Use of color Doppler echocardiography to assess the development of valvular regurgitation in Standardbred trotters

Rikke Buhl, DVM, PhD; Annette K. Ersbøll, PhD; Lis Eriksen, DVM, DVSc; Jørgen Koch, DVM, PhD

Objective—To evaluate the incidence and development of valvular regurgitation and its effect on racing performance in Standardbred trotters from 2 to 3.5 years of age.

Design—Longitudinal observational study.

Animals—103 horses.

Procedure—Horses were examined via echocardiographic imaging 4 times at 6-month intervals. Two-dimensional and M-mode echocardiographic examinations were performed in each horse, and color Doppler imaging was used to detect and evaluate regurgitant blood flow at each valve.

Results—For all cardiac valves, the frequency of valvular regurgitation increased significantly during the 18-month study period. Regurgitation was mild in all valves in which it was detected, and no progression in severity was observed at any valve. Tricuspid regurgitation was more prevalent in horses that raced regularly and was diagnosed more frequently in males and horses with larger left ventricular mass and left ventricular internal diameter during diastole. No relationship between racing performance and valvular regurgitation was observed.

Conclusions and Clinical Relevance—The incidence of valvular regurgitation increased during the study period, and it was common at 3.5 years of age. It was not possible to determine whether the increase was a result of maturity or training. The study revealed that there is a high prevalence of mild valvular regurgitation at this age, but apparently, the regurgitation had no effect on racing performance in this age group. Whether regurgitation will progress or influence future performance is not known. (J Am Vet Med Assoc 2005;227:1630–1635)

Color Doppler echocardiography is a noninvasive and sensitive diagnostic modality used for detecting regurgitant blood flow through the cardiac valves. Regurgitant turbulent flow signals from leaking valves have been detected by use of color Doppler imaging in clinically normal Thoroughbreds with and without audible murmurs indicative of valvular regurgitation. An increased incidence of murmurs that were characteristic of mitral and tricuspid valve regurgitation was detected by means of auscultation in Thoroughbreds after 9 months of race training, but auscultation is less sensitive at detecting regurgitant blood flow than echocardiography. Small regurgitant jets are often found in humans and dogs without detectable heart disease. Valvular regurgitation is significantly more common in human athletes than in sedentary control subjects, although the severity of regurgitation is similar in controls and athletes. An age-related increase in valvular regurgitation in elderly humans has been reported, but in another study, there was a higher prevalence of tricuspid and pulmonic valve regurgitation in younger (ie, < 30 years) versus older (30 to 49 years) human subjects.

Few studies have been conducted that investigated the prevalence and development of valvular regurgitation by use of color Doppler echocardiography in racehorses, and the effects of age and training and whether regurgitation affects performance have not been reported. Substantial valvular regurgitation that resulted in hemodynamic disturbances and a detriment to athletic performance would likely render affected horses unable to reach racing fitness and more likely to be retired. For this reason, including racing horses in a study may introduce a biased subpopulation with regard to valvular regurgitation. If a cross-sectional study of racehorses is used, the prevalence and severity of valvular regurgitation in horses that never participate in a race remain unknown. Therefore, we proposed to evaluate the effect of valvular regurgitation on the racing performance of horses by means of a prospective longitudinal study.

The aim of the study was to determine the incidence and monitor the development of valvular regurgitation by use of Doppler echocardiography in healthy Standardbred trotters 2 to 3.5 years of age over a period of 18 months. We also compared the incidence of regurgitation in horses that were racing regularly with that in horses that trained but did not race, with the goal of determining whether valvular regurgitation influences racing performance in Standardbred trotters.

Materials and Methods

Selection of horses—One hundred thirty-two Standardbred trotters (76 females and 56 males) were initially examined. All horses were born in 1999 and had a mean age of 22.3 months (SD, 1.2 months) at the time of the first examination in March 2001. Owners and trainers gave informed consent for the study. The study period lasted 18 months; each horse was examined 4 times at an interval of 6 months. To fulfill the conditions for inclusion in the study, each horse had to be evaluated on the first and fourth examinations and could miss a maximum of one of either the sec-
ond or third examinations. At the fourth examination, 103 horses (58 females and 45 males) met the criteria. All horses were intended for racing, but the amount of previous training differed among the horses. The primary reasons why 29 horses did not complete the study included that they were sold and lost to follow-up (14 horses), retired because they did not race satisfactorily (6), lameness (4), gastrointestinal tract disease (1), and pregnancy (1), and in 3 instances, owners did not want the horse to complete the study period. Of 103 horses that completed the study, 63 were racing regularly (eg, had raced ≥ 3 times; median, 8 races; range, 3 to 22 races). Data with regard to racing performance were provided by The Danish Trotting Association and included the individual best 1-km trotting time (ie, kilometer time), total earnings, and percentage victories.

Registration of training status—The horses were trained mainly in Denmark, but some horses were in training yards located in Poland and Sweden. The trainers or owners completed a questionnaire before each echocardiographic examination to describe the training history. Training was categorized as high-grade or low-grade. High-grade training included horses with ≥ 3 months training during the preceding 6-month period, that had ≥ 3 training days/wk, and that were in full training or had been untrained for no more than 1 month at the time of the examination. Low-grade training included horses that had been trained < 3 months, had < 3 training days/wk, or had been untrained for longer than 1 month at the time of examination.

Clinical, ECG, and echocardiographic examinations—The examinations were performed in training yards or at private farms and included auscultation, an ECG, and echocardiographic examination. All examinations were performed by the same operator. Standard 2-dimensional and M-mode echocardiographic examinations were performed according to a described technique. Only data derived from color Doppler examinations are described in the present report. The tricuspid, pulmonic, mitral, and aortic valves were all examined via color Doppler echocardiography with a 1.5-MHz phased-array sector transducer with harmonic imaging. All valves were identified in 2-dimensional mode and then evaluated with color Doppler echocardiography. If regurgitant blood flow was detected, the imaging plane was angled to reveal the maximal size of the regurgitant flow. A zoom feature was not used. The procedure was performed in triplex. Signals of very short duration arising immediately after valve closure were ignored; such signals were attributed to valve closure artifact or movement of blood in front of closing valve leaflets. The tricuspid valve was examined in the right parasternal long-axis and long-axis tipped views. The pulmonic valve was examined in the right parasternal long-axis and long-axis apical views. The aortic valve was examined in the left parasternal long-axis and 5-chambered views. On the basis of the area of regurgitation in relation to the approximate size of the respective atrium for regurgitation in the mitral and tricuspid valves, 4 groups were defined as follows: group 1, very small jet (< 10% of the area of the atrium); group 2, small jet (≥ 10% to 30%); group 3, medium jet (≥ 30% to 50%); and group 4, large jet (≥ 50%). For regurgitation at the aortic and pulmonic valves, the maximal diameter of the regurgitant blood flow just below the aortic and pulmonic valves was measured. For 6 horses (4 horses in the first examination and 1 each in the second and third examinations), it was not possible to maintain the heart rate consistently < 45 beats/min, and the horses were sedated lightly via IV administration of 0.04 mg of romifidine hydrochloride/kg.

Statistical analyses—At each examination, 3 repeated measurements were obtained from 3 images each of tricuspid, pulmonic, mitral, and aortic valve regurgitation. For descriptive analyses, the mean value of the 3 measurements of regurgitant flow at the pulmonic and aortic valves and the median value of the measurements of regurgitant flow at the tricuspid and mitral valves were used, respectively. Regurgitation was designated as present or absent and was recorded as present whenever the mean (for the pulmonic and aortic valves) or median (for the tricuspid and mitral valves) value for regurgitation was > 0. This procedure was repeated for each valve on each examination day.

A repeated-measurements logistic analysis was performed to evaluate the factors associated with regurgitation at the tricuspid, pulmonic, mitral, and aortic valves, respectively. Sex (male or female), age at time of the study (20 to 21, 22, 23, and 24 to 25 months), training status (eg, low- or high-grade), and examination round (1 through 4) were included as fixed effects. Body weight was included as a covariate. The autocorrelation between repeated measures in the same horse was accounted for by including an autoregressive covariance structure. Backward elimination was used to obtain the resulting models.

The association between racing and valvular regurgitation at the fourth examination was evaluated for tricuspid, pulmonic, mitral, and aortic valve regurgitation in horses that had raced ≥ 3 times. Because the response variables were dichotomous (present or absent), logistic regression analyses were performed. The outcomes were tricuspid, pulmonic, mitral, and aortic valve regurgitation. Having participated in ≥ 3 races (yes or no) was included as a fixed effect, as were sex (male vs female), age at inclusion in study (20 to 21, 22, 23, and 24 to 25 months), and training status (low- vs high-grade). Body weight was included as a covariate. The Spearman correlation coefficients between echocardiographic measurements at the fourth examination and racing performance were calculated. All analyses were performed with commercially available software. Significance was set at a value of P < 0.05.

Results
All horses had been only lightly trained prior to the first examination. Therefore, the training before the study was characterized as primarily disciplinary in nature. Because of the low-intensity physical demands, such training was difficult to characterize according to the study criteria (ie, low- vs high-grade training). During the first 6 months of the study, 65 of 103 (63%) horses were categorized in the high-grade training group, which increased to 83 of 103 (81%) by the end of the study. The auscultatory examinations and ECGs revealed no pathologic arrhythmias or other abnormal findings.

Descriptive data for the frequency and size of valvular regurgitant flows were summarized (Table 1). Fifteen of 103 (15%) horses had tricuspid valve regurgitation and 1 to 3 of 103 had pulmonic, mitral, or aortic valve regurgitation at the first examination. At the fourth examination 18 months later, the incidence of regurgitation detected for all 4 valves had increased significantly, with 66 of 103 (64%) horses having tricuspid valve regurgitation (P < 0.001), 44 of 103 (43%) having aortic valve regurgitation (P < 0.001), 22 of 103 (21%) having pulmonic valve regurgitation (P = 0.006), and 23 of 103 (22%) having mitral valve regurgitation (P = 0.006). For the mitral and tricuspid regurgitant flows, the median size was categorized as very small, occupying < 10% of the approximate size of the atria. The
diameter of the pulmonic and aortic regurgitant flows remained constant between 0.82 and 1.05 cm.

Fifty-five percent (91/166) of the examinations that revealed tricuspid valve regurgitation also had auscultatory evidence of regurgitant flow. For horses with mitral and aortic valve regurgitation, the regurgitation was audible in 7 of 47 (15%) and 9 of 97 (9%) examinations, respectively. Audible murmurs were not detected in any horses in which pulmonic valve regurgitation was identified with Doppler echocardiography.

The repeatability of measurements of regurgitation was summarized (Table 2). At the time of the first examination, 15 horses had tricuspid valve regurgitation; of those, 11 continued to have tricuspid valve regurgitation during the next 3 examinations. At the second examination, 24 new horses had tricuspid valve regurgitation, and of those, 14 continued to have tricuspid valve regurgitation during the next 2 examinations. Finally, 18 horses had tricuspid valve regurgitation diagnosed for the first time at the third examination, and of those, 13 had tricuspid valve regurgitation at the last examinations. Generally, regurgitation at the pulmonic and mitral valves had the weakest repeatability (0% to 50%), whereas regurgitation at the tricuspid and aortic valves was more constant (53% to 73%).

No significant association with sex, body weight, age at time of initial examination, or training status and pulmonic, mitral, and aortic valve regurgitation was detected. For tricuspid valve regurgitation, there was an association with age at the time of initial examination, but regurgitation at the tricuspid valve was more frequent in males, compared with females (P = 0.003), and horses with a history of high-grade training had significantly (P = 0.017) more tricuspid valve regurgitation than did horses with a history of low-grade training (Table 3). The resulting logistic regression model for the probability of presence of tricuspid valve regurgitation (p) is given by the following formula:

\[
p = \frac{1}{1 + \exp[-(\text{intercept} + \text{sex} + \text{training} + \text{examination})]}
\]

Colts had odds 2.56 times those of fillies for having tricuspid valve regurgitation. High-grade–trained horses had a risk of developing tricuspid valve regurgitation 1.9 times that of low-grade–trained horses. The risk of developing tricuspid valve regurgitation increased with the number of examinations and at the fourth examination was 11.1 times the risk at the first examination. The probability for tricuspid valve regurgitation was estimated at 6.2% for low-grade–trained males at the fourth examination.

Horses that were racing (n = 63) had significantly (P = 0.04) higher incidence of tricuspid valve regurgitation at the fourth examination than horses that had not been racing (40) at 3.5 years of age. In addition, horses that were racing regularly had been trained significantly (P = 0.017) more than unraced horses. There was no significant difference between racing versus nonracing horses for pulmonic, mitral, and aortic valve regurgitation at the fourth examination.

The median value and range of estimated left ventricular (LV) mass, left ventricular internal diameter

<table>
<thead>
<tr>
<th>Examination</th>
<th>First (n = 103)</th>
<th>Second (100)</th>
<th>Third (96)</th>
<th>Fourth (103)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tricuspid</td>
<td>15 (15)</td>
<td>37 (37)</td>
<td>48 (50)</td>
<td>66 (64)</td>
</tr>
<tr>
<td>Frequency</td>
<td>1 (1–3)</td>
<td>1 (1–2)</td>
<td>1 (1–2)</td>
<td>1 (1–2)</td>
</tr>
<tr>
<td>Pulmonic</td>
<td>2 (2)</td>
<td>11 (11)</td>
<td>17 (18)</td>
<td>22 (21)</td>
</tr>
<tr>
<td>Frequency</td>
<td>1.02 (0.16)</td>
<td>0.85 (0.17)</td>
<td>0.85 (0.21)</td>
<td>0.89 (0.22)</td>
</tr>
<tr>
<td>Mitral</td>
<td>1 (1)</td>
<td>11 (11)</td>
<td>12 (13)</td>
<td>23 (22)</td>
</tr>
<tr>
<td>Size (cm)</td>
<td>1 (1)</td>
<td>1 (1–2)</td>
<td>1 (1–1)</td>
<td>1 (1–1)</td>
</tr>
<tr>
<td>Aortic</td>
<td>3 (3)</td>
<td>20 (20)</td>
<td>30 (31)</td>
<td>44 (43)</td>
</tr>
<tr>
<td>Frequency</td>
<td>1.05 (0.26)</td>
<td>0.91 (0.24)</td>
<td>0.82 (0.24)</td>
<td>0.95 (0.24)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Examining factors associated with tricuspid regurgitation in Standardbred trotters.</th>
<th>OR (95% CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>NA</td>
<td>-2.709</td>
</tr>
<tr>
<td>Sex</td>
<td>Male</td>
<td>0.941</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>1</td>
</tr>
<tr>
<td>Training (grade)</td>
<td>High</td>
<td>0.641</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>0</td>
</tr>
<tr>
<td>Examination</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1.303</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1.781</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>2.406</td>
</tr>
</tbody>
</table>

OR = Odds ratio. CI = Confidence interval. NA = Not applicable. — Referent category.

in diastole (LVId), kilometer time, total earnings, and percentage of wins were calculated (Table 4). No significant relationship was detected between size of the heart (ie, LV mass and LVId) or racing performance (ie, kilometer time, total earnings, and percent-

| Table 1—Frequency (percentage at each examination [horses examined every 6 months for 18 months]) and size of valvular regurgitation detected by use of color Doppler echocardiography in a group of 103 Standardbred trotters 2 to 3.5 years of age. For tricuspid and mitral valve regurgitation, size of the regurgitant jet was categorized (group 1, 0% to 10% of the size of the atrium; group 2, ≥10% to 30% of the size of the atrium; group 3, ≥30% to 50% of the size of the atrium; and group 4, ≥50% of the size of the atrium), and scores were reported as median (range). For pulmonic and aortic valve regurgitation, data are presented as mean (SD) diameter of the regurgitant flow in centimeters. |

| Table 2—Repeatability of detection of valvular regurgitation in a group of 103 Standardbred trotters 2 to 3.5 years of age examined every 6 months for 18 months and size of valvular regurgitation detected by use of color Doppler echocardiography. The numerator represents the number of horses with regurgitation that was consistently diagnosed at each examination. The denominator represents the number of horses in which valvular regurgitation was diagnosed at each examination. Data are presented as frequency (percentage at each examination [horses examined every 6 months for 18 months]). No significant association with sex, body weight, age at time of initial examination, or training status and pulmonic, mitral, and aortic valve regurgitation was detected. For tricuspid valve regurgitation, there was an association with age at the time of initial examination, but regurgitation at the tricuspid valve was more frequent in males, compared with females (P = 0.003), and horses with a history of high-grade training had significantly (P = 0.017) more tricuspid valve regurgitation than did horses with a history of low-grade training (Table 3). The resulting logistic regression model for the probability of presence of tricuspid valve regurgitation (p) is given by the following formula: |

<table>
<thead>
<tr>
<th>Table 3—Results of logistic regression analysis of factors associated with tricuspid valve regurgitation in Standardbred trotters.</th>
<th>Level</th>
<th>Estimate</th>
<th>OR (95% CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>NA</td>
<td>-2.709</td>
<td>NA</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Sex</td>
<td>Male</td>
<td>0.941</td>
<td>2.56</td>
<td>1.40-4.70</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training (grade)</td>
<td>High</td>
<td>0.641</td>
<td>1.90</td>
<td>1.13-3.20</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Examination</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1.303</td>
<td>3.68</td>
<td>2.05-6.61</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1.781</td>
<td>5.94</td>
<td>3.07-11.50</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>2.406</td>
<td>11.12</td>
<td>5.50-22.48</td>
</tr>
</tbody>
</table>

OR = Odds ratio. CI = Confidence interval. NA = Not applicable. — Referent category.
regurgitation than cardiac auscultation, especially when
phy is a more sensitive technique for detecting valvular
comparable with findings from a previous study , a but the
via auscultation (91/166 [55%] horses). That result was
detected by use of Doppler echocardiography was also detected
most frequent site at which regurgitant flow as detected
detectable by auscultation. The tricuspid valve was the
detected with color Doppler echocardiography were
ies1,2 , a of mature Thoroughbreds.
findings from color Doppler echocardiographic stud-
tion when horses were 3.5 years of age was similar to
and regular training. In our study , the high incidence of
ly different. In the previous study , a investigators using
ly) than horses without tricuspid valve regurgitation.
However, there was no association between variables of
valvular regurgitation.
None of the 6 horses that were retired because of
lack of talent had large regurgitant flows; 2 horses had
tricuspid valve regurgitation that was categorized as
very small, 1 had mitral valve regurgitation that was
characterized as very small, and 1 had aortic valve
regurgitation with a maximal diameter of 1.1 cm.

Discussion
The results indicated that the incidence of valvular
regurgitation increased significantly over the 18
months of the study period. Similar findings have been
described in Thoroughbreds evaluated by auscultation,
and in previous studies1,10,19 it has been suggested that
there is a relationship between valvular regurgitation
and regular training. In our study, the high incidence of
valvular regurgitation observed at the final examination
when horses were 3.3 years of age was similar to
findings from color Doppler echocardiographic stud-
ies2,3 of mature Thoroughbreds.

In our study, up to 55% of the regurgitant flow jets
detected with color Doppler echocardiography were
detectable by auscultation. The tricuspid valve was the
most frequent site at which regurgitant flow as detected
by use of Doppler echocardiography was also detected
via auscultation (91/166 [55%] horses). That result was
comparable with findings from a previous study3 but the
results regarding mitral valve regurgitation were marked-
dly different. In the previous study3 investigators using
auscultation detected 41% of the horses that had mitral
valve regurgitation as diagnosed by use of color Doppler
echocardiography. In our study, only 7 of 47 (15%) hors-
es that had mitral valve regurgitation diagnosed echocar-
diographically had corroborating auscultation findings.
Two studies21,24 have revealed that Doppler echocardiog-
raphy is a more sensitive technique for detecting valvular
regurgitation than cardiac auscultation, especially when
regurgitation is mild. This may explain the discrepancy
between auscultatory and Doppler echocardiographic
findings in the present study.

In the Standardbred trotters studied, the sizes of the
valvular regurgitant flows were generally small and
increases in size of the flows were not observed over
time. Small sizes for regurgitant flows in Thoroughbreds
have also been reported.13 However, the classifications
used in those studies are not directly comparable to
those in the present study. There have been few investi-
gations of the progression of valvular regurgitation in
racehorses. A substantial increase in the grade of heart
murmurs indicative of tricuspid regurgitation in horses
after 6 to 9 months of race training has been reported.13
Echocardiographic studies8-12 in humans have revealed
an increased frequency of valvular regurgitation among
athletes, compared with untrained control subjects, but
no difference in the size of the regurgitant flows was
observed between groups. Results of the present study
indicated that horses in training may develop valvular
regurgitation similar to human athletes. In our horses,
the regurgitant flow jets were generally very small and
there was little or no progression. However, quantifica-
tion of mitral and tricuspid valve regurgitation, in par-
ticular, was coarse, and because of the way in which the
jets were categorized, it is possible that minor increases
in severity of the regurgitation were missed.

The repeatability of the regurgitant jets between
examinations was low. Regurgitation at the mitral and
pulmonic valves was especially difficult to detect during
subsequent examinations, whereas tricuspid and aortic
valve regurgitation were observed more consistently.
These results were comparable to those from a previous
validation study20 in which repeatability of small regurgi-
tation jets was generally low. Reasons for the low repea-
tability could include physiologic factors, such as trans-
valvular pressure gradients, orifice area, compliance of the
receiving chambers, and interactions of the regurgitant
jet with the cardiac walls. Instrument settings and field depth
also influence quantification of regurgitant flows21,24.

Light sedation with romifidine was required for 6 of
402 examinations. Data from those examinations were
included in the analyses because our personal experience
is that sedation under those conditions does not sub-
stantially affect the frequency or severity of regurgitation.

Table 4—Echocardiographic and racing performance values in Standardbred trotters evaluated for
valvular regurgitation. Spearman correlation coefficient data were calculated with regurgitation at each
valve classified as present or absent.

<table>
<thead>
<tr>
<th>Variable</th>
<th>LV mass (g)</th>
<th>LVIDd (cm)</th>
<th>Kilometer time (s)</th>
<th>Total earnings (Dkr)</th>
<th>Wins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fourth examination</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>3,226</td>
<td>12.05</td>
<td>79.20</td>
<td>9,550</td>
<td>10</td>
</tr>
<tr>
<td>Range</td>
<td>2,323-4,490</td>
<td>10.12-14.01</td>
<td>73.4-88.8</td>
<td>0-390,226</td>
<td>0-43</td>
</tr>
<tr>
<td>No. of horses</td>
<td>103</td>
<td>103</td>
<td>63</td>
<td>63</td>
<td>63</td>
</tr>
<tr>
<td>Spearman correlation coefficient (P value)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tricuspid valve</td>
<td>0.30 (0.002)</td>
<td>0.23 (0.017)</td>
<td>0.05 (0.68)</td>
<td>-0.04 (0.76)</td>
<td>0.05 (0.67)</td>
</tr>
<tr>
<td>Pulmonary valve</td>
<td>0.18 (0.07)</td>
<td>0.15 (0.13)</td>
<td>-0.07 (0.56)</td>
<td>-0.01 (0.92)</td>
<td>-0.08 (0.51)</td>
</tr>
<tr>
<td>Mitral valve</td>
<td>0.03 (0.76)</td>
<td>0.13 (0.21)</td>
<td>0.01 (0.92)</td>
<td>0.005 (0.97)</td>
<td>0.04 (0.76)</td>
</tr>
<tr>
<td>Aortic valve</td>
<td>0.04 (0.72)</td>
<td>0.05 (0.66)</td>
<td>-0.06 (0.66)</td>
<td>-0.01 (0.91)</td>
<td>-0.02 (0.85)</td>
</tr>
</tbody>
</table>

*LV = Left ventricular. LVIDd = Left ventricular internal diameter during diastole. Dkr = Danish krone ($100 = 618 Dkr). Fourth examination = Echocardiographic examination performed 18 months after the first exami-
nation.*
To differentiate whether the progression of valvular regurgitation observed in the present study was caused by age-related changes or training-induced changes, it would require an untrained age-matched control group. The lack of such a group in the present study made it impossible to directly assess the effects of maturity and training. However, a higher incidence of tricuspid valve regurgitation was detected among horses that were racing regularly, and those horses had been trained significantly more than the unraced horses. This indicates that, at least for tricuspid valve regurgitation, the increase can be explained in part by the effects of training.

Our group recently reported that substantial eccentric cardiac hypertrophy developed in the horses during the 18-month study period. In the present study, horses with larger LV mass and LVIDd had a higher frequency of tricuspid regurgitation. Although there were no important associations between LV mass or LVIDd and pulmonic, mitral, and aortic valve regurgitation, the data indicate that eccentric hypertrophy of the myocardium may be important in the development of valvular regurgitation in horses. Results of echocardiographic studies in human and equine athletes reveal that there is an increase in LV size after athletic training. The increase is often referred to as training-induced eccentric hypertrophy and is characterized by an increase in ventricular diameter as well as increased myocardial mass. Whether the altered geometric features of the ventricle are responsible for the development of valvular regurgitation is not known, but it is possible that with the morphologic changes accompanying eccentric hypertrophy, the seal created by valve leaflets or chordae tendineae would become incompetent and regurgitation of blood would result. However, in 1 study, no important enlargement of the cardiac chambers was detected in a group of human female athletes, despite the fact that regurgitation was more frequently observed in the athletic women, compared with sedentary control subjects.

Although many studies have investigated LV function in human athletes, there are relatively few studies concerning the right side of the heart. Both the right atrium and right ventricle are larger in human athletes, compared with control subjects, indicating that similar adaptations are taking place on the right side of the heart as occur in the left side. The repeatability of echocardiographic measurements of the right atrium and right ventricle in the horse is poor. For that reason, measures of the right atrium and ventricle were not included in the present study; similar reasoning has been used in previous studies. Nevertheless, it is possible that changes in the right ventricle and right atrium may explain the high prevalence of tricuspid valve regurgitation observed in the present and previous studies. In horses engaged in strenuous exercise, pulmonary arterial systolic pressure (PASP) more than doubles, compared with that in resting horses. Such increases in pulmonary arterial pressure in response to exercise are much greater than the increases observed in other mammals, including humans. Athletic humans develop higher PASP during exercise, compared with untrained subjects, and the tricuspid regurgitation flow velocity is higher in athletes. Those findings led the authors to hypothesize that the high rate of tricuspid regurgitation observed in athletes was a result of higher PASP. The high PASP is likely associated with increased stroke volume and increased left atrial pressure in athletic individuals, although the relative contributions remain unclear. The relationship between PASP and valvular regurgitation has not been studied in horses.

Colts had increased frequency of tricuspid regurgitation, compared with fillies. This finding may reflect the fact that males have a larger LV mass than females, as reported previously in this group of horses, or that males may have larger stroke volumes and PASPs than females. Colts that have been trained intensively have larger ventricles and thus may also have a higher risk of tricuspid valve regurgitation.

Although the frequency of valvular regurgitation in this group of horses was high, none appeared to have clinical signs of cardiovascular disease or reductions in performance. Furthermore, the frequency of pulmonic, mitral, and aortic valve regurgitation did not differ between the groups of horses that were racing regularly at 3.5 years of age and horses that did not race. None of the 6 horses that were retired because of poor talent had severe valvular regurgitation.

Our results indicated that mild valvular regurgitation was well tolerated in young Standardbred trotters. These results are in agreement with a previous study in Thoroughbreds, in which no significant association between murmurs detected via auscultation and performance was detected. In contrast, other data suggest that marked and moderate valvular regurgitation may be associated with subtle decrements in performance in National Hunt racehorses, but that regurgitation does not necessarily preclude success as a racehorse.

The examinations of the horses were carried out at rest, with the heart rate as close to a resting value as possible. It was not possible to assess how the level of exercise affected regurgitation. Physical maneuvers that raise the heart rate to 80 beats/min or higher increase the frequency of all systolic heart murmurs, including functional murmurs (ie, associated with normal blood flow) and murmurs associated with valvular regurgitation. No echocardiographic studies on valvular regurgitation in horses before and immediately after exercise have been published.

At the end of the 18 months of the present study, horses were 3.5 years of age; this is the age at which race training of Standardbred trotters is increasing in intensity to prepare horses for the most prestigious races as 4-year-olds. A continuation of the study period so that horses 4 and 5 years of age were included would increase available information about the development and progression of valvular regurgitation as well as its effects on performance.

Our results indicated that there was a significant increase in the frequency of valvular regurgitation detected in Standardbred trotters as they aged from 2 to 3.5 years, with the tricuspid valve being most frequently affected. Regurgitation was mild at all valves, and no progression in severity was observed. Whether the increased frequency in valvular regurgitation was a result of maturity, training, or both could not be determined with this study design. The clinical implication of our findings is that small regurgitant flows are not
abnormal and that affected horses do not have clinical signs pertaining to cardiovascular disease. There was no relationship between valvular regurgitation and performance, but the possibility that valvular regurgitation may lead to a decrease in performance in older horses cannot be excluded. Echocardiographic examination immediately after strenuous exercise would provide insight into the function of the valves and the physiologic importance of regurgitant valves in racehorses.


References


