Suitability of modified tandem-bicycle ergometer for the improvement of physical fitness and athletic performance

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\textbf{Abstract} In the present study, a tandem-bicycle ergometer was developed, because it is believed that such an ergometer can be used to eliminate differences in signaling between single- and tandem-exercise in cardiorespiratory responses, and is able to quantify interdependence in one load. It is necessary to verify whether cardiorespiratory responses to submaximal exercise are the same between single and tandem-bicycle ergometers. Accordingly, we compared cardiorespiratory variables during exercise in three conditions: 1) with a general bicycle single saddle using a general bicycle ergometer, 2) with a tandem bicycle front saddle using a tandem ergometer, and 3) with a tandem bicycle rear saddle using a tandem ergometer. Eleven healthy males participated in this study. The subjects exercised for 15 min at three intensities (1.5, 2.0 and 2.5 kp) in each condition. The pedaling rate was constantly kept at 60 rpm. Heart rate (HR), oxygen uptake (\(\text{VO}_2\)), and the rating of perceived exertion (RPE) were measured during the last minute of each intensity. There were no significant differences in the variables HR, \(\text{VO}_2\), and RPE at each load among the three conditions. The ranges of coefficient of variation (CV) values were 3.0 - 4.8\%: HR and 4.2 - 5.1\%: \(\text{VO}_2\). It was reported that between-day CV for HR and \(\text{VO}_2\) during treadmill running was 1.0 - 10.7\% and 1.9 - 11.6\%. Given these CV values of present and previous studies, it can be seen that physiological response is stable during developed tandem-bicycle ergometer exercise. These results suggest that cardiorespiratory responses to exercise are at comparable levels between a normal bicycle ergometer and the newly developed tandem-bicycle ergometer.

\textbf{Keywords} : tandem-bicycle ergometer, heart rate, oxygen uptake, coefficient of variations, rating of perceived exertion

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**Introduction**

A bicycle ergometer has been utilized to more precisely determine physiological responses during exercise at different intensities, and, as a result, find new ways to improve aerobic capacity. We developed the tandem-bicycle ergometer (Fig. 1). To our knowledge, this is the first ergometer developed specifically for tandem bicycle use. It has three characteristics, a new design, tandem sharing of one load, and pist type braking. Another important characteristic of this newly designed ergometer is that a load device exists between the front and rear crankshafts. We assume that this tandem bicycle ergometer will be a useful instrument in the field of sports, welfare and athletic rehabilitation.

Previous studies have reported changes in heart rate (HR) and oxygen uptake ($\dot{V}O_2$) during cycling exercise on a single bicycle ergometer\(^1\)\(^-\)\(^7\). However, the changes have never been examined in HR and $\dot{V}O_2$ during tandem bicycle ergometer exercise. We believe that the tandem-bicycle ergometer can be used to eliminate differences in signaling between single- and tandem-exercise in cardiorespiratory responses, and is able to quantify interdependence in one load. Here, it is necessary to verify whether cardiorespiratory responses to submaximal exercise are the same between single and tandem-bicycle ergometers. As an initial approach to elucidate this, we compared cardiorespiratory variables during exercise in three conditions: 1) with a general bicycle single saddle (SIN) using a general bicycle ergometer, 2) with a tandem bicycle front saddle (FRO) using a tandem ergometer, and 3) with a tandem bicycle rear saddle (REA) using a tandem ergometer.

**Methods**

Eleven healthy males (age: 21.0 ± 1.1 years, height: 170.0 ± 4.7 cm, body mass: 64.6 ± 3.1 kg, peak oxygen uptake: 48.4 ± 2.2 ml·kg⁻¹·min⁻¹, mean ± SD) participated in this study. All procedures were approved by the Ethics Committee of the Kawasaki University of Medical Welfare and conformed to the Declaration of Helsinki (#306).

The experiments in each condition were performed at the same time on different days. The subjects exercised individually for 15 min at the three intensities (1.5, 2.0 and 2.5 kp) in each condition (SIN, FRO and REA; 5 min each). Subjects were randomly assigned to each condition. The pedaling rate was constantly kept at 60 rpm with the aid of a metronome.

HR, $\dot{V}O_2$, and the rating of perceived exertion (RPE) were measured during the last minute of each intensity. Expired gases were collected into a Douglas bag. Gas fractions were analyzed by a mass spectrometer (ARCO-2000; Arco System) that was calibrated and confirmed before each test. The expired gas volume was measured with a certified dry gas meter (DC-5; Shinagawa). RPE was counted with the Borg scale\(^8\).

The coefficient of variation (CV) for the variables among SIN, FRO and REA conditions was calculated. In addition, one-way ANOVA was used to compare continuous variables among the three conditions at each load.

**Results and Discussion**

Table 1 shows mean values of HR, $\dot{V}O_2$, and RPE during each load. There were no significant differences in the variables among the three conditions.

The present study indicated that there were no significant differences in HR and $\dot{V}O_2$, and among the three conditions and ranges of CV, the values were 3.0 - 4.8% and 4.2 - 5.1%. It was reported that between-day CV for HR and $\dot{V}O_2$ during treadmill running was 1.0 - 10.7% and 1.9 - 11.6%\(^9\). Other studies showed that the within-subject variation for maximum oxygen uptake during treadmill running was 3.8 - 8.3%\(^10\). Given these CV values of present and previous studies, it was found that physiological response is stable during tandem-bicycle ergometer exercise regardless of the position where the subject sits (front or rear), suggesting that the tandem-bicycle ergometer is applicable to experiments of physiological response during cycling exercise. Nonetheless, future studies will be needed to determine cardiorespiratory responses when two subjects simultaneously pedal a tandem-bicycle ergometer and share a single load.

In this study, there were no significant differences in $\dot{V}O_2$ and HR among the three conditions, and the range of CV was 4.2 - 5.1% for $\dot{V}O_2$ and 3.0 - 4.8% for HR. These are in agreement with results found in previous studies. It could be considered that the CV for RPE was higher than the CV for both $\dot{V}O_2$ and HR. However, there was little change in the index of RPE when scaled up and down. Accordingly, this may be due to the wide distribution of RPE rather than physiological indexes during exercise. Thus, it is clear that the tandem-bicycle ergometer has the same function as a general bicycle ergometer.
Conclusion

These results suggest that cardiorespiratory responses to exercise are at comparable levels between a general bicycle ergometer and the newly developed tandem bicycle ergometer.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this article.

Acknowledgments

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References


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<th>Load(kg)</th>
<th>SIN</th>
<th>FRO</th>
<th>REA</th>
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<tr>
<td>1.5</td>
<td>111.2 ± 9.3</td>
<td>113.3 ± 6.9</td>
<td>112.7 ± 8.6</td>
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<td>2.0</td>
<td>129.9 ± 7.9</td>
<td>132.5 ± 7.6</td>
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<tr>
<td>2.5</td>
<td>148.7 ± 11.1</td>
<td>152.3 ± 8.3</td>
<td>151.1 ± 7.1</td>
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<tr>
<td>1.5</td>
<td>19.1 ± 1.3</td>
<td>19.8 ± 1.5</td>
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<tr>
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<td>25.1 ± 2.2</td>
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<td>13.1 ± 1.5</td>
<td>12.8 ± 1.4</td>
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</table>

All data are expressed as means ± standard deviations (SD).
SIN: single saddle condition, FRO: front saddle condition and REA: rear saddle condition.