

# Effects of analgesia of the digital flexor tendon sheath on pain originating in the sole, distal interphalangeal joint or navicular bursa of horses

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## Abbreviations

DDFT	Deep digital flexor tendon
DFTS	Digital flexor tendon sheath
DIPJ	Distal interphalangeal joint
NB	Navicular bursa
ODSL	Oblique distal sesamoidean ligament
SDFT	Superficial digital flexor tendon
SDSL	Straight distal sesamoidean ligament

## Summary

**Reasons for performing study:** Specific analgesic techniques are required in diagnosis of lameness to isolate the exact origin of pain to the many structures of the foot that may be involved.

**Objective:** To determine if analgesia of the digital flexor tendon sheath (DFTS) results in anaesthesia of other portions of the foot, such as the sole, distal interphalangeal joint (DIPJ), or navicular bursa (NB).

**Methods:** Lameness caused by pain in the dorsal margin or heel region of the sole of the foot was induced in 18 horses by: using set-screws to create solar pressure (*Trial 1*: n = 5); or administering endotoxin intrasynovially into the DIPJ (*Trial 2*: n = 6) and NB (*Trial 3*: n = 7). The gait of each horse was evaluated by examining videotape recorded before and after creation of lameness and after administration of mepivacaine hydrochloride into the DFTS.

**Results:** Median lameness scores in *Trial 1* at 10 min post injection of the DFTS were not significantly different from those before administration of local anaesthetic solution into the DFTS ( $P \geq 0.05$ ), but median lameness scores were reduced significantly at 20 min ( $P \leq 0.05$ ). In *Trials 2* and *3*, median lameness scores were not significantly different at observations made at 10 and 20 min post injection of the DFTS.

**Conclusions:** Analgesia of the DFTS has little effect on lameness caused by pain originating in the sole, DIPJ or NB.

**Potential relevance:** Improvement of lameness in horses after intrasynovial analgesia of the DFTS is probably caused by attenuation of pain within the structures contained in the DFTS.

## Introduction

Analgesia of the digital flexor tendon sheath (DFTS) has been useful in the diagnosis of desmitis of the palmar annular ligament of the fetlock, digital tenosynovitis (Schramme and Smith 2003) or intrasynovial tears of the superficial or deep digital flexor tendons (SDFT or DDFT) (Smith and Wright 2006), because it ameliorates or abolishes lameness caused by these conditions. More recently, clinical observations have suggested that lameness caused by tendonitis of the digital portion of the DDFT or desmitis of the oblique and straight distal sesamoidean ligaments (ODSL and SDSL) may also be improved or eliminated by instilling local anaesthetic solution into the DFTS (Schneider *et al.* 2003, 2005). Local anaesthetic solution can be administered into the DFTS in areas where pouches of the sheath bulge when the sheath is distended with fluid. Possible sites for synoviocentesis include the proximal lateral, distal palmar, proximal lateral collateral and distal lateral collateral pouches (Schramme and Smith 2003), and the palmar axial sesamoidean approach (Hassel *et al.* 2000).

The advent of MRI has confirmed the importance of injuries to the DDFT and distal sesamoidean ligaments as causes of foot lameness in horses (Schramme *et al.* 2002; Dyson *et al.* 2005; Schneider *et al.* 2005). Although analgesia of the distal interphalangeal joint (DIPJ) or navicular bursa (NB) also improves lameness in many horses with injuries to the digital portion of the DDFT, neither of these analgesic techniques is sufficiently specific to isolate pain to the DDFT (Schramme *et al.* 2002; Dyson *et al.* 2003). Having an additional analgesic technique available that desensitises the DDFT without simultaneously affecting other structures in the foot would, therefore, be useful. Intrasynovial analgesia of the DFTS could potentially fulfil this role, but might result in desensitisation of

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other portions of the foot in addition to the DDFT, either because of direct anaesthesia of the palmar digital nerves lying in close proximity or because mepivacaine diffuses rapidly from the DFTS to other synovial structures, such as the DIPJ and NB (Schumacher *et al.* 2003).

The aim of this study, therefore, was to investigate whether intrasynovial analgesia of the DFTS would affect lameness caused by pain in the sole, DIPJ or NB. Based on the observations that intrasynovial analgesic techniques in the feet of horses are imprecise and cannot always localise pain accurately within the foot, we hypothesised that analgesia of the DFTS would also attenuate pain in the sole, DIPJ or NB.

## Materials and methods

### Subjects

Eighteen horses, free of clinically apparent forelimb lameness when trotted on a hard surface in a straight line, were selected by 2 of the investigators (J.H. and Jo.S.) for the study. These horses were used to evaluate the ability of a local anaesthetic solution administered into the DFTS of a forelimb to ameliorate lameness caused by pain arising from different regions of the foot. Five horses had pain created in the toe and the heel region of the sole of the foot, 6 others had pain created in the DIPJ and another 7 had pain created in the NB. Horses were age 1–20 years (mean  $\pm$  s.d.  $10.4 \pm 6.5$  years) and weighed 315–555 kg ( $490.3 \pm 71.7$  kg).

### Protocol

During the 3 trials, the horses were evaluated for the effects of 1 ml/50 kg bwt 2% mepivacaine hydrochloride (Carbocaine)<sup>1</sup> administered into the DFTS using the palmar axial sesamoidean approach (Hassel *et al.* 2000). To perform this approach, the fetlock joint was flexed to a dorsal angle of 225°, and a 20 gauge, 40 mm needle placed through the skin at the level of the midbody of the lateral proximal sesamoid bone, through the palmar annular ligament, 3 mm axial to the palpable palmar border of the lateral proximal sesamoid bone and immediately palmar to the palmar digital neurovascular bundle. The needle was inserted in a transverse plane and advanced at an angle of 45° to the sagittal plane, aimed toward the central intersesamoidean region to a depth of 1.5–2.0 cm. Distension of one of the pouches of the DFTS during administration of the anaesthetic solution, was considered indicative of correct needle placement. In addition, the needle was considered to be correctly placed within the DFTS, only if a mixture of synovial fluid and injected anaesthetic solution could be aspirated from the DFTS after completion of the injection. After performing analgesia of the DFTS, each horse was walked until gaits were video recorded. Video recordings were made while trotting in a straight line on a hard surface, toward the camera, before and after creation of pain within the foot, 10 and 20 min after analgesia of the DFTS, and again after anaesthesia of the palmar digital nerves (*Trial 1*), analgesia of the DIPJ (*Trial 2*) or NB (*Trial 3*). All intrasynovial injections were preceded by aseptic preparation of the injection site. An attempt was made to trot each horse at the same slow pace with a loose lead line throughout the entire sequence of observations to avoid a change in the appearance of the lameness associated with a change in speed or restraint. The horses were evaluated for residual lameness the day following induction of lameness by observing

them walk while at pasture. The University's Instructional Animal Care and Use Committee approved all procedures.

*Trial 1:* The fore feet of 5 horses were shod with custom shoes within 3 weeks of the trial. One shoe had a 1 cm, fine-thread (9.7 cm) nut welded to the inside of each branch at the dorsal margin of the sole (*Trial 1A*), and the other shoe had a similar nut welded to the inside of each branch at the angles of the sole (*Trial 1B*). The 2 shoe types were applied randomly to both fore feet, with one type shod to one foot and the other type shod to the opposite foot. Two 1 cm set-screws were applied into nuts located either at the dorsal margin of the sole of one fore foot or at the angles of the sole of the contralateral fore foot of each horse. Set-screws were tightened to induce lameness that was consistent and easy to detect with a marked head nod when the horses were trotted in a straight line on a hard surface. The gait of each horse was video recorded before set-screw application, after development of lameness and at 10 and 20 min after analgesia of the DFTS. To ensure no residual lameness was present in that limb after the set-screws were removed, the palmar digital nerves of that foot were anaesthetised so the opposite limb could be evaluated. Similar gait sequences were video recorded before and after lameness was created by positioning set-screws into nuts located at the alternative location of the sole of the contralateral fore foot.

*Trial 2:* Lameness was induced in 6 horses by administering 20 ng bacterial lipopolysaccharide, *Escherichia coli* 055:B5 endotoxin<sup>2</sup>, reconstituted with sterile water to make a stock concentration of 50 ng/ml, into the DIPJ of a randomly selected forelimb (Palmer and Bertone 1994). Centesis of the DIPJ was performed using a dorsal parallel approach into the dorsal pouch (Moyer *et al.* 2007). Successful centesis was assumed if synovial fluid was seen to drip from the needle hub, by ease of injection, and if the syringe barrel partly refilled with a mixture of local anaesthetic solution (i.e. mepivacaine hydrochloride) and synovial fluid, when pressure on the plunger was released after the solution was administered. The gait of each horse was video recorded before administration of endotoxin, after development of lameness, 10 and 20 min after analgesia of the DFTS with 2% mepivacaine (1 ml/50 kg bwt), and after analgesia of the DIPJ with 6 ml 2% mepivacaine.

*Trial 3:* Lameness was induced in 7 horses by administering 10 ng of bacterial lipopolysaccharide, *Escherichia coli* 055:B5 endotoxin, reconstituted with sterile water to make a stock concentration of 50 ng/ml, into the NB of a randomly selected forelimb (Palmer and Bertone 1994). Centesis of the NB was performed using a distal, palmar approach to the 'navicular position' described by Verschooten *et al.* (1991). Accurate centesis of the NB was assumed by the depth of needle penetration before striking bone, initial ease of administration of 3.5 ml solution, that gradually became more difficult as pressure increased during administration, and refilling of the syringe barrel after releasing pressure on the syringe plunger. The gait of each horse was video recorded before administration of endotoxin, after development of lameness, 10 and 20 min after analgesia of the DFTS with 2% mepivacaine (1 ml/50 kg bwt), and after analgesia of the NB with 3.5 ml of 2% mepivacaine.

### Subjective analysis of lameness

Four investigators evaluated subjectively video recorded sequences of each of the 10 observations for each horse in *Trial 1*

and each of the 6 and 7 observations for each horse in *Trials 2* and *3*, respectively. All video recorded sequences were arranged so that investigators reviewing the sequences were blinded to the site of lameness (sole, NB or DIPJ), the treatment, and the time after treatment for all sequences. The investigators examined video recorded gaits and assessed subjectively severity of lameness of the horse in each sequence by assigning a score from a visual analogue grading scale of 0 to 10, in which 10 represented a nonweightbearing lameness of one limb, 1 a barely discernable lameness and 0 a sound limb (Wright 1993).

*Statistical analysis*

Effects of treatment were evaluated by using the Cochran-Mantel-Haenszel method applied to repeated measurements and by using rank scores (Stokes *et al.* 1995). Observer agreement was evaluated as a weighted kappa coefficient with perfect agreement having a value of 1 and agreement equalling that of chance having a value of 0 (Stokes *et al.* 1995). Values of  $P \leq 0.05$  were considered significant.

**Results**

Subtle lameness (*grade 1* or *2*) was detected by some observers in video recorded segments of 2 horses prior to inducing lameness in each trial. But, because these horses had a high lameness score after induction of lameness, data generated were not excluded. When horses were evaluated for lameness the day following induction of lameness, none were lame at a walk.

*Trial 1A*

After induction of lameness by set-screw application at the dorsal margin of the soles, median lameness scores were increased compared to preset-screw application in the affected forelimb (Table 1). Median lameness scores did not significantly change at

**TABLE 1: Median (range) lameness scores of 4 observers of 5 horses before and after creation of solar pain and after injection of the digital flexor tendon sheath with 1 ml/50 kg bwt mepivacaine hydrochloride**

Horse	Set-screw location	PreSSA*	Post SSA	Post IMH 10 min	Post IMH 20 min*
1	DAS	0	6	6	5
2	DAS	0	7.5	7.5	5
3	DAS	0.5	6.5	4	3.5
4	DAS	0.5	5.5	5.5	4.5
5	DAS	0	8	8.5	5
Median		0	6.5	6	5.0
(Range)		(0–2)	(4–8)	(3–9)	(2–8)

  

Horse	Set-screw location	PreSSA*	Post SSA	Post IMH 10 min	Post IMH 20 min
1	PAS	0	7	6.5	6
2	PAS	0	8	8	7.5
3	PAS	0	8	8	7
4	PAS	0	6	6	6
5	PAS	0	7.5	7	7.5
Median		0	7.5	7	7
(Range)		(0–1)	(4–9)	(4–9)	(3–9)

DAS = dorsal aspect of sole; PAS = palmar aspect of sole; SSA = set-screw application; IMH = injection of mepivacaine hydrochloride. \*Significantly different from Post SSA at level of  $P = 0.025$ .

**TABLE 2: Median (range) lameness scores of 4 observers of 6 horses before and after injection of the distal interphalangeal joint with endotoxin and of the digital flexor tendon sheath with 1 ml/50 kg bwt mepivacaine hydrochloride**

Horse	PreDIP IE*	Post DIP IE	Post IMH 10 min	Post IMH 20 min	Post DIP IMH 10 min*
1	0	6.5	6.5	6.5	0.5
2	0	8	8.0	8.5	0
3	0	7	8.5	8.0	2
4	0	7	6.5	6.5	1.5
5	0	7	9	9	5
6	0	6	7	7	4.5
Median	0	7	7.5	7.5	1.8
(Range)	(0–1)	(5–9)	(6–9)	(5–9)	(0–6)

DIP = distal interphalangeal joint; IE = injection with endotoxin; IMH = injection with mepivacaine hydrochloride. \*Significantly different from Post DIP IE at level of  $P = 0.014$ .

observations made 10 min after administration of 1 ml/50 kg bwt 2% mepivacaine into the DFTS, but median lameness scores were significantly reduced at 20 min (Table 1). One of 5 horses improved by at least one lameness grade at 10 min and 4/5 horses improved by one or more lameness grades at 20 min after injection. Improvement was never more than 3 lameness grades out of 10 and horses remained markedly lame with a median lameness score of 5/10. High lameness scores induced by applying set-screws to the dorsal margin of the sole were markedly reduced immediately after set-screws were removed. Residual lameness, if present, was resolved by anaesthetising the medial and lateral palmar digital nerves of the affected limb. Agreement of lameness scores among observers was good (mean weighted kappa coefficient of 0.66).

*Trial 1B*

After induction of lameness by set-screw application at the angles of the sole, median lameness scores were increased compared to preset-screw application in the affected and opposite forelimb (Table 1). Median lameness scores did not change significantly at observations made 10 and 20 min after administration of 1 ml/50 kg bwt 2% mepivacaine into the DFTS (Table 1). None of the horses showed an improvement in lameness grade at 10 min, but 1/5 horses improved by 1 lameness grade after 20 min post injection. High lameness scores induced by applying set-screws to the angles of the sole were markedly reduced immediately after set-screws were removed. Residual lameness, if present, was resolved by anaesthetising the medial and lateral palmar digital nerves of the affected limb. Agreement of lameness scores among observers was good (mean weighted kappa coefficient of 0.66).

*Trial 2*

Administration of endotoxin into the DIPJ caused a significant increase in the median lameness score of the treated compared to contralateral limb and compared to the same limb before administration of endotoxin (Table 2). Lameness ideal for evaluation usually occurred between 3 and 6 h after administration of endotoxin. After administration of 1 ml/50 kg bwt 2% mepivacaine into the DFTS, the median lameness scores did not change significantly at observations made at 10 and 20 min (Table 2). Median lameness scores showed a significant

**TABLE 3: Median (range) lameness scores of 4 observers of 6 horses before and after injection of the navicular bursa with endotoxin and of the digital flexor tendon sheath with 1 ml/50 kg bwt mepivacaine hydrochloride**

Horse	PreNB IE*	Post NB IE	Post IMH 10 min	Post IMH 20 min	Post NB IMH 10 min**
1	0	8.5	8	5.5	0.5
2	0	8	8	8	0
3	0	3	5	4.5	0.5
4	0	4	4	2.5	2
5	0	3	3	2	0
6	0.5	3.5	3	1	0
7	0	4.5	4.5	4.5	2
Median	0	3.8	4.5	3.5	0.3
(Range)	(0–1)	(2–9)	(0–9)	(0–8)	(0–3)

NB = navicular bursa; IE = injection with endotoxin; IMH = injection with mepivacaine hydrochloride. \*Significantly different from Post NB IE at level of  $P = 0.0085$ . \*\*Significantly different from Post NB IE at level of  $P = 0.0082$ .

improvement after local anaesthetic solution was instilled into the DIPJ, although 2 horses remained markedly lame (Table 2). None of the horses showed any improvement in lameness grade at either 10 or 20 min after injection. Agreement of lameness scores among observers was good (mean weighted kappa coefficient of 0.71).

### Trial 3

Administration of endotoxin into the NB caused a significant increase in the median lameness score of the treated limb compared to the contralateral limb and compared to the same limb before administration of endotoxin (Table 3). Lameness ideal for evaluation usually occurred between 3 and 6 h after administration of endotoxin. After administration of 1 ml/50 kg bwt 2% mepivacaine into the DFTS, the median lameness scores did not change significantly at observations made at 10 and 20 min (Table 3). None of the horses showed any improvement in lameness grade after 10 min, but 4 horses improved by at least 1 grade at 20 min. Improvement never amounted to more than 3 lameness grades out of 10. Median lameness scores showed a significant improvement after local anaesthetic solution was instilled into the NB ( $P = 0.0082$ ) (Table 3). Agreement of lameness scores among observers was good (mean weighted kappa coefficient of 0.68).

### Discussion

The results of this study indicate that intrasynovial anaesthesia of the DFTS using 1 ml/50 kg bwt local anaesthetic solution does not affect lameness caused by pain within the NB, DIPJ or the sole at the dorsal margin or heel region of the foot when results of treatment are evaluated within 20 min. Other authors, however, have warned that it is important to test the skin sensation at the level of the bulbs of the heel after intrasynovial analgesia of the DFTS, because inadvertent desensitisation of the foot is common following this procedure (Schneider *et al.* 2005). Although skin sensation at the heels was not assessed in this study, the lack of significant improvement in lameness in horses with solar, articular or bursal pain in the foot, suggests that heel sensation was not affected by intrasynovial analgesia of the DFTS in this study. One possible explanation for this discrepancy may lie in the different techniques used for injection of the DFTS in the studies.

Schneider *et al.* (2003) reported injecting the DFTS at the level of the proximal lateral collateral pouch, by introducing an 18 gauge needle into the triangular space between the base of the lateral proximal sesamoid bone, the proximal lateral insertion of the proximal digital annular ligament and the dorsal border of the DDFT. This site has also been described for introduction of an arthroscope during tenoscopy of the DFTS (Nixon 1990). The lateral palmar nerve is located close to the injection site (Nixon 1990) and backflow of local anaesthetic solution from the 18 gauge needle puncture hole in the DFTS could possibly result in partial or complete anaesthesia of the lateral palmar digital nerve. For the purpose of this study, the palmar axial sesamoidean approach was used for injection of the DFTS (Hassel *et al.* 2000). In this approach, the palmar neurovascular bundle lies immediately dorsal to the injection site while the limb is in flexion, but moves dorsally, 15–20 mm away from the injection site while the limb is weightbearing. In addition, a smaller needle and the presence of a fibrous tissue layer in the annular ligament, through which the needle is inserted obliquely into the DFTS, may both result in reduced backflow of local anaesthetic solution. As a result, a smaller chance of inadvertent anaesthesia of the palmar digital nerve may exist with the palmar axial sesamoidean approach than with the proximal lateral collateral approach. In conclusion, the risk of inadvertent anaesthesia of the palmar digital nerve may vary between different injection techniques for the DFTS, and may be lowest with the palmar axial sesamoidean approach.

Even though median lameness scores in this study did not improve after analgesia of the DFTS, a mild improvement in lameness grade was observed by some of the investigators in some individual horses. Possible explanations for this observation include diffusion of local anaesthetic solution from the DFTS into adjacent synovial structures (i.e. the DIPJ and the NB) or around the palmar digital nerve where it lies in direct contact with the DFTS, or backflow of local anaesthetic solution from the needle puncture site to the area of the palmar digital nerve. The higher number of horses with mild improvement in lameness grade after 20 min than after 10 min suggests that diffusion, rather than leakage of local anaesthetic solution through a needle tract, affects the palmar digital nerve. Nevertheless, none of the horses improved more than 3/10 lameness grades 10 min after injection of the DFTS, indicating that in this study the effect of analgesia of the DFTS on induced foot lameness was minimal. However, lameness following induced foot pain was more severe than lameness typically seen during examination of horses in clinical practice. It is possible (though unlikely) that this same improvement of 3 lameness grades or less might appear more significant and misleading to the clinician, if it was observed following analgesia of the DFTS in some horses with mild foot lameness.

The amount of intrasynovial pain created by administration of endotoxin in *Trials 2* and *3* varied. Individual horses may experience different degrees of joint pain associated with the synovial reaction to endotoxin. The timing of the inflammatory reaction to endotoxin may also differ between horses. For some horses, pain within the DIP joint or NB may have been resolving when analgesia of these synovial structures was performed. Other horses may have been experiencing increasing pain in the DIP joint or NB at the time response to analgesia of these structures was evaluated. This may explain why some horses did not have complete resolution of lameness after analgesia of the DIP joint or

NB because, for some horses, the inflammation created by endotoxin is sufficiently severe to prevent complete analgesia by administration of mepivacaine hydrochloride.

Radiographic control of intrasynovial injection techniques was not used in this study. It has been demonstrated previously, with cadaver limbs and live animal studies, that adherence to simple anatomical guidelines when performing these injections results in a high incidence of success, even in the hands of inexperienced clinicians (Hassel *et al.* 2000; Schramme *et al.* 2000; Piccot-Crezollet *et al.* 2005). Using the palmar axial sesamoidean approach for injection of the DFTS, Hassel *et al.* (2000) reported no failures in 16 cadaver limbs. In a similar study of injection techniques for the navicular bursa, Schramme *et al.* (2000) demonstrated 92% accuracy with the use of the 'navicular position' as reference point for injection without radiographic control. In addition, depth of needle penetration before striking the navicular bone, ease of administration of 3.5 ml bacterial lipopolysaccharide solution or mepivacaine and refilling of the syringe after releasing injection pressure were all used to support the accuracy of the technique in this study. Despite the discussion above, the authors recognise that the lack of radiographic control in *Trial 3*, allows the possibility for errors that could have altered the results.

Sack (1975) described the innervation of the DFTS by deep branches of the medial palmar nerve ( $n = 2$ ), of the lateral palmar nerve ( $n = 2$ ), of the medial digital nerve ( $n = 5$ : i.e. the 3rd, 4th, 5th and 6th branches) and of the lateral digital nerve ( $n = 2$ : i.e. the 3rd and 4th branches). In addition, the distal sesamoidean ligaments are supplied by the 4th deep branch of the medial digital nerve, which also innervates the DFTS. Branches that innervate the flexor tendons were only described in the metacarpal region by Sack (1975): 3 deep branches arising from the lateral palmar nerve just distal to the communicating branch, one long thin branch arising from the medial palmar nerve at the level of the distal row of carpal bones and another deep branch arising from the medial palmar nerve just distal to the communicating branch. To the authors' knowledge, no other reports describe the detailed innervation of the digital part of the DDFT. Nevertheless, because lameness caused by injury of the DDFT within the foot failed to improve significantly after analgesia of the palmar digital nerves, the DIPJ, or the navicular bursa in 30–40% of horses (Dyson 2003), we believe that a portion of the DDFT within the foot receives its sensory supply from some of the deep branches of the medial and lateral palmar and digital nerves that Sack (1975) describes as entering the DFTS. A report of improvement of lameness in horses with lesions of the DDFT after intrasynovial analgesia of the DFTS (Schneider *et al.* 2003) supports this belief.

Performing intrasynovial analgesia of the DFTS may be useful for horses with lameness that resolves after regional anaesthesia of the foot but for which no radiographic abnormalities are identified. Because local analgesia of the DFTS does not ameliorate lameness caused by pain in other parts of the foot, resolution of lameness after intrasynovial analgesia of the DFTS justifies suspicion of a lesion of the digital portion of the deep digital flexor tendon or other structures associated with the DFTS (e.g. distal sesamoidean ligaments, SDFT, palmar annular ligaments of the fetlock, and digital annular ligaments).

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## Manufacturers' addresses

<sup>1</sup>Pharmacia and Upjohn Co., Kalamazoo, Michigan, USA.

<sup>2</sup>Charles Rivers Laboratories, Inc., Charleston, South Carolina, USA.

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**Author contributions** J.H., J.S. and J.S. initiated, conceived and planned this study and its execution was by J.H., J.S., J.S. and M.S. Statistics were by F.D. and all authors contributed to the writing.