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Prevalence and risk factors for medical events following exercise at Australian Greyhound race meetings

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Aim A prospective, observational study to determine the prevalence of post-exercise conditions at Australian Greyhound race meetings and to assess association with race performance, and other environmental, race and dog related factors, was undertaken.

Methods A total of 4020 starters were observed (2813 Greyhounds, 1009 trainers, 536 races, 52 race meets, 48 race dates and 11 race tracks) following a race. The presence of diaphragmatic flutter (DF), ataxia, seizure, collapse or sudden death was recorded. Risk factors were screened by univariable logistic regression prior to multivariable backward stepwise model building.

Results In this study, 962 starters (n = 768 dogs) had DF (23.9%), 16 starters were ataxic (0.4%), and there was no observed cases of collapse, seizure or sudden death. Race track location, increasing race distance, race grade based on increasing 1st place prize value, lower (earlier) race number at the meeting, age, a previous observation of DF at the last start, females, colour (white) and better finishing position were all associated with an increased risk of a Greyhound being observed with DF. However, when logistic regression assessing the random effect of dog was performed, the presence of previous DF was not significant. In this cohort, DF was common following strenuous exercise in Greyhounds and on its own does not appear to result in reduced performance or distress to the animal.

Conclusion The incidence of ataxia was low and collapse, seizure and sudden death were not observed. However, even though uncommon, ataxia has welfare concerns for racing Greyhounds that warrants further investigation.

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Keywords ataxia; diaphragmatic flutter; Greyhounds; post-exercise distress (PEDS); thumps

Abbreviations Á, intraclass correlation coefficient; CI, confidence interval**;** DF, diaphragmatic flutter**;** EIA, exercise-induced ataxia**;** OR, odds ratio**;** PEDS, post-exercise distress syndrome**;** ROC, receiver-operating characteristic**;** SD, standard deviation; VIF, variance inflation factor

Post-exercise distress syndrome (PEDS) is a term used colloquially in the Greyhound industry to describe a group of poorly understood non-orthopaedic conditions often observed in Greyhounds during the immediate recovery period following strenuous exercise.[1] Our group has proposed the following working conditions be classified as PEDS if observed shortly after exercise: diaphragmatic flutter (DF), ataxia (EIA), seizure, collapse and sudden death. Some racing industry organisations require notification if such events occur, but it is not mandated across all jurisdictions. As a result, the prevalence of post-exercise medical conditions has not been previously characterised in the Australian setting and it is unknown whether there is a geographical tendency or association with other factors.

Diaphragmatic flutter is colloquially better known as 'thumps' and is an asynchronous movement of the thoracic wall, such that it appears the muscles are 'thumping'. In endurance horses, DF is considered a welfare issue and horses are disqualified from events if DF is observed by the attending veterinarian. Anecdotally, DF is thought to be more common and less severe in Greyhounds than in horses and has been attributed to poor performance, racing interference and weather conditions without statistical analysis to confirm any of these.[2] Greater knowledge of the occurrence of DF and other conditions following exercise in racing Greyhounds is an important component of improving the welfare of these dogs.

This observational study was made at a range of Australian Greyhound race meetings and the main objective was to determine the prevalence of all non-orthopaedic conditions in racing Greyhounds. A secondary objective was to determine association of these conditions with a variety of factors such as weather, race location, race grade and performance of the dog.

Materials and methods

This project was designed as a prospective observational study, and all observations were undertaken by one observer (SK).

The 52 official race meetings attended at registered Greyhound racing clubs were held in three Australian states from May to September 2011 and from January to February 2012. This consisted of 8 meetings in a 9-day period at three racetracks in Western Australia (WA), 6 meetings in a 6-day period at three racetracks in South Australia (SA) and 29 meetings in a 4-month period at the five racetracks in Victoria (VIC) closest to the metropolitan area. A further 9 meetings were attended during January and February 2012 at the same 5 Victorian racetracks, when the predicted day-time temperature was greater than 30°C.

Permission for the observer to attend race meetings was given by the Chief Steward from each state. Owners and trainers were made aware of the purpose of the observations through communications from their state controlling body. The study was approved by the Animal Ethics Committee of the University of Melbourne (AEC ID: 1111953.1).

The following definitions were used for classification of medical conditions. Diaphragmatic flutter was defined as a transient unilateral or bilateral movement of the lateral thorax and abdomen, generally synchronous with heart rate but independent of respiration; EIA was defined as a transient, pronounced forelimb hypermetria with or without truncal ataxia and head ventroflexion; collapse was defined as any collapse shortly after exercise that occurred with no other localising signs (e.g. muscular cramp); and sudden death was defined as any unexpected death that occurred after strenuous exercise during the observation period.

Greyhounds were observed from the completion of a race until the dog was returned to its secure kennel, which was generally within 10 min. The occurrence of DF, EIA, collapse or sudden death was recorded. The time of onset of any event was recorded to the nearest 30 s after race completion. If no abnormalities occurred, the latest time that the animal was available to be observed was recorded. This time period varied according to the racetrack protocol, as well as trainer preference. In WA, alternative arrangements were made to further observe Greyhounds in their kennels for 8–10 min following exercise.

Statistical analysis

Potential risk factors predisposing to exercise-associated disease were chosen from the literature, unpublished preliminary data and a priori hypotheses.

Meeting-related variables considered were: state, race track, race date, meeting time of day, temperature at the time of the race and race day humidity as obtained from the Bureau of Meteorology.[3]

Race-related variables were: distance (m), race grade, 1st place prize value (A$) and race number at the meeting.

Greyhound-related variables obtained from each state's website were: Greyhound, trainer, sire, dam, paternal sire, maternal sire, age (months), colour, sex, finishing position in the race, speed (m/s), margin behind the winner (lengths) and starting price (A$).

Prior performance-related variables obtained from the official form guide were: total prize money earned (A$), race starts, wins (1st) and minor placings (2nd or 3rd) prior to the start.

The study had statistical power of at least 80% to identify a significant association ($P < 0.05$) if the odds ratio in the population was e 1.4 and the prevalence of exposure in the control group was 0.1.

Descriptive statistics for continuous variables (environmental, race-related and Greyhound-related variables) were assessed for best fit of the variable, and reviewed for categorical variables. Identified risk factors for the development of DF were assessed using univariable logistic regression. To account for some of the clustering around Greyhounds with multiple starts observed, a transition model was used with the creation of a dummy variable (Greyhound had a last start observed) and the first observation for each Greyhound was set to zero.[3] Entry of a variable into multivariable logistic regression model building was based on a likelihood ratio test P-value < 0.25. Variables were selected for inclusion in the model if it was considered biologically plausible or supported by the literature. Parameters were estimated by a backward stepwise model building process. Variables were retained in the multivariable model if likelihood ratio test P-values were < 0.05. The Wald test P-value was used when comparing categories with the reference category.[4] Correlation coefficients were calculated for binary and continuous variables in the final model; all were below 0.8 and not examined further.

All statistical analyses were performed with Stata 14.2 (StataCorp, College Station, TX, USA).

Results

Descriptive statistics for continuous variables (environmental, race-related and Greyhound-related variables) were assessed for best fit of the variable (Table 1). There were 4020 starts observed, encompassing 2813 Greyhounds, 1009 trainers, 536 races, 52 race meetings, 48 race dates and 11 race tracks. The 2813 observed Greyhounds had a total of 210 sires, 1524 dams, 83 paternal sires and 241 maternal sires. There were 2813, 854, 260, 73, 14, 4, 1 and 1 Greyhounds observed for 1, 2, 3, 4, 5, 6, 7 and 8 starts, respectively.

Of the 4020 starts, there were 962 occurrences of DF in 768 dogs (23.9%), 16 occurrences of EIA (0.4%), and no occurrences of collapse or sudden death.

Mean time of onset of DF was 6.2 min (standard deviation (SD) 1.6; range 2–10; median 6). The mean latest time of observation was 6.6 min (SD 1.8; range 2–10; median 7). Results of the univariable analysis for DF are provided in Online Supplementary Table 1, and the statistically significant risk factors are shown in Table 2. Of the 27 variables assessed at the univariable level, 19 were included in the initial backward stepwise multivariable model building process.

In the final multivariable model (Table 3) race track, race distance, race grade based on 1st place prize value, race number at the meeting, a previous observation of DF at the last observed start, sex, age, colour (white higher incidence than black) and finishing position were significantly associated with a Greyhound being observed with DF. However, when a logistic regression with a random effect of dog was used, the effect of an observation of DF at the previous observed start was not significant (odds ratio (OR) 1.15; 95% confidence interval 0.51–2.60; P=0.73).

All coefficients in the final multivariable model changed by < 20% when those variables that were eliminated from the model building process were resubmitted one at a time. The exception was ‘meeting time of day’, where some ‘track’ coefficients changed because of their complete confounding and so it was not included in the final model.

The variance inflation factor (VIF), also known as the design effect, was estimated by the equation VIF = 1 + Á(n–1), where n = mean number of observations per cluster.[5] The residual intraclass correlation coefficient[5] (Á) and VIF were estimated for Greyhound (Á0.59, VIF 1.25), trainer (Á0.045, VIF 1.13), race meeting (Á1.56×10^{-6}, VIF 1.00), race (Á1.27×10^{-7}, VIF 1.00), sire (Á0.049, VIF 1.89), dam (Á0.10, VIF 1.16), paternal sire (Á0.029, VIF 2.38) and maternal sire (Á0.020, VIF 1.31).

There were sufficient cases per variable to justify the complexity of the model.[6] The Hosmer-Lemeshow goodness-of-fit statistic was 4.89 (8 degrees of freedom, P=0.77), indicating no evidence of poor fit. The area under the receiver-operating characteristic (ROC) curve was 0.67.

Regression diagnostics were performed and identified 1st place prize value (per A$1000) had 16 highly influential values (two Group One races) that when removed altered its significance in the model (OR 0.98, P = 0.50) and similarly reduced its significance as a univariable (OR 0.99, P = 0.64). When model building was repeated, all the coefficients of variables shown in Table 3 changed by < 4%, except for main colour and racing grade (1st place prize value per A$1000), which were removed from the final model. The Hosmer-Lemeshow goodness-of-fit statistic was 10.43 (8 degrees of freedom, P=0.24), indicating no evidence of a poor fit. The area under the ROC curve was still 0.67. Given the 16 observations were valid, they were retained within the model; however, the importance of main colour and racing grade should be interpreted with some caution.

A total of 15 individual Greyhounds (8 males, 7 females), trained by 15 different trainers, were ataxic within 2 min of racing, and all showed complete resolution within 3 min of onset. Of these 15 Greyhounds, 3 were observed on more than one occasion: 1 female had ataxia at two of two observations, 1 male had ataxia at one of two observations and 1 male at ataxia at one of five observations. Two Greyhounds developed EIA that resolved and then they developed DF. There were 10 individual sires, 15 individual dams, 7 individual paternal sires and 14 individual maternal sires of the dogs that showed EIA. One sire was present in 9 of 15 pedigrees. Because of the low number of observations of EIA, assessment of race- or Greyhound-related variables was not undertaken.

Discussion

To our knowledge, this is the first study to evaluate multiple risk factors for the development of post-exercise conditions in a large population of racing Greyhounds. A previous study assessed the prevalence of DF in one Australian state, but only evaluated sex as a risk factor.[2]

The overall proportion of starters with DF (23.9%) was not significantly different between states, suggesting that DF is common in Greyhounds after strenuous exercise regardless of location within Australia. This contrasts with unpublished data collected from April to October 2009 that documented DF to vary from 7% in NSW (2 race meetings) to 50% in WA (2 race meetings).[1] Additional unpublished data from WA found 39.34% of 1004 starters had DF, higher than found in our study.[2] The most likely explanations for the variation in prevalence between studies are interobserver differences and the method of observation. In our study, one observer (SK) performed all observations (visually rather than by palpation) and so comparisons between locations were more valid. Other potential reasons for the discrepancy in observations include the duration of each observation, the experience of the observer and the willingness of trainers to cooperate and allow sufficient time for observation. For Greyhounds that started on two or more occasions, our analysis suggested a high degree of recurrence for DF (OR 7.73), which suggests a repeatable underlying aetiology for DF in individual dogs; however, this finding may also be related to repeated observations of the same dogs at some Victorian racetracks.

Greyhounds in our study were only recorded as having DF if visual signs were evident. This can be difficult to assess when the intensity of abdominal wall movements is mild compared with rapid post-exercise respiration or when observations are made in dimly lit areas, and is a possible reason for the lower observation rates in our study. Dimly lit observational areas may have led to a false increase in the proportion of white dogs observed with thumps (OR 1.43) compared with the reference category (black), or alternatively a genetic predisposition may exist among white Greyhounds. As noted in the results, interpretation of the effect of colour should be done with some caution given the variable was removed from the final model when two Group One races were removed from the data set.

During this study it was noted that the intensity of DF changed over time, increasing quickly to a peak before slowly resolving. Because of the difficulties in examining all Greyhounds at a race meeting in a secure environment, not all starters could be observed for an equal period. The mean time for dogs being returned out of view to their secure kennels was 6.6 min and this suggests that some dogs may have developed DF, but not within the observed time. The discriminatory ability of the multivariable model may have improved if all dogs were observed for an equal period. However, the length of the observation period depended on track and trainer management protocols and the proximity of the kennel house to the racetrack. Small changes in the duration of the observation period may have contributed to the overall significant effect of racetrack and therefore the true prevalence of DF may be higher than reported in this study. The higher prevalence of DF between the reference track and other Victorian tracks may also be in part related to the observer developing a better rapport with trainers at the reference track and being able to conduct longer observations there.

Diaphragmatic flutter is well described in endurance horses but less so in Thoroughbred racing horses,[7, 8] and has been considered to occur more frequently in longer Greyhound races.[2, 9] Our study supports the premise that distance (and therefore potentially workload) is associated with the occurrence of DF, as the odds of developing DF increased for every 100 m increase in distance (OR 1.25). However, it is worth noting that the mean increase in distance for Greyhounds with DF was only 9.2 m and that only 8.5% of starters competed over races longer than 550 m. Therefore, although the increased risk is statistically significant, DF still occurs frequently over shorter distances and the increase in distance is not substantial.

Females were significantly more likely to have DF than males (OR 1.31); at present there is no obvious explanation for this. The ratio of male to female starters was 1.42 : 1 in this study, with previous studies suggesting a reduced athletic ability of female Greyhounds.[10] In endurance horses showing synchronous DF, plasma lactate was significantly higher than controls[7] and is potentially associated with increased workload. Female dogs are smaller than males[10, 11] and therefore may perform a greater absolute workload to cover the same distance in the same time, but biochemical measurements are required to confirm this assumption.

Greyhounds in the USA have been shown to lose increasing amounts of weight from panting and salivation during the race day confinement period, the duration of which is dependent on race number;[10] we strongly suspect this progressive dehydration also occurs in Australian

Greyhounds, but this theory would suggest that DF would occur more commonly in hot weather[2, 9] and higher race number, but our study found that with each increasing race number, the odds of DF decreased (OR 0.96) and there was no effect of ambient temperature or humidity on the prevalence of DF. The observation of decreased prevalence of DF with higher (later) race number may in part be caused by 80% of maiden races (no previous wins) being scheduled for races 1–4. However, race grade was considered in the final model indirectly through a 1st place prize variable. Similarly, age was accounted for, with the risk of developing DF reducing with every month of age (OR 0.98). Other possible explanations for the observation of decreased odds of DF with increasing race number include length of observation or inadvertent observer fatigue. It is also possible that the period of confinement prior to racing may allow for normalisation of any pre-race supplementation or acid–base derangements that may predispose to DF.

Poor performance is hard to assess in racing dogs because many factors could contribute, such as trainer effects (e.g. training regimen, diet, husbandry), individual dog effects (e.g. athletic ability, chasing desire, fitness) and race effects (e.g. interference, track conditions, ability of opposition). Anecdotal association between poor performance and DF has been reported by on-track veterinarians. In our study, DF was more prevalent in Greyhounds that finished in the first three places (OR 1.29) and for every A$1,000 increase in 1st place prize of the race the odds of DF increased (OR 1.02). Within each state, as a Greyhound's racing grade improves based on previous performance, the prize value of its race increases. However, interpretation of the significant effect of racing grade should be done with some caution, given that the variable was removed from the final model if two Group One races (that included 9 of 16 starters with DF) were removed from the data set. We do not believe that DF is the sole cause of poor performance, given its high occurrence in a seemingly normal population and lack of association with poor performance. However, DF may occur together with other factors in animals that perform below expectation.

The mean time of onset of DF was 6.2 min after completing the race. Few studies have compared pre- and post-exercise blood parameters in Greyhounds, but those that have established that marked anaerobic glycolysis, metabolic acidosis and fluid shifts occur.[12-17] Changes in most parameters reach their maximum deviation from rest at 5 min into recovery and return to resting states by 30 min.[12] Hypokalaemia develops within 5 min after exercise,[13-17] which coincides with the nadir pH, partial pressure of CO_2 (PCO_2), bicarbonate and peak partial pressure of oxygen (PO_2) and blood lactate concentrations.[13] Metabolic disturbances, including hypocalcaemia,[18] hypokalaemia, alkalosis,[8, 19] hypomagnesaemia and hyperlactacidaemia[7] have been reported in horses with DF. Further investigation of these factors as they relate to the incidence of DF in Greyhounds is warranted.

Greyhounds with EIA were no more likely to have DF than dogs without ataxia, confirming that the conditions are independent of each other. In our study, EIA was seen in 0.40% of starters of both sexes, with marked forelimb hypermetria being the most obvious clinical sign. Onset of EIA was within 2 min of completing racing and complete resolution was seen within 3 min. In the more severe cases, truncal ataxia, head ventroflexion and sudden bursts of motor activity were observed in addition to marked overflexion on protraction of the limbs, suggesting an ataxia of cerebellar origin. The EIA reported in racing Greyhounds differs in many ways from the exercise-induced collapse in Labrador Retrievers, which is induced by a dynamin-1 gene mutation. In affected Labradors, 5–15 min of strenuous exercise leads to a 'wobbly gait' that then progresses to flaccid paraparesis and loss of control of the hindlimbs, and sometimes all limbs.[20] According to the trainers of Greyhounds with EIA, recurrence was relatively common (12 of 15 Greyhounds, pers. comm.). Based on initial assessment of the pedigrees of affected dogs, a familial predisposition is suspected but has not been investigated or confirmed. The potential welfare implications of this condition warrant further investigation.

Although no Greyhounds were observed to collapse, seizure or die unexpectedly, it should be noted that during the study period this did occur at other race meetings within Australia. Therefore, we can conclude that while rare, these events unfortunately do occur after strenuous exercise and require further evaluation.

Conclusion

Diaphragmatic flutter as a sole clinical sign in Greyhounds following strenuous exercise is a common occurrence, affecting one in four starters following racing in our study. On its own, DF is unlikely to result in reduced performance and does not appear to be distressing to the animal, but DF can be seen together with other clinical signs in distressed or poor-performing animals.

Race track, increasing race distance, race grade based on increasing 1st place prize value, higher (later) race number at the meeting and age, female sex, colour (white) and better finishing position were associated with an increased risk of a Greyhound being observed with DF. However, the true significance of the colour and race distance is open to interpretation.

Exercise-induced ataxia is a welfare concern for racing Greyhounds and warrants further investigation. Track veterinarians should be aware of and monitor Greyhounds that show signs of ataxia and discuss their suitability to continue competition with officials.

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Conflicts of interest and sources of funding

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The primary investigator, Dr Karamatic, is currently employed by Greyhound Racing Victoria, in the role of Greyhound Racing Industry Veterinary Officer. Dr Karamatic performed all the observations, but neither Greyhounds Australasia nor Greyhound Racing Victoria had any influence over the development of the manuscript. The other authors declare no conflicts of interest for the work presented here.

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Table 1. Descriptive statistics for continuous variables that were potential risk factors for Greyhounds developing diaphragmatic flutter (DF) after racing in Australia

Variable (n = 4020)	Minimum	25th percentile	Median	Mean	75th percentile	Maximum
Environmental variables						
Ambient temperature (°C)	6	11	14	16.1	17	35
Relative humidity (%)	16	46	60	59.7	77	90
Race-related variables						
Race distance (m)	297	405	515	480.5	525	725
First place prize value (per A$1000)	0.415	0.740	1.095	1.762	1.165	100.000
Race number at meeting	1	3	6	6.1	9	12
Greyhound-related variables prior to start						
Age at start (months)	17	25.9	30.4	32.1	37.6	68.3
Prize money earned prior to start (A$)	0	1040	3955	10649	10640	570528
Total race starts prior to start	0	8	20	25.9	38	209
Total wins prior to start	0	1	3	4.4	6	37
Total minor placings prior to start	0	2	5	7.7	11	70
Starting price odds (A$)	1.2	4.6	9.2	13.42	18.2	95.9
Greyhound performance-related variables at start						
Margin behind winner (lengths)	0	3	7.25	7.92	11.5	40
Average speed (m/s)	13.881	16.770	16.992	16.988	17.233	18.235

Table 2. Results of univariable logistic regression analysis showing statistically significant race- and Greyhound-related risk factors for Greyhounds developing diaphragmatic flutter (DF) after racing in Australia.

Variable	**Total n = 4020**	**DF (%) n = 962**	**No DF (%) n = 3058**	**P value**	**OR**	**95% CI**
Race-related variables						
Race distance (per 100 m)*	4020	962 [4.87; 0.78]	3058 [4.78; 0.80]	**0.002**	1.16	1.06–1.27
Longer race				**0.14**		
< 551 m	3679	869 (23.6)	2810 (76.4)		1 (REF)	
> 550 m	341	93 (27.3)	248 (72.7)	0.13	1.21	0.94–1.56
Race grade						
1st place prize value (per A$1000)*	4020	962 [2.2; 7.9]	3058 [1.6; 3.9]	**0.011**	1.02	1.00–1.03
Maiden				**0.001**		
No	3175	724 (22.8)	2451 (77.2)		1 (REF)	
Yes	845	238 (28.2)	607 (71.8)	0.001	1.33	1.12–1.58
Higher class (> A$2,000 1st place)				**0.28**		
No	3558	842 (23.7)	2716 (76.3)		1 (REF)	
Yes	462	120 (26.0)	342 (74.0)	0.27	1.13	0.91–1.41
Race number at meeting*	4020	962 [5.7; 3.2]	3058 [6.3; 3.3]	**<0.0001**	0.95	0.93–0.97
Greyhound-related variables prior to start						
DF observed at last start				**<0.0001**		
No	3712	786 (21.2)	2926 (78.8)		1 (REF)	
Yes	308	176 (57.1)	132 (42.9)	<0.0001	5.00	3.91–6.30
Greyhound had a last start observed				**0.19**		
No	2813	657 (23.4)	2156 (76.6)		1 (REF)	
Yes	1207	305 (25.3)	902 (74.7)	0.19	1.11	0.95–

						1.30
DF at last start, given a last start was observed#				**<0.0001**		
No	899	129 (14.3)	770 (85.7)		1 (REF)	
Yes	308	176 (57.1)	132 (42.9)	<0.0001	7.96	5.94–10.67
Sex				**<0.0001**		
Male	2357	511 (21.7)	1846 (78.3)		1 (REF)	
Female	1663	451 (27.1)	1212 (72.9)	<0.0001	1.34	1.16–1.56
Age at start (months)*	4020	962 [30.6; 7.9]	3058 [32.5; 8.4]	**<0.0001**	0.97	0.96–0.98
Prize money earned prior to start (per A$1000)*	4020	962 [10.8; 27.9]	3058 [10.6; 23.6]	**0.86**	1.00	1.00–1.00
Total race starts prior to start*	4020	962 [22.8; 22.1]	3058 [26.9; 23.5]	**<0.0001**	0.99	0.99–1.00
Total wins prior to start*	4020	962 [4.1; 4.8]	3058 [4.4; 4.9]	**0.10**	0.99	0.97–1.00
Total minor placings prior to start*	4020	962 [6.7; 7.4]	3058 [8.0; 7.9]	**<0.0001**	0.98	0.97–0.99
Starting price odds (A$)*	4020	962 [12.2; 11.4]	3058 [13.8; 12.2]	**0.001**	0.99	0.98–1.00
Greyhound performance-related variables at start						
Finishing position				**0.0001**		
Unplaced (4th–8th)	2460	538 (21.9)	1922 (78.1)		1 (REF)	
Placed (1st–3rd)	1560	424 (27.2)	1136 (72.8)	0.0001	1.33	1.15–1.54

*[Mean; SD values for continuous variables]; bold values are likelihood ratio test P-values and other values are Wald test P-values; #information only, as not submitted to final model because of the use of a transition model.

CI, confidence interval; EIA, exercise-induced ataxia, OR, odds ratio.

Table 3. Results of multivariable logistic regression analysis assessing risk factors for Greyhounds developing diaphragmatic flutter (DF) after racing in Australia

Variable	Total n = 4020	DF (%) n = 962	No DF (%) n = 3058	P value	OR	95% CI
Race track				**0.017**		
Geelong (VIC)	944	262 (27.8)	682 (72.2)		1 (REF)	
Meadows (VIC)	640	150 (23.4)	490 (76.6)	<0.001	0.61	0.46–0.80
Sandown (VIC)	626	146 (23.2)	480 (76.8)	<0.001	0.60	0.46–0.79
Ballarat (VIC)	529	116 (21.9)	413 (78.1)	0.012	0.71	0.55–0.93
Angle Park (SA)	308	78 (25.3)	230 (74.7)	0.13	0.78	0.56–1.07
Cranbourne (VIC)	248	47 (19.0)	201 (81.0)	0.020	0.65	0.45–0.93
Mandurah (WA)	231	50 (21.6)	181 (78.4)	0.54	0.89	0.62–1.28
Northam (WA)	186	41 (22.0)	145 (78.0)	0.26	0.79	0.53–1.18
Cannington (WA)	153	43 (28.1)	110 (71.9)	0.47	0.86	0.56–1.29
Gawler (SA)	78	13 (16.7)	65 (83.3)	0.14	0.62	0.32–1.17
Strathalbyn (SA)	77	16 (20.8)	61 (79.2)	0.30	0.73	0.41–1.31
Other race-related variables						
Race distance (per 100 m)*	4020	962 [4.87; 0.78]	3058 [4.78; 0.80]	**0.001**	1.25	1.10–1.42
Racing grade						
1st place prize value (per A$1000)*	4020	962 [2.2; 7.9]	3058 [1.6; 3.9]	**0.011**	1.02	1.00–1.03
Race number at meeting*	4020	962 [5.7; 3.2]	3058 [6.3; 3.3]	**<0.001**	0.96	0.94–0.98
Greyhound-related variables prior to start						
DF observed at last start				**<0.0001**		
No	3712	786 (21.2)	2926 (78.8)		1 (REF)	
Yes	308	176 (57.1)	132 (42.9)	<0.000	7.73	5.74–

				1		10.42
Greyhound had a last start observed				**<0.0001**		
No	2813	657 (23.4)	2156 (76.6)		1 (REF)	
Yes	1207	305 (25.3)	902 (74.7)	<0.0001	0.56	0.46–0.70
Sex				**0.001**		
Male	2357	511 (21.7)	1846 (78.3)		1 (REF)	
Female	1663	451 (27.1)	1212 (72.9)	0.001	1.31	1.12–1.52
Age at start (months)*	4020	962 [30.6; 7.9]	3058 [32.5; 8.4]	**<0.0001**	0.98	0.97–0.99
Main colour				**0.048**		
Black	2191	494 (22.5)	1697 (77.5)		1 (REF)	
Blue	192	46 (24.0)	146 (76.0)	0.57	1.11	0.77–1.59
Brindle	599	146 (24.4)	453 (75.6)	0.54	1.07	0.86–1.35
Fawn	506	125 (24.7)	381 (75.3)	0.33	1.13	0.89–1.43
White	532	151 (28.4)	381 (71.6)	0.002	1.43	1.14–1.78
Greyhound performance-related variables at start						
Finishing position				**0.001**		
Unplaced (4th–8th)	2460	538 (21.9)	1922 (78.1)		1 (REF)	
Placed (1st–3rd)	1560	424 (27.2)	1136 (72.8)	0.001	1.29	1.10–1.50

*[Mean; SD values for continuous variables]; bold values are likelihood ratio test P-values and other values are Wald test P-values; Hosmer-Lemeshow goodness-of-fit P=0.77; area under the receiver-operating characteristic curve 0.67

CI, confidence interval; EIA, exercise-induced ataxia; OR, odds ratio; SA, South Australia; VIC, Victoria; WA, Western Australia.