead>
<tr>
<th>n=11</th>
<th>age (yrs)</th>
<th>height (cm)</th>
<th>weight (kg)</th>
<th>$V_{O2\text{ max}}$ (ml/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>pedaling</td>
</tr>
<tr>
<td>mean</td>
<td>26.2</td>
<td>172.1</td>
<td>68.5</td>
<td>3415.6</td>
</tr>
<tr>
<td>SD</td>
<td>6.8</td>
<td>6.2</td>
<td>9.1</td>
<td>439.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>running</td>
</tr>
<tr>
<td>mean</td>
<td>27.0</td>
<td>180.5</td>
<td>75.0</td>
<td>3720.1</td>
</tr>
<tr>
<td>SD</td>
<td>6.2</td>
<td>7.1</td>
<td>8.0</td>
<td>472.3</td>
</tr>
</tbody>
</table>

Another purpose was to evaluate whether or not it was possible to obtain the relative contributions of differentiated perceived exertion correspond to the exercise modes and exercise intensities.

**Experimental Protocols**

**Test 1**

In one trial, following 3 minutes’ rest and a 3-min warm-up, the subjects performed an exhaustion test on the treadmill (WOODWAY™, ELG-2) or the cycle ergometer (BODY GUARD™, Ergometer 990). Using an electric metronome, the pedaling rate was kept at 60 rpm on the cycle ergometer. The first exercise intensity value was 540 kpm/min and this was increased in increments of 90 or 180 kpm/min, depending on the fitness of the subjects. In the treadmill test, the first running speeds were 100, 120 or 140 m/min, depending on the fitness of the subjects and the speed was increased by 10 or 20 m/min, depending on the fitness of the subjects. The treadmill grade was kept at 3% throughout the trial. $V_{O2\text{ max}}$ was almost equal in both exercise modes and not significantly different.

**Test 2**

After determining the $V_{O2\text{ max}}$, each subject performed test 2. Test 2 was administered about one week apart from test 1. In test 2, the subjects rested for three minutes and then performed three 4-min stages of exercise, for both pedaling and running. The exercise intensities (%$V_{O2\text{ max}}$) corresponded to 46.7±6.8 %$V_{O2\text{ max}}$ for pedaling and 52.9±5.6%$V_{O2\text{ max}}$ for running in the 1st stage, 60.2±7.3%$V_{O2\text{ max}}$ and 63.3±5.8%$V_{O2\text{ max}}$ in the 2nd stage, and 73.6±8.7%$V_{O2\text{ max}}$ and 75.0±9.3%$V_{O2\text{ max}}$ in the 3rd stage and were not significantly different.

**Measurements**

The subjects breathed through a mask connected via 1.0 m of flexible tubing to a turbine flowmeter. Expired gas was continuously sampled by a mass spectrometer (WESTRON, WSMR-1400) and a respiromonitor (MINATO, RM-300i), and the analysis was performed breath-by-breath using a personal computer (NEC, PC9801BX). Gas-exchange data were analyzed continually during the tests. Each set of data was averaged and printed every 30 sec. and included oxygen uptake ($V_{O2}$, l/min), carbon dioxide output ($V_{CO2}$, l/min), pulmonary ventilation ($V_{E}$, l/min), breathing frequency (f, breaths/min), tidal volume (TV, ml/min), and heart rate (HR, beats/min). Blood samples were taken from the earlobe immediately after each stage and Bla was measured (Lactate Pro™, ARKRAY).

Perceptual variables including the new VAS and a Japanese translation (20) of the original RPE (2) were asked at the end of each stage. The new VAS consisted of four scales consisting of a 20 cm line with labels for the extremes at either end. The first (VAS 1: Fig. 1) asked “How hard is your exertion?” and subjects marked their overall levels of perceived exertion on a line from 0% to 100%. The second scale (VAS 2: Fig. 2) asked “Please indicate which is stronger, central pain or local pain” and subjects marked the relative magnitude of their central pain or local pain on the line. Central pain refers to breathing difficulty and heart pain. Local pain refers to arm pain and leg pain. The third scale (VAS 3: Fig. 3) asked “Please indicate which is stronger, arm pain or leg pain” and subjects marked the relative magnitude of arm pain or leg pain on the line. The fourth (VAS 4: Fig. 4) asked “Please indicate which is greater, breathing difficulty or heart pain” and subjects marked the relative levels of breathing difficulty or heart pain on the line.

**Statistical treatments**

Means and standard deviations were determined for all data. Data analysis in relation with %$V_{O2\text{ max}}$ was carried out. The statistical treatment used one-way ANOVA in test 1 and two-way repeated measures of ANOVA in test 2. Linear regression analysis was used for calculating correlation coefficients. In all
Results

Tables 2 and 3 show the physiological variables at rest (Table 2) and during exercise (Table 3) for both pedaling and running. Although the $V_i_e$ for both running and pedaling were almost equal, the $f$ in running was significantly higher than during pedaling ($F1,44=52.741, p<0.01$). TV showed an inverse relationship with $f$ in that TV was significantly higher for pedaling than for running ($F1,44=38.370, p<0.05$). In Bla a significant interaction (mode, stage) was also obtained ($F2,44=3.652, p<0.05$). Figure 5 shows the relationship of Borg’s RPE related with $V_i_o$. Pedaling RPE was significantly higher than running RPE ($F1,40=15.012, p<0.01$). Figures 6 to 9 show the relationships of VAS 1 to VAS 4 related with $\%V_o_{max}$. The VAS 1 of pedaling was significantly higher than that of running ($F1,44=12.856, p<0.01$). A significant interaction in VAS 1 (mode, stage) was obtained ($F2,44=4.807, p<0.05$). VAS 2 measured the relative strength of central pain and local pain. The VAS 2 of pedaling was significantly higher than that of running ($F1,44=9.660, p<0.01$). VAS 3 measured the relative strength of arm pain and leg pain. In both pedaling and running, leg pain became stronger than arm pain. However, the ratio was significantly higher in pedaling than in running ($F1,40=10.859, p<0.01$). VAS 4 measured the relative intensity of breathing difficulty and heart pain. It showed that during running, breathing difficulty and heart pain were almost equal in perceived intensity. However, during pedaling, breathing difficulty became greater than heart pain as the intensity increased.

Table 4 shows the correlation coefficients between physiological variables including $V_i_o$, $V_i_o/wt$, HR and Bla and perceived exertion including Borg’s RPE and VAS 1 used in this study for both pedaling and running. Correlation coefficients were almost equal for both pedaling and running.

Discussion

In this study, the correlation coefficients of VAS 1 with physiological variables were equivalent to those of Borg’s RPE (Table 4). VAS 1 gave similar results to those using Borg’s RPE, in that perceived exertion increased linearly with exercise intensity, with the VAS 1 of pedaling being significantly higher than that of running. This agreed with previous studies (Borg, 1973; Neely et al., 1992). VAS 1 might be better than Borg’s RPE regarding the psychophysical description of perceived exertion (Borg, 1998). Thus, it is suggested that the new VAS 1 would be as good an indicator as Borg’s RPE to evaluate the overall perceived exertion.

In relation to the exercise intensities at each stage during pedaling and running, the $V_i_o$. ($\%V_o_{max}$) and HR for both pedaling and running were not significantly different. The Bla in pedaling, however, was significantly higher than that in running and a significant interaction was also obtained. The Bla value under 0.8 mmol/l was given as “LOW” instead of the actual numerical value as a result of the limitations of the instrument used in this study. These values were therefore removed from our calculations, raising the value of the Bla results. It was inferred from the Bla that the exercise intensity of the 1st stage ($2.9\pm1.3$ mmol/l) was under the VT, in the 2nd stage ($4.8\pm2.7$ mmol/l) it was just around VT and in the 3rd stage ($6.6\pm3.8$ mmol/l) it was over VT for pedaling. In running, it seems that the exercise intensities of the 1st stage ($2.2\pm0.5$ mmol/l) and 2nd stage ($2.7\pm0.5$ mmol/l) were under VT and the exercise intensity of 3rd stage ($3.3\pm0.9$ mmol/l) was around VT. Regarding the RPE, it was $11.5\pm1.1$ in the 1st stage, $13.2\pm1.7$ in the 2nd stage and $14.9\pm2.2$ in the 3rd stage in pedaling and $9.8\pm1.6$ in the 1st stage, $11.3\pm1.1$ in the 2nd stage.

![Fig. 1 Visual analog scale 1–4.](Ueda, T et al. J Physiol Anthropol, 25: 171–177, 2006)

higher than running RPE (F1,40=15.012, p<0.01). Figures 6 to 9 show the relationships of VAS 1 to VAS 4 related with $\%V_o_{max}$. The VAS 1 of pedaling was significantly higher than that of running ($F1,44=12.856, p<0.01$). A significant interaction in VAS 1 (mode, stage) was obtained ($F2,44=4.807, p<0.05$). VAS 2 measured the relative strength of central pain and local pain. The VAS 2 of pedaling was significantly higher than that of running ($F1,44=9.660, p<0.01$). VAS 3 measured the relative strength of arm pain and leg pain. In both pedaling and running, leg pain became stronger than arm pain. However, the ratio was significantly higher in pedaling than in running ($F1,40=10.859, p<0.01$). VAS 4 measured the relative intensity of breathing difficulty and heart pain. It showed that during running, breathing difficulty and heart pain were almost equal in perceived intensity. However, during pedaling, breathing difficulty became greater than heart pain as the intensity increased.

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![Fig. 1 Visual analog scale 1–4.](Ueda, T et al. J Physiol Anthropol, 25: 171–177, 2006)
Boutcher et al. (1989) observed that RPE at LT were from 9.0 to 10.6 in pedaling and from 10.4 to 12.0 during running for males. Purvis and Cureton (1981) reported that RPE at the ventilatory threshold (VT) was 14.2 for males during pedaling. Mahon et al. (1998) showed that RPE at VT was 11.5 during pedaling for adults. Thus, it could be said that our speculations regarding the exercise intensities at each stage from viewpoint of Bla and RPE are not so far from the previous studies (Boutcher et al., 1989; Mahon et al., 1998; Purvis and Cureton, 1981).

Both VAS 1 and Borg’s RPE could evaluate the differentiated perceived exertion. The evaluations for differentiated perceived exertion using Borg’s RPE, however, would obtain close values at certain exercise intensities. It might be difficult to use Borg’s RPE to distinguish the relative relationships of differentiated perceived exertion (Ueda et al., 1993). From this point of view, the use of the new VAS was a more practical way to clarify these relationships. That is, the idea of the new VAS was that the subjects were always asked to judge the relative contributions in relation to the opposite (or the pair) in differentiated perceived exertion such as central pain or local pain, breathing difficulty or heart pain, and leg pain or arm pain.

In relation to differentiated perceived exertion, from the results using VAS 2, the subjects indicated that local pain became stronger than central pain in pedaling. On the other hand, local pain was almost equal to central pain during running. Mahon et al. (1998) and Green et al. (2003) found that RPE-L was significantly greater than RPE-C at the VT during pedaling. Hetzler et al. (1991) showed that RPE-L was significantly greater than RPE-C throughout an incremental cycling test and that RPE-L was not significantly greater than RPE-C at 2.0 and 4.0 mmol/l Bla during treadmill running.
While various factors showed a strong correlation with perceptual responses, RPE estimations are based on the integration of numerous cues rather than any single cue (Pandolf, 1982). Robertson et al. (1986) provided strong evidence that metabolic acidosis signals local RPE. However, it was noted that the contribution was likely to be minimal prior to LT or at the point where significant acid-base shifts occur. So, RPE-C is closely associated with $\dot{V}_E$, $\dot{V}_O_2$, HR, and $f$ (Robertson, 1982). However, RPE-O is thought to represent the integration of central and local cues (Pandolf, 1982; Robertson et al., 1979). Cafarelli (1977) has demonstrated that local factors (ratings) provide primary sensory signals, and central factors (ratings) act as amplifiers or gain modifiers. Logically, then, RPE-O should mirror changes in central and local RPE and the complete uncoupling of overall and differentiated RPE

![Table 3 Means and standard deviations of physiological variables for both pedaling and running](image)

<table>
<thead>
<tr>
<th>Item</th>
<th>Exercise mode</th>
<th>1st stage</th>
<th>2nd stage</th>
<th>3rd stage</th>
<th>Main effect</th>
<th>Interaction</th>
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<tr>
<td>$\dot{V}_O_2$ (ml/min)</td>
<td>pedaling</td>
<td>1582</td>
<td>2045</td>
<td>2498</td>
<td>ns</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>running</td>
<td>1722</td>
<td>2061</td>
<td>2436</td>
<td>ns</td>
<td>381</td>
</tr>
<tr>
<td>$\dot{V}_O_2$/wt (ml/kg/min)</td>
<td>pedaling</td>
<td>23.3</td>
<td>30.1</td>
<td>36.7</td>
<td>ns</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>running</td>
<td>25.2</td>
<td>30.1</td>
<td>35.5</td>
<td>ns</td>
<td>2.2</td>
</tr>
<tr>
<td>$\dot{V}_E$ (l/min)</td>
<td>pedaling</td>
<td>42.1</td>
<td>53.1</td>
<td>65.6</td>
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<td>ns</td>
</tr>
<tr>
<td></td>
<td>running</td>
<td>42.1</td>
<td>53.1</td>
<td>65.6</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>$f$ (breaths/min)</td>
<td>pedaling</td>
<td>28.8</td>
<td>33.7</td>
<td>38.7</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td></td>
<td>running</td>
<td>50.9</td>
<td>52.7</td>
<td>57.6</td>
<td>ns</td>
<td>11.5</td>
</tr>
<tr>
<td>TV (ml/min)</td>
<td>pedaling</td>
<td>1491.0</td>
<td>1744.0</td>
<td>1995.0</td>
<td>**</td>
<td>**</td>
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<tr>
<td></td>
<td>running</td>
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<td>1051.0</td>
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<td>ns</td>
<td>218.0</td>
</tr>
<tr>
<td>$\dot{V}_C0_2$ (ml/min)</td>
<td>pedaling</td>
<td>1591</td>
<td>2173</td>
<td>2681</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td></td>
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<td>1535</td>
<td>245</td>
<td>2394</td>
<td>ns</td>
<td>385</td>
</tr>
<tr>
<td>HR (beats/min)</td>
<td>pedaling</td>
<td>123.0</td>
<td>145.4</td>
<td>162.7</td>
<td>ns</td>
<td>14.5</td>
</tr>
<tr>
<td></td>
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<td>122.3</td>
<td>159.2</td>
<td>155.4</td>
<td>ns</td>
<td>11.2</td>
</tr>
<tr>
<td>Bla (mmol)</td>
<td>pedaling</td>
<td>2.9</td>
<td>4.8</td>
<td>6.6</td>
<td>ns</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
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<td>2.2</td>
<td>2.7</td>
<td>3.3</td>
<td>ns</td>
<td>0.9</td>
</tr>
</tbody>
</table>

** $p<0.01$, * $p<0.05$

![Fig. 5 Relationships between %$\dot{V}_O_2$max and VAS 3 for both pedaling and running.](image)

![Fig. 6 Relationships between %$\dot{V}_O_2$max and VAS 4 for both pedaling and running.](image)

![Table 4 Correlation coefficients between physiological variables and perceived exertion](image)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pedaling</th>
<th>Running</th>
</tr>
</thead>
<tbody>
<tr>
<td>Borg's RPE</td>
<td>0.829</td>
<td>0.576</td>
</tr>
<tr>
<td>VAS 1</td>
<td>0.828</td>
<td>0.649</td>
</tr>
<tr>
<td>Borg's RPE</td>
<td>0.859</td>
<td>0.608</td>
</tr>
<tr>
<td>VAS 1</td>
<td>0.843</td>
<td>0.678</td>
</tr>
<tr>
<td>HR (beats/min)</td>
<td>0.808</td>
<td>0.505</td>
</tr>
<tr>
<td>VAS 1</td>
<td>0.778</td>
<td>0.595</td>
</tr>
<tr>
<td>Bla (mmol)</td>
<td>0.886</td>
<td>0.767</td>
</tr>
<tr>
<td>VAS 1</td>
<td>0.888</td>
<td>0.647</td>
</tr>
</tbody>
</table>

Pedaling: Borg's RPE = 0.465 * VAS 1 + 8.501 (r=0.912)
Running: Borg's RPE = 0.341 * VAS 1 + 9.105 (r=0.689)
responses is unlikely. In this study, the subjects were required
to decide the relative magnitude on the relation between central
and local pain in VAS 2. Since the physical summation and
absolute burden on the lower limbs were compared between
running and pedaling, they might be stronger during running
than during pedaling, because the subjects have to support
their own body weight during running. However, during
pedaling the subjects mainly exerted their lower limbs,
especially the thigh muscle group. As the ratio of local pain
increased during pedaling, the ratio of central pain decreased
correspondingly. In this mean, the subjects might evaluate
local pain as stronger than central pain in pedaling, but they
were almost equal in running, with regard to the exercise
intensities (50–80% V̇O₂max) in the present study.

The question was whether the new VAS reflected the results
obtained in this study or not. Bla in pedaling became higher
than that in running and leg pain became stronger in pedaling
than that in running. Moreover, breathing difficulty was greater
than heart pain at higher exercise intensities obtained with
higher V̇E and TV and with lower f in pedaling. Robertson et
al. (1986) has shown that the differentiated RPE-C was
attenuated under induced alkalosis, associated with a reduction
in V̇E primarily through f and occurred only at work loads
above the lactate threshold (Robertson, 1982; Robertson et al.,
1986). TV was not affected by bicarbonate ingestion during
continuous exercise (Robertson et al., 1986). On the other
hand, Swank and Robertson (1989) showed that RPE-C was
attenuated during induced alkalosis irrespective of the dose
schedule of bicarbonate but was not related to attenuation in
V̇E or f. At rest, ventilatory function is controlled by central
and peripheral mechanoreceptors in the chest wall and lungs
(Robertson, 1982). These sensory receptors responded to
changes in lung volume, lung pressure, and respiratory muscle
tension that are the primary determinants of TV (Wolkove et
al., 1981). Wolkove et al. (1981) reported that transmission
signals from the mechanoreceptors of the lungs to the sensor
motor cortex (feedback mechanism) are consciously monitored,
when TV exceeds 700 ml. Respiratory mechanoreceptors that
regulate TV would appear to provide potent signals to the
effort sense, when V̇E is elevated in response to increased
metabolic rates during exercise (Robertson, 1982). The present
study did not manipulate V̇E and the physiological meanings of
exercise intensities for both pedaling and running were
different. It was thought that the differentiated perceived
exertion measured using the new VAS reflected the relative
relations of the differentiated perceived exertion corresponding
to physiological changes at certain exercise intensities.

In conclusion, the new VAS was found to be useful for
monitoring exercise intensity. It can provide us more
information in relation to the differentiated perceived exertion
at moderate exercise intensity ranging from 50 to 80% V̇O₂max.
When more detailed information about the differentiated
perceived exertion for certain exercise modes and intensities is
needed, this new VAS is a useful index.

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