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Original Paper

Comparison of the Heart Rate and %$\dot{V}O_2$peak between the Front and the Rear Rider in a 2-hour Endurance Tandem-bicycle Ride

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Key words: tandem-bicycle, relative exercise intensity, heart rate, %$\dot{V}O_2$peak

Abstract

The purpose of this study was to prove that in tandem bicycles the front rider has more physiological stress than the rear rider. Twelve healthy Japanese adult males (front riders (n=6) and rear riders (n=6)) participated in a two-hour endurance race held at OKAYAMA International Circuit (3.7km around). The course was divided into three roads by undulation, that is, the horizontal road (A), the uphill road (B) and the downhill road (C). Measurement items were heart rate and %$\dot{V}O_2$max measured during each of the three road conditions. Urinary catecholamine corrected by creatinine was measured before and after the riding. %$\dot{V}O_2$peak was the comparison of the difference in the relative physiological stresses between the uphill road and downhill road; those in the front riders were significantly greater than those in the rear riders ($p < 0.05$). These results indicate that the %$\dot{V}O_2$peak of the front rider is greater than that of the rear rider during uphill roads. These differences are caused by handle, brake and gear operations and wind pressure. The relative exercise intensity of the front rider was higher than that of the rear rider when divided as per uphill and downhill cycling during the 2-hour tandem-bicycle ride.

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1. Introduction

A tandem bicycle is a two-person bicycle in which the front and rear riders work together to propel the bicycle[1]. As per research, the exercise intensity for the front rider during tandem-bicycle exercise is larger than that for the rear rider[2,3,6-8]. We have studied the changes in the relative exercise intensity in a 2-hour[2,3], 3-hour[6], and 5-hour[7] endurance tandem-bicycle ride. These studies suggested that even if the time becomes long the physiological stress shown for the front and rear rider measure out the same.

In the present study, experiments were conducted with multiple subjects so that statistical results could be obtained. The novelty of this study is to prove the present hypothesis from statistical analysis. We used OKAYAMA International Circuit because its motorsport race track has a horizontal road, uphill road and downhill road. And, OKAYAMA International Circuit had the conditions to achieve the aim of this study. Furthermore, we chose the motorsport race track (OKAYAMA International Circuit) for safety and the avoidance of accident risk. We studied the changes in heart rate, $\%\dot{V}O_2$max and urinary catecholamine during the two hour endurance tandem-bicycle ride, which covered the horizontal, uphill and downhill roads. We hypothesized that in tandem bicycles, the front rider has more $\%\dot{V}O_2$peak than the rear rider. The purpose of this study was to prove this hypothesis.

2. Methods

Twelve healthy Japanese adult males (front riders (n=6): age, 25 ± 5 years, height, 172.3 ± 5.3 cm; body weight, 66.6 ± 6.7 kg; and peak oxygen uptake, 44.9 ± 5.0 ml/kg/min and rear riders (n=6): age, 25 ± 5 years; height, 170.8 ± 6.9 cm; body weight, 77.0 ± 13.9 kg; and peak oxygen uptake, 45.4 ± 6.5 ml/kg/min) participated in a two-hour endurance race held at OKAYAMA International Circuit (3.7km around). For the sample size, 6-7 tandem riders were selected by substituting the following factors: $\Delta = 1$ (effect size), $1-\beta = 0.8$ (detection power), d = 0.05 (significance level). Regarding the two groups of front riders and rear riders, the chosen age and peak oxygen uptake of the combinations of the six pairs was agreed to before the test. This study was approved by the Ethics Committee of Kawasaki University of Medical Welfare (#306) and conformed to the Declaration of Helsinki.

The course was laid out into three different roads by altitude difference, that is, the horizontal road (A), the uphill road (B) and the downhill road (C) (Figure 1, Okayama Prefecture Japan)[5]. The place information was detected by GPS (Global Positioning System). During the ride, heart rate was measured by using a heart rate monitor (M400; POLAR, Sweden), and $\%\dot{V}O_2$max was measured after each complete circuit. Subjects had a short rest (seven min.) after three laps. Individual $\%\dot{V}O_2$peak was evaluated by the pre-determined HR- $\dot{V}O_2$ relationship for each subject. There is a linear relationship between heart rate and $\%\dot{V}O_2$. Therefore, we measured the linear relationship using the bicycle ergo for each person in advance. $\%\dot{V}O_2$peak was calculated by peak oxygen uptake and average heart rate of one lap. Urinary catecholamine corrected by creatinine (adrenalin, noradrenalin and dopamine; creatinine correction) was measured before and after the ride. We measured urinary catecholamine using the HPLC method (High Performance Liquid Chromatography method). The data was analyzed by SPSS ver. 12.0 for Mac. All the obtained data are expressed by means and standard deviations. An unpaired t-test was used to test the difference between each of the data, and the significance level was less than 5%.

3. Results

Each pair cycled 12 laps around a 3.7-km track for 2 hours. The average speed was 27.0 km/h ± 2.8 for each lap. The average lap time of the 12 laps remained in the range of 8'06 min.' sec ± 0'52 of one track.

Table 1 shows the average heart rate (mean ± SD) of the front and the rear riders (each pair of six) on the horizontal, uphill and downhill road. The average heart rate of the front riders and the rear riders (each pair of six) on the horizontal road were front; 167.3 bpm ± 12.0, rear; 148.0 bpm ± 24.8. The average heart rate of the front riders and the rear riders (each pair of six) on the uphill road were front; 164.3 bpm ± 16.1,

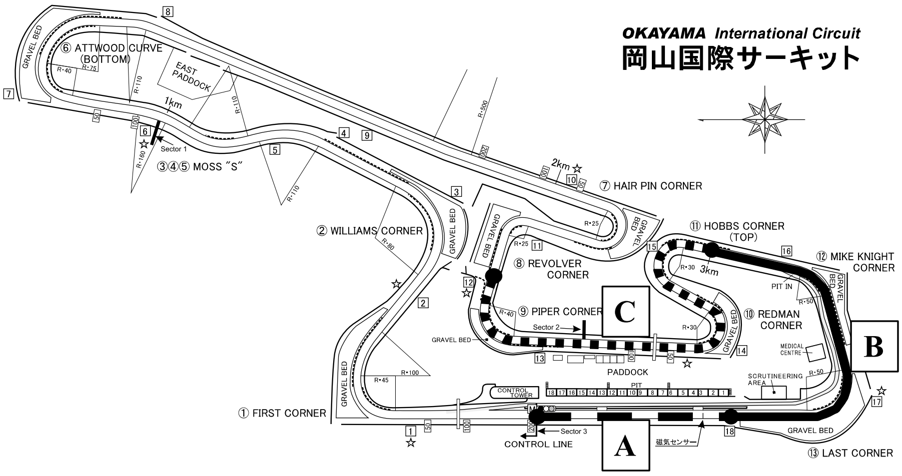

Figure 1 Race circuits[5)]

A : Horizontal part
B : Uphill part
C : Downhill part

Table 1 Comparison of heart rate between front and rear rider

	Horizontal part	Uphill part	Downhill part
Front rider	167.3 ± 12.0	164.3 ± 16.1	158.4 ± 13.7
Rear rider	148.0 ± 24.8	148.3 ± 24.2	143.1 ± 27.0

(bpm) (mean ± SD)

Uphill part vs. Downhill part *$p<0.05$

rear; 148.3 bpm ± 24.2. The average heart rate on the downhill road were front; 158.4 bpm ± 13.7, rear; 143.1 bpm ± 27.0.

Table 2 shows the average %$\dot{V}O_2$peak (mean ± SD) of the front and the rear riders (each pair of six) on the horizontal road, uphill and downhill road. The average %$\dot{V}O_2$peak of the front riders and the rear riders (each pair of six) on the horizontal road were front; 69.4 % ± 8.2, rear; 57.8 % ± 16.2. The average %$\dot{V}O_2$peak of the front riders and the rear riders (each pair of six) on the uphill road were front; 66.5 % ± 12.9, rear; 56.7 % ± 20.8 ($p<0.05$). The average %$\dot{V}O_2$peak on the downhill road were front; 60.1 % ± 12.9, rear; 52.1 % ± 20.4($p<0.05$). Table 2 shows the comparison of the difference in %$\dot{V}O_2$peak between the uphill road and downhill road; those in the front riders were significantly greater than those in the rear riders ($p < 0.05$).

Table 2 Comparison of %$\dot{V}O_2$peak between front and rear rider

	Horizontal part	Uphill part	Downhill part
Front rider	69.4 ± 8.2	66.5 ± 12.9 †	60.1 ± 12.9 †
Rear rider	57.8 ± 16.2	56.7 ± 20.8	52.1 ± 20.4

(%) (mean ± SD)

Front rider vs. Rear rider †$p<0.05$

Table 3 shows urinary adrenalin, urinary noradrenalin and urinary dopamine of the front and the rear riders; compared before and after. Rate of increase of front riders from before to after: urinary adrenalin; 240%, urinary noradrenalin; 198% and urinary dopamine; 100%, and the rear riders: urinary adrenalin; 152%, urinary noradrenalin; 138% and urinary dopamine; 107%. Rate of increase of urinary adrenalin and urinary noradrenalin was higher when compared with that of rear riders. However, there was no-significant difference.

Table 3 Comparison of catecholamines pre and post tandem bicycle riding between front and rear rider

	Adrenaline		Noradrenalin		Dopamine	
	pre	post	pre	post	pre	post
Front rider	10.4 ± 4.6	24.9 ± 7.8	73.6 ± 13.9	145.9 ± 13.3	444.0 ± 70.8	466.0 ± 95.8
Rear rider	15.2 ± 7.1	23.1 ± 11.4	89.7 ± 37.7	124.2 ± 47.9	379.6 ± 71.8	404.3 ± 88.7

(ng/mgCr) (mean ± SD)

4. Discussion

The hypothesis of this study was proved by statistical analysis. We have studied the changes in the relative exercise intensity in a 2-hour[2,3], 3-hour[6], and 5-hour[7] endurance tandem-bicycle ride. During the 2-hour[2,3] endurance tandem-bicycle ride the relative exercise intensity of the subject in the front was higher than that of the rear rider. During the 3-hour[6] endurance tandem-bicycle ride, the relative exercise intensity of the rear rider was as high as that of the front rider. During the 5-hour endurance tandem-bicycle ride these results supported the study speculation[7]. The physiological stress of the front and rear riders appeared to be the same after the 3-hour tandem bicycle ride.

As for the body weight of the subjects, a tandem bicycle is one load when the weights of two people are combined. Therefore, a tandem bicycle rider does not have a separate load. The subject's body weight affects physiological responses such as heart rate and oxygen uptake. In order to eliminate this effect, it is converted to oxygen uptake per body weight so that it does not affect the body weight.

In the front rider, the values of the difference in relative $\%\dot{V}O_2$peak and heart rate were significantly higher than those for the rear riders during the uphill and downhill rides. There is a proportional relationship between changes in heart rate and oxygen uptake. The relational expression between heart rate and oxygen uptake was calculated using the proportional relation. $\%\dot{V}O_2$peak/kg was calculated by substituting the heart rate during exercise into the proportional relation formula. Heart rate is an absolute value. On the other hand, $\%\dot{V}O_2$peak/kg is a relative value. From these, relationships are clarified by comparing relative values. Therefore, it might not match between the heart rate and the $\%\dot{V}O_2$peak/kg comparison. These tendencies were obtained from the previous study, too. The results of previous study supported the results of this study.

The rate of increase in urinary adrenalin and urinary noradrenalin showed no statistical difference between pre and post riding, with no statistical difference, and with no mental stress.

The present data support previously reported findings[2,3,6-8]. The lap order is horizontal road, uphill road, downhill road and horizontal road again. The subject's load increases when transitioning from the horizontal road to the uphill road and from the downhill road to the horizontal road. However, the subject's load decreases when transitioning from the uphill road to the downhill road. The slope was 2% for uphill road, 3% for downhill road, and 0% for horizontal road. Therefore, the cause of the significant difference is considered to be the change in slope. It was considered that the difference in front and rear rider was about seventeen percent of relative exercise intensity at uphill road, and that these differences were caused by handle, brake and gear operations and wind pressure[8,9]. In sum, these results indicate that the relative physiological stress of front riders is greater than that of rear riders during uphill rides.

5. Conclusion

The relative exercise intensity of the front rider was higher than that of the rear rider when divided as per uphill and downhill cycling during the 2-hour tandem-bicycle ride.

Conflicts of Interest

The author has no conflict of interest to disclose with respect to this presentation.

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