Changes over time in echocardiographic measurements in young Standardbred racehorses undergoing training and racing and association with racing performance

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Objective—To evaluate changes over time in echocardiographic measurements in young Standardbred racehorses undergoing training and racing and determine whether there was any relationship between cardiac dimensions and racing performance.

Design—Longitudinal observational study.

Animals—103 horses.

Procedure—2-dimensional and M-mode echocardiography was performed 4 times at 6-month intervals.

Results—Significant cardiac enlargement took place during the study period as indicated by increases in left ventricular internal diameter in diastole (LVIDd), estimated left ventricular muscle mass (LV mass), and mean wall thickness attributable to eccentric left ventricular hypertrophy. Estimated body weight was positively correlated with left ventricular size, and males had significantly larger LVIDd and LV mass than did females. Horses that were racing regularly had larger LVIDd and LV mass than did untrained horses. A significant relationship between left ventricular size and racing performance was observed. The relationship was strongest at the time of the fourth examination.

Conclusions and Clinical Relevance—Results suggest that age must be taken into account when interpreting results of echocardiography in young Standardbred racehorses because significant cardiac enlargement takes place with age and training. A larger heart was found in horses that were racing, and size of the heart was correlated with athletic performance of the horse. (J Am Vet Med Assoc 2005;226: 1881–1887)

In the world of horse racing, various criteria have been used to identify the most talented young horses. Traditionally, there has been a commonly held belief that horses with a relatively larger heart have higher athletic capacity. Thoroughbred racehorses have a larger heart and spleen, relative to their body weight, than do horses of other breeds, and it has been shown that the hearts of Thoroughbred racehorses in training are larger than the hearts of untrained Thoroughbreds.

Echocardiography has most often been used as a method for diagnosing congenital and acquired heart diseases, but it has also recently been used to study the effects of training in racehorses, and the association between various echocardiographic measurements and subsequent racing performance has been evaluated in Thoroughbred racehorses. However, echocardiographic techniques differed among studies, and while some authors have stated that heart size is an important factor for racehorse performance, others did not observe a significant relationship. A linear relationship between performance and heart size was reported for National Hunt horses, which usually are raced over distances of 3,000 to 6,000 m, but not for horses engaged in flat racing for shorter distances, and it was suggested that maximal oxygen consumption and heart size are more important predictors of performance for horses that run longer distances because their energy consumption is mainly aerobic.

Echocardiographic studies of human athletes participating in a wide variety of sports have shown that athletic training may be associated with an increase in the size of the left ventricle secondary to increased wall thickness, increased chamber diameter, or both. In addition, it has been suggested that these morphologic changes may differ among athletes participating and training in endurance (eg, middle- or long-distance running) versus strength (eg, weight lifting) sports.

On the other hand, other studies indicate that factors other than conditioning may play an important role in the cardiac enlargement process. Some echocardiographic studies on the heredity of cardiac size in humans have shown a significant genetic effect on cardiac size, whereas others suggest that any genetic effect is small.

To our knowledge, no studies of the effects of training on heart size in Standardbred racehorses have been published. The purposes of the study reported here were to evaluate changes over time in echocardiographic measurements in young Standardbred racehorses undergoing training and racing (ie, from 2 to 3.5 years of age), compare cardiac dimensions in horses that did not race by 3.5 years of age with dimensions in horses that were racing regularly by this age, and determine whether there was any relationship between cardiac dimensions and racing performance.

Materials and Methods

Horses—A total of 132 Standardbred trotters (76 females and 56 males) were enrolled in the study by their
owners and trainers. Each horse was examined 4 times with an interval of 6 months between examinations. The first examination was performed in March 2001, and the fourth examination was performed in September 2002. All horses had been born in 1999. Mean ± SD age at the time of the first examination was 22.3 ± 1.2 months (range, 20 to 25 months). Horses were trained mainly in Denmark, but some horses were located in training yards in Poland and Sweden.

Clinical, ECG, and echocardiographic examinations—Examinations were performed at the horses’ training yards or private farms. Horses were examined in a quiet environment. Body weight was estimated by measuring chest girth. A stethoscope was used to assess heart rate and cardiac rhythm and to identify any murmurs; however, it was not possible to measure the true resting heart rate because most of the horses were transported or moved prior to the echocardiographic examination and were stabled in unfamiliar surroundings. A standard limb lead ECG consisting of a minimum of 15 heart cycles was recorded at a paper speed of 25 mm/s and amplitude of 10 mm/mV to evaluate cardiac rhythm. M-mode echocardiography was performed with a 1.5-MHz phased-arrayed sector transducer with harmonic imaging. A base-apex ECG was superimposed for timing. Images were only tape. In addition, cardiac cycles of all echocardiographic heartbeats. A single operator (RB) performed all echocardiographic examinations were digitally stored for later analysis. After the examination, 5 nonconsecutive cardiac cycles (5 frames) were measured, and a mean value was calculated for each individual measurement. Care was taken to ensure that each of the selected frames was of good quality and separated by at least 3 to 10 heartbeats. A single operator (RB) performed all echocardiographic examinations and did all measurements and calculations. Images consisted of a short-axis view of the left ventricle obtained from the right parasternal location. Left ventricular internal diameter in systole and diastole (LVIDs and LVIDd), interventricular septum thickness in systole and diastole (IVSs and IVSd), and left ventricular free wall thickness in systole and diastole (LVFWs and LVFWd) were measured from the stored images. Fractional shortening (FS), mean wall thickness (MWT), relative wall thickness (RWT), and left ventricular muscle mass (LV mass) were calculated by use of the following formulas:

\[ FS = \frac{(LVIDd - LVIDs)}{LVIDd} \times 100 \]

\[ MWT = \frac{(LVFWd + IVSd)}{LVIDd} \]

\[ RWT = \frac{(LVFWd + IVSd)}{LVFWd + IVSd} \]

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

Horses in which it was not possible to keep the heart rate below 45 beats/min during echocardiography were sedated with romifidine hydrochloride (0.04 mg/kg [0.018 mg/lb], IV). This was necessary for 4 horses during the first examination, 1 horse during the second examination, and 1 horse during the third examination.

Determination of training intensity—Before each examination, the trainer was asked to fill out a questionnaire regarding training during the 6 months prior to the day of the examination. Questions included the number of training sessions per week every month, the amount of physical training, and whether and why the horse had any long breaks in training. If the horse had been retired, the cause was given. From this information, horses were placed in 1 of 2 training categories. High-grade training included horses that fulfilled the following criteria: > 3 months training during the previous 6-month period with > 3 training days/wk and horses either were in full training or had been untrained for a maximum of 1 month at the time of the examination. Low-grade training included horses that fulfilled the following criteria: < 3 months training during the previous 6-month period or < 3 training days/wk or untrained for > 1 month prior to the time of the examination.

Determination of racing performance—After the fourth examination, information regarding athletic performance of the horses was obtained from the Danish Trotting Association. Data that were collected included the individual best time when trotting a 1-km distance (kilometer time), total earnings, and percentage of victories.

Statistical analyses—Long-term effects of estimated body weight, sex, training intensity (low- vs high-grade), age at the time of enrollment (20 to 21 months, 22 months, 23 months, or 24 to 25 months), and examination number (1 through 4) on LVIDd, LV mass, MWT, RWT, and FS were evaluated by means of repeated-measures ANCOVA with a general linear mixed model. Sex, training intensity, and examination number were included as fixed effects. Estimated body weight was included as a fixed covariate, and horses were included as a random effect. Two-way interactions between fixed effects (including estimated body weight) were included. The autocorrelation between repeated measurements on the same horse was taken into account by use of an unstructured covariance matrix.

Differences between horses participating in races and horses not participating in races in regard to LVIDd, LV mass, MWT, RWT, and FS measured during the fourth examination were evaluated by means of ANCOVA with a general linear model. The fixed effect of participating in races (yes vs no) was evaluated as well as estimated body weight, sex, training intensity, and age at enrollment.

Associations between racing performance (kilometer time, total earnings, and percentage victories) and echocardiographic measures obtained at the first and fourth examinations were evaluated by means of ANCOVA with a general linear model; racing results were used as the outcome variables. The fixed effects of estimated body weight, sex, training intensity, and age at enrollment were included in the model as well.

Correlations between measures of racing performance and echocardiographic measures were calculated by means of the Pearson correlation coefficient. Furthermore, the pooled within-class correlation coefficient was calculated for horses grouped on the basis of estimated body weight (< 400 kg [880 lb], 400 to 460 kg, and ≥ 460 kg [1,012 lb]) and sex (male and female).

Assumptions for use of the general linear mixed model and the general linear model were evaluated by means of visual inspection of residual plots (evaluating equal variances) and the Shapiro-Wilk test for normal distribution. All analyses were performed with standard software, values of \( P < 0.05 \) were considered significant.

Results

Horses were considered to have completed the study if they were available for the first and fourth examinations and at least 1 of the other 2 examinations (ie, the second and third examination). On this basis, 103 of the 132 horses enrolled in the study completed it. Fourteen horses did not complete the study because they were sold or moved abroad, and 6 did not complete the study because of a perceived lack of racing ability. Other reasons horses did not complete the study included orthopedic problems (n = 4), a lack of owner willingness to participate (3), gastrointestinal tract disease (1), and unintended pregnancy (1). Of the 103 horses that completed the study, 100 were available for the second examination
and 96 were available for the third examination. In addition, 63 of the 103 had participated in ≥ 3 races (mean ± SD, 9.0 ± 4.8 races) by the time of the fourth examination.

Results of auscultation and electrocardiography were unremarkable. No severe murmurs or pathologic arrhythmias were detected.

At the time of the first examination, none of the horses had undergone any substantial training. During the introduction to training, horses were allowed to acclimate to the sulky and training gear and light exercise (ie, walk and slow trot) was performed 2 to 4 days/wk. Training performed prior to enrollment in the study therefore could be characterized as mainly disciplinary, and because of the low physical demands, this kind of training was difficult to characterize as high- or low-grade intensity on the basis of our established criteria. Most horses had undergone high-grade training prior to the second, third, and fourth examinations (Table 1).

Estimates of body weight, LVIDd, LV mass, and MWT increased from the first to the fourth examination (Table 2), but RWT was unchanged, and FS decreased. Estimated body weight was significantly associated with LV mass and MWT (Table 3), and the interaction between estimated body weight and examination number was significantly associated with LVIDd. Sex was significantly associated with LVIDd and LV mass, with higher values in males than in females. There were no significant differences between stallions and geldings in regard to any of the echocardiographic measures except for IVSd, which was significantly (P = 0.034) larger in stallions than in geldings. Training intensity was significantly associated with LVIDd; however, the difference was so small that it had no practical implications and was therefore excluded from consideration. Similarly, the interaction between examination number and training intensity was found to be significantly associated with RWT, and the interaction between age at enrollment and examination number was found to be significantly associated with FS. However, the effects of these interactions were so small that they had no practical implications. Therefore, these 2 interactions were also excluded.

Horses that were racing regularly at the time of the fourth examination had significantly larger LVIDd (P = 0.004) and LV mass (P = 0.003) than did horses that...
had not been racing. No significant differences between racing and nonracing horses were observed for MWT (P = 0.33), RWT (P = 0.30), and FS (P = 0.59). In addition, horses that were racing regularly had significantly (P = 0.017) higher training intensity and significantly (P = 0.002) lower estimated body weight than did horses that were not racing.

For the 63 horses that had participated in ≥3 races by the time of the fourth examination, mean ± SD racing distance was 2,031 ± 71 m. Mean kilometer time was 79.53 ± 2.71 seconds, mean total earnings was 34,237 ± 61,939 Danish kroner, and mean victory percentage was 13.2 ± 13.8%. Correlations between echocardiographic measures obtained at the first

### Table 3—Results of repeated-measure ANCOVA of serial echocardiographic measurements for 103 young Standardbred racehorses.

<table>
<thead>
<tr>
<th>Outcome Variable</th>
<th>Category</th>
<th>Coefficient</th>
<th>Mean</th>
<th>SE</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LVIDd (cm)</td>
<td>Intercept</td>
<td>9.974</td>
<td>—</td>
<td></td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>0.262</td>
<td>11.65</td>
<td>0.09</td>
<td>0.031</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>0</td>
<td>11.39</td>
<td>0.09</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>Estimated body weight</td>
<td>0.0029</td>
<td>—</td>
<td></td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>Examination number</td>
<td>0.0035</td>
<td>—</td>
<td></td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>First</td>
<td>0.0019</td>
<td>—</td>
<td></td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>Second</td>
<td>0.0029</td>
<td>—</td>
<td></td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>Third</td>
<td>0.0035</td>
<td>—</td>
<td></td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>Fourth</td>
<td>0.0044</td>
<td>—</td>
<td></td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>Training intensity</td>
<td>0.0019</td>
<td>—</td>
<td></td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>–0.112</td>
<td>11.46</td>
<td>0.08</td>
<td>0.043</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>0</td>
<td>11.56</td>
<td>0.07</td>
<td>—</td>
</tr>
<tr>
<td>LV mass (g)</td>
<td>Intercept</td>
<td>1.767</td>
<td>—</td>
<td></td>
<td>0.011</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>162</td>
<td>2.937</td>
<td>49.6</td>
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</tr>
<tr>
<td></td>
<td>Female</td>
<td>0</td>
<td>2.774</td>
<td>45.8</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>Estimated body weight</td>
<td>2.95</td>
<td>—</td>
<td></td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>Examination number</td>
<td>0.0019</td>
<td>—</td>
<td></td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>First</td>
<td>–795</td>
<td>2,434</td>
<td>38.4</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Second</td>
<td>–452</td>
<td>2,773</td>
<td>40.9</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Third</td>
<td>–245</td>
<td>2,964</td>
<td>41.2</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Fourth</td>
<td>0</td>
<td>3,230</td>
<td>44.3</td>
<td>—</td>
</tr>
<tr>
<td>MWT (cm)</td>
<td>Intercept</td>
<td>1.84</td>
<td>—</td>
<td></td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>Estimated body weight</td>
<td>0.0029</td>
<td>—</td>
<td></td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>Examination number</td>
<td>0.0035</td>
<td>—</td>
<td></td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>First</td>
<td>–0.19</td>
<td>2.22</td>
<td>0.02</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Second</td>
<td>–0.09</td>
<td>2.33</td>
<td>0.02</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Third</td>
<td>–0.04</td>
<td>2.38</td>
<td>0.02</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Fourth</td>
<td>0</td>
<td>2.42</td>
<td>0.02</td>
<td>—</td>
</tr>
<tr>
<td>FS</td>
<td>Intercept</td>
<td>30.844</td>
<td>—</td>
<td></td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>Examination number</td>
<td>0.0019</td>
<td>—</td>
<td></td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td></td>
<td>First</td>
<td>3.149</td>
<td>33.99</td>
<td>0.515</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Second</td>
<td>1.102</td>
<td>31.95</td>
<td>0.433</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Third</td>
<td>1.378</td>
<td>32.22</td>
<td>0.416</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Fourth</td>
<td>0</td>
<td>30.84</td>
<td>0.395</td>
<td>—</td>
</tr>
</tbody>
</table>

Mean values are least-square means. — = Not applicable. a-dFor each variable, values with different superscripts were significantly (P < 0.05) different. See Table 2 for remainder of key.

### Table 4—Correlation between serial echocardiographic measurements and measures of racing performance in 103 young Standardbred racehorses.

<table>
<thead>
<tr>
<th>Racing performance</th>
<th>First examination</th>
<th>Fourth examination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kilometer time</td>
<td>(0.021)</td>
<td>(0.032)</td>
</tr>
<tr>
<td>Total earnings</td>
<td>(0.042)</td>
<td>(0.038)</td>
</tr>
<tr>
<td>Victory percentage</td>
<td>(0.052)</td>
<td>(0.007)</td>
</tr>
</tbody>
</table>

Echocardiography was performed 4 times at 6-month intervals; racing performance was assessed after the fourth examination. Values represent correlation coefficient (P value). See Table 2 for key.
examination and measures of racing performance were generally low (Table 4), and only LV mass and LVIDd were significantly correlated with measures of racing performance. For echocardiographic measures obtained at the fourth examination, only LV mass and MWT were significantly correlated with measures of racing performance.

To compensate for the effects of estimated body weight and sex on echocardiographic measures, pooled within-class correlation coefficients were calculated (Table 5). On the basis of these analyses, LV mass and LVIDd measured at the first examination and LV mass, MVIDd, and MWT measured at the fourth examination were found to be significantly correlated with measures of racing performance.

**Discussion**

Results of the present study indicate that significant cardiac enlargement takes place in young Standardbred racehorses between 2 and 3.5 years of age. Mean left ventricular wall thickness, LVIDd, and LV mass all increased during the study period, whereas RWT remained unchanged. Results of the present study were comparable with results of a previous study involving Thoroughbred racehorses, except that RWT increased significantly in the Thoroughbred racehorses. Increases in both wall thickness and left ventricular internal diameter are indicative of eccentric left ventricular hypertrophy, whereby the relationship between wall thickness and diameter is unchanged. These changes are characteristic for endurance-trained athletes. In the present study, LVIDd, LV mass, and MWT increased by 12.0%, 40.3%, and 11.6%, respectively, and estimated body weight, sex, examination number, and, to a lesser extent, training intensity all had significant influences on these echocardiographic measures. Fractional shortening decreased significantly during the study but was independent of estimated body weight and sex. Owing to this considerable growth of the left ventricle, age of the horse should always be taken into consideration when echocardiography is performed in young horses.

Standardization of the echocardiographic procedure is essential to achieving highly repeatable results. The echocardiographic procedure used in the study was previously validated, demonstrating the precision of the involved measures. For measurements of LVIDd, LV mass, and RWT, minimum changes between serial measurements to be considered significant were 5.0%, 13.9%, and 8.2%, respectively. In the present study, changes in LVIDd and LV mass were greater than this (12.0% and 40.3%, respectively), suggesting that measurement error probably was not the sole source of the difference.

For the 6 horses in which sedation was necessary, romifidine was chosen because a previous study showed that romifidine has only minimal effects on left ventricular systolic performance, with no significant effects on diastolic dimensions. Echocardiographic changes identified in this previous study were small in comparison to the relatively high day-to-day variation in echocardiographic measurements. Therefore, we included measurements from sedated horses in the present study.

A strong positive correlation between heart size and estimated body weight of the horses was observed in the present study. Previous studies in humans and horses have also demonstrated a significant correlation between body dimensions and heart size. Body weight was estimated from chest girth in the present study, which may have introduced some bias. However, true body weights may also be misleading to some extent because they do not take into account changes in body composition that occur as athletes train and achieve race fitness. The amount of fat-free mass is high in human athletes, compared with nonathletes, and similar changes have been observed in racehorses. In a study of the relationship between maximal oxygen consumption and body composition, it was shown that percentage of fat-free mass or lean body mass was significantly related to maximal oxygen consumption. Lean body mass may therefore be a more appropriate measure in assessing metabolic function of athletic horses. Consequently, lean body mass might be a better measure than absolute body weight or body weight estimated from chest girth.

In comparison to females in the present study, males had significantly larger left ventricles. This is in agreement with results of previous studies involving humans and horses. The mechanism that induces these quantitative differences is unknown at present, but some studies in rodents indicate that sex-specific differences may be partly explained by higher circulating concentrations of endogenous anabolic hormones in males, which promote increased growth of skeletal and cardiac muscle mass. There was no clear evidence in the present study that geldings had smaller hearts in comparison to stallions, and only IVSd was significantly larger in the stallions. However, the number of geldings was limited in this study, and we did not include the exact time of castration.

Training programs in horses and human athletes are usually designed to the individual, and the types of exercise and intensity are usually determined by the individual’s fitness. Suitable training programs that are designed to achieve optimal results in horses and in human athletes must therefore be tailored to each athlete’s needs.
and intensity of exercise vary from horse to horse. Exact quantification of exercise is difficult to achieve in a field study, and in the present study, the amount of training could not be measured with complete accuracy or standardized. We therefore decided to categorize training intensity into only 2 categories. In the high-grade training category, we allowed horses to be off training for up to 1 month before the echocardiographic examination was performed providing they had been trained regularly the previous 3 months. This criterion was based on results of a previous study, which showed that echocardiographic measures did not change during the first month after training ended in Standardbred trotters.

Results showed that the training stimulus had a significant effect on the internal diameter of the left ventricle. Similarly, human studies have shown exercise-induced hypertrophy of the left ventricle in trained versus untrained control subjects. Because of the lack of an untrained, age-matched control group in the present study, we were unable to directly document whether training-induced hypertrophy was taking place. We did however find that the greatest amount of hypertrophy occurred in the group of horses that was racing regularly, and these horses had also been trained most intensively, which suggests that they had training-induced cardiac hypertrophy.

In the present study, LV mass and LVIDd were significantly smaller in the 40 horses that did not participate in a race than in the racing horses. The reason for this discrepancy could be that the unraced horses were trained significantly less intensively than the racing horses. In addition, the unraced horses were heavier than the horses that were racing regularly, which is also seen in humans. Other factors, such as differences in plasma volume or autonomic nervous system function between the 2 groups, and genetic influences may be associated with the cardiac changes seen in the present study.

Of the 103 horses that completed the study, only 63 were racing regularly by the end of their third year of age. This is a normal success rate for Standardbred trotters in Denmark. In general, only a few horses will make their début in racing after their third year of age. Because of the number of horses that did not finish the study and the relatively low fraction of horses that managed to race, a large study group was necessary. An even larger study group (ie, 300 horses) would increase the statistical power, but because of the resources used to examine horses in their various training yards, it was not possible to include more horses in the study.

In the present study, the same individual who contacted the owners and trainers performed all echocardiographic examinations and handled all of the data. At the first examination, the horses had received only limited training and the trainer, owner, and examiner did not know each individual horse's performance ability. However, at the third and fourth examinations, the talented and less talented horses were well known, and this information could have biased the result, even though the procedure was carried out as objectively as possible.

To validate the performance of a horse that has not been raced or only raced a few times is fairly difficult. Therefore, we only used horses that had raced at least 3 times, which is in agreement with others. To compare the fitness of different horses, performance-related variables must be as objective and representative as possible. Among the performance indexes of Standardbred trotters, total earnings, kilometer time, and victory percentage are used most commonly. In the present study, a substantial proportion of the racing horses had no or very low earnings, while a small proportion of the horses had high total earnings. Total earnings were therefore difficult to handle statistically. Because racing distance was typically approximately 2,000 m for horses in the present study, the kilometer time appeared to be the best performance parameter for statistical analysis. In the horses' fourth and fifth years of age, the differentiation of sprinters (1,600 m) and stayers (> 2,500 m) would be more manifest and the kilometer time will differ among the 2 groups, with sprinters having a faster kilometer time than the stayers. At that age, the total earnings will probably be a more reliable performance measure.

In the present study, the LV mass had the strongest relationship with racing performance. Left ventricular mass includes both LVIDd and MWT, which suggests that both measures are important for the performance of the horse. The relationship was stronger at the fourth examination, compared with the first examination, with r values increasing from a range of 0.25 to 0.29 to a range of 0.27 to 0.34 for the uncorrected correlations. When estimated body weight and sex of the horses were included in the analysis, the correlations coefficients generally increased, with r values ranging from 0.27 to 0.32 for the first examination and from 0.33 to 0.44 for the fourth examination. A previous study has demonstrated a significant relationship between echocardiographic measurements of the left ventricle and official racing time in National Hunt horses, with r values ranging from 0.32 to 0.40. In contrast, no such relationship could be found in sprinters engaged in flat racing. The authors did not describe whether the results were corrected for body weight and sex, and the age group of the horses was not reported. It has previously been documented that Thoroughbred racehorses with high earnings (> $10,000/race start) had larger hearts than low earners (< $2,000/race start). In addition, the study showed that sprinters (< 1,400 m) had smaller hearts than routers (> 1,700 m). The horses in this previous study were flat-racing Thoroughbreds, and the echocardiographic techniques and statistical methods differed from the present study.

Resting left ventricular contractility measured as FS decreased significantly during the present study. In the literature, conflicting results exist with regard to FS for both equine and human athletes, but the general belief is that the measure is unaffected by training. We did not find a significant relationship between FS and performance, which is in agreement with others.

In conclusion, the present study showed that significant cardiac changes and enlargement took place during the study period. The study design was not able
to define the extent to which normal physiologic growth, training, management, and genetic effects separately influenced the degree of cardiac changes. It appears that some echocardiographic measures are related to racing performance, with estimated LV mass showing the strongest relationship. However, it should be noted that the observed correlations were relatively low, which indicates that excellent cardiac function is only one of the important requirements to become a successful athletic horse.

References