ORIGINAL ARTICLES

CARDIAC MONITORING DURING EXERCISE TESTS IN THE HORSE
2. Heart Rate Responses to Exercise

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Introduction

In a previous paper (Hall et al 1975), a number of techniques used for cardiac monitoring in the horse before, during and after exercise were described. Because the best results were obtained with a portable magnetic tape recording system, this equipment was used for investigations that were carried out on Thoroughbred horses stabled in the vicinity of Flemington Racecourse.

The general aim was to establish a basis for defining resting heart rates, pre-exercise heart rates, the “anticipatory” rise in heart rate just prior to exercise, the influence of speed of work on heart rate and recovery heart rates. As standard training practices in Australia include regular fast and slow working days for all horses, the influence of this factor on heart rate was also examined.

The investigation was also designed to permit study of the differences in heart rate response between horses classed as having normal, borderline and abnormal electrocardiograms (ECG’s) as determined from conventional electrocardiography at rest. It was hoped that better identification and definition of the factors affecting heart rate responses would aid the assessment of fitness and help in determining how pre-existing cardiac abnormalities, detected at rest, were likely to affect performance.

Materials and Methods

The exercise tests were conducted in the manner previously described (Hall et al 1975). The results to be presented concern 34 Thoroughbred horses in full training that were tested on 99 occasions. There were 18 horses tested on at least one fast and one slow working day. There were 5 tested only on fast days and 7 only on slow days. One horse with atrial fibrillation was tested on numerous occasions and the others once as a result of specific requests.

Resting ECG’s were recorded from 29 of the 34 horses using the technique and criteria for interpretation described by Steel (1963). The ECG of each horse was then classified as being normal, borderline or abnormal.

All heart rates were calculated on the basis of the number of beats occurring in the last 6 seconds of a specified period of ECG tracing. This figure was multiplied by 10 to produce “beats/min”. The periods selected for study are shown in the key to Table 1.

Heart rates were also calculated during speeds of work that varied from 300-1000 metre/min. These were plotted so that heart rate could be determined as a function of speed.

Heart rates were also calculated at the end of exercise and at 15, 30 and 45 sec, and 1, 3, 5 and 10 min after completion of exercise. Finally a comparison of heart rates, calculated during various speeds of work, was made on horses whose resting ECG’s had been classified as normal, borderline or abnormal.

Results

Heart Rates at Rest

Table 1 shows a mean resting heart rate of 31.7 beats/min which is lower than the rate of 35 beats/min reported by Detweiler (1952) and Steel (1963), who used standard ECG’s to determine heart rates. It is also distinctly lower than the mean rate of 40 beats/min reported by Stewart (1972a) who used a stethoscope.

Pre-Exercise Heart Rates

The mean rise in heart rate between the horse’s home stall and the preparation shed at the racetrack was approximately 21 beats/min.

Between leaving the preparation shed and reaching the track proper, there was a further anticipatory rise in heart rate to about 100 ± 21 beats/min. During preliminary slow trotting or cantering around the track to the point where work for the day actually started, the mean heart rate showed a further increase to 153 ± 23 beats/min.

The Influence of “Fast” and “Slow” Working Days on Pre-Exercise Heart Rates

Because the horse has always been regarded as an animal which can be trained to respond to situations in a reproducible manner, it was thought that horses regularly trained at Flemington Racecourse might respond during the pre-exercise activity in a manner which was related to the type of work to be undertaken.

The speed and duration of work varied in a regular manner depending on the day of the week and the type of track available for training. The grass-surfaced track was available for fast work...
TABLE 1
Pre-Exercise Heart Rates in Thoroughbred Horses

<table>
<thead>
<tr>
<th>Calculation</th>
<th>Stall</th>
<th>Shed</th>
<th>Walk</th>
<th>Track</th>
<th>Pre-work Min.</th>
<th>Pre-work Max.</th>
<th>Start</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>31.7</td>
<td>52.9</td>
<td>80.5</td>
<td>99.7</td>
<td>105.0</td>
<td>146.3</td>
<td>153.3</td>
</tr>
<tr>
<td>S.D.</td>
<td>9.9</td>
<td>14.6</td>
<td>19.1</td>
<td>21.0</td>
<td>16.8</td>
<td>24.7</td>
<td>23.7</td>
</tr>
<tr>
<td>S.E.</td>
<td>1.7</td>
<td>2.5</td>
<td>3.3</td>
<td>3.7</td>
<td>2.9</td>
<td>4.2</td>
<td>5.2</td>
</tr>
<tr>
<td>n</td>
<td>32</td>
<td>34</td>
<td>34</td>
<td>32</td>
<td>34</td>
<td>34</td>
<td>34</td>
</tr>
</tbody>
</table>

Key
"Stall": The heart rate observed in a box stall before the horses left the stable to walk to the track.
"Shed": The heart rate observed in the preparation shed located at the racetrack.
"Walk": The maximum heart rate recorded during walking from the preparation shed to the track proper.
"Track": The maximum heart rate recorded at the point when the horse entered the track proper.
"Pre-work Minimum": The minimum heart rate observed on the track prior to the start of the exercise.
"Pre-work Maximum": The maximum heart rate observed on the track prior to the start of exercise.
"Start": The heart rate recorded at the point when the jockey indicated that he was commencing the exercise period.

On Tuesday, Thursday and Saturday mornings. On other days, the grass track was closed and only tracks surfaced with soil or sand were available. These training practices raised the question as to whether horses would exhibit cardiac responses which might indicate that they distinguished between slow and fast working days before they commenced their exercise.

Using "Student's t test" as a basis for comparison, it was found that the usual anticipatory rise in heart rate when horses entered the training track did not differ significantly on slow or fast working days. However, during the pre-work activity that occurred on the track before exercise commenced, there was a significant difference between the maximum heart rates observed on the different types of work day (P < 0.05). This response was further emphasized by a significant difference (P < 0.01) between the heart rates observed at the actual start of the exercise period. Whereas the mean heart rate for all horses at the start of the exercise period was 153 beats/min, the mean heart rate on fast working days was 158, and on slow working days 135 beats/min. These observations indicate that the heart rate response was less on a slow working day, but this only became evident when the sensory cues received by the horse were more clearly defined than at the time of entering the training track.

**Exercise Heart Rates**

Because the horses studied were undergoing their normal training programmes, it was not possible to impose critical standards for speed of work or the distance covered during any one exercise test. This was determined by the instructions given to the jockey by the trainer. The circumstances were such that it was difficult to compare the results of successive observations from any one horse. There was also variation between horses due to age, sex, degree of fitness, innate ability and cardiac condition.

Despite the inherent variability in the background against which observations were made, it was possible to pool the data and determine the relationship between heart rate and speed of work within the speed range of 400-1000 metre/min. This was done by plotting the 377 heart rate/speed of work observations and calculating the linear regression equations. The results shown in Figure 1 indicate that the heart rate-speed relationship was linear in the speed range of 400-800 metre/min (r^2 = 0.74, P < 0.001).

Although the regression line in Figure 1 represents a line of best fit, the error bars represent only 5% of all observations. Thus, an estimated heart rate calculated by use of the graph and a given speed would be expected to have a reasonable degree of accuracy. For example, at "half pace", with a working speed of about 660 metre/min, the expected heart rate would be about 175 beats/min. At "three-quarter pace" ("even time") or 800 metre/min, the
expected heart rate would be about 200 beats/min.

It should be noted that the linear relationship does not apply to speeds achieved during actual racing conditions which are frequently in the order of 1000 metre/min. In the present study, the maximum heart rates observed during exercise were usually between 200-220 beats/min (mean 203 ± 10). In most horses, the speed of work at this time was in excess of 800 metre/min.

**Recovery Heart Rates**

In man, the time for heart rate recovery has been shown to be related to the intensity of exercise, with a longer period being required after intense exercise. The present investigation showed a similar response in the horse.

There was a significant difference in recovery heart rates measured on fast and slow working days with an almost constant difference between averaged observations of 62 beats/min at the end of the exercise period and for the first 30 seconds of the recovery period. On both fast and slow days, the heart rate fell gradually after this point in the recovery period. During the next four minutes, a mean difference of about 30 beats/min between heart rates on the two types of day was observed. A significant difference in rate of about 15 beats/min was still present between the two groups at 10 minutes into the recovery period (Figure 2).

**Influence of Resting ECG Classification on Heart Rate Response**

Although other workers (Asheim et al, 1970; Bayer, 1970; Ehrlein et al, 1968, 1970; Marsland, 1968; and Senta et al, 1970) have studied the relationship between heart rate and speed of work, and made observations regarding the occurrence of arrhythmia, there appears to have been no study in which heart rate responses to exercise were compared in horses with resting ECG’s that had been classified as normal, borderline or abnormal.

Table 2 shows the cardiac diagnoses made from resting ECG’s recorded from 29 Thoroughbred horses. There were 11 horses with ECG’s classed as normal, 4 as borderline, and 14 as abnormal. An examination of factors such as age and sex showed no bias among the 3 groups. Heart rate (dependent variable) was then plotted as a function of speed (independent variable) within the speed range of 400-800 metre/min. A computer programme was used to calculate
heart rates of horses have been determined before, during and after exercise. The lower on one hand and the abnormal and borderline groups on the other (P < 0.001). It is of interest that the highest heart rates observed were in the small group of horses classified as having borderline ECG's.

Discussion

Using a magnetic tape recording system, the heart rates of horses have been determined before, during and after exercise. The lower resting heart rates observed during this study may have been due to the technique which allowed the observed to remove himself from the vicinity of the horse when observations were being made. It may also have been due to the time of day at which observations were made, and, if so, the values reported could be looked upon as close to basal heart rates.

Although the heart rates recorded at the race-track during preparation for work were distinctly higher than the resting rates, the anticipatory rise that occurred when the horse stepped on to the track was striking and it continued during the activity that preceded the formal working period. Similar observations have been made in horses by Asheim et al (1970) and Stewart (1972a), in female athletes by Skubic and Hilgen-dorf (1964) and in male skiers by Astrand (1967). The mechanisms responsible for anticipatory rises in heart rate are apparently complex because Stewart (1972b) found that the response was still present in horses clinically tranquillized with promazine. On the other hand, in the present study, there were significant differences in the mean maximum heart rates observed at the start of work on fast and slow days.

In horses, the rise in heart rate that occurs before the commencement of work represents about a five fold increase in rate above the resting level. This must constitute a considerable adjustment to the requirement for increased cardiac output before exercise begins.

The linear relationships between heart rate and speed of work reported by others has been confirmed in this study over the speed range of 400-800 metre/min. At low speeds of work, psychosomatic factors or overt heart disease are probably the most important determinants of heart rate. At the highest speeds of work, the attainment of physiological limits may produce a plateauing effect or there may be an individual maximum. The mean maximum heart rate of 203 ± 10 beats/min observed in this study is in general accord with the heart rates recorded by other workers.

It seems possible that significant rises in heart rate beyond about 220 beats/min may be associated with lack of fitness, cardiac disease or a situation in which the time available for cardiac events becomes a factor limiting capacity for equine performance.

With respect to recovery heart rates, there was a constancy of difference on fast and slow working days between the two sets of mean observations made at the end of the exercise period and during the first 10 minutes of recovery. The difference of 62 beats/min during the first 30 seconds of recovery may represent the adaptation of the horse to the harder exercise required on fast working days. This interpretation is supported by the fact that in the initial stages of recovery, when heart rate is plotted as a function of time, the gradients of recovery curves for both fast and slow working days were indistinguishable.

Criteria for the diagnosis of abnormalities in the equine electrocardiogram were put forward by Steel (1963). Additional support for these criteria is provided by this study in which there were significant differences in heart rate over a range of speeds of work when the resting ECG of the horses tested had been classified as normal or abnormal. Although only a small group of horses had ECG's classified as borderline, they developed higher heart rates than the abnormal group. This may be due to the horse with a borderline ECG reflecting an active process of myocardial irritability and the abnormal animal exhibiting signs of established, but more stable, myocardial injury. Further work is required to confirm these observations.

Summary

Data on resting heart rates, pre-exercise heart rates, the anticipatory rises before exercise, the influence of speed of work and recovery heart rates have been presented. Some observations on differences in the heart rate response on slow and fast working days are also recorded.

In conformity with other workers, a linear relationship between heart rate and working speed within the range of 400-800 metre/min was observed. When the speed of work was between 400-800 metre/min, horses with resting ECG's
classed as abnormal had significantly higher heart rates than those regarded as normal. It was also observed that the abnormal animals showed lower heart rates than a small number classed as borderline. The significance of these findings is discussed and the need for further work indicated.

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References

Hall, M. C., Fenelon, A. R., McDonald, R. D. and Steel, J. D. (1975)—Aust. vet. J.

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BOOK REVIEW

FARMING THE RED DEER

This report is a detailed account of work undertaken by the Rowett Research Institute and the Hill Farming Research Organisation over the period 1970-73.

Although the project has only been in existence for such a short period much useful information has been accumulated, and it is particularly interesting to compare this with findings from New Zealand (for example Deer farming research findings, N.Z. J. Agric. (1974) 129: 50).

Areas of particular importance which are well-documented are procurement of foundation stock, fencing and yards, reproduction, food conversion and carcase quality.

Perhaps the greatest value of this book is its potential to bring any starry-eyed entrepreneur down to earth, but it is also essential reading for all scientists interested in animal production and/or wildlife. The next contribution is awaited with keen anticipation.

B. L. Munday