# Use of ultrasound-guided autologous bone marrow transfer for treatment of suspensory ligament desmitis in 30 race horses (2003–2010)

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**Objective** To evaluate the racing performance of horses that underwent ultrasound-guided intralesional injection of autologous bone marrow aspirate for treatment of selected forelimb suspensory ligament (body or branch) core lesions.

**Design** Retrospective cohort study of 13 Standardbred and 17 Thoroughbred race horses.

**Methods** Autologous bone marrow aspirated from the sternebrae was injected, under ultrasound guidance, into suspensory ligament core lesions (body or branch). Racing records were reviewed for a comparison of performance before and after surgery.

**Results** Of the 13 Standardbreds, 9 (69%) had one or more starts within the follow-up period and 9 (69%) had five or more starts. Of the 17 Thoroughbreds, 15 (88%) had one or more starts within the follow-up period and 12 (71%) had five or more starts. Eight Standardbred horses had at least one start both before and after surgery. Earnings per start did not differ significantly between the three starts immediately after surgery compared with the three starts immediately prior to surgery. Thirteen Thoroughbred horses had at least one start both before and after surgery. Earnings per start were less for the three starts immediately after surgery compared with the three starts immediately prior to surgery.

**Conclusions and clinical relevance** A horse with a core lesion in the branch or body of the suspensory ligament has a good prognosis for return to racing after treatment with intralesional injection of bone marrow aspirate.

**Keywords** bone marrow; desmitis; horses; suspensory ligament

**Abbreviation** COMP, cartilage oligomeric matrix protein

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Lesions involving the interosseous muscle, commonly known as the suspensory ligament, are a problem commonly encountered by equine veterinarians.[1] Suspensory ligament injuries are an important cause of morbidity and mortality in race horses.[2] Injuries may involve the proximal part, the body or the branches of the suspensory ligament and/or the bone at its origin (avulsion fractures).[1,3] Diagnosis of body and branch lesions is routinely made using a combination of physical examination and ultrasonography.[4–7]

Type 0 and type 1 lesions are isoechoic and slightly hypoechoic, respectively.[7] Type 2 lesions are classified as having mixed echogenicity (50% anechoic) and type 3 lesions are mostly anechoic.

Natural healing of suspensory ligament tissue often leads to an inferior scar that is enlarged, less organised and stiffer than normal ligament. Therefore, the goals of treatment include early granulation and maximisation of type 1 collagen production, organisation and elasticity.[8]

Non-steroidal anti-inflammatory drugs, cold therapy and compression are all used to decrease the initial inflammation in suspensory desmitis.[9] Therapies aimed at improving long-term outcome include therapeutic ultrasound, laser and magnetic fields, but information regarding the efficacy of these treatments is sparse, with no large trials having been conducted. Controlled rehabilitation and exercise programs are advocated by several authors, and are generally combined with other treatment modalities.[1,6,9] Intralesional treatments include using platelet-rich plasma and autologous bone marrow,[1,10] but there is little long-term follow-up of these treatments that has involved significant numbers of racehorses.

The use of autologous bone marrow for treatment of suspensory desmitis was first suggested by Herthel.[10] Bone marrow aspirate contains mesenchymal stem cells and growth factors,[11] but its use in vivo is controversial.[6] Autologous bone marrow as treatment has shown some positive results in vitro with suspensory ligament fibroblast cultures.[12] Synthesis of cartilage oligomeric matrix protein (COMP) and total protein synthesis were increased in cultures treated with either autologous bone marrow or platelet-rich plasma.[9] Schnabel et al.[3] investigated whether blood-derived products stimulate suspensory ligament matrix synthesis, thereby having potential as regenerative therapies for suspensory ligament desmitis. Their results indicated that 100% acellular bone marrow aspirate stimulated decorin and COMP messenger RNA synthesis more than any other treatment, including plasma, blood, platelet-rich and platelet-poor plasma, across all the concentrations investigated. Their findings add support to the clinical use of autologous bone marrow for the treatment of suspensory desmitis.

We report on the outcome of Standardbred and Thoroughbred racehorses with a grade 2 or 3 lesion of the body and/or branch of the suspensory ligament treated with intralesional injection of autologous bone marrow. Racing performance prior to surgery was compared with that after surgery. Comparisons between Standardbreds and Thoroughbreds, horse age at surgery and lesion site (body or branch) were also conducted.

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## Materials and methods

### *Selection of cases*

The medical records of Thoroughbred and Standardbred racehorses that were diagnosed with an acute forelimb suspensory ligament lesion at Goulburn Valley Equine Hospital between January 2003 and December 2008 were reviewed.

All lesions had been discovered by the trainer/owner within 3 weeks of presentation and were considered to be new injuries. Lesions included in the study were defined as having abnormal fibre alignment, hypoechogenicity and >15% of the cross-sectional area of the ligament affected.[7]

Subjects were excluded if they did not have a grade 2 or 3 lesion, if they had been retired upon diagnosis, if there was no evidence of an avulsion fracture at the origin of the suspensory or if their race records were unobtainable.

Information obtained from medical records included subject details (age, breed, sex), lesion grade and lesion location (branch, body).

Information on racing performance for the three races immediately prior to surgery and for the five races immediately after surgery was obtained from two electronic databases (Sirius Racing Victoria, sirius.racingvictoria.net.au; Harness racing Australia, http://www.harness.org.au). Data for the number of starts and total earnings were obtained for each horse and statistical comparisons were made. Further follow-up information was gained via telephone conversation with owners and trainers, using a standardised questionnaire.

### *Surgical procedure*

All horses received preoperative penicillin (22,000 IU/kg IM) and phenylbutazone (4.4 mg/kg IV). Preoperative sedation included acepromazine (0.03 mg/kg IV) administered 20 min prior to induction and xylazine (1.1 mg/kg IV) given 5–10 min prior to induction. All horses had anaesthesia induced using 0.1 mg/kg IV diazepam and 2.2 mg/kg IV ketamine, and were maintained on gaseous anaesthesia using halothane.

For intralesional injection of autologous bone marrow, horses were placed in lateral recumbency and the proposed treatment site was aseptically prepared with chlorhexidine gluconate 4% surgical scrub. A 15 × 10 cm area overlying the sternum was clipped and scrubbed with surgical scrub and alcohol. A stab incision was made through the skin with a No. 11 scalpel blade. An 11g, 10-cm Jamshidi bone marrow biopsy needle (Jamshidi, Allegiance Healthcare Corporation, McGraw Park, IL, USA) was then introduced through the stab incision and advanced until it contacted the ventral midline surface of the fifth or sixth sternebrum. The needle was advanced into the medullary cavity using a slow twisting motion. The central trocar was removed from the Jamshidi needle, a 10-mL syringe was attached and gentle negative pressure applied to aspirate bone marrow.[8]

Under ultrasonographic guidance, 1.5-inch × 18g needles were inserted perpendicular to the long axis of the ligament every 2 cm along the entire length of the lesion. Bone marrow was injected into the lesion until resistance to injection was met or bone marrow leaked out through another needle. A total injected volume of 8 mL of bone marrow was not exceeded.

A sterile bandage was applied to the limb following surgery and the limb remained bandaged for the next 5 days. All animals received phenylbutazone (2.2 mg/kg PO once daily) for 5 days postoperatively.

A recommendation was made to each trainer/owner that the horse should undertake a graded exercise program during the first 6 months of rehabilitation.

### *Statistical analysis*

For horses with at least one start both before and after surgery, average earnings per start for the three starts immediately after surgery were compared with those for the three starts immediately before surgery using a Wilcoxon matched-pairs signed rank test. Comparisons were made within breeds. For horses with one or two starts either before or after surgery, average earnings per start were calculated for these starts. Statistical analyses were performed using Stata 11.1 (StataCorp, College Station, TX, USA).

Using Fisher's exact test, proportions of horses that had any postoperative starts and at least five postoperative starts were compared between Standardbreds and Thoroughbreds separately. Horse age at surgery (<5 years or ≥5 years) and lesion site (body or branch) were also compared between breeds.

The time to first start after surgery was described separately for Standardbreds and Thoroughbreds using Kaplan-Meier failure distributions. These horses contributed to the analysis up to the follow-up date or euthanasia date, whichever occurred first; their records were right-censored on that date. Horses retired from racing or sold prior to when the authors contacted the person who owned the horse when surgery was performed were assumed to still be alive at date of contact unless they were known to have been euthanased. Two Standardbreds that did not race after surgery were excluded from analysis of time to first start because the owners could not be contacted to ascertain whether the horses had been euthanased. Equalities of the survivor functions for time to first start were compared between Standardbreds and Thoroughbreds, horse age at surgery (<5 years or ≥5 years) and lesion site (body or branch) using log-rank tests. Total earnings between surgery and the follow-up date were compared between Standardbreds and Thoroughbreds, horse age at surgery (<5 years or ≥5 years) and lesion site (body or branch) using Wilcoxon rank sum (Mann-Whitney) tests. These comparisons were also made between breeds for horses with at least five starts after surgery.

## Results

### *Description of cases*

A total of 179 acute forelimb suspensory ligament lesions were diagnosed using ultrasonography and of these, 121 horses were excluded from the study because there was no core in the lesion into which autologous bone marrow could be injected (i.e. they had type 0 or 1 lesions). Of the remaining 58 horses, we excluded 18 that had been retired upon diagnosis, 7 that had been presented under a pseudonym and racing records could not be retrieved and 3 that had evidence of an avulsion fracture diagnosed on ultrasound or radiography.

A total of 30 core lesions were treated using bone marrow transfer: 13 (43%) Standardbreds and 17 (57%) Thoroughbreds were enrolled

(5 (17%) females, 25 (83%) males). The suspensory ligament body was affected in 9 (30%) horses, the branch was affected in 20 (67%) horses and the site was not recorded for 1 horse. Of the affected branches, there were 5 proximal, 10 middle and 5 distal/insertion core lesions.

### *Racing performance*

Owners were contacted via telephone between 2 and 5 years post-surgery. One horse was euthanased prior to returning to work because of colitis and subsequent laminitis, one horse was lost to follow-up after successfully completing three races and two horses were lost to follow-up because owners/trainers were not contactable.

Subsequent racing performance was assessed from surgery to follow-up date or euthanasia date, whichever occurred first. Subsequent racing performance was assessed for a median time of 4.9 years for Standardbreds (range 1.8–6.7 years; Table 1) and 4.0 years for Thoroughbreds (range 0.2–7.0 years; Table 2).

Of the 13 Standardbreds, 9 (69%) had one or more starts within the follow-up period and 9 (69%) had five or more starts. Of the

**Table 1.** Racing performance[a] after bone marrow transfer surgery for Standardbred horses with suspensory ligament lesions

| Variable | No. horses | Median | Range |
|---|---|---|---|
| No. of starts after surgery | | | |
| Total no. of starts after surgery | 13 | 15 | 0–78 |
| Average no. of starts per year after surgery | 11[b] | 5 | 0–14 |
| Earnings after surgery (AUD) | | | |
| Total earnings after surgery | 13 | $11,675 | $0–$93,769 |
| Average earnings per year after surgery | 11[b] | $3,860 | $0–$19,263 |
| Average earnings per start after surgery | 9[c] | $578 | $215–$6,251 |
| Average earnings per start for first 3 starts after surgery | 9[c,d] | $1,166 | $0–$5,526 |
| Total earnings from 5th start after surgery | 9[e] | $13,570 | $2,100–$50,045 |
| Average earnings per year from 5th start after surgery | 9[e] | $4,859 | $477–$12,224 |
| Average earnings per start from 5th start after surgery | 9[e] | $519 | $210–$2,996 |

[a]Performance to follow-up date or euthanasia date, whichever occurred first.
[b]Two Standardbreds that did not race after surgery were excluded from these analyses because the owners could not be contacted during the data collection period to ascertain whether the horses had been euthanased.
[c]Calculated only for 9 of the 13 horses (69%) that had one or more starts within the follow-up period.
[d]All 9 horses had at least three starts after surgery.
[e]Calculated only for 9 of the 13 horses (69%) that had five or more starts within the follow-up period.
AUD, Australian dollars.

**Table 2.** Racing performance[a] after bone marrow transfer surgery for Thoroughbred horses with suspensory lesions

| Variable | No. horses | Median | Range |
|---|---|---|---|
| No. of starts after surgery | | | |
| Total no. of starts after surgery | 17 | 7 | 0–37 |
| Average no. of starts per year after surgery | 17 | 2 | 0–9 |
| Earnings after surgery (AUD) | | | |
| Total earnings after surgery | 17 | $2,965 | $0–$777,250 |
| Average earnings per year after surgery | 17 | $1,030 | $0–$116,635 |
| Average earnings per start after surgery | 15[b] | $832 | $0–$28,787 |
| Average earnings per start for first 3 starts after surgery | 15[b,c] | $171 | $0–$41,850 |
| Total earnings from 5th start after surgery | 12[d] | $3,258 | $0–$747,252 |
| Average earnings per year from 5th start after surgery | 12[d] | $2,077 | $0–$168,063 |
| Average earnings per start from 5th start after surgery | 12[d] | $751 | $0–$32,489 |

[a]Performance to follow-up date or euthanasia date, whichever occurred first.
[b]Calculated only for 15 of the 17 horses (88%) that had 1 or more starts within the follow-up period.
[c]For horses with 1 or 2 starts after surgery, average earnings per start were calculated for these starts.
[d]Calculated only for 12 of the 17 horses (71%) that had 5 or more starts within the follow-up period.
AUD, Australian dollars.

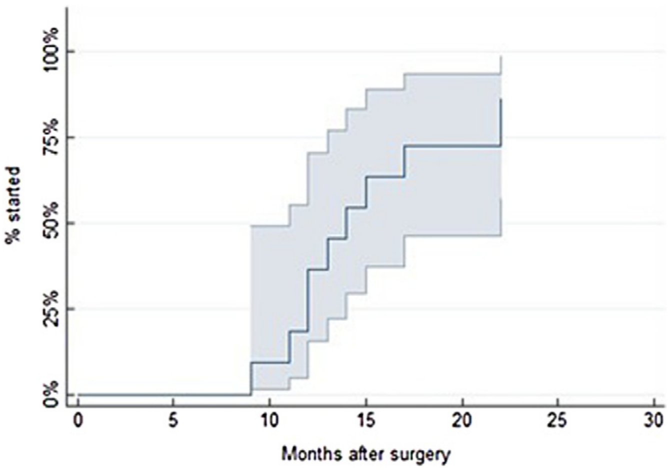


**Figure 1.** **Kaplan-Meier failure curves for time to first start after bone marrow transfer surgery for 11 Standardbred horses with suspensory ligament lesions. Shaded area is the 95% point-wise confidence interval.**

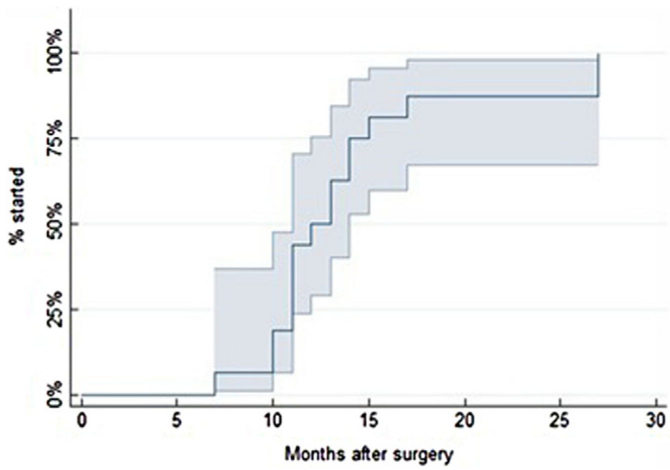


**Figure 2.** **Kaplan-Meier failure curves for time to first start after bone marrow transfer surgery for 17 Thoroughbred horses with suspensory ligament lesions. Shaded area is the 95% point-wise confidence interval.**

17 Thoroughbreds, 15 (88%) had one or more starts within the follow-up period and 12 (71%) had five or more starts.

The proportions of horses having one or more starts and five or more starts did not differ significantly between Standardbreds and Thoroughbreds (P = 0.360 and 1.000, respectively).

Kaplan-Meier failure curves are shown in Figures 1 and 2. The median time to first start was 14 months for Standardbreds (range 9–22 months, mean 14 months) and 12 months for Thoroughbreds (range 7–27 months, mean 13 months). Time to first start did not differ significantly between Standardbreds and Thoroughbreds (P = 0.281).

Total earnings after surgery to follow-up date did not differ significantly between Standardbreds and Thoroughbreds (P = 0.524). However, for horses with at least five starts after surgery, there was some evidence that total earnings from their fifth start after surgery to follow-up date were higher among Standardbreds relative to Thoroughbreds (P = 0.088).

Eight Standardbred horses had at least one start both before and after surgery. Earnings per start did not differ significantly between the three starts immediately after surgery compared with the three starts immediately prior to surgery (P = 0.889). For these horses, the median of the average earnings per start for the three starts immediately after surgery was A$1,133 (range $0–$5,526), compared with $863 (range $0–$5,133) for the three starts immediately prior to surgery. The median change in average earnings per start for the three starts before surgery compared with the three starts after surgery for these horses was −$16 (range −$4,033–$4,576).

Thirteen Thoroughbred horses had at least one start both before and after surgery. Earnings per start were less for the three starts immediately after surgery compared with the three starts immediately prior surgery (P = 0.006). For these horses, the median of the average earnings per start for the three starts immediately after surgery was $171 (range $0–$41,850) compared with $11,333 (range $666–$190,166) for the three starts immediately prior to surgery. The median change in average earnings per start for the three starts before surgery compared with the three starts after surgery for these horses was −$5,734 (range −$181,500–$2,184).

The proportions of horses having one or more starts and five or more starts did not differ significantly between age categories (both P = 1.000).

Kaplan-Meier failure curves by age category are shown in Figure 3. Kaplan-Meier median time to first start was 14 and 12 months for horses aged <5 years and ≥5 years at the time of surgery, respectively. Times to first start after surgery did not differ significantly between the two age groups for all horses (P = 0.281). Two further Standardbreds aged <5 years that did not race after surgery were excluded from these analyses because the owners could not be contacted during the data collection period to ascertain whether the horses had been euthanased. Total earnings after surgery to follow-up date did not differ significantly between horses aged <5 years and ≥5 years (P = 0.673). Similarly, for horses with at least five starts after surgery, total earnings from their fifth start after surgery to follow-up date did not differ significantly between the two age groups (P = 0.751).

### *Subsequent racing performance by site of lesion*

The suspensory ligament body was affected in 9 horses, the branch was affected in 20 horses and the site was not recorded for 1 horse. Of the 9 horses in which the body was affected, 6 (67%) had one or more starts within the follow-up period and 5 (56%) had five or more starts. Of the 20 horses in which the branch was affected, 18 (90%) had one or more starts within the follow-up period and 16 (80%) had five or more starts. The proportions of horses having one or more starts and five or more starts did not differ significantly between these groups (P = 0.287 and 0.209, respectively).

Kaplan-Meier failure curves by lesion site are shown in Figure 4. Kaplan-Meier median time to first start was 15 and 12 months for horses in which the body was affected and those in which the branch was affected, respectively. Times to first start after surgery did not differ significantly between these groups (P = 0.146), nor did total

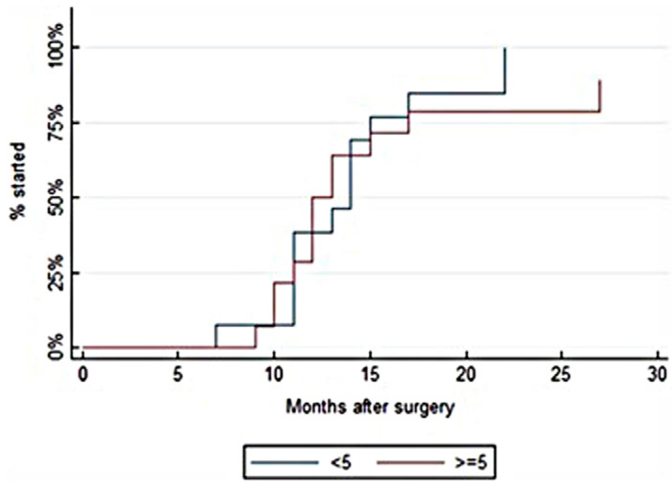


**Figure 3.** **Kaplan-Meier failure curves for time to first start after bone marrow transfer surgery for 28 horses with suspensory lesions by age at surgery: <5 years (n = 13) or ≥5 years (n = 15).**

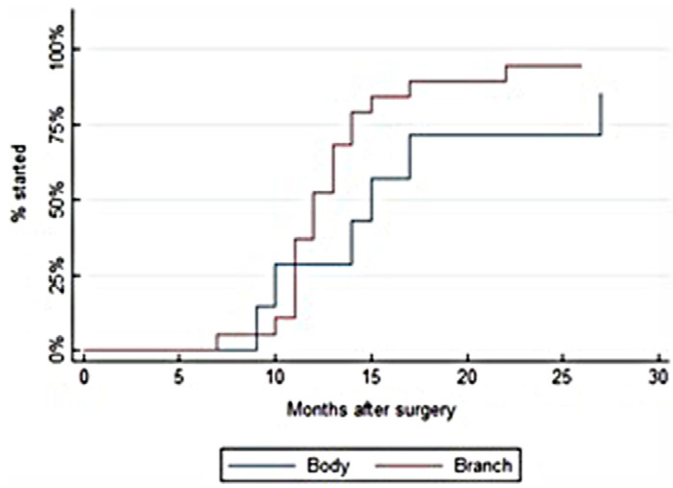


**Figure 4.** **Kaplan-Meier failure curves for time to first start after bone marrow transfer surgery for 29 horses with suspensory lesions by lesion site: body (n = 9) or branch (n = 20).**

earnings after surgery to follow-up date (P = 0.566). Similarly, for horses with at least five starts after surgery, total earnings from their fifth start after surgery to follow-up date did not differ significantly between these groups (P = 0.483).

## Discussion

Results of this study suggest that horses with suspensory ligament desmitis of the body or branches treated by intralesional injection of autologous bone marrow have a good prognosis for returning to racing and for having five starts or more (69% and 71% for Standardbreds and Thoroughbreds, respectively).

Given the importance of suspensory desmitis as a cause of loss within the racing industry, surprisingly little literature exists with regard to the treatment and prognosis of such injuries.[10,11] In the study that originally described the use of autologous bone marrow for treatment of suspensory desmitis, 92% of sport horses were able to return to previous levels of competition;[10] however, the injuries treated were to the origin of the suspensory ligament and may not be comparable to those treated in the present study. Waselau et al.[1] used intralesional injection of platelet-rich plasma, followed by controlled exercise, for treatment of mid-body suspensory ligament desmitis in Standardbred racehorses. They reported a success rate of 100% in regard to horses returning to racing. However, numbers in their study were low (n = 9) and earnings per start during the first year after treatment were significantly lower for case horses than for comparison horses.

We followed up the cases in this report for at least five starts where possible. O'Meara et al.[13] suggested that five or more starts were necessary to determine the usefulness of treatment with regard to superficial digital flexor tendonitis. A decreased success rate was noted in Thoroughbreds after five starts compared with three starts, but not in Standardbreds. O'Meara et al. also noted that racehorse performance is difficult to quantify because there is no established method of measuring the change in performance of racehorses before and after treatment of a medical or surgical condition.[13] We consider that, as well as being a useful measure of success per se, competing in five or more races post-surgery is a useful indicator that the trainer/owner considers the horse to be competitive.

The protocol used in our study required general anaesthesia in all cases. The procedure could be performed using sedation and local anaesthesia if preferred.[10] In our clinic, general anaesthesia allows the best use of the clinicians' time and is also safer for staff. We consider there is more control over needle placement in the immobile, anaesthetised animal. Inadvertent fatal pneumopericardium during this procedure in an anaesthetised horse has been described previously.[14]

A total of 8 mL of bone marrow was not exceeded, as this was the largest volume needed to fill the largest core lesions. The minimum volume necessary to fill the lesion was withdrawn from the sternum, based on the observation in humans that the highest concentration of progenitor cells is found in the first few millilitres of aspirated bone marrow.[15]

Telephone conversations with owners and trainers were used in conjunction with race records for follow-up of all horses. This is a well-recognised procedure for analysis of the success of treatments.[1,16]

There are several selection biases in this study. Lesions without a core (types 0 and 1) were not considered suitable for treatment. We were unable to determine from the literature if this was likely to positively or negatively bias the results. Further, not all horses that presented with suspensory ligament core lesions were treated with bone marrow, largely for economic reasons, as perceived by owners, with older horses and females being over-represented in the retired category (unpubl. data); however, we also discouraged surgery on horses with very severe injuries, which would have also positively biased the results.

It was impossible to ascertain the degree to which trainers adhered to the controlled exercise program, so we could not determine the effect of this on outcome. The equine literature is generally encouraging of the use of a controlled exercise program in the rehabilitation of suspensory ligament injuries, but peer-reviewed evidence is lacking.[1,10,17]

The greatest problem with this study, the few others that describe treatment for suspensory body and branch lesions and those describing treatment of similar injuries in the superficial digital flexor tendon is that controlled studies have not been performed. The present study was a retrospective cohort study. It would have been ideal to undertake a randomised control trial, but this was not possible. Therefore, the advantage of this treatment over simple rehabilitation remains unclear. There is a pressing need for randomised control trials of the treatment in horses with similar lesions. It is also important that the population of horses is controlled for by sporting discipline, as Dyson found that the re-injury rate of superficial digital flexor tendons increased from showjumpers to event horses to National Hunt horses to flat racehorses.[18] It seems likely that the same will be true for suspensory body and branch lesions.

## Conclusion

The results of this retrospective cohort study suggest that autologous bone marrow treatment of body or branch suspensory ligament desmitis in racehorses gives a comparable outcome to other treatments. A Thoroughbred or Standardbred racehorse has a good prognosis to race (5 starts or greater) after autologous bone marrow has been injected into body or branch suspensory ligament lesions and our results suggest it is a reasonable treatment for suspensory ligament core lesions.

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