Kawasaki Journal of Medical Welfare Vol. 22, No. 1, 2016 47－52

Material

Changes in Relative Exercise Intensity during a Two Hour Endurance Race Using a Tandem-Bicycle for Exercise

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(Accepted June 15, 2016)

Key words: tandem-bicycle, relative exercise intensity, heart rate, blood pressure, RPE

1. Introduction

It is well known that changes in heart rate during cycling exercise are in proportion to the oxygen uptake on a single seat bicycle[1-3]. Heart rate and oxygen uptake increase depending upon the work intensity[1-3]. Some laboratory experiment studies reported a similar tendency in heart rate and oxygen uptake during tandem bicycle riding[4,5]. However, there are few reports about field studies of the tandem bicycle. As far as tandem bicycle riding is concerned, it was reported that the exercise intensity of a person on the front saddle during tandem-bicycle exercise was larger than that of the person on the rear saddle[6]. In the present study, we verified whether or not exercise intensity on the front saddle was higher than that of the rear saddle and a two hour endurance tandem-bicycle trail was used for this experiment.

The aim of this study was to investigate the relative exercise intensity of the front saddle cyclist and the rear saddle cyclist by measuring the urinary catecholamine level, relative exercise intensities and rectal temperature; adding the subjective index of rating of perceived exertion (RPE).

2. Methods

Two healthy male subjects (on the front saddle: age; 23years, height; 173 cm, body weight; 80 kg, peak oxygen uptake; 45.2 ml/kg/min, and on the rear saddle: age; 25years, height; 161 cm, body weight; 72 kg, peak oxygen uptake; 45.1 ml/kg/min, respectively) volunteered for this study. All procedures were approved by the Ethics Committee of Kawasaki University of Medical Welfare and conformed to the Declaration of Helsinki (#306). Peak oxygen uptake ($\dot{V}O_2$ peak) for subjects was measured by the Douglas bag method using a bicycle ergometer. The trail used was the same as that used for the two hour endurance race at the OKAYAMA circuit held in 2014. Heart rate was measured by using the radio conveyance-type telemeter (RS800CX; POLAR, Sweden). Blood pressure was checked by using the aneroid sphygmomanometer

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(501;KENZMEDICO, Japan). Rectal temperature was measured by using the thermoelectric thermometer (YSI4000, NIKKISO, Japan). And the rating of perceived exertion (RPE : by Borg Index[7]) was taken at rest and after every three laps. Subjects had a short rest (5 min.) after each of three laps. Heart rate was recorded by the pales watch method between rest and the end of the trail. Urinary catecholamine composited by adrenalin, noradrenalin and dopamine was measured before and after the race and was normalized by creatinine correction. Relative exercise intensity（$\%\dot{V}O_2$ peak）was calculated by peak oxygen uptake and average heart rate at each point. The $\%\dot{V}O_2$ peak was estimated during each point on the HR- $\dot{V}O_2$ relationship for each subject as determined from maximal exercise test results.

The subjects performed ten laps around a 3.7 km track, the OKAYAMA International Circuit[8] (Fig. 1). We divided the circuit into three sections (X-Y, Y-Z and Z-X) from the load intensity caused by the rise and fall. X-Y was the section of uphill, and Y-Z was the section from downhill to uphill road. Z-X was the section from long downhill to long uphill. The location information was detected by GPS (Global Positioning System). The temperature was 5 degrees Celsius and humidity 57 percent. The trial is the same as used for the annual endurance race of the OKAYAMA International Circuit and consisted of three categorie(two hour, three hour and five hour trials) and was organized by the OKAYAMA Cycling Association and the office of OKAYAMA International Circuit.

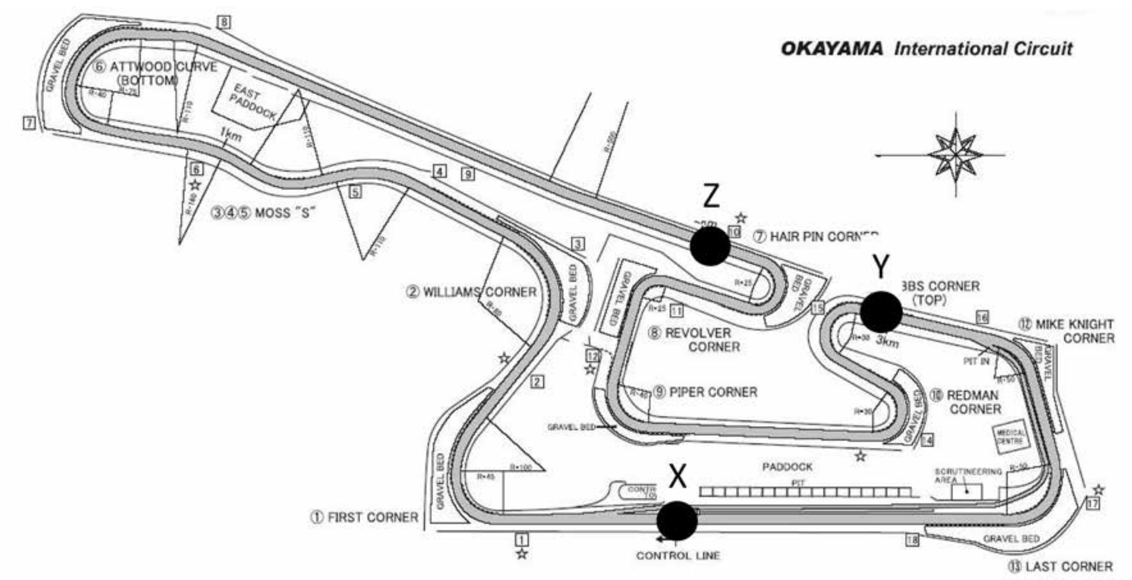

Fig. 1 A sketch of the OKAYAMA International Circuit
The sketch shows X-Y: uphill road, Y-Z: from downhill to uphill road, and Z-X: from long downhill to long uphill road. (fig. 1. Modified from OKAYAMA International Co., Ltd.)

3. Results and Discussion

Table 1 shows the average speed of the tandem bicycle for each lap. The average speed of 10 laps was 21.9 ± 1.7 km/h for each of then times around the trail. To calculate heart rate and the relative oxygen uptakes ($\%\dot{V}O_2$ peak) GPS was used. Figure 2a (X-Y: an uphill road), Figure 2b (Y-Z: from downhill to uphill) and Figure 2c (Z-X: from long downhill to long uphill) show the typical information of the relation between heart rate and location information in the front saddle cyclist and rear saddle cyclist for each lap. In the front and rear saddle trials, Table 2 shows the relative oxygen uptakes ($\%\dot{V}O_2$ peak) of each lap and the average relative oxygen uptakes ($\%\dot{V}O_2$ peak) of each place. It is well known that oxygen uptake is an index of exercise intensity. The difference of the average relative oxygen uptakes could be about thirteen percent. It was considered that the difference of thirteen percent on a bicycle ergometer was about 0.4 kp from converting relative oxygen uptakes into work load[4].

Table 3 shows the rectal temperature of the front saddle cyclist and rear saddle cyclist. The change of quantity compared with the rest was 0.82, 0.97, 0.84 and 0.59 degrees Celsius (front saddle cyclist), 0.48, 0.73, 0.71 and 0.48 degrees Celsius (rear saddle cyclist). The rectal temperature is an index of the core temperature. It could be considered that the rate of increase of core temperature corresponds with the rate of increase of the physical activity. These changes suggest that exercise intensity of a person on the front saddle is higher than that of the rear saddle. The blood pressure of the front saddle cyclist and rear saddle cyclist were shown in Table 3. The blood pressure of the subject on the front saddle was higher than that on the rear saddle in most laps. It was considered that exercise intensity of a person on the front saddle was higher than that of the rear saddle. It could be considered that the rate of increase of blood pressure corresponds with the rate of increase of the physical activity. The RPE of the front saddle cyclist and rear saddle cyclist were shown in Table 3. RPE is an index of subjective exercise intensity. To compare RPE of front saddle cyclist with rear saddle cyclist, RPE of the subject on the front saddle showed a marked tendency to increase. It may be considered that exercise intensity of a person on the front saddle was higher than that of the rear saddle.

Urinary adrenalin, noradrenalin and dopamine were shown in Table 4. The change of urinary adrenalin, noradrenalin and dopamine quantity compared with the rest was 13.3 ng/mgCr, 71.6 ng/mgCr and 25.2 ng/mgCr (front saddle), 8.3 ng/mgCr, 15.5 ng/mgCr, and -164.3 ng/mgCr (rear saddle). Those hormones are indices of physical and mental work stress. It is considered that the increase of those hormones corresponds with the increase of physical and mental work stress.

In the front saddle cyclist, the values of measurement indices were successively higher compared to the rear saddle cyclist during tandem-bicycle trail riding. The present data supports the findings of previous reports[6]. It may be possible to consider that it is reasonable and reproducible as to values of heart rate, because GPS pinpoints the position of the aspect. It was considered that the differences in the front and rear saddles were about thirteen percent of relative exercise intensity, and that these differences were caused by handle, brake and gear operations and wind pressure[9,10]. A front saddle cyclist of a tandem-bicycle is called the pilot. The pilot must operate the handle to select the safety course and brake and/or gear to control the speed. Especially, wind resistance may be the large physiological stress of the pilot. Consequently, it could be considered that the role of the pilot is a factor of increasing the heart rate, urinary catecholamine and RPE. On the other hand, previous studies reported that these differences allow for cyclists with different fitness levels to cycle together and still enjoy the benefits of exercise[5].

Table 1 Average speed of the tandem bicycle for each lap

Sub. ／ Lap	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Time（min'sec.）	11'05	9'53	9'48	9'48	9'37	9'42	9'51	10'21	10'49	10'42
Speed（km/h）	20.0	22.5	22.7	22.7	23.1	22.9	22.5	21.4	20.5	20.7

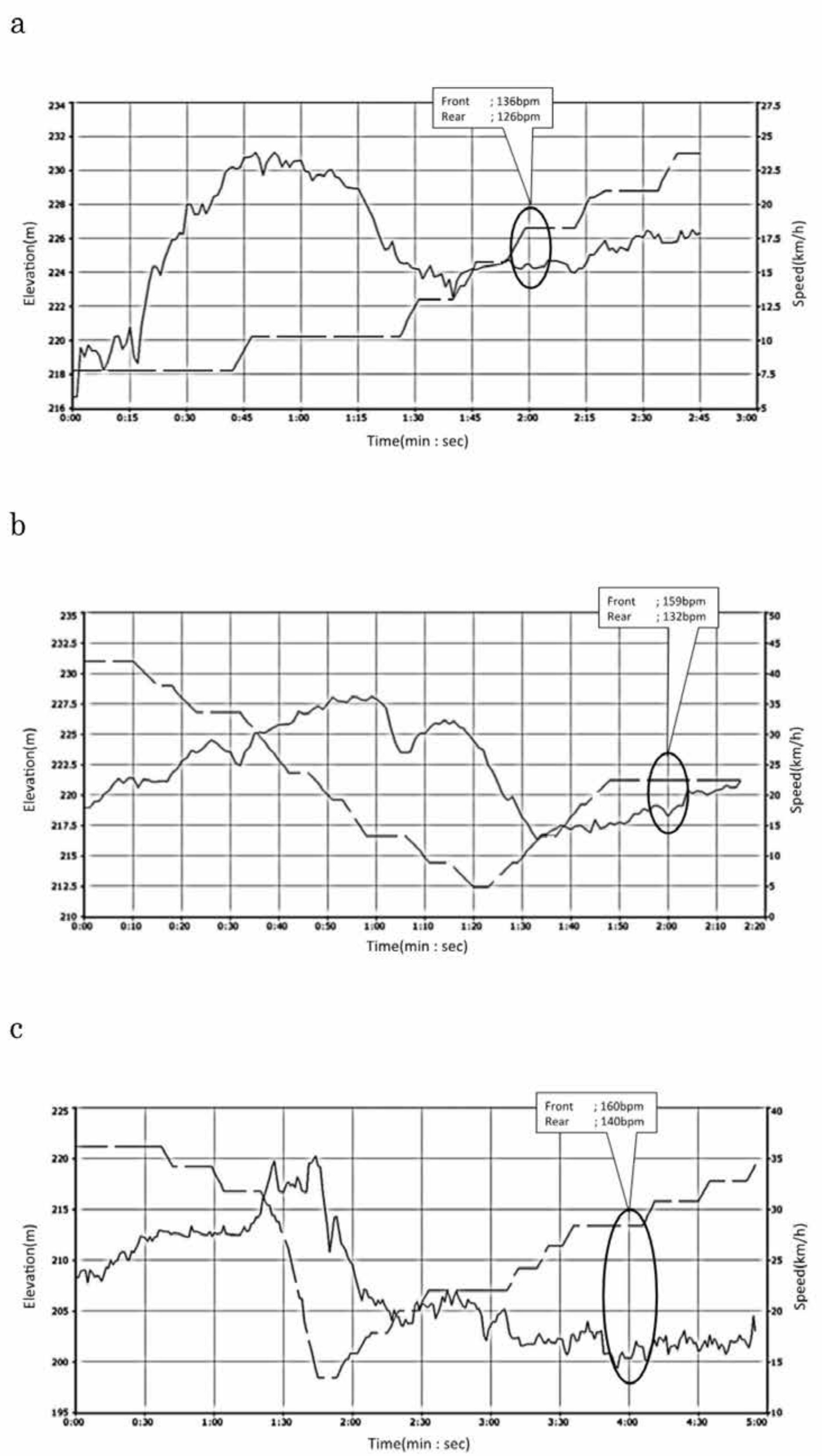

Fig. 2 The typical information of heart rate between front and rear saddles during X-Y(a), Y-Z(b) and Z-X(c). The solid line shows speed(km/m), and the dashed line shows elevation(m).

Table 2 Comparison of relative oxygen uptakes (%$\dot{V}O_2$ peak) between front and rear saddles during X-Y (a), Y-Z (b) and Z-X (c).

Sub. ／ Lap		1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	mean ± SD
X-Y	Front	48.6	61.0	72.0	50.9	61.0	76.2	66.8	70.5	69.0	67.5	64.6	64.4 ± 8.5
	Rear	38.8	47.8	64.9	30.7	56.8	64.9	53.7	62.8	54.7	41.7	47.8	51.3 ± 11.2
Y-Z	Front	47.2	69.7	62.5	64.6	58.8	65.3	69.0	66.1	53.7	57.3	50.9	60.5 ± 7.5
	Rear	27.6	56.8	45.7	52.8	56.8	56.8	54.7	53.7	42.6	35.7	33.8	47.0 ± 10.6
Z-X	Front	66.1	70.5	72.0	66.1	70.5	71.1	70.5	74.0	72.0	74.0	63.1	70.0 ± 3.5
	Rear	52.8	55.9	58.7	62.8	61.8	61.8	56.0	50.9	50.9	64.9	43.8	56.4 ± 6.4

Table 3 Changes in the rectal temperature (℃), the blood pressure (mmHg) and the RPE of subjects on front saddle and rear saddle, respectively.

Sub. ／ Lap		Rest	3rd	6th	9th	Final lap
RT (℃)	Front	37.69	38.51	38.63	38.53	38.28
	Rear	37.46	37.92	38.19	38.17	37.94
BP (mmHg)	Front	130/82	170/76	152/68	142/78	144/64
	Rear	134/62	146/70	156/70	150/72	142/70
RPE	Front	6	13	14	15	12
	Rear	6	12	13	15	12

Table 4 Changes in urinary adrenalin, noradrenalin (ng/mgCr) and dopamine (ng/mgCr) concentrations between before and after the trial.

	Adrenalin		NorAdrenalin		Dopamine	
	Rest	Final lap	Rest	Final lap	Rest	Final lap
Front	13.9	27.2	97.7	169.3	330.0	355.2
Rear	15.9	24.2	152.8	168.3	797.2	632.9

(ng／mgCr)

4. Conclusion

In conclusion, the relative exercise intensity of the subject in the front saddle was higher than that of the subject in the rear saddle during the two-hour tandem-bicycle race.

Conflict of Interest

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

Acknowledgments

The authors wish to show Mr. Yuki Ogasawara appreciation for his cooperation with the research data. This study was supported by JSPS KAKENHI Grant Number 15K01509.

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