Return to sports after stress fractures of the tibial diaphysis: a systematic review

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Abstract

Introduction: This review aims to provide information on the time taken to resume sport following tibial diaphyseal stress fractures (TDSFs).


Areas of agreement: Twenty-seven studies were included: 16 reported specifically on anterior TDSFs and 5 on posterior TDSFs. The general principles were to primarily attempt non-operative management for all TDSFs and to consider operative intervention for anterior TDSFs that remained symptomatic after 3–6 months. Anterior TDSFs showed a prolonged return to sport.

Areas of controversy: The best time to return to sport and the optimal management modalities for TDSFs remain undefined.

Growing points: Management of TDSFs should include a full assessment of training methods, equipment and diet to modify pre-disposing factors.

Areas timely for developing research: Future prospective studies should aim to establish the optimal treatment modalities for TDSFs.

Key words: tibial diaphyseal stress fractures, return to sport, systematic review

Introduction

Stress fractures account for over 10% of all sports injuries seen by medical practitioners and can comprise as much as 30% of all injuries seen in running sports. Reported incidences of stress fractures are as high as 1% of the general population and 20% of elite...
The most common site for stress fractures is the tibial diaphysis accounting for up to 75% of all stress fractures. Out of all sporting injuries, stress fractures have one of the longest recovery times with regards to return to sport, with the potential for significant morbidity, failure to return to sport and a high chance of re-injury. As participation in athletic activity continues to grow, the public health impact of these injuries has been predicted to increase. Therefore, medical practitioners need to be able to inform patients on the likelihood and time frame of return to high-demand sports activity after such injuries.

There are two distinct types of tibial diaphyseal stress fractures (TDSFs): those of the anterior cortex and those of the posterior cortex (Fig. 1). Management of TDSFs is well defined, with modified rest the recognised first-line management option for both types. This can be supplemented by adjunctive therapies such as ultrasound or pneumatic braces and should be accompanied by a thorough review of diet, health, training methods and footwear. This is often the definitive management for posterior TDSFs. However, for anterior TDSFs, symptoms commonly fail to resolve with conservative measures alone, and operative intervention is often required. Various surgical techniques have been described for this, including IM Nailing, plate fixation and excision and drilling, and such interventions often provide definitive correction of the condition.

Despite this, information on return to sport following TDSFs is limited. Examining the literature, few studies provide data on the rate and time of return to pre-injury sports activity following TDSFs. The aim of this review is to provide an overview of the prognosis of these injuries in athletes, and the time they will take to resume sports activity. In our search, we have excluded acute fractures of the tibial diaphysis. The modified Coleman methodology score (CMS) was used to assess study quality. This has previously been used to assess the quality of studies reporting outcomes on sport-related fractures as well as in multiple other domains of orthopaedic medicine.

### Methods

#### Literature search

A comprehensive literature search was performed in August 2014 using Medline (PubMED), EMBASE, CINHAL, Cochrane Collaboration Database, Web of Science, Physiotherapy Evidence Database (PEDro), Sports Discus, Scopus and Google Scholar. This was to identify articles published in English in peer-reviewed journals, reporting data and information on return to sports after TDSFs, without any distinction for type and severity of fracture, level and type of sports activity.


The inclusion and exclusion criteria, designed in accordance with the PRISMA protocol, are detailed in Figure 1 and Table 1. Two authors (G.A.R., A.M.W.)
independently assessed the abstract of each publication, deciding it suitable for inclusion on the basis of its content. Biomechanical reports, studies on animals, cadavers, *in vitro* or animal studies, case reports, literature reviews, technical notes, letters to editors and instructional course were excluded. When inclusion or exclusion was not possible based on the abstract, the full-text versions were downloaded. The reference lists of the selected articles were also reviewed by hand to identify articles not included at the first electronic search. The search results and the relative selection process are shown in the quality of reporting of meta-analyses (QUORUM) flow diagram in Figure 2.

### Quality assessment

The papers were evaluated using the CMS, a 10-criteria validated scoring system assessing the quality of the study method, with the final score ranging from 0 to 100.\(^6\) The process and scoring system used was that described by Del Buono *et al.*\(^6\) Essentially, for a study to achieve 100, it must demonstrate a perfect methodology with its results free from the influence of chance, bias or confounding factors. Each study was rated by the two investigators using the CMS. When the scores differed by more than two points, the results were discussed, until a mutual score was agreed. The rating process was repeated by the two investigators following a 10-day interval, with the mean of the two scores being taken as the final result. The inter-observer reliability of the scores between the two investigators was assessed using intra-class correlation, achieving an intra-class correlation coefficient of 0.88 (95% confidence interval (CI) 0.85–0.91). Data on patient demographics, location and type of fracture, duration of preceding symptoms, radiological method of diagnosis, operative and non-operative management techniques, rate of return to sports, time to return to sports, complications and predictive factors for return to sports were recorded.

Time to return to sports was measured from commencement of non-operative modalities for conservatively managed patients and from primary surgical treatment for operatively management patients.

### Statistics

When cohort sizes were of sufficient size, statistical comparisons were made between the synthesis data. Univariate statistical comparisons between continuous variables were performed using the Student *t*-test between two groups. Univariate statistical comparisons between categorical variables were performed using the $\chi^2$ test (with Fisher’s exact test as required). The significance level was set at $P < 0.05$.

### Results

#### Search

The initial search returned the following number of papers: MEDLINE: 1162 results, Cochrane: 1 result, Sports discus: 2094 results, EMBASE: 613 results, CINHAL: 67 results, Web of Science: 327 results, Scopus: 935 results and PEDro: 0 results—a total of 5199 results (Fig. 1). Google Scholar found over 41 800 results. Ninety-nine articles investigating sports-related outcomes following TDSFs were identified. Seventy-two articles were excluded, because they were of inappropriate study methodology, did not report appropriate sports-related outcome data or were related to paediatric populations or epidemiology of injuries.

#### Patient demographics

We identified 27 relevant publications, published from 1956\(^{14}\) to 2013,\(^{15}\) focussing on clinical and functional outcomes of patients who returned to sports activity after TDSFs.\(^{14–40}\) Twenty-three were

### Table 1 Inclusion and exclusion criteria

<table>
<thead>
<tr>
<th>Inclusion criteria</th>
<th>Exclusion criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stress fractures of the tibial diaphysis</td>
<td>Paediatric fractures</td>
</tr>
<tr>
<td>Elite or recreational athletes</td>
<td>Reviews, systematic reviews, case reports, abstracts or anecdotal articles</td>
</tr>
<tr>
<td>Time taken to return to activity, sport or competition</td>
<td>Soft tissue injuries to the lower leg</td>
</tr>
<tr>
<td>Peer-reviewed journals</td>
<td>Epidemiological studies</td>
</tr>
<tr>
<td>Use of English language</td>
<td>Acute fractures of the tibial diaphysis</td>
</tr>
</tbody>
</table>
retrospective studies,\textsuperscript{14-26,28-30,32,34-35,37-40} three were prospective studies\textsuperscript{27,33,36} and one was a randomized controlled trial.\textsuperscript{31}

Of the 653 patients (9 with bilateral stress fractures), 329 (50\%) were males (3 with bilateral stress fractures), 167 (26\%) were females (6 with bilateral stress fractures) and 157 (24\%) were not specified.

Selected articles and their average CMS are shown in Tables 2–4. Of the 662 fractures recorded, follow-up data were achieved for 655 (98.9\%). The mean age

\textbf{Fig. 2} Selection of articles for inclusion in the review in accordance with the PRISMA protocol.
Table 2 Stress fractures of the anterior tibial diaphysis

<table>
<thead>
<tr>
<th>Author</th>
<th>n</th>
<th>Fracture location</th>
<th>Treatment</th>
<th>Duration of preceding symptoms (range)</th>
<th>Sport activity</th>
<th>Coleman score</th>
<th>Return time (range)</th>
<th>Return time (range) by treatment modality</th>
<th>Return rate</th>
<th>Return rate by treatment modality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batt et al.</td>
<td>16</td>
<td>Anterior mid diaphysis</td>
<td>Pneumatic bracing (4)</td>
<td>9 (3–14) months</td>
<td>Netball (2), Runner (1), Ballet (1)</td>
<td>44</td>
<td>12 (11–14) months</td>
<td>Bracing: 12 (11–14) months</td>
<td>4/4</td>
<td>Bracing: 4/4 (100%)</td>
</tr>
<tr>
<td>Beals and Cook</td>
<td>17</td>
<td>Anterior mid diaphysis</td>
<td>Modified rest (7)</td>
<td>-</td>
<td>Basketball (10), American Football (2), Gymnastics (2), Ballet (1)</td>
<td>39</td>
<td>12 (3–24) months</td>
<td>IM nailing: 12 months</td>
<td>11/15</td>
<td>Rest: 4/7 (57%), IM nailing: 1/1 (100%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>IM nailing (1) Plating (3) Excision and grafting (2)</td>
<td>Plating: 14.3 (10–18) months</td>
<td>Plating: 14.3 (10–18) months</td>
<td></td>
<td></td>
<td>E and G: 24 months</td>
<td></td>
<td>E and G: 3/3 (100%)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Excision, drilling and grafting (2)</td>
<td>E and G: 24 months</td>
<td>E, D and G: 4 (4–4) months</td>
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<td></td>
<td>Plating: 3/3 (100%)</td>
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<td>Plating: 3.1 (2.5–4) months</td>
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<td>Plating: 4/4 (100%)</td>
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<td>Plating: 4/4 (100%)</td>
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<tr>
<td>Borens et al.</td>
<td>18</td>
<td>Anterior diaphysis</td>
<td>Tension-band plating (4)</td>
<td>10.8 (4–18) months [8.3 (4–12) months therapy prior to surgery]</td>
<td>Track and Field (3), Volleyball (1)</td>
<td>58</td>
<td>3.1 (2.5–4) months</td>
<td>Plating: 3.1 (2.5–4) months</td>
<td>4/4</td>
<td>Plating: 4/4 (100%)</td>
</tr>
<tr>
<td>Burrows</td>
<td>14</td>
<td>Anterior mid diaphysis (1 Complete #)</td>
<td>Modified rest (1) cast (complete #) (1) Excision and grafting (3)</td>
<td>9.9 (.5–22) months [19 (15–22) month to E and G]</td>
<td>Ballet (5)</td>
<td>44</td>
<td>10.4 (1.5–23) months</td>
<td>Cast: 14 months E and G: 12.3 (1.5–23) months</td>
<td>5/5</td>
<td>Rest: 1/1 (100%), Cast: 1/1 (100%)</td>
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<td></td>
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<td></td>
<td>Excision and grafting (3)</td>
<td>[2–5 months rest prior to E and G]</td>
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<td>E and G: 3/3 (100%)</td>
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<tr>
<td>Cruz et al.</td>
<td>15</td>
<td>Anterior diaphysis</td>
<td>Tension-band plating (4)</td>
<td>8.8 (3–14) months [4.5 (0–6) months therapy prior to surgery]</td>
<td>Ballet (2), Soccer (1), Pole Vaulter (1)</td>
<td>54</td>
<td>2.8 (2.5–3) months</td>
<td>Plating: 2.8 (2.5–3) months</td>
<td>4/4</td>
<td>Plating: 4/4 (100%)</td>
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</table>

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<table>
<thead>
<tr>
<th>Author</th>
<th>n</th>
<th>Fracture location</th>
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<th>Duration of preceding symptoms (range)</th>
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<th>Coleman score</th>
<th>Return time (range) by treatment modality</th>
<th>Return rate</th>
<th>Return rate by treatment modality</th>
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</thead>
<tbody>
<tr>
<td>Green et al.</td>
<td>4</td>
<td>Anterior mid diaphysis</td>
<td>Cast and EMG (1) Excision and grafting (2) IM nailing (1)</td>
<td>2.8 (0–15) months [10 (8–12) months to E and G [6 months to IM nail]</td>
<td>American Football (1), Cycling (1), Unknown (2)</td>
<td>37</td>
<td>E and G: 3 months IM nailing: 7 months</td>
<td>3/4 (75%)</td>
<td>Cast and EMG: 0/1 (0%) E and G: 2/2 (100%) IM Nailing: 1/1 (100%)</td>
</tr>
<tr>
<td>Johansson et al.</td>
<td>14</td>
<td>Anterior mid diaphysis</td>
<td>Modified rest (10) Excision and grafting (2) Drilling and grafting (2)</td>
<td>13.9 (1–36) months</td>
<td>Long distance Running (4), Handball (2), Volleyball (1), Triathlon (1), Decathlon (1)</td>
<td>58</td>
<td>NA</td>
<td>NA</td>
<td>1/14 (7%)</td>
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<tr>
<td>Liimatainen et al.</td>
<td>49</td>
<td>Anterior mid diaphysis</td>
<td>Drilling (20) Plating (29)</td>
<td>NA [min 1–4 months rest prior to surgery]</td>
<td>Running (23), Soccer (11), Jumpers (5), Dancers (4), 400 m runner (4), Cross-Country Ski (1), Orienteer (1)</td>
<td>62</td>
<td>By 6 months</td>
<td>Drilling: by 6 months Plating: by 6 months</td>
<td>49/49 (100%)</td>
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<tr>
<td>Miyamoto et al.</td>
<td>8</td>
<td>Anterior mid diaphysis</td>
<td>Drilling and grafting (5) Reamed IM nailing (3)</td>
<td>25.8 (4–48) months [min 8–12 weeks rest prior to surgery]</td>
<td>Dancing (8)</td>
<td>44</td>
<td>D and G: 5.5 (4–9) months IM nailing: 10 (6–12) months</td>
<td>8/8 (100%)</td>
<td>D and G: 5/5 (100%) IM nailing: 3/3 (100%)</td>
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<tr>
<td>Moretti et al.</td>
<td>4</td>
<td>Anterior proximal (1) and mid (3) diaphysis</td>
<td>Extracorporeal shock wave therapy (4)</td>
<td>6.3 (4–10) months</td>
<td>Soccer (4)</td>
<td>50</td>
<td>ESWT: 3.3 (3–4) months</td>
<td>4/4 (100%)</td>
<td>ESWT: 4/4 (100%)</td>
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<tr>
<td>Study</td>
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<td>Treatment Details</td>
<td>Time to Return to Sport</td>
<td>Return to Sport Details</td>
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<td>Orava &amp; Hulkko</td>
<td>7</td>
<td>Anterior mid diaphysis</td>
<td>Modified rest (2), Excision and drilling (5)</td>
<td>5.7 (2–12) months</td>
<td>Rest: 3 months</td>
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<td>E and D: 7 (2–12) months, Rest: 2–5 (2–3) months (min 1–2 months rest prior to surgery)</td>
<td>4 (3–5) months</td>
<td>E and D: 4.5 (4–5) months</td>
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<td>Running (3), Sprinting (2), Pole Vault (1), Soccer (1)</td>
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<td>Orava et al.</td>
<td>17</td>
<td>Anterior mid diaphysis</td>
<td>Modified rest (8), Biopsy and drilling (9)</td>
<td>8.4 (3–24) months;</td>
<td>Rest: 6 (3–10) months</td>
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<td>Rest: 7 (3–24) months; B and D: 9.5 (5–14) months</td>
<td>6.6 (3–16) months</td>
<td>B and D: 7.1 (4–16) months</td>
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<td>Long distance Running (4), High Jumper (3), Middle Distance Running (2), Pole Vaulter (2), 400 m runner (2), Cross-Country Ski (1), Soccer (1), Dance Instructor (1), Volley ball (1)</td>
<td>41</td>
<td>17/17 Rest: 8/8</td>
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<tr>
<td>Rettig et al.</td>
<td>7</td>
<td>Anterolateral mid diaphysis</td>
<td>Rest and EMG (6), Excision and grafting (1)</td>
<td>4.4 (1–12) months [11 months to E and G]</td>
<td>Rest and EMG: 14 months</td>
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<td>Basketball (7)</td>
<td>12.5 (10–19) months</td>
<td>E and G: 19 months</td>
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<tr>
<td>Rolf et al.</td>
<td>2</td>
<td>Anterior diaphysis</td>
<td>Compression plating (2)</td>
<td>12 (12–12) months</td>
<td>By 12 months Plating: by 12 months</td>
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<td></td>
<td>Soccer (2)</td>
<td>49</td>
<td>2/2 (100%) Plating: 2/2</td>
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<tr>
<td>Uchiyama et al.</td>
<td>5</td>
<td>Anterior mid diaphysis</td>
<td>Low-intensity pulsed ultrasound (5)</td>
<td>5.2 (3–7) months</td>
<td>3 (2–4) months LIPUS: 3 (2–4) months</td>
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<td></td>
<td></td>
<td></td>
<td>Basketball (2), Soccer (1), Tennis (1), Judo (1)</td>
<td>45</td>
<td>5/5 (100%) LIPUS: 5/5 (100%)</td>
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<tr>
<td>Varner et al.</td>
<td>11</td>
<td>Anterior mid diaphysis</td>
<td>Reamed IM nailing (11)</td>
<td>12 (6–24) months</td>
<td>IM nailing: 4 (3–5) months</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Basketball (8), Running (3)</td>
<td>54</td>
<td>11/11 IM nailing: 11/11</td>
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</tbody>
</table>

Only patients with follow-up data included. Mean values unless otherwise stated.

IM, intra medullary; EMG, electromagnetic stimulation; LIPUS, Low Intensity Pulsed Ultrasound; ESWT, extracorporeal shock wave therapy; B, Biopsy; D, Drilling; E, Excision; G, Grafting.
<table>
<thead>
<tr>
<th>Author</th>
<th>n</th>
<th>Fracture location</th>
<th>Treatment</th>
<th>Duration of preceding symptoms (range)</th>
<th>Sport activity</th>
<th>Coleman score</th>
<th>Return time (range)</th>
<th>Return time (range) by treatment modality</th>
<th>Return rate by treatment modality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brand et al.</td>
<td>7</td>
<td>Postero-medial diaphysis</td>
<td>Low-intensity ultrasound (7)</td>
<td>NA</td>
<td>Soccer, Basketball</td>
<td>32</td>
<td>Immediately</td>
<td>LIUS: Immediately</td>
<td>7/7 (100%)</td>
</tr>
<tr>
<td>Johansson et al.</td>
<td>32</td>
<td>Postero-medial proximal (9), mid (12) and distal (11) diaphysis</td>
<td>Modified rest (32)</td>
<td>3.75 (2–10) months</td>
<td>Orienteering (19), Soccer (4), Dancing (3), Triathlon (1), Basketball (1), Badminton (1), Tennis (1)</td>
<td>58</td>
<td>12.4 (8–24) weeks</td>
<td>Rest: 12.4 (8–24) weeks</td>
<td>32/32 (100%)</td>
</tr>
<tr>
<td>Swenson et al.</td>
<td>18</td>
<td>Posterior distal 2/3 of diaphysis</td>
<td>Modified rest (8) Pneumatic bracing (10)</td>
<td>30 days (4–96 days)</td>
<td>Cross-Country Running (4), Track and Field (3), Recreational (3), American Football (2), Field Hockey (2), Soccer (1), Marathon runner (1), Cheerleader (1), Aerobics (1)</td>
<td>58</td>
<td>46 days (median)</td>
<td>Rest: 77 days (median) Bracing: 21 days (median)</td>
<td>18/18 (100%) Rest: 8/8 Bracing: 10/10 (100%)</td>
</tr>
<tr>
<td>van der Velde and Hsu</td>
<td>3</td>
<td>Posterior proximal (2) and distal (1) diaphysis</td>
<td>Modified rest (3)</td>
<td>3 (0–8) weeks</td>
<td>Marathon runner (1), Jogger (1), Hill-walking (1)</td>
<td>40</td>
<td>3.3 (2–8) weeks</td>
<td>Rest: 5.3 (2–8) weeks</td>
<td>3/3 (100%)</td>
</tr>
<tr>
<td>Whitelaw et al.</td>
<td>17</td>
<td>Postero-medial diaphysis</td>
<td>Pneumatic bracing (17)</td>
<td>–</td>
<td>Track and Field (9), Aerobic (2), Lacrosse (2), American Football (1), Soccer (1), Volleyball (1), Basketball (1)</td>
<td>70</td>
<td>5.3 (5–7) weeks</td>
<td>Bracing: 5.3 (5–7) weeks</td>
<td>17/17 (100%)</td>
</tr>
</tbody>
</table>

Mean values unless otherwise stated.
LIUS, Low-intensity ultrasound.
<table>
<thead>
<tr>
<th>Author</th>
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<th>Duration of preceding symptoms (range)</th>
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<tr>
<td>Devas</td>
<td>17</td>
<td>Diaphysis: Distal (14), Mid (2), Proximal (1)</td>
<td>Modified rest (16), Biopsy (1)</td>
<td>5 (3–20) weeks</td>
<td>Running (14), School sports (2), Athletics (1), Ballet (1)</td>
<td>31</td>
<td>3 (1–5) months</td>
<td>Rest: 3 (1–5) months</td>
<td>14/17</td>
<td>Rest 13/16 (82%)</td>
</tr>
<tr>
<td>Dickson and Kichline</td>
<td>7</td>
<td>Diaphysis</td>
<td>Pneumatic bracing (7)</td>
<td>6 weeks</td>
<td>Track and Field, Basketball, Soccer (6)</td>
<td>43</td>
<td>Immediately</td>
<td>Bracing: immediately</td>
<td>7/7</td>
<td>Bracing: 7/7 (100%)</td>
</tr>
<tr>
<td>Ekstrand and Torstveit</td>
<td>6</td>
<td>Diaphysis</td>
<td>Modified rest (6)</td>
<td>88 (13–231) days</td>
<td>Rest: 88 (13–231) days</td>
<td>34</td>
<td>88 (13–231) days</td>
<td>Rest: 6/6 (100%)</td>
<td>6/6</td>
<td>Rest: 6/6 (100%)</td>
</tr>
<tr>
<td>Gregori</td>
<td>2</td>
<td>Distal diaphysis (2 complete #s)</td>
<td>Cast (1), IM nailing (1)</td>
<td>3 months</td>
<td>Golf (2)</td>
<td>27</td>
<td>9.5 (9–10) months</td>
<td>Cast: 9 months, IM nailing: 10 months</td>
<td>2/2</td>
<td>Cast: 1/1 (100%)</td>
</tr>
<tr>
<td>Heaslet and Kanda-Mehtani</td>
<td>47</td>
<td>Diaphysis</td>
<td>Modified rest (47)</td>
<td>8.8 weeks</td>
<td>Marathon runner(23), Track and Field/Cross-country Running (13), Casual runner (7), Fitness walker (4)</td>
<td>50</td>
<td>18.8 weeks</td>
<td>Rest: 18.8 weeks</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Hulkko and Orava</td>
<td>182</td>
<td>Diaphysis: Distal (66), mid (27), proximal (89)</td>
<td>Modified rest (176), Drilling (5), Plating (1)</td>
<td>NA</td>
<td>Long and middle distance runner (103), Sprinters/Hurdlers (28), Jogging (23), Skiing (20), Orienteering (18), Ball Games (13), Jumping (12)</td>
<td>40</td>
<td>NA</td>
<td>Rest: NA, Drilling: NA, Plating: NA</td>
<td>182/182 (100%)</td>
<td>Drilling: 5/5 (100%), Plating: 1/1 (100%)</td>
</tr>
<tr>
<td>Matheson et al.</td>
<td>157</td>
<td>Diaphysis</td>
<td>Modified rest (157)</td>
<td>12.6 weeks</td>
<td>-</td>
<td>39</td>
<td>11.7 weeks</td>
<td>Rest: 11.7 weeks</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

Mean values unless otherwise stated.
IM, intra medullary.
at the time of injury ranged from 16.7 to 39.0 years, and the sports activities commonly practised were running (short and long distance), track and field, orienteering, skiing, basketball, dancing, ballet, American football and soccer. The type of sports activity is listed in Tables 2–4.

Methods of radiological imaging
Radiographs alone were used to confirm the diagnosis of a TDSF in 12 studies.14,15,17–19,22,23,26,29,32,34,37 The combination of radiographs and bone scans was used in nine studies.20,28,30,31,33,35,38–40 Four studies used a combination of radiographs, bone scans and CT scans,16,24,25,27 one study used a combination of radiographs, bone scans and MRI scans,36 and one study used a combination of all four imaging modalities.21

Fracture location and classification
Fifteen studies included TDSFs of the anterior tibial cortex only:14–19,21–29 all but one of these TDSFs were of the mid diaphysis;14–19,21,22,24–29 one was of the proximal diaphysis23 (Table 2).

Four studies included TDSFs of the posterior tibial cortex only:30–33 two studies reported on TDSFs of the postero-medial cortex,30,33 one study on TDSFs of the postero-distal cortex31 and one study of TDSFs of the postero-proximal and postero-distal cortex32 (Table 3).

One study included both TDSFs of the anterior (mid-diaphyseal) cortex and the posterior (postero-medial) cortex20 (Tables 2 and 3).

Seven studies reported on TDSFs but failed to qualify if they were in the anterior or posterior cortex34–40 (Table 4).

There were 160 anterior TDSFs (109 males, 51 females), with 111 being surgically managed and 49 being conservatively managed.14–29 There were 77 posterior TDSFs (33 males, 44 females) with all being managed conservatively.20,30–33 Three studies (n = 6) reported on completed fractures that occurred from preceding TDSFs.14,19,37

No formal classification was used in any study.

Preceding symptoms
For anterior TDSFs, the mean duration of preceding symptoms prior to diagnosis and management ranged from 3 to 26 months.14–16,18–20,22–29 Following diagnosis, the duration of attempted conservative management before proceeding with operative management ranged from 1 to 6 months.14,15,19,21,22,24

For posterior TDSFs, the mean duration of preceding symptoms prior to diagnosis and management ranged from 3 weeks to 4 months.20,31,32

Study design
The mean CMS for all the studies was 45.0 (range: 27–70).14–40 For the ‘anterior TDSF’ studies, the mean CMS was 46.9 (range: 28–58) (Table 2).14–29 For the ‘posterior TDSF’ studies, the mean CMS was 51.6 (range: 32–70) (Table 3).20,30–33 For the ‘general TDSF’ studies, the mean CMS was 37.7 (range: 27–50) (Table 4).34–40

Management
Anterior tibial stress fractures
For management of anterior TDSFs, the general principles were to attempt an initial period of conservative management, in the form of modified rest ± associated therapies, for a period for up to 6 months.14–29 If this failed to alleviate symptoms, surgical management of the fracture should be considered.14,15,17–22,24–27,29 The surgical procedures are listed in Table 2. Postoperatively, careful rehabilitation with gradual increase in weight bearing was recommended in the majority of the studies.15,18–22,25,27,29

Posterior tibial stress fractures
For management of posterior TDSFs, the general principles were to employ modified rest ± associated non-surgical therapies, for as long as required to allow the symptoms to resolve.20,30–33 The various methods are listed in Table 3.

Completed tibial stress fractures
For management of completed TDSFs, the general principles were to treat these as acute fractures of the tibial diaphysis, with cast immobilization for undisplaced fractures14,19,37 and operative management for
displaced fractures.\textsuperscript{19,37} Conservatively managed fractures that displace in cast, fail to heal or remain symptomatic may require operative intervention.\textsuperscript{17,37}

**Functional assessment**

Only 13 studies used measures to assess post-intervention functional status;\textsuperscript{14–18,20–23,26,28,30,35} none had been formally validated. Measures employed included ‘Return to Same Level of Sport’;\textsuperscript{14,16,22,23,26,28,35} ‘Final Unimpaired Sporting Function’;\textsuperscript{15,18,21} ‘Return to Sport Symptom Free’;\textsuperscript{17} Visual Analogue Pain Scoring;\textsuperscript{30} Number of Stepdowns achieved per minute;\textsuperscript{30} and Rating of Functional Outcome as ‘excellent’ (no symptoms), ‘good’ (pain occasionally), ‘fair’ (pain during or after exercise but not at rest) and ‘poor’ (ceased activity due to persisting pain).\textsuperscript{20}

**Return to sports**

**Anterior tibial stress fractures**

Of the 160 anterior TDSFs, 142 (88.8\%) returned to sports (Table 2 and Fig. 3a).\textsuperscript{14–29}

Of the 49 anterior TDSFs treated conservatively, 35 returned to sport (71.4\%).\textsuperscript{14,16,17,19,20,23–26,28}

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**Fig. 3** (a) Return rates for anterior tibial diaphyseal stress fractures. (b) Return rates for posterior tibial diaphyseal stress fractures.
Those treated with low-intensity pulsed ultrasound (LIPUS) \((n = 5)\) had a return rate of 100%\(^\text{18,19,26}\); those treated with extracorporeal shock wave therapy (ESWT) \((n = 4)\) had a return rate of 100%\(^\text{16,19,26}\); those treated with electromagnetic stimulation (EMG) \((n = 7)\) had a return rate of 86%; those treated with pneumatic bracing \((n = 4)\) had a return rate of 100%\(^\text{16,28}\) and those treated with modified rest \((n = 29)\) had a return rate of 55%\(^\text{.14,17,20,24,25}\)

Of the 111 anterior TDSFs treated surgically, 107 returned to sport \((96.4\%)\)^\text{14,15,17–22,24–27,29}\). Those treated with IM Nailing \((n = 16)\) had a return rate of 100%\(^\text{15,17,18,21,27}\); those treated with Plating \((n = 42)\) had a return rate of 100%\(^\text{15,17,18,21,27}\) and those treated with Excision and Drilling \((n = 53)\) had a return rate of 92.5%\(^\text{.14,17,19–22,24–26}\)

The return rates for the conservatively managed anterior TDSFs were significantly lower than those for the surgically managed anterior TDSFs \((P < 0.001)\).

Ten ‘anterior TDSF’ studies reported return rates to full-level sport with no persisting symptoms\(^\text{14–16,18,20–23,26,28}\). Seven reported return rates of 100% to full-level sport;\(^\text{15,16,18,22,23,28}\) four included surgically managed cohorts\(^\text{15,18,22,26}\) and four included conservatively managed cohorts.\(^\text{16,23,26,28}\) One study reported on anterior TDSFs managed with Plating compared with Drilling and reported a ‘full-level’ return rate of 76% \((plating 93\%; drilling 50\%)\).\(^\text{21}\) One study reported on anterior TDSFs managed with excision and drilling compared with Rest and reported a ‘full-level’ return rate of 60% \((excision and drilling 67\%; rest 50\%)\).\(^\text{14}\) One study reported on anterior TDSFs managed with excision and drilling compared with rest and reported a ‘full-level’ return rate of 7% \((excision and drilling 25\%; Rest 0\%)\).\(^\text{20}\)

**Posterior tibial stress fractures**

Of the five studies on posterior TDSFs \((n = 77)\), all reported return rates of 100% (Table 3 and Fig. 3b).\(^\text{20,30–33}\) All five studies involved patients treated conservatively—three involved use of modified rest \((n = 43)\),\(^\text{20,31,32}\) two pneumatic bracing \((n = 27)\)\(^\text{31,33}\) and one low-intensity ultrasound (LIUS) \((n = 7)\).\(^\text{30}\) All treatment modalities demonstrated return rates of 100%.

The return rates for the posterior TDSFs were significantly higher than those for the anterior TDSFs \((P < 0.001)\).

Two ‘posterior TDSF’ studies reported return rates to full-level sport with no persisting symptoms. One study, using LIUS, reported a return rate to ‘full-level’ sport of 100%.\(^\text{30}\) One study, using modified rest, reported a return rate to ‘full level’ to sport of 91%\(^\text{.20}\)

**Completed tibial stress fractures**

Of the three studies that included completed TDSFs \((n = 6)\),\(^\text{14,19,37}\) two reported ‘return to sport’ rates of 100%\(^\text{14,37}\) and one a return rate of 67%.\(^\text{19}\) Two patients were treated with IM Nail with a return rate of 100%.\(^\text{19,37}\) Three patients were treated with cast with a return rate of 67%.\(^\text{14,19,37}\) One patient was treated with Excision and Drilling with a return rate of 100%.\(^\text{19}\)

**Generalized tibial stress fractures**

Of the 215 ‘generalized’ TDSFs, 212 \((98.6\%)\) returned to sports (Table 4).\(^\text{35}\) Only one of these studies reported return rates to full-level sport.\(^\text{35}\) This study employed a pneumatic brace and reported a ‘full-level’ return rate of 100%\(^\text{.35}\)

**Time to return to sports**

**Anterior tibial stress fractures**

From the 16 studies with anterior TDSFs that resumed sports \((n = 142)\), the mean times to return to sport ranged from 3 to 10 months (mean 7 months, median 6 months) (Table 2 and Fig. 4a).\(^\text{14–29}\)

Of the 10 studies with cohorts of conservatively managed anterior TDSFs \((n = 35)\), the mean time to return to sport ranged from 3 to 14 months (mean 7 months, median 6 months).\(^\text{14,16,17,19,20,23–26,28}\) For the anterior TDSFs treated with LIPUS \((n = 5)\), the mean time to return to sport was 3 months;\(^\text{28}\) for ESWT \((n = 4)\), the mean time was 3 months;\(^\text{23}\) for EMG \((n = 6)\), the mean time was 14 months;\(^\text{19,26}\) for pneumatic bracing \((n = 4)\), the mean time was 12 months\(^\text{16}\) and for modified rest alone \((n = 16)\), the mean time was 6 months.\(^\text{14,17,20,24,25}\)

Of the 13 studies with cohorts of surgically managed anterior TDSFs \((n = 107)\), the mean time to sport ranged from 3 to 24 months (mean 7 months,
For the anterior TDSFs treated with modified rest ($n = 43$), the mean time to return to sports was 3 months; for pneumatic bracing ($n = 27$), the mean time was 1 month; for LIUS ($n = 7$), all returned to sport immediately following commencement of treatment.

The return times for the posterior TDSFs were significantly lower than those for the anterior TDSFs ($P < 0.001, 95\% CI 16.93–23.20$).

**Completed tibial stress fractures**

From the three studies which included completed TDSF which resumed sports ($n = 5$), mean times to return to sport ranged from 3 to 14 months. For the two treated with cast, time to return to sport included 9 and 14 months. For the two treated with IM Nailing, time to return to sport included 7 and 10 months. For the one treated with excision and drilling, the time to return to sport was 3 months.

**Generalized tibial stress fractures**

From the seven studies with generalized TDSFs which resumed sports ($n = 212$), the mean time to return to sport ranged from 0 to 10 months (mean 4 months, median 3 months) (Table 4).

**Time to healing**

For anterior TDSFs, the mean time to disappearance of stress fracture on radiographs ranged from 2 to 11 months. For posterior TDSFs, the mean time to disappearance of stress fracture on radiographs ranged from 1 to 6 months. For completed TDSFs, the mean time to union ranged from 4 (excision and graft) to 7 months (IM nailing).

**Complications**

**Anterior tibial stress fractures**

Of the 16 studies on anterior TDSFs, 8 reported complications. These included recurrence of stress fractures ($n = 6$; three drilling, three rest)—all successfully managed conservatively with resolution of symptoms between 3 and 12 months; symptomatic metalwork ($n = 3$; all plating)—all underwent removal of plate and symptoms resolved following; requirement for repeat operations due to...
delayed healing \((n = 5; \text{four drilling,}^{17,21,25} \text{one plating})^{21}\)—three cases of drilling required conversion to plating,\(^{17,21,25}\) one case of drilling required redrilling\(^{21}\) and one case of plating was redrilled\(^{21}\) with all returning to sport over a period of 6 to 16 months; medial tibial pain \((n = 3; \text{one drilling})^{21,22}\)—all underwent delayed fasciotomies up to 2 years post-surgery with symptoms resolving following; asymptomatic non-union \((n = 1; \text{bracing})^{16}\)—no treatment required; anterior knee pain \((n = 1: \text{IM nailing})^{29}\)—treated with corticosteroid injection and symptoms resolved completely; posterior tibial tendinitis \((n = 1; \text{drilling})^{22}\)—this was managed with analgesia, physiotherapy, and orthotics and symptoms resolved with return to full activity.

**Posterior tibial stress fractures**
Of the five studies on posterior TDSFs, one reported a complication.\(^{32}\) This involved recurrence of a stress fracture at 16 months following an initial treatment period of 2 months modified rest.\(^{32}\) This was managed with three further months of rest and the symptoms resolved.\(^{32}\)

**Completed tibial stress fractures**
One of the three studies on completed TDSFs reported a complication.\(^{37}\) This was a patient who underwent attempted conservative management in a cast, but the fracture displaced so the patient required IM nail insertion.\(^{37}\) The fracture healed and the patient returned to sports at 10 months.\(^{37}\)

**Generalized tibial stress fractures**
Of the seven studies on generalized TDSFs, two reported complications.\(^{35,36}\) One study on elite footballer reported a recurrence rate of 50% within 1 year following treatment with modified rest.\(^{36}\) One study, which used a pneumatic brace, reported recurrence of a stress fracture after 1 year, which resolved following reapplication of the brace.\(^{35}\)

**Predictive factors**
One study found that only 1 of 14 anterior TDSFs returned to sport while 32 of 32 posterior TDSFs returned with 29 of these returning symptom free.\(^{20}\) Another study assessing the outcomes of different surgical modalities as treatment for anterior TDSFs found that plate fixation resulted in a statistically better outcome (93% good results) compared with drilling (50% good results) \((P < 0.002).^{21}\)

**Discussion**
The main findings of this study are that most patients with TDSFs successfully return to sports activity, yet those with anterior TDSFs demonstrate longer return times, greater need for operative intervention and decreased return rates.

In comparison to previous systematic reviews on return to sports following fractures, the methodological quality of the studies included in this review was improved and the number of studies suitable for inclusion was increased.\(^{6}\) However, despite established management principles for TDSFs,\(^{5}\) the optimal modalities for management and rehabilitation have yet to be ascertained, and this is reflected by the lack of Level one studies on this topic.

From this review, it would appear that conservative management continues to comprise the standard treatment for posterior TDSFs. For anterior TDSFs, however, treatment comprises initial attempted conservative management, and if symptoms persist for 3–6 months, operative intervention is then considered. This difference is a result of the decreased vascularity of the anterior tibial cortex as well as the tension nature of the anterior TDSF, which limits the potential for this fracture to heal with non-operative measures alone.\(^{5}\)

It was found that over 70% of anterior TDSFs required operative intervention; thus, when attempting initial conservative management of these injuries, clinicians must remain aware that dedicated regular follow-up is required to assess for persisting symptoms, with operative intervention offered accordingly in a timely fashion.\(^{5}\)

There was a large duration of preceding symptoms noted prior to diagnosis of TDSFs, ranging up to 26 months. This was higher for anterior TDSFs. This is an area to target as better education of athletes, sports team and physicians can allow for earlier detection and management of TDSFs, and so quicker return to sports.\(^{5}\)
An important factor in the timely diagnosis of TDSFs is appropriate use of imaging.\textsuperscript{1,5} To note, radiographs alone have a reported sensitivity of 10\% for detecting stress fractures, so medical practitioners must remain aware of their limitations, and consider other imaging modalities when these are negative.\textsuperscript{1} This is reflected in our findings, with over half of the studies employing secondary imaging modalities such as bone scans, CT and MRI scans.

It is well documented that the different types of TDSFs have different prognoses, with the anterior TDSFs being high-risk injuries requiring prolonged treatment with lower return rates to sport.\textsuperscript{5} This was reflected in our findings with anterior TDSFs having a mean return rate to sport of 89\% and a mean time to return to sport of 7 months, while posterior TDSFs had a mean return rate of 100\% and a mean time to return of 2 months. This was despite the fact that several ‘anterior TDSF’ studies reported ‘times to return to sports’ from primary surgical intervention, with several of them attempting up to 6 months of conservative management prior to this.\textsuperscript{14,15,19,21,22,24}

With the management of posterior TDSFs, it was found that pneumatic bracing\textsuperscript{31,33} and LIUS\textsuperscript{30} can reduce time to return to sport. With non-operative management of anterior TDSFs, it was found that LIPUS\textsuperscript{28} and ESWT\textsuperscript{23} can reduce time to return to sport, while use of modified rest alone\textsuperscript{14,17,20,24,25} can result in a high rate of non-return to sport. With operative management of anterior TDSFs, it was found that use of an IM nail can result high return rates and reduced times to return to sport, with an acceptable complication profile.\textsuperscript{17,19,22,29} However, given the limited numbers of patients included in the studies, it remains difficult to formally recommend any such treatment modality. In view of the limited evidence, management decisions should be directed by informed consultations between the patient and experienced clinicians.

While the principles of management have been well analysed in these studies, the description of rehabilitation protocols used in the studies was often limited.\textsuperscript{14–40} As such there is limited evidence on the optimal modality of rehabilitation for these injuries. Future studies should publish more extensive information on rehabilitation programs used, and further research can explore the optimal design of these accordingly.

From this systematic review, the studies included limit the ability to clearly define the best timing to return to sports after TDSFs, given the heterogeneity of the fracture types included, the varying methods of management and outcome measures utilized, as well as the low scientific quality of some of the studies.\textsuperscript{14–40} Many of the included studies only briefly refer to return to sports, and very few given comprehensive definitions regarding level of sport returned to and persistence of impeding symptoms.\textsuperscript{14–40} Future studies should aim to provide clear comprehensive data on time to return to full-level sport and final level of sporting function attained. This should be achieved through well-designed prospective studies that employ validated assessment tools to record functional outcome.

There are several limitations to our review. Firstly, we did not correspond with the authors of the included studies; thus, our assessment of the results and scientific validity of the papers may have been biased by the quality of reporting of the studies. Secondly, with the heterogeneity of the studies included, the results could only be pooled for location of fracture but not for severity of stress fracture,\textsuperscript{1} sporting activity or sporting level. Thirdly, the methods used to report functional outcome were entirely subjective, with no formal validated outcome score employed throughout. Fourthly, due to the multiple treatment modalities employed, as well as the limited cohorts from the different studies, it was not possible to draw definite conclusions on the optimal treatment methods for the different fracture types. Lastly, due to the heterogeneity of the studies included, it was not feasible to perform a meta-analysis on the recorded data, and as such this is instead a systematic quantitative review.

**Conclusion**

Most athletes, who suffer a TDSF, can expect to return to sport; however, those with anterior TDSFs often require a prolonged treatment period. Conservative management forms the first-line treatment for all TDSFs. This is very effective in allowing posterior...
TDSFs to return to sport. However, with anterior TDSFs, symptoms often fail to settle with conservative measures alone, with operative intervention required in as many as 70% of cases to allow resumption of sporting activities. Nevertheless, despite a good understanding of the general principles of management of TDSFs, the optimal modalities for treatment are not yet established.

Future research in this field should aim to create prospective studies stratifying for fracture location, treatment method and activity level, and employing objective-validated outcome measures.

**Conflict of interest statement**

The authors have no potential conflicts of interest.

**References**


