

Retrospective study on the athletic development of Warmblood horses after cardiac examination

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Summary: Predicting the influence of cardiac findings on the athletic development of a horse represents a delicate balance for clinicians. Therefore, this study investigates the impact of cardiac findings on the athletic trajectory of horses. Understanding these factors can enhance our knowledge of equine career longevity and success, offering valuable prognostic information for veterinarians and horse owners. The study analyses data from 450 Warmbloods sourced from the German Riding Association's (FN) database. All Horses had undergone both a general and a specific cardiac examination and were found in the database. The study examines associations between cardiac abnormalities and career outcomes. The study lacks a control group and must be interpreted with caution and primarily in relation to the study population. Results indicate that horses with cardiac dimensional changes are more likely to end their athletic careers around the time of diagnosis. Atrial fibrillation also correlates with setbacks in performance. Veterinarian prognostic assessments are notably accurate, especially for cases with less favourable prognoses. Additionally, the study explores the detailed consequences of cardiac dimensional changes on sports performance post-diagnosis, revealing a significant decline in athletic ability. Future research should consider additional factors such as weight, age, size, severity of valvular regurgitation and veterinary recommendation bias. Enhancing routine documentation in clinics can improve the precision of retrospective studies, and exploring international sports-related databases could provide further insights.

Keywords: equine cardiology, echocardiography, sports medicine, performance development, cardiovascular impact

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Introduction

Accurate predictions regarding the future athletic development and utility of a Warmblood horse based on the interpretation of various parameters in equine cardiac ultrasound pose significant challenges^[1]. Based on current knowledge, the clinical significance of most cardiac findings detected in horses during routine examinations or within pre-purchase assessments considered to have limited clinical significance. Only a small amount of findings carry noteworthy implications for the performance of the horse^[2]. Previous studies report that atrial fibrillation (AF), enlargement of the left atrium (LA), ventricular and supraventricular premature contractions (VPC, SVPC) and significant mitral valve regurgitation (MR) can lead to exercise intolerance^[1,3]. Precise outcomes regarding athletic performance metrics such as career duration, winnings, or utilization following echocardiographic diagnosis in Warmbloods are rare. However, studies substantiate that cardiac characteristics have influence on performance-determining factors in healthy thoroughbreds^[4]. The aim of this study was to provide more detailed insights into the ongoing athletic potential of horses following a diagnosis through cardiac examination including transthoracic cardiac ultrasound and

echocardiogram (ECG), hypothesizing that different cardiac findings have a diverse impact on the athletic careers of horses. Therefore, the study analysed the athletic trajectories of 450 Warmblood horses sourced from the German Riding Federation's (FN) database in relation to their diagnoses.

Materials and methods

All Warmblood horses which were presented between January 1, 2000, and November 27, 2018, to a specialized referral clinic in Northern Germany were included, if they had a complete comprehensive clinical examination including echocardiography and electrocardiography. All examinations were performed and assessed by veterinarians with a minimum of five years of experience, who are board-certified (German Federal Veterinary Surgeons' Association - BTK) specialists in equine medicine and hold post-graduate Doctor of Veterinary Medicine (Dr. med. vet.) degrees.

The athletic life performance of 450 Warmblood horses with diverse cardiac ultrasound diagnoses were retrospectively analysed, with a particular focus on their sporting achievements

within the 5-year period following the diagnosis. The sports related data utilized in this study were sourced from the FN database in October 2023. Horses had to be listed in this database with placement to be included in the study.

The examination results, relevant information such as age, sex, breed, as well as findings from the clinical examination, auscultatory findings, and results of echocardiographic and electrocardiographic examinations were recorded in the patient database with the approval of the horse owners. Images and videos from the echocardiographic examination were also stored in the digital patient records using "easyVET" (Veterinärmedizinisches Dienstleistungszentrum (VetZ) GmbH Sattlerstraße 40 D-30916 Isernhagen). The examination results and the prognosis originating from this database were extracted in June 2022. The data were retrospectively collected from the clinic's video and image archive, as well as from reports authored by the examining veterinarians.

The same horses were also part of a different study on the association between auscultatory and echocardiographic cardiac findings^[5].

Only the results of the first examination were included in the study for each horse, with subsequent examinations for the same horse disregarded.

Clinical examination

As part of each examination, a general clinical examination was conducted with a focus on the cardiovascular system. Of particular interest were clinical symptoms of performance insufficiency and circulatory issues such as oedema, cyanosis, syncope, and dyspnoea. Upon their arrival at the clinic, the presented horses were auscultated. Auscultation was performed according to current standards^[6]. The cardiac murmurs were described based on their apparent severity on the left and/or right side of the chest and classified accordingly from Grade 1 to Grade 6. They were characterized as systolic, diastolic, or continuous at each time point^[7].

Echocardiography

The performed ultrasound examination included B- and M-modes, as well as colour Doppler echocardiography of all four heart valves and septal defects, if present. If valve regurgitations (VR) or ventricular septal defects (VSD) were identified, they were classified as mild, moderate, or severe according to the size of the jet^[7,8]. Heart dimensions were measured and recorded in millimetres (mm). The left atrium (LA) and left ventricle (LV) were considered enlarged if they exceeded a size of 135 mm^[7]. The right atrium (RA) and right ventricle (RV) were considered enlarged if they exceeded 80 mm^[7].

Electrocardiography (ECG)

A resting ECG examination with a standardized base-to-apex lead^[9] was performed on all horses. In cases of irregular heart rhythm or unexplained performance insufficiency during exer-

cise, an exercise ECG was conducted using telemetry ECG (Televet 100 – Veterinary ECG Device, Engel Engineering Services GmbH). Electrodes were placed in a modified base-to-apex configuration on the left and right thorax sides and on the sternum^[1,9]. The electrodes were secured with a lunge girth and connected to a transmitter. Data was transmitted via Bluetooth to a computer equipped with appropriate software for analysis. The horses were exercised on the lunge line according to their usual training intensity. Findings were defined in accordance with the description by van Loon^[10]. Atrial or ventricular extrasystoles were considered pathological if more than 2 occurred during exercise, if paroxysmal atrial fibrillation was present, or if more than five isolated premature contractions were observed during the recovery phase^[11].

Sports-related data

The data on horses' sporting achievements, lifetime earnings, career duration, total placements (placement is defined as being in the top third of participants), highest placement, and discipline were extracted from the FN Database. Horses were uniquely identified in the system based on their UELN (Unique Equine Life Number). The horses were categorized as "placement level consistent before and after the diagnosis", "highest placement before diagnosis", "highest placement after diagnosis", "career halted prior to or in the year of diagnosis" (last result was during this period). The years following the examination were examined in more detail, noting whether, and if so, in which class the horses were placed. This was done separately for the first 2 years after the examination, the 3rd and 4th year after the examination, and the 5th year and beyond.

The horses were additionally categorized based on their highest achievements. In these classifications, we grouped horses that demonstrated their highest placements at the "E" (Entry) or "A" (Beginner) levels. Subsequently, we classified horses that achieved success up to the "L" (Easy) level, horses that excelled up to the "M" (Medium) level, horses that performed at the "S*" (lowest heavy class) level, and horses that excelled beyond "S*" up to "S*****" (Championship level).

Statistical analysis

The data was analysed using IBM SPSS Statistics software (IBM Corp. Released 2021. IBM SPSS Statistics for Windows, Version 28.0. Armonk, NY: IBM Corp). Associations between findings were evaluated using the Chi-square test or Fisher's exact test (when at least 25% of the cells had an expected count less than 5). Additionally, the odds ratio (OR) including a 95% confidence interval was determined, indicating how much higher the risk of one finding is in one group compared to the reference group. The significance level was set at 5%.

Results

Among the patients were 64.9% geldings, 8.0% stallions and 27.1% mares. The age of the patients at the time of the examination varied between a minimum of 2.15 years and a

maximum of 29.61 years. The median age was 8.31 with an interquartile range from 5.42 to 12.54 years.

Performance

In the study, 48.7% (219 out of 450) of the horses were placed in a competition during the year of investigation. Among these horses, an equal number participated in dressage and show jumping, accounting for 44.7% each (201 out of 450 for each discipline). Additionally, 9.3% of the horses were involved in eventing (42 out of 450), 0.9% in driving (4 out of 450), and one horse was dedicated to vaulting (0.2%; 1 out of 450). The study included horses of all levels (Figure 1). The lifetime earnings of the horses ranged from a minimum of € 0.00 to a maximum of € 384,455.00, with a median of € 490.00 and an interquartile range from € 151.50 to € 1,378.25. (Figure 2). The athletic careers of the study population ranged from a singular tournament appearance to a maximum career duration of 16 years (Figure 3). The count of placements varied between 1 and 159 (Figure 4).

Clinical examination

Out of 450 horses surveyed, 163, constituting 36%, displayed clinical abnormalities in the study. Horses showing clinical abnormalities significantly more often concluded their sporting

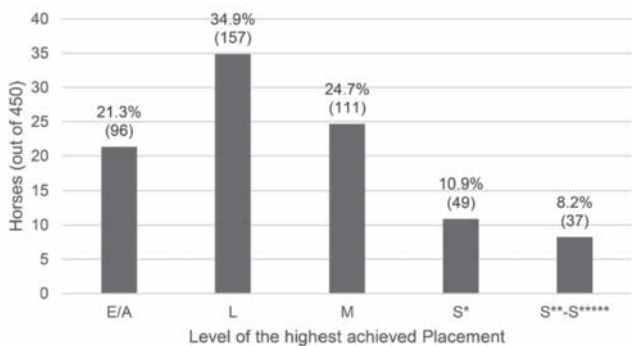


Fig. 1 Level of the highest achieved placement: E–Entry or A–Beginner, L–Easy, M–Medium, S*–lowest heavy class level, S**–S****–excelling S* up to Championship level. | Klasse der höchsten erreichten Platzierung: E–Einsteiger oder A–Anfänger, L–Leicht, M–Mittel, S*–niedrigste schwere Klasse, S**–S****– von S* bis zur Championatsklasse.

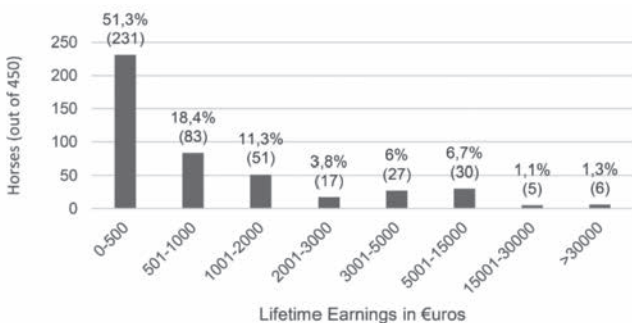


Fig. 2 Lifetime Earnings in Euros within the study population of 450 Warmblood horses. | Lebensgewinnsummen in Euro innerhalb der Studienpopulation bei 450 Warmblütern.

careers. Of these, 55.8% (91 out of 163) terminated their careers before or following the diagnosis, whereas among clinically unremarkable horses, only 35.2% (101 out of 287) did so. The p-value was below 0.001, while the odds ratio (OR) was 2.328 (95% Confidence interval 1.572–3.447). The chance for clinically abnormal horses to achieve an improvement in their athletic performance after diagnosis was 28.8% (47 out of 163), while the chance for clinically unremarkable horses was 50.9% (146 out of 287). There was a significantly higher risk of being less placed in the subsequent years following the diagnosis. In the first two years after diagnosis, the chance of at least one placement was 14.2% lower for clinically abnormal horses compared to clinically unremarkable ones. In years 3 and 4 after the diagnosis, the chance of at least one placement was 16.2% lower, and for the 5th year and beyond, clinically abnormal horses had 18.7% fewer chances.

Ultrasound and echocardiogram

Horses with valve regurgitations (VR) were more frequently placed in comparison to horses without VR in the later years following the diagnosis in the study. In the 5th year and beyond after diagnosis, horses with VR (34% (113 out of 330)) had a 1.4 times higher chance to achieve placements than horses without VR (24.2% (29 out of 120)). The p-value was 0.042, the odds ratio (OR) was 1.634 (95% confidence interval 1.015–2.630). Atrial Fibrillation (AF) directly led to horses not achieving placements in the years following diagnosis: In the first two years after diagnosis, one fifth (22.9% (11 out of 48)) of horses with AF were still able to achieve placements com-

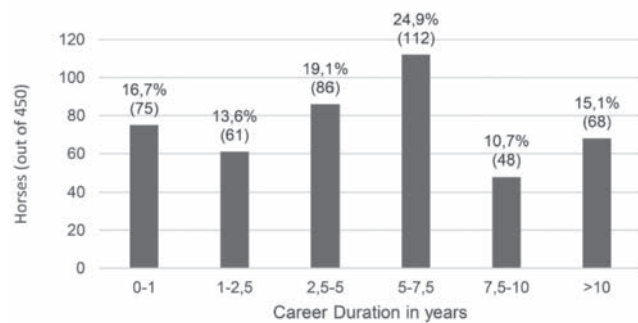


Fig. 3 Career duration in years within the study population of 450 Warmblood horses. | Dauer der Karrieren in Jahren innerhalb der Studienpopulation bei 450 Warmblütern.

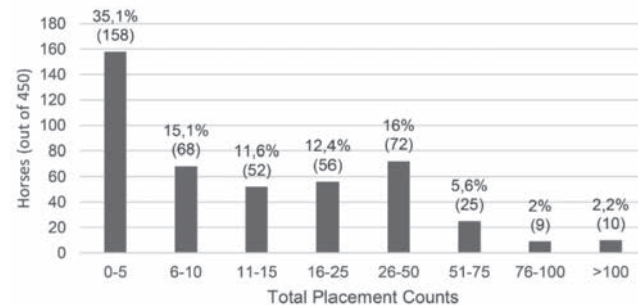


Fig. 4 Total Placement Counts in 450 Warmblood horses undergoing cardiac examination. | Totale Anzahl der Platzierungen bei 450 Warmblütern mit kardiologischer Untersuchung.

pared to horses without AF, of which 47.3% (190 out of 402) achieved placements. The p-value was 0.001, with an odds ratio (OR) of 0.332 (95% confidence interval 0.165–0.669). In the third- and fourth-years post-diagnosis, the difference between horses with and without AF was less pronounced. One fifth (20.8% (10 out of 48)) of horses with AF achieved placements in competitions, while those without AF achieved placements at a rate of 39.3% (158 out of 402). The p-value was 0.012, with an OR of 0.406 (95% confidence interval 0.197–0.839). In the fifth year and beyond after diagnosis, the success rate for horses with AF was 12.5% (6 out of 48), while horses without AF achieved placements nearly three times more at a rate of 33.8% (136 out of 402). The p-value was 0.003, with an OR of 0.279 (95% confidence interval 0.116–0.674). AF was significantly associated with horses that could not improve their athletic performance following the diagnosis. Horses with AF were able to enhance their performance in one fifth (20.8% (10 out of 48)) of cases, while for horses without AF, this percentage was 45.5% (183 out of 402). The p-value was 0.001 with an OR of 0.315 (95% confidence interval 0.153–0.649). AF led to career termination in 70.8% (34 out of 48) of cases, while in horses without AF, career termination was impending in 39.3% (158 out of 402) of cases. The p-value is less than 0.001, with an OR of 3.75 (95% confidence interval 1.951–7.211). Dimensional changes in echocardiography generally had significant effects on the athletic careers of Warmbloods. While one fifth (23.3% (31 out of 133)) improved in their athletic careers following

a diagnosis of heart dimensional changes, it was half (51.4% (162 out of 317)) of the horses without dimensional changes. The p-value was below 0.001 with an OR of 0.291 (95% confidence interval 0.182–0.454; Figure 5).

Dimensional changes in cardiac ultrasound also had direct impacts on sports performance in the two subsequent years following diagnosis. Horses without dimensional changes still achieved athletic success in half (49.5% (157 out of 317)) the cases, while horses with dimensional changes only succeeded in one third (33.1% (44 out of 133)). The p-value indicates significance at 0.001, with an OR of 0.504 (95% confidence interval 0.330–0.769). Similar observations were made regarding the 3rd and 4th years following diagnosis, as well as the 5th year and subsequent years after diagnosis. Here, statistically significant differences were evident, with horses exhibiting dimensional changes showing consistently lower placement odds in all categories. The presence of an enlarged LA had a notable impact on the discontinuation of a horse's sports career and made discontinuation nearly three times more likely. Analysis revealed a highly significant association, reflected in a p-value of < 0.001 and an OR of 2.908 (95% confidence interval 1.793–4.717). Even more, the presence of an enlarged left ventricle (LV) was a significant factor making the termination of a horse's sporting career more than three times more likely. The statistical significance of this effect is underscored by a p-value of < 0.001 and an OR of 3.62 (95% confidence interval 2.006–6.534). In contrast, the diag-

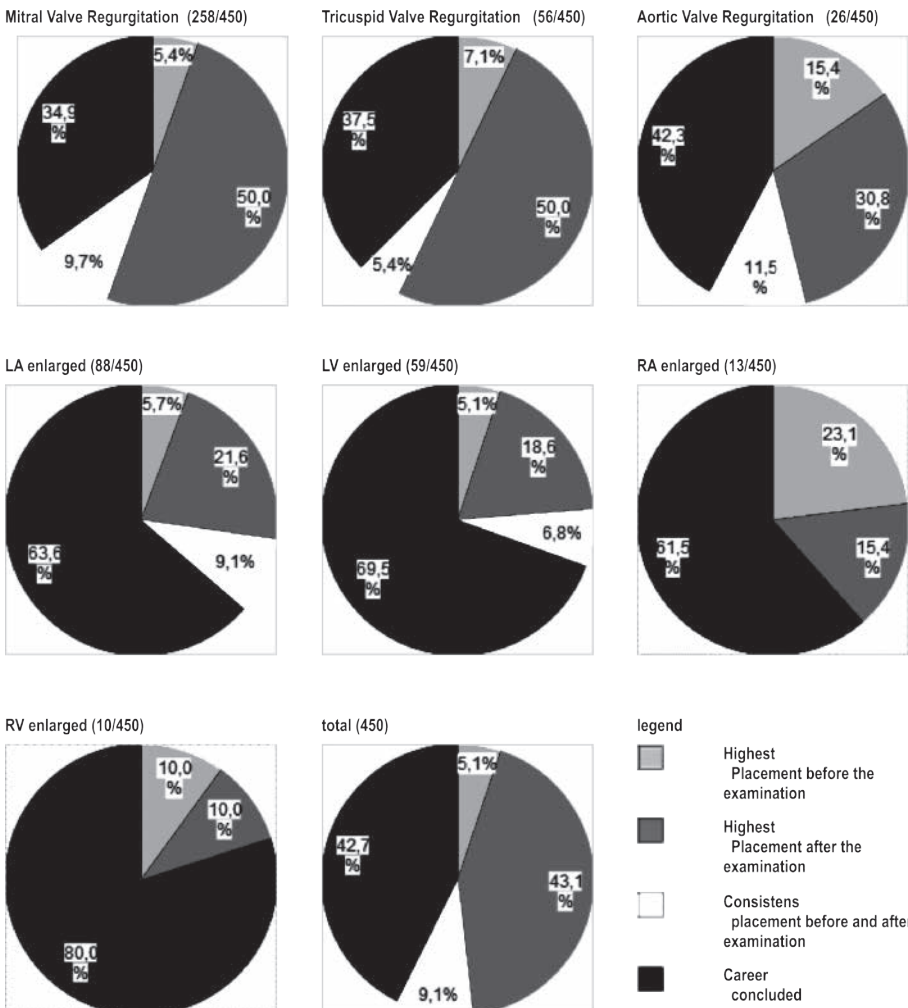


Fig. 5 Evaluation of performance development across different cohorts within the study population. | Vergleichende Bewertung der Leistungsentwicklung verschiedener Studienkohorten.

nosis of aortic enlargement did not yield significant career alterations within the following four years. Nevertheless, horses with aortic enlargement displayed a diminished likelihood of continued competition beyond the five-year threshold. Nearly half (15.6% (5 out of 32)) were able to engage in competition for five or more years post-diagnosis, compared to 32.8% (137 out of 418) of horses without aortic enlargement. The p-value was 0.044 with an OR of 0.38 (95% confidence interval 0.143–1.008). In contrast to aortic enlargement, aortic regurgitation (AR) led to significantly more horses having a career duration longer than 12 years. Among horses with AR, the career duration exceeded 12 years in 19.2% (5 out of 26) of cases, while in horses without AR, 7.1% (30 out of 424) had a career duration greater than 12 years. The p-value was 0.025, with an OR of 3.127 (95% confidence interval 1.101–8.878). Lastly, the enlargement of the pulmonary artery was a significant factor in terminating a sports career, as 85.7% (12 out of 14) of horses with this condition ceased competition, whereas 58.7% (256 out of 436) of horses without pulmonary artery enlargement continued their careers. The p-value was below 0.001 and the OR was 8.533 (95% confidence interval 1.887–35.591).

Prognosis and performance

Among horses with a favourable prognosis, 52.0% (167 out of 321) demonstrated performance improvement following the cardiac examination, while 6.2% (20 out of 321) exhibited better performance prior to the examination, and 11.2% (36 out of 321) experienced no change in their performance. Remarkably, even among horses with a positive prognosis, 30.5% (98 out of 321) ultimately concluded their sports careers.

Conversely, for horses with a conservative prognosis, 27.1% (26 out of 96) demonstrated improvement, 5.2% (5 out of 96) maintained their performance level, and 63.5% (61 out of 96) retired from competitive sports. Intriguingly, 4.2% (4 out of 96) displayed superior performance prior to the examination, despite the conservative prognosis.

Horses with a poor prognosis invariably ceased their sports careers, with 100% (33 out of 33) discontinuing their participation.

Discussion

The study aimed to enhance predictions regarding the athletic development of Warmbloods based on various initial cardiac diagnoses. The veterinarian faces the challenging task of providing the most accurate prognosis, especially concerning the animal's use and value. The study reveals significant disparity in the development of athletic careers following a diagnosis of cardiac conditions, specifically VR, dimensional changes, AF and clinical abnormalities on the long-term athletic performance and career trajectories of horses.

AF emerged as a detrimental factor for competitive success. Furthermore, AF significantly associated with an impaired ability to improve athletic performance post-diagnosis and

was a substantial factor leading to career termination. This observation was not surprising. AF is known to cause clinical limitations. In a study from 2002^[12], it was found that 42% of all patients were reported to have exhibited performance insufficiency prior to the examination, and therapy was unsuccessful in 35%. The clinical relevance of AF is undisputed^[10]. But the significance of the results regarding athletic success in atrial fibrillation of this study should be interpreted with caution: The subsequent actions of owners regarding treatment decisions were not documented. This implies that successfully treated horses were examined within the same cohort experiencing recurrences.

Horses without dimensional changes displayed a notably higher success rate in achieving athletic success. These trends persisted over time. In each category, horses exhibiting dimensional changes consistently demonstrated lower placement odds compared to those without such changes, highlighting that dimensional changes indicate an at least moderate cardiac disease^[6] and the impact of these cardiac alterations on the long-term athletic performance of Warmbloods.

The dimensional change of the LA stands out as a particularly significant factor leading to the cessation of a horse's athletic career. This is a comprehensible result, as an enlarged LA is well-known to be more likely associated with AF, and this association is accompanied by performance insufficiency^[8]. Owners of horses exhibiting an enlarged LA may lean towards retiring their horses or refraining from using them in athletic activities, also following veterinarians' recommendations, as they are likely to recommend career cessation in cases of severe heart disease.

These findings underscore the recommendation of monitoring and controlling dimension-related changes in echocardiography to optimize the athletic potential and well-being of equine athletes^[8]. This holds significance as it is evident that heart diseases can progress, and subclinical findings may become relevant in the future^[13].

The impact of an enlarged LV on a horse's career was substantial as well in this study. This may lead to a considerable percentage of horses discontinuing competition following such a diagnosis because of being an indicator predicting the severity of AR^[14].

The diagnosis of an enlarged RA and RV marks likelihood of career termination. It is known that alterations in the dimensions of the right heart are indicative of an advanced stage of cardiac disease^[1]. These findings emphasize the impact of right-sided cardiac abnormalities on the ability of horses to sustain competitive activities.

AR has influenced the development of the athletic career in an unexpected direction. Horses with AR in this study population displayed a higher proportion of careers lasting longer than 12 years compared to those without this condition. Suggesting a potential protective effect of AR on the longevity of sports careers is probably false. It would have been interesting to investigate various grades of aortic insufficiency in more detail. Many mild cases may have obscured the outcomes of more severe cases. Isolating severe cases could have poten-

tially led to significant results with opposing outcomes. It is also very important to see results in relation to the study population which is only horses visiting an equine clinic for a cardiac examination. Therefore, horses with only AR might have a better chance on a longer career but only in comparison to the rest of the study population that includes horses with different severe findings. Contemporary literature confirms that AR frequently occurs and is only occasionally associated with a decrease in performance, despite the potentially increased risk of sudden cardiac death^[15]. Another explanatory approach may be that AR occurs more frequently in older horses^[16]. Horses with AR in this study may have reached an above-average age, allowing them to engage in longer athletic careers. This could potentially clarify why horses with aortic enlargement were not significantly prone to immediate career alterations within the initial four years post-diagnosis. Nevertheless, those with aortic enlargement exhibited a decreased probability of sustained participation in competition beyond this timeframe.

The enlargement of the pulmonary artery significantly contributed to the cessation of sports careers, with a substantial majority of horses affected by this condition ceased participating in competitions, aligning with the guidance of the consensus statement^[8] indicating owners' tendency to adhere to veterinarians' recommendations in such cases.

In contrast, a notable percentage of horses without pulmonary artery enlargement continued their careers. These findings suggest that pulmonary artery dimensions have a determining effect on continuation or discontinuation of athletic pursuits in Warmbloods. It is worth noting that other diseases like severe equine asthma increase the likelihood of an enlarged pulmonary artery^[17], and it cannot be ruled out that the careers of the horses were terminated due to other circumstances or illnesses. For instance, in the case of an enlarged pulmonary artery resulting from pulmonary issues.

The prognoses given to patients in this study were quite precise, aligning with another study by *Ter Woort*^[2] stating that prognoses of pre-purchase examinations on athletic performance were generally accurate, but it is important to consider that an owner tends to stop training and investing when a vet gives a poor prognosis, which has an important bias.

Limitations of the study

The study lacks a control group as well as factors such as riders experience, genetic capacity, nutrition, training, education, character, influence of vet advice, emphasizing the critical need for assessments to be made exclusively in relation to the corresponding subset of the study population. Evaluations, especially when comparing distributions to the overall population, should be approached with caution due to potential significant biases.

Moreover, relying solely on a national database for international and exported horses comes with limitations. Horses participating in competitions abroad are often not recorded in the national database. This fact distorts investigations into the athletic development of the horse. Nevertheless, the insights from the study are valuable, as they

provide a context for understanding the severity of a particular diagnosis in relation to the severity of various other cardiac conditions. The robustness of the study's conclusions is further impacted by the fact that heart dimensions were not evaluated in relation to body dimensions, age, gender, or training status. According to *Trachsel*^[18], training has an additive effect on LA size, the female sex adds to LA size, and age has an additive effect on both LV and LA size.

Data for this study were collected over an 18-year period, necessitating evaluation in light of the technological advancements that occurred during this time frame. Results may have become more precise or evolved over time due to newly acquired knowledge. In fact, ultrasound technology has remained precise and well-suited for documenting relevant cardiological findings even during the years of the initial study data^[7].

Conclusions

The study underscores the diverse impacts of various cardiac dimensions on sports careers and the complexity of equine cardiac health in relation to athletic performance. These nuanced findings may contribute to a deeper understanding of the factors influencing the duration and success of sports careers in Warmblood horses, providing valuable insights for both veterinary practitioners and horse owners.

The study found that horses, especially those having cardiac dimensional changes or atrial fibrillation, were likely to end their athletic careers and experience deterioration in sporting performance. Veterinarians' prognostic assessments, particularly for cases with a less favourable prognosis, were notably fair.

The absence of confounding factors affecting performance, the lack of a control group and the failure to account for possible bias in veterinary advice distort the results and subsequent discussions.

To enhance the precision of future findings, it is recommended to undertake comparable studies with larger sample sizes. Additionally, incorporating additional variables as severeness of the VR and more precise documentation in routine operations, particularly in relation to sports-related data, such as the integration of international databases, and considering more relevant medical parameters, may contribute to a more comprehensive analysis.

Abbreviations

VR	=	Valve regurgitation
AF	=	Atrial fibrillation
MR	=	Mitral valve regurgitation
VSD	=	Ventricular septal defect
TR	=	Tricuspid valve regurgitation
AR	=	Aortic valve regurgitation
LA	=	Left atrium
AO	=	Aorta
LV	=	Left ventricle
RA	=	Right atrium

OR = Odds ratio
 VPC = Ventricular premature contractions
 SVPC = Supraventricular premature contractions

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