Heart Size and Heart Rate Variability of the Top Earning Racehorse in Japan, T. M. Opera O

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T. M. Opera O is considered as one of the greatest racehorses in the history of horseracing in Japan. Only a very few data is available on circulatory function of elite Thoroughbred racehorses. Recently, we obtained data on circulatory parameters of T. M. Opera O. The left ventricular mass of T. M. Opera O, as measured on an echocardiogram, was 4.60 kg. The resting heart rate (HR) of T. M. Opera O was 25 beat/min. The low-frequency and high-frequency power, as determined by an analysis of HR variability, were 13,900 and 5.963 ms², respectively, which were considerably higher than those of the other racehorses. These results suggest that a large heart, formed by genetic factors and training, markedly enhanced the parasympathetic nervous activity and reduced the resting HR of T. M. Opera O. The data we obtained from T. M. Opera O is invaluable for understanding the physical fitness of elite Thoroughbreds and for further developing their athletic performance.

Key words: athletic performance, heart rate variability, left ventricular mass

Thoroughbred racehorses have been selectively bred for racing by humans for several hundreds years. Thoroughbred horses are the only animal that can run more than 60 km/hr while carrying a man for more than 3 min. The superior race performance of Thoroughbreds is thought to depend on their extraordinarily high cardiopulmonary function [5].

The ratio of heart weight to body weight of Thoroughbred horses is more than double the human ratio. The maximal heart rate (HR) and stroke volume of Thoroughbred horses during high intensity exercise are 210–230 beat/min and approx. 1.6 l, respectively. In Thoroughbreds, the maximal oxygen consumption, which is one of the best indicators of aerobic work capacity, exceeds 160 ml/kg/min [3, 4]. Comparing this parameter to that of human marathon runners (approx 80 ml/kg/min) reveals the excellent cardiopulmonary function of Thoroughbreds.

Previous reports on circulatory parameters of Thoroughbred horses have often been based on data collected from horses that were not for racing. Thus, the athletic performance of elite Thoroughbred racehorse can be expected to be far higher.

T. M. Opera O began his racing career at the age of 2-year-old in the summer of 1998, and he has won 14 of the 26 races including 7 G1 races until the end of 2002. Total earning money through his career was 1,835,189,000 Japanese yen, more than any other horse in the Japan Racing Association (JRA). He is considered as one of the greatest racehorses in the history of horseracing in Japan. Recently, we obtained data on circulatory parameters of T. M. Opera O with cooperation of owner and trainer. Since only few data is available on circulatory function of elite Thoroughbred racehorses, the data we obtained from T. M. Opera O is invaluable for understanding the physical fitness of elite Thoroughbreds and for further developing their athletic performance.
Heart rate during exercise and blood lactate concentrations after the exercise

All data from T. M. Opera O (5 years old) was obtained in 2001. In that year, T. M. Opera O participated in 7 races including 5 G1 races and 2 G2 races. We measured HR during exercise (intense exercise prior to each race, referred as a “work-out”) and blood lactate concentrations after the work-out. At the work-out on the day of 11 and 4 days before each of the 7 races, heart rate during exercise was measured by HR monitor (Polar Electro Oy, Kempele, Finland). Blood samples were obtained from the left jugular vein at 10 min after the end of galloping to measure blood lactate concentrations using 2300 STAT Plus (YSI Inc., Yellow Springs, OH, USA).

Electrocardiographic recording and analysis

Electrocardiograms (ECGs) for measuring HR and HR variability at rest were recorded by base-apex lead using Holter-type electrocardiograph (SM-60, Fukuda Denki, Tokyo) in their own stall for 3 hr. Electrocardiograms were analyzed using the ECG processor analyzing system (Softron, Inc., Tokyo) described previously [7]. The program first detected R waves and calculated the R-R interval tachogram as the raw HR variability in sequential order. Any noise that the computer detected as an R wave was eliminated manually and/or any variability that lay outside 75–125% of the mean was eliminated. From this tachogram, data sets of 512 points were resampled at 200 milliseconds. The tachogram length was selected as that which constituted the best compromise between the need for a large time-series to achieve the greatest accuracy and the ease of short recording periods [10]. Each set of data was applied to the Hamming window and the fast Fourier transform to obtain the power spectrum of the fluctuation. Low-frequency (LF) power was set at 0.01 to 0.07 Hz, and high frequency (HF) power at 0.07 to 0.6 Hz. Power spectrum analysis of HR variability in the HF power is generally thought to primarily reflect parasympathetic nervous functions [10]. On the other hand, both the sympathetic and parasympathetic nervous systems have been shown to contribute to the LF power [10]. The HR, LF power, HF power, and the LF:HF ratio were obtained from each recording. These values were used as the indices of autonomic nervous functions.

Echocardiography

An ultrasound unit (EUB-6000; Hitachi Ltd., Tokyo) were used for each examination. The transducer was placed in the left fifth to sixth intercostals space. Left ventricular internal diameter (LVID), interventricular septal (IVS) and left ventricular free wall thicknesses (LVFW) in diastole (d) were measured; the left ventricular mass was calculated from these data. The left ventricular mass was calculated using the following equation [2]:

\[ \text{LV mass} = 1.04 \times [(\text{LVIDd} + \text{LVFWd} + \text{IVSd})^3 - \text{LVIDd}^3] - 13.6 \]

Statistical analysis

Significant differences were analyzed using a paired t-test. A p-value of less than 0.05 was considered to be significant.

Heart rate during the exercise and blood lactate concentrations after the exercise

In 2001, T. M. Opera O participated in 7 races (five G1 races and two G2 races). In Japan, horse race meeting takes place on every weekend. Racehorses scheduled to participate in the race are usually given one or two sessions of intense exercise, i.e., work-out, each week. We measured HR and blood lactate concentrations of T. M. Opera O during these work-outs on the day of 11 and 4 days before each of the 7 races. The work-out exercise program was consisted of warming up and running for 1,800 m as a main exercise on the oval wood-tip course. The speed of running gradually increased from the point at about 1,200 m from the end of the goal, with reaching peak speed at final 400–600 m from the end of goal. The exercise program was basically the same for each work-out session.

The mean speed during the last 1,200 m of the work-outs did not differ significantly between day 11 before the race (868 ± 8.8 (s.d.) m/min) and day 4 before the race (888 ± 18.7 m/min). The mean speed during the last 600 m on day 11 before the race (926 ± 10.2 m/min) was approximately equal to that on day 4 (932 ± 20.2 m/min). The peak HR during the exercise did not differ significantly between day 11 (216 ± 5.4 beats/min) and day 4 (212 ± 4.5 beats/min). On the other hand, the blood lactate concentrations at 10 min after the end of galloping differed significantly between day 11 (13.0 ± 2.5 mmol/l) and day 4 (16.0 ± 1.9 mmol/l). Considering that the accumulation of blood lactate during intense exercise can be altered by even a slight change in speed or duration of the exercise, a slight difference in the running speed may have led to the
significant difference in blood lactate concentrations observed between the two work-out sessions.

Heart rate and HR variability at rest

The resting HR of T. M. Opera O was 25 beat/min. This was considerably lower than the HR recorded from other 15 racehorses (30.3 ± 1.2 (s.e.) beat/min; 14 males and 1 female, 3.7 ± 0.2 year-old). The LF and HF power, as determined by an analysis of HR variability, were 13,900 and 5,963 ms\(^2\), respectively, which were considerably higher than those of the other racehorses (Table 1). These results suggest that the parasympathetic nervous activity of T. M. Opera O might be activated more than other racehorses. Our previous study demonstrated that by conducting 7 months of training, resting HR of Thoroughbreds decreased from pre-training value of 41.5 ± 0.8 (s.e.) beat/min to a post-training value of 38.7 ± 0.4 (s.e.) beat/min, accompanied by a significant increase in LF and HF power [8]. These findings suggest that training increases the parasympathetic nervous activity and reduces the resting HR of Thoroughbreds. The low resting HR, the high HF and LF observed in T. M. Opera O may be attributable to an increase in parasympathetic nervous activity following adequate training.

Echocardiography

Left ventricular internal diameter in diastole, IVSd and LVFWd of T. M. Opera O, as measured on an echocardiogram, were 11.5, 2.7, and 3.9 cm, respectively. Therefore, left ventricular mass of T. M. Opera O was 4.60 kg. The same parameter averaged 3.37 ± 0.34 (s.e.) kg in well-trained 2-year-old Thoroughbreds. Young et al. reported that the left ventricular mass of Thoroughbreds averaged 3.366 ± 0.822 (s.d.) kg [12]. These data allow us to conclude that T. M. Opera O has a very large heart.

The heart of mammals is thought to account for approx. 0.6 % of their body weight [11]. This percentage is reported to be approx. 1.4 % for well-trained Thoroughbreds [6]. Large hearts seem to support the high athletic performance of Thoroughbreds [5]. For humans, a close correlation has been observed between the left ventricular mass and aerobic exercise capacity [1, 9]. A positive correlation between the left ventricular myocardial mass and maximum oxygen consumption has also been reported for Thoroughbreds, indicating that Thoroughbreds with a larger heart have a higher aerobic exercise capacity [12]. Young et al. reported that the left ventricular mass of two-year-old Thoroughbreds increased significantly following 18 weeks of training [13].

In conclusion, T. M. Opera O had low resting HR (25 beat/min), large heart size, and high HF power. These results suggest that a large heart, formed by genetic factors and training, markedly enhanced the parasympathetic nervous activity and reduced the resting HR of T. M. Opera O.

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References


Table 1. Summary of heart rate and heart rate variability

<table>
<thead>
<tr>
<th></th>
<th>Heart rate (beat/min)</th>
<th>LF power (ms(^2))</th>
<th>HF power (ms(^2))</th>
<th>LF/HF ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>T. M. Opera O</td>
<td>25</td>
<td>13,900</td>
<td>5,963</td>
<td>2.3</td>
</tr>
<tr>
<td>Mean value of 15 racehorses (± SE)</td>
<td>30.3 ± 1.2</td>
<td>3,819 ± 459</td>
<td>1,248 ± 321</td>
<td>4.1 ± 0.5</td>
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