

Return to sport following toe phalanx fractures: A systematic review

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Abstract

BACKGROUND

Evidence-based guidance on return to sport following toe phalanx fractures is limited.

AIM

To systematically review all studies recording return to sport following toe phalanx fractures (both acute fractures and stress fractures), and to collate information on return rates to sport (RRS) and mean return times (RTS) to the sport.

METHODS

A systematic search of PubMed, MEDLINE, EMBASE, CINAHL, Cochrane Library, Physiotherapy Evidence Database, and Google Scholar was performed in December 2022 using the keywords 'Toe', 'Phalanx', 'Fracture', 'injury', 'athletes', 'sports', 'non-operative', 'conservative', 'operative', 'return to sport'. All studies which recorded RRS and RTS following toe phalanx fractures were included.

RESULTS

Thirteen studies were included: one retrospective cohort study and twelve case series. Seven studies reported on acute fractures. Six studies reported on stress fractures. For the acute fractures ($n = 156$), 63 were treated with primary conservative management (PCM), 6 with primary surgical management (PSM) (all displaced intra-articular (physeal) fractures of the great toe base of the proximal phalanx), 1 with secondary surgical management (SSM) and 87 did not specify treatment modality. For the stress fractures ($n = 26$), 23 were treated with PCM, 3 with PSM, and 6 with SSM. For acute fractures, RRS with PCM ranged from 0 to

100%, and RTS with PCM ranged from 1.2 to 24 wk. For acute fractures, RRS with PSM were all 100%, and RTS with PSM ranged from 12 to 24 wk. One case of an undisplaced intra-articular (physeal) fracture treated conservatively required conversion to SSM on refracture with a return to sport. For stress fractures, RRS with PCM ranged from 0% to 100%, and RTS with PCM ranged from 5 to 10 wk. For stress fractures, RRS with PSM were all 100%, and RTS with surgical management ranged from 10 to 16 wk. Six cases of conservatively-managed stress fractures required conversion to SSM. Two of these cases were associated with a prolonged delay to diagnosis (1 year, 2 years) and four cases with an underlying deformity [hallux valgus ($n = 3$), claw toe ($n = 1$)]. All six cases returned to the sport after SSM.

CONCLUSION

The majority of sport-related toe phalanx fractures (acute and stress) are managed conservatively with overall satisfactory RRS and RTS. For acute fractures, surgical management is indicated for displaced, intra-articular (physeal) fractures, which offers satisfactory RRS and RTS. For stress fractures, surgical management is indicated for cases with delayed diagnosis and established non-union at presentation, or with significant underlying deformity: both can expect satisfactory RRS and RTS.

Key Words: Acute; Stress; Fracture; Toe; Phalanx; Return; Sport; Rate; Time

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Core Tip: We performed a systematic review, assessing studies that recorded return rates (RRS) and return times (RTS) to sports following acute and stress fractures of the toe phalanges. Thirteen studies were included. Seven studies reported on acute fractures ($n = 156$); six studies on stress fractures ($n = 26$). For acute fractures, 63 underwent primary conservative management (PCM), 6 primary surgical management (PSM), and 1 sary surgical management (SSM). For stress fractures, 23 underwent PCM, 3 PSM, and 6 SSM. For acute fractures, PCM conferred acceptable RRS and RTS. PSM was indicated for displaced intra-articular proximal phalanx fractures. For stress fractures, PCM, when successful, conferred acceptable RTS. Significant delays to diagnosis or associated deformity often necessitated the conversion to SSM: this was invariably successful at returning athletes to sport.

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INTRODUCTION

Acute toe phalanx fractures are a relatively common injury, comprising 3%-4% of all traumatic fractures [1-4]. Most of these fractures occur within the first and fifth toes, with the majority being undisplaced or minimally displaced, and suitable for conservative management[5]. The functional results following these injuries have shown promising results[5].

While 16% of all acute toe fractures occur during sport, the incidence and outcome of these fractures in the athlete remain poorly defined[6]. Traumatic toe phalanx fractures have been found to comprise 4.5% of all sport-related fractures, and occur at an incidence of 0.06 per 1000 of the general population [6].

By comparison to acute fractures, the epidemiology of toe phalanx stress fractures is less well described[7]. While a significant proportion of these fractures are sport-related, the current literature on this injury type comprises a limited number of case series and case reports[7]. While there are emerging theories that link biomechanical deformities to their occurrence (*e.g.* hallux valgus and great toe proximal phalanx stress fractures), a comprehensive description of this fracture type has yet to be presented[8].

The most common causative sports for acute toe phalanx fractures are soccer, gymnastics, and judo [9]. The most common causative sports for stress-toe phalanx fractures are sprinting, soccer and long-distance running[7]. For acute toe phalanx fractures, the common sporting mechanisms of injury include tackle and dismount[9].

Regarding treatment, with the vast majority of acute toe phalanx fractures being undisplaced or minimally displaced and extra-articular, they are managed conservatively, with toe strapping and

protected weight-bearing[5,9]. Those that are significantly displaced or intra-articular, are often managed with closed +/- open reduction with k-wire or screw fixation[9]. Open fractures require fracture site washout +/- fixation[9]. Stress fractures of the toe phalanx are routinely managed conservatively in the first instance, with protected weight-bearing and avoidance of relevant sporting activities [7]. However, those with significantly delayed presentation (> 1 year) and established non-union, or those that are associated with a significant causative deformity, often require surgical intervention[7].

Despite this treatment framework, there is very limited information in the current literature to guide the optimal management of these fractures in the athlete[7,9-11]. Similarly, there is very limited published data, which illustrates the expected morbidity that such fractures will have on the athlete[7,9-11].

This systematic review aims to provide a comprehensive overview of the current literature which records return to sport following acute fractures and stress fractures of the toe phalanges in the athlete.

MATERIALS AND METHODS

Literature search

The authors performed a systematic analysis of the listed databases in December 2022: PubMed, MEDLINE, EMBASE, CINAHL, Cochrane Library, Physiotherapy Evidence Database (PEDro), and Google Scholar.

The search aimed to identify all peer-reviewed studies, which recorded return rates to sport (RRS) and return times to sport (RTS) in patients who sustained toe phalanx fractures. The search terms used were 'toe', 'phalanx', 'fracture', 'injury', 'athletes', 'sports', 'non-operative', 'conservative', 'operative', 'surgical', and 'return to sport'. All articles were considered, regardless of the date of publication or level of the sport.

The review was structured along the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) guidelines[12]. Two authors (X.X.X., X.X.X.) searched for and reviewed the articles. Table 1 records the inclusion and exclusion criteria. The QUOROM Process for the review is illustrated in Figure 1.

The authors excluded technical notes, case reports, instructional course reports, biomechanical reports, articles of expert opinion, and literature reviews, unless these manuscripts contained relevant patient data. Similarly, articles reporting on return to sport following toe sesamoid fractures were excluded. A stepwise process of article assessment was performed, first reviewing all the relevant titles, then abstracts, then full-length articles as required. Relevant reference lists and review studies were also assessed to locate further studies, which were appropriate for inclusion. Any disagreement in article inclusion was confirmed through consensus agreement or liaison with the senior author.

Data extraction

The recorded data from each study included: Demographic details, mechanism of injury (for acute fractures), duration of preceding symptoms (for stress fractures), pre-operative imaging investigations, fracture location, fracture nature (acute *vs* stress) and fracture severity, conservative and surgical treatment methods, RRS, RTS, return rates to pre-injury level of sport, complications, outcome scores recorded, and relevant predictive factors.

Acute fractures and stress fractures were grouped separately. For the acute fracture studies, some papers recorded the fractures with no differentiation regarding fracture type or location: These studies were grouped as 'general cohort' studies. Other studies specifically described the management of intra-articular (physeal) fractures of the base of the great toe proximal phalanx: These were grouped as 'Intra-Articular (Physeal) Base of Proximal Phalanx Fractures'.

Outcome measures

The primary outcome data was RRS and RTS. The secondary outcome data included 'return to pre-injury level of sport' rates and relevant complications.

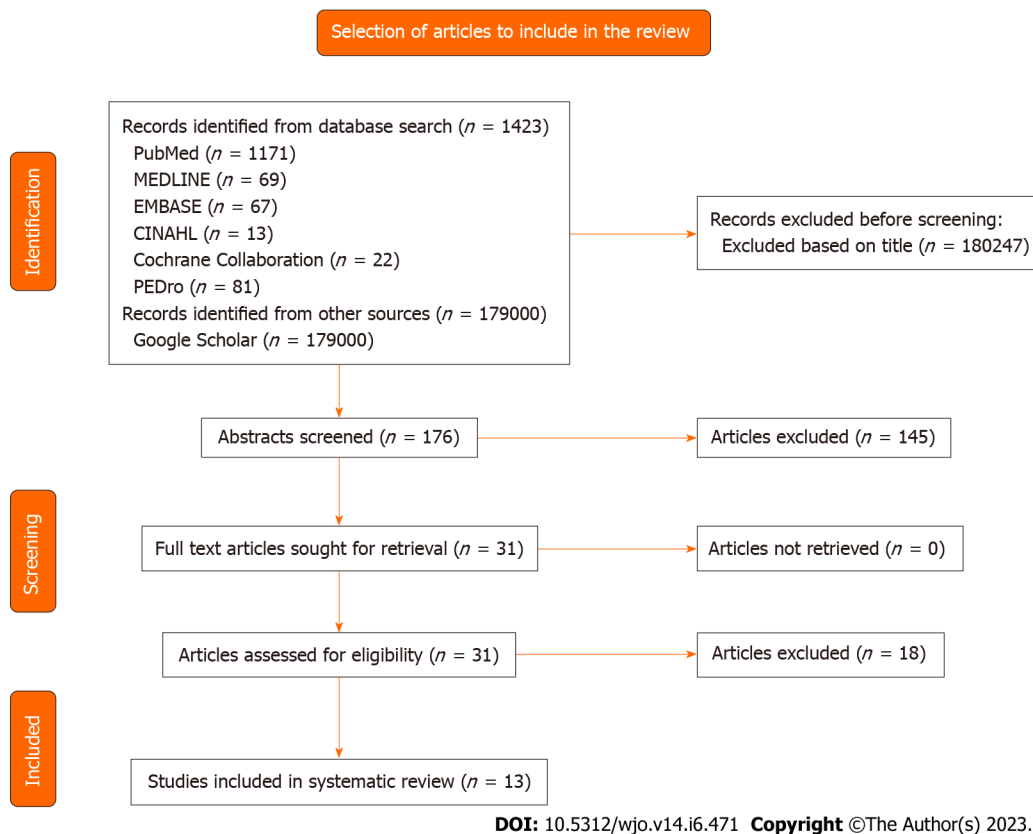
Study definitions

RRS was defined as the percentage of athletes who successfully returned to sport with the designated treatment modality. Where conversion to a further treatment was required, with RRS not possible from the initial treatment method, this was recorded as a non-return to sport for the method in question. For conservative treatment, RTS was defined as the time from the commencement of conservative treatment to return to sport. For surgical treatment, RTS was defined as the time from the commencement of the relevant surgical treatment to return to sport[13].

If surgical management was chosen as the first-line treatment, this was referred to as 'primary surgical management' (PSM). If surgical management was chosen following failed conservative management, this was referred to as 'secondary surgical management' (SSM). Return times to sport for 'secondary surgical management' were recorded from the relevant surgical procedure.

Table 1 Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Acute toe phalanx fractures	Toe sesamoid fractures
Stress toe phalanx fractures	Toe joint dislocation without fracture
Elite or recreational athletes	Toe joint fracture dislocation
Return rate to sporting activity reported	Toe ligament injuries
Time to return to sporting activity reported	No sporting outcome data reported
Two or more injuries reported	Concomitant upper or lower limb fractures
Peer-reviewed journals	Reviews, case reports, abstracts, or anecdotal articles
English language	Animal, cadaver, or <i>in vitro</i> studies

**Figure 1 Selection of articles to include in for inclusion in the review by in accordance with the PRISMA protocol[12].**

Quality assessment

Study quality was quantified by the modified Coleman Methodology Score (CMS), as described by Coleman *et al*[14]. Study quality was also assessed by the Methodological Index for Non-Randomized Studies (MINORS) Score. Two of the authors calculated the modified CMS and the MINORS Score for each study (X.X.X, X.X.X). Inter-observer reliability of the modified CMS and MINORS scoring processes were quantified using the intra-class correlation co-efficient statistic. For the modified CMS, this was 0.98 (95%CI: 0.96-1.00). For the MINORS scores, this was 0.92 (95%CI: 0.89-0.94).

Statistics

There was insufficient data to perform data synthesis or meta-analysis comparisons within the data. Thus, the available data was presented as a systematic review, without the use of analytic statistics. The intra-class correlation co-efficient statistic was used to assess the inter-observer reliability of the Modified Coleman Scores and the Methodological Index for Non-Randomized Studies Scores using IBM SPSS Statistics, Version 27.0 (Armonk, NY, United States).

RESULTS

Search

The details of the review process for the included articles are provided in [Figure 1](#). In total, 176 abstracts and 31 articles were reviewed.

Quality of the included studies

The mean CMS for all the studies was 49.6 (range 34-67)[8,15-26] (Tables 2 and 3). For the studies reporting on acute fractures, the mean CMS was 53.1 (range 39-67)[15-21] (Table 2). For the studies reporting on stress fractures, the mean CMS was 45.5 (range 34-55)[8,22-26] (Table 3).

The mean MINORS score for all the studies was 10.3 (range 8-18)[8,15-26] (Tables 2 and 3). For the studies reporting on acute fractures, the mean MINORS score was 12.1 (range 9-18)[15-21] (Table 2). For the studies reporting on stress fractures, the mean MINORS score was 8.2 (range 8-9)[8,22-26] (Table 3).

Patient demographics

13 relevant studies[8,15-26] were identified, (year of publication from 1986[22] to 2022[18]), which recorded return to sports data for patients who sustained toe phalanx fractures (Table 2). One of these studies was a retrospective cohort study[18], and 12 were case series[8,15-17,19-26].

There were 156 acute toe phalanx fractures and 26 stress fractures. Eight of the acute fractures were specifically described as intra-articular (physeal) (all great toe bases of the proximal phalanx). Of the acute fractures, 14 occurred in the great toe, 1 in the second toe, and 1 in the third toe, and the location was not specified for 140. Of the stress fractures, 22 occurred in the proximal phalanx of the great toe and 4 in the proximal phalanx of the second toe. Of the 26 stress fracture patients, 16 (of the 22 great toe proximal phalanx stress fracture patients) had associated 'hallux valgus' deformity, and 1 (of the 4-second toe proximal phalanx stress fracture patients) had associated 'claw toe' deformity (Table 3). Regarding the etiology of the deformities, only one case noted the deformity to have developed secondary to the stress fracture[26].

Of the 156 acute fractures, 129 (83%) occurred in male patients, 23 (15%) in female patients, and 4 (3%) failed to specify gender. None of the studies reported bilateral fractures. Follow-up data were available for 154 (99%) of the 156 acute fractures. The mean age at the time of injury ranged from 12.5 years[19,21] to 21.1 years[15], and the causative sports included soccer, gymnastics and judo (Table 2).

Of the 26 stress fractures, 10 (38%) occurred in male patients, and 16 (62%) in female patients. None of the studies reported bilateral fractures. Follow-up data were available for all 26 (100%) of the stress fractures. The mean age at the time of injury ranged from 13.7 years[23] to 29.0 years[24], and the causative sports included sprinting, soccer, long-distance running, rugby, Japanese Fencing/Kendo, triathlon, gymnastics, baseball and volleyball (Table 3). The recorded duration of symptoms before diagnosis ranged from 1 wk to 2 years[24,26].

Fracture nature and classification

Seven of the studies reported on acute toe phalanx fractures exclusively[15-21]. Three of these studies reported on acute intra-articular (physeal) fractures of the base of the great toe proximal phalanx specifically[19-21]. Six of the studies reported on stress-toe phalanx fractures exclusively[8,22-26].

Of the acute fracture studies, one 'general cohort' study used the AO classification to describe the fracture types[15]. All of the acute 'intra-articular (physeal) fracture' studies used the Salter-Harris Fracture Classification to describe the fracture types[19-21]. None of the stress fracture studies used classification systems to describe the fracture patterns[8,22-26].

Of the 156 acute fractures, 69 (44%) specified treatment modality. Of these, 63 (91%) were treated with 'primary conservative management', and 6 (9%) with 'primary surgical management'. One fracture was converted to 'secondary surgical management' after failed conservative treatment (Table 4). Of the 8 intra-articular (physeal) acute fractures, all (100%) specified treatment modalities: 6 (75%) underwent 'primary surgical management' and 2 (25%) underwent 'primary conservative management'. One intra-articular fracture was converted to 'secondary surgical management' after failed conservative treatment. This was following a re-fracture on return to sport (Table 4).

Of the 26 stress fractures, all (100%) specified treatment modality: 23 (88%) were treated with 'primary conservative management', and 3 (12%) were treated with 'primary surgical management' (Table 5). Six stress fractures were converted to 'secondary surgical management' after failed conservative treatment (Table 5). Of these six, two were associated with a delayed diagnosis (1 year and 2 years respectively), and 4 were associated with an underlying deformity [hallux valgus ($n = 3$), claw toe ($n = 1$)] (Table 5).

Choice of radiological imaging

Plain radiography was the diagnostic imaging modality used in acute fracture studies[15-21]. All the stress fracture studies used plain radiography as first-line diagnostic imaging[8,22-26]. In addition to this, one stress fracture study used magnetic resonance imaging/computed tomography Scan to aid diagnosis[26], and another study used Tc-99 Bone scanning as second-line imaging[22].

Table 2 Demographic data - acute fractures

Ref.	n	Study type	Mean age (yr)	Male:Female	Follow-up, %	Sport	Level of sport	Most common MOI	Location	Modified coleman score	MINORS score
General cohort											
Robertson <i>et al</i> [15], 2012	8	Case series	21.1	8:0	6 (75)	Soccer	General population	Tackle (50%)	Great toe (<i>n</i> = 6) 2 nd Toe (<i>n</i> = 1); 3 rd Toe (<i>n</i> = 1)	44	12
Larsson <i>et al</i> [16], 2016	18	Case series	N/A	18:0	18 (100)	Soccer	Elite/Professional	N/A	N/A	39	12
Chan <i>et al</i> [17], 2021	53	Case series	N/A	32:21	53 (100)	US Collegiate Sports	Collegiate	N/A	N/A	54	12
Diaz <i>et al</i> [18], 2022	69	RCS	N/A	69:0	69 (100)	Soccer	Elite	N/A	N/A	41	18
Intra-Articular (Physeal) base of proximal phalanx fractures											
Maffulli [19], 2001	2	Case series	12.5	2:0	2 (100)	Soccer (<i>n</i> = 1), Judo (<i>n</i> = 1)	Recreational	Tackle	Great toe proximal phalanx	65	9
Perugia <i>et al</i> [20], 2014	4	Case series	13-15	N/A	4 (100)	Gymnastics (<i>n</i> = 4)	Adolescent high level	Dismount	Great toe proximal phalanx	67	11
Bariteau <i>et al</i> [21], 2015	2	Case series	12.5	0:2	2 (100)	Gymnastics (<i>n</i> = 2)	Elite	Dismount	Great toe proximal phalanx	62	11

MOI: Mechanism of injury; RCS: A retrospective cohort study.

Table 3 Demographic data - stress fractures

Ref.	n	Study type	Mean age (yr)	Male:Female	Follow-up, %	Sport	Level of sport	Location	Associated deformity	Modified coleman score	MINORS score
Yokoe <i>et al</i> [22], 1986	3	Case series	16.3 (12-21)	1:2	3 (100)	Sprinting (<i>n</i> = 1), Rugby (<i>n</i> = 1), Kendo (<i>n</i> = 1)	Amateur	Great Toe Proximal Phalanx	Hallux valgus (<i>n</i> = 3)	34	8
Shiraishi <i>et al</i> [23], 1993	3	Case series	13.7 (12-17)	1:2	3 (100)	Volleyball (<i>n</i> = 1), Long Distance Running (<i>n</i> = 1), Soccer (<i>n</i> = 1)	Amateur	Great toe proximal phalanx		51	9
Yokoe <i>et al</i> [8], 2004	10	Case series	16.3 (12-21)	2:8	10 (100)	Sprinting (<i>n</i> = 6), Distance Running (<i>n</i> = 1), Basketball (<i>n</i> = 1), Rugby (<i>n</i> = 1), Kendo (<i>n</i> = 1)	N/A	Great toe proximal phalanx	Hallux valgus (<i>n</i> = 9)	35	8
Pitsis <i>et al</i> [24], 2004	2	Case series	29 (17-41)	0:2	2 (100)	Triathlon (<i>n</i> = 1), Gymnastics (<i>n</i> = 1)	Non-professional/Elite	Great toe proximal phalanx	Hallux valgus (<i>n</i> = 1)	46	8
Munemoto <i>et al</i> [25], 2009	4	Case series	14.5 (13-17)	2:2	4 (100)	Short track running (<i>n</i> = 3), Soccer (<i>n</i> = 1)	Amateur	Great toe proximal phalanx	Hallux valgus (<i>n</i> = 3)	55	8
Yamaguchi <i>et al</i> [26], 2017	4	Case series	14.8 (13-16)	4:0	4 (100)	Soccer (<i>n</i> = 3), Baseball (<i>n</i> = 1)	N/A	2 nd toe proximal phalanx	Claw toe (<i>n</i> = 1)	52	8

Management

Acute fractures: Conservative management: There were 63 acute fractures treated with 'primary conservative management' (Table 4).

Table 4 Outcome data - acute fractures

Ref.	n	Treatment (%)	Return to sport (%)	Return to the same level of sport (%)	Return time to sport	Secondary surgery - return rate (RR)/Return time (RT)	Persisting symptoms (%)	Complications
General cohort								
Robertson <i>et al</i> [15], 2012	6	PCM (100)	3 (50)	3 (50)	7.0 wk (mean)		3 (50)	Nil
Larsson <i>et al</i> [16], 2016	18	N/A	N/A	N/A	26 d (mean)		N/A	1 re-fracture
Chan <i>et al</i> [17], 2021	53	PCM (100)	53 (100)	N/A	8.5 d (median)		N/A	1 re-fracture
Diaz <i>et al</i> [18], 2022	69	N/A	N/A		30 d (median)		N/A	Nil
Intra-articular (Physeal) base of proximal phalanx fractures								
Maffulli[19], 2001	2	PCM (50) PSM (50)	2 (100)	2 (100)	By 6 mo		0 (0)	0 (0)
Perugia <i>et al</i> [20], 2014	4	PSM (100)	4 (100)	4 (100)	By 3 mo		0 (0)	0 (0)
Bariteau <i>et al</i> [21], 2015	2	PCM (50) PSM (50)	1 (50) (PSM)	1 (50) (PSM)	5 mo	1 - RR 100%/RT 14 wk	0 (0)	1 re-fracture (PCM)

PCM: Primary conservative management; PSM: Primary surgical management.

Table 5 Outcome data - stress fractures

Ref.	n	Treatment (%)	Return to sport (%)	Return to the same level of sport (%)	Time to return to sport (mean)	Secondary surgery - return rate (RR)/Return time (RT)	Factors associated with secondary surgery	Persisting symptom (%)	Complications (%)
Yokoe <i>et al</i> [22], 1986	3	PCM (67) PSM (33)	3 (100)	N/A	PCM - 3 mo; PSM - N/A			0 (0)	0 (0)
Shiraishi <i>et al</i> [23], 1993	3	PCM (100)	3 (100)	3 (100)	6 wk			1 (33)	1 non-union for a patient who did not stop training (33)
Yokoe <i>et al</i> [8], 2004	10	PCM (100)	6 (60)	6 (60)	N/A	4 (40) - RR 100%	Hallux valgus deformity (n = 3)	0 (0)	3 delayed unions with PCM (50)
Pitsis <i>et al</i> [24], 2004	2	PCM (100)	0 (0) ^a	0 (0) ^a	N/A	1 (50) - RR 100%	2-yr delay to diagnosis	0 (0)	1 non-union with PCM (50)
Munemoto <i>et al</i> [25], 2009	4	PCM (50) PSM (50)	4 (100)	4 (100)	PCM - 8.5 wk, PSM - 10 wk			0 (0)	1 mild deformity with PCM (50)
Yamaguchi <i>et al</i> [26], 2017	4	PCM (100)	3 (75)	3 (75)	5 wk	1 (25) - RR 100%/RT 4 mo	1-yr delay to diagnosis/Claw toe deformity	0 (0)	1 non-union and claw toe deformity with PCM (25)

^a1 no return due to fear of re-injury. PCM: Primary conservative management; PSM: Primary surgical management.

Only two of the 'general cohort' studies specified the type of management[15,17]. Both studies used conservative management for the fractures[15,17]. The type of conservative management was not described[15,17].

All the 'intra-articular (physeal) fracture' studies described the type of management selected[19-21]. Of the two which employed conservative management, the techniques included: heel weight-bearing in a forefoot offloading shoe for 6 wk, referral to physiotherapy at 6 wk, the commencement of training at 12 wk[19]; and 6 wk of non-weight bearing with immobilization, with a return to sport at 3 mo[21].

Surgical management: There were six acute 'intra-articular (physeal) fractures' treated with primary surgical management[19-21]. The described techniques included: open reduction with K-wire fixation (n

= 4), open reduction with screw fixation and cancellous bone graft ($n = 1$), and open reduction with no fixation ($n = 1$) [19-21]. One fracture was managed with secondary surgical management, using open reduction and screw fixation [21].

The post-operative regimes included heel weight-bearing in a forefoot offloading shoe for 6 wk, with the removal of K-wire and referral to physiotherapy at 6 wk, and commencement of training at 12 wk [19]; non-weight bearing with cast immobilization for 4 wk, with subsequent removal of K-wire at 4 wk and commencement of weight-bearing [20]; non-weight bearing in a moon boot orthotic for 6 wk, with progressive weight-bearing for the next 4 wk in the orthotic, then gradual weaning from the orthotic, with the commencement of impact activities at 10 wk post-op [21].

Stress fractures

Conservative management: There were 23 stress fractures treated with 'primary conservative management' (Table 5). All studies described the management techniques used [8,22-26].

The management techniques fell into three categories: cessation of sporting activities, with no formal immobilization or other restrictions, for 4 to 8 wk [22,23,25,26]; immobilization of the foot in a cast for 5 wk [25]; non-weight bearing on the affected side with crutches for 3 to 6 wk [24].

All regimes were then followed with a graduated return to sporting activities [8,22-26], which could be supplemented by shoes with shock-absorbing insoles [23], foot orthoses with medial arch support, and a metatarsal pad [26] or a 2nd to 5th metatarsal bar orthosis [24].

Surgical management: There were 3 stress fractures treated with 'primary surgical management' (Table 5). The reported techniques were: Open reduction with drilling, screw and K-wire fixation ($n = 1$), open reduction with drilling and screw fixation ($n = 1$), and osteotomy for hallux valgus correction ($n = 1$) [22,25]. There were 6 stress fractures treated with 'secondary surgical management' (Table 5). The reported techniques were: Open reduction internal fixation ($n = 3$), osteotomy for hallux valgus correction ($n = 1$), open reduction with scar tissue debridement, screw and K-wire fixation ($n = 1$), surgical excision of the non-union, open reduction with cancellous bone graft and screw fixation ($n = 1$) [8,24,26].

The post-operative regimes included: immediate weight-bearing, with the commencement of activities 8 wk post-operatively [25] (- 'primary surgical management'); non-weight bearing for 4 wk, with the removal of K-wire and commencement of heel weight-bearing at 4 wk, and commencement of mobilization exercises at 6 wk [26] (- 'secondary surgical management'); non-weight bearing for 6 wk, then partial weight bearing in a walker boot for 6 wk, then a graduated return to training [24] (- 'secondary surgical management').

Functional assessment

Two of the acute fracture studies used formal scores to record post-treatment outcomes [20,21]. These included: a 'Visual Analog Pain' scale, the 'American Orthopaedic Foot and Ankle Society (AOFAS) Hallux Metatarsal Phalangeal' scale, the 'Short Form-36 (SF-36) Physical Component Summary (PCS)' and the 'Short Form-36 (SF-36) Mental Component Summary (MCS)' [20,21].

None of the stress fracture studies used formal scores to record post-treatment outcomes [8,22-26].

Return rates to sports

Acute fractures: Conservative management: Four studies recorded RRS following conservative management of acute fractures [15,17,19,21]. The RRS ranged from 0 to 100% [15,17,19,21] (Table 4 and Figure 2A).

The return rates to pre-injury level sports for the conservatively-managed acute fractures ranged from 0% to 100% [15,19,21] (Table 4).

Surgical management: Three studies recorded RRS following PSM of acute fractures [19-21], and one study recorded RRS following SSM of acute fractures [21]. The recorded RRS were 100% for PSM [19-21], and 100% for SSM [21] (Table 4 and Figure 2A).

The return rates to pre-injury level sports for the surgically-managed acute fractures were all 100% [19-21] (Table 4).

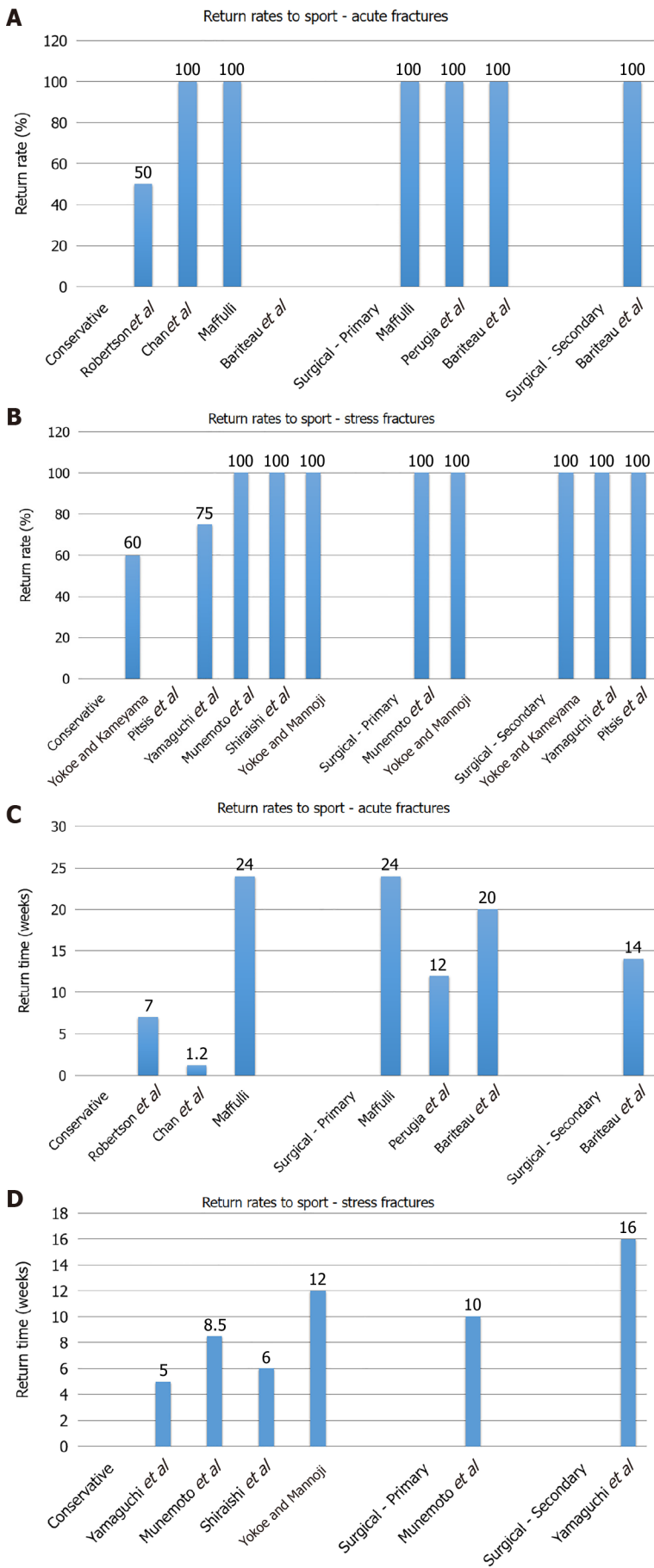
Stress fractures

Conservative management: Six studies recorded RRS following conservative management of stress fractures [8,22-26]. The RRS ranged from 0 to 100% [8,22-26] (Table 5 and Figure 2B).

The return rates to pre-injury level sports for the conservatively-managed stress fractures ranged from 0% to 100% [8,23-26] (Table 5).

Surgical management: Two studies recorded RRS following PSM of stress fractures [22,25], and three studies recorded RRS following SSM of stress fractures [8,24,26]. The recorded RRS was 100% for PSM [22,25], and 100% for SSM [8,24,26] (Table 5 and Figure 2B).

The return rates to pre-injury level sports for the surgically-managed stress fractures were 100% [25] (Table 5).



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Figure 2 Return rates to sport. A: Acute Fractures; B: Stress Fractures; C: Acute Fractures; D: Stress Fractures.

Return times to sports

Acute fractures: Conservative management: Three studies recorded RTS following conservative management of acute fractures[15,17,19]. The RTS ranged from 8.5 d to 6 mo[15,17,19] (Table 4 and Figure 2C).

Surgical management: Three studies recorded RTS following PSM of acute fractures[19-21], and one study recorded RTS following SSM of acute fractures[21]. The RTS ranged 3 to 6 mo for PSM[19-21], and was 14 wk for SSM[21] (Table 4 and Figure 2C).

Stress fractures

Conservative management: Four studies recorded RTS following conservative management of stress fractures[22,23,25,26]. The RTS ranged from 5 wk to 3 mo[22,23,25,26] (Table 5 and Figure 2D).

Surgical management: One study recorded RTS for PSM of stress fractures[25], and one study recorded RTS for SSM of stress fractures[26]. The recorded RTS for PSM was 10 wk[25], and for SSM was 4 mo[26] (Table 5 and Figure 2D).

Radiographic union

One of the acute fracture studies recorded radiographic union, with a 100% final union rate[21]. Five of the stress fracture studies recorded radiographic union[22-26]. Four of the studies reported a 100% final union rate[22,24-26], and one study reported a 67% final union rate[23].

Complications

Acute fractures: Three of the acute fracture studies recorded complications, which were re-fracture (Table 4).

Stress fractures: Five of the stress fracture studies recorded complications, which were delayed union with primary conservative management, non-union with primary conservative management, and residual deformity (Table 5).

Predictive factors

While the majority of sport-related toe phalanx fractures were treated with 'primary conservative management', acute intra-articular (physeal) fractures had high rates of 'primary surgical management', especially when displaced[19-21].

Sixteen of the twenty-two 'great toe' phalanx stress fractures had an associated hallux valgus deformity[8,22-25]. One of the four 'second toe' proximal phalanx stress fractures had an associated claw toe deformity[26].

Three of the four 'second toe' proximal phalanx stress fractures had a history of stress fractures at other locations, with two of the patients having a history of stress fractures at multiple locations[26].

Of the six stress fractures that required 'secondary surgical management', one-third of cases ($n = 2$) had a significant delay to diagnosis (1 year and 2 years respectively)[24,26], and two-thirds of cases ($n = 4$) had an associated deformity [hallux valgus ($n = 3$)/claw toe ($n = 1$)] [8,26].

DISCUSSION

This systematic review found that the majority of sport-related toe phalanx fractures are treated with 'primary conservative management', with satisfactory results for RRS and RTS. For acute fractures, intra-articular (physeal) fractures, especially when displaced, had high rates of 'primary surgical management'. Such fractures had uniform good RRS, though had prolonged RTS, due to the required post-operative restrictions. For stress fractures, those with significantly delayed diagnosis or with significant underlying causative deformity were at risk of requiring surgical intervention. Again, such fractures, when treated surgically, demonstrated good overall RRS, though with prolonged RTS due to the required post-operative restrictions. However, given the limited, heterogenous data available, it was difficult to draw firm conclusions from this review.

The quality of the included studies in this review was lower than that of similar studies[13,27-31], with a mean CMS of 49.6. This was particularly true for the stress fracture studies, with a mean CMS of 45.5.

From the review data, it is difficult to conclude the optimal management of acute sport-related toe phalanx fractures[15-21]. The results appear to support 'primary conservative management' of extra-articular, non or minimally displaced fractures, with overall acceptable RRS and RTS[15-21]. 'Primary surgical management' should be reserved for extra-articular fractures which are significantly displaced, rotated, or open[9]. However, there is no evidence to guide such recommendations[15-21]. Surgery is also indicated for displaced, intra-articular (physeal) fractures[9]. There is moderate evidence to support this recommendation, with the need to restore joint surface congruency, especially in the adolescent athlete[19-21]. However, if these fractures are non or minimally displaced, they can be treated with

'primary conservative management' [19-21]. The review shows reasonable RRS and RTS for both primary conservative and surgical management of these fractures, however, surgical management has longer RTS, due to post-operative restrictions [15-21]. Refractures following 'primary conservative management' necessitating 'secondary surgical management' is associated with a notably prolonged RTS [21].

Regarding the optimal surgical technique for intra-articular fractures, several methods have been described, though the evidence is inadequate to conclude which is best [19-21]. Compared to K-wire fixation, screw fixation avoids the risk of pin-track infection and may allow for a quicker return to non-contact training activities (no risk of catching and dislodging the K-wire), but such theories are yet to be proved [19-21,32].

With a variety of rehabilitation techniques described, it is difficult to confirm which is the optimal method [15-21]. It would appear that heel weight-bearing in a forefoot offloading shoe can be recommended, both with 'primary surgical management' and 'primary conservative management' [15-21]. This avoids the need for complete non-weight bearing, allowing more muscle mass preservation [15-21]. Following such restrictions, for between 4 to 6 wk, a graduated return to activities can be commenced [15-21].

Reviewing the common sporting mechanisms of injury (tackle and dismount), it would appear there may be a future role for improved protective footwear, to reduce the incidence of traumatic toe phalanx fractures [15,19-21]. Modification of technique, especially in gymnastics, may also allow for future reduction in the incidence of such fractures. However, further research on this topic is required to confirm such theories [32].

Similar to acute fractures, with the limited, heterogeneous data available, it remains difficult to conclude the optimal management for sport-related, toe phalanx stress fractures [8,22-26]. Anatomically, these should be 'low-risk' stress fractures, so conservative management should form the first line of treatment [7,33,34]. This has been shown to provide acceptable RRS and RTS [8,22-26]. However, due to variations in the anatomy of the foot, some of these fractures can be associated with an underlying deformity (*e.g.* hallux valgus), which can create a biomechanically 'tension-sided', 'high risk' type [8,22,24-26,33,34]. For instance, with hallux valgus, it has been advocated that the medial-sided structures (medial collateral ligament and abductor hallucis) provide an adverse traction force, that potentiates a shear force during exercise, which propagates the stress fracture [8]. In such cases, 'primary surgical management' may be necessary to correct the fracture or the deformity [8,22].

Assessing the data available, it would appear that conservative management is acceptable first-line management for all toe phalanx stress fractures [8,22-26]. 'Primary surgical management', however, can be considered for cases with significant underlying deformity, especially when they show delayed healing with initial conservative management. It can also be considered for cases with significant delays to diagnosis (> 1 year), with evidence of established non-union at presentation [8,22-26]. Such 'primary surgical management' could prevent delayed recovery, due to unnecessary prolonged initial conservative management [8,22-26].

Regarding the optimal surgical technique, there is insufficient data to conclude this [8,22,24-26]. One may consider that the surgeon must correct any underlying significant deformity, at the time of surgical treatment [8,22,24-26]. However, the available data shows that this is not always necessary, to facilitate a successful, timely return to sport [8]. Deformity correction at the time of surgery may reduce the chance of recurrence of the stress fracture on return to sport [8]. However, the more complex surgical technique required may incur a higher risk of complications, prolonged post-operative immobilization and a prolonged return to sport [8]. As such, the optimal strategy for this problem remains to be defined [8]. With established non-unions, the adjunct of biological stimulus (*e.g.* bone grafting) should be considered [24].

Regarding the optimal rehabilitation with 'primary conservative management', it would appear that initial cessation of sporting activities for around 4 to 8 wk is an appropriate first-line plan [8,22-26]. If successful, this should be followed by a graduated return to sport [8,22-26]. For surgical management, heel weight-bearing in a forefoot offloading shoe for 6 wk, followed by a graduated return to sports is similarly an appropriate regime [8,22,24-26].

While modifiable predisposing factors have been extensively reviewed for stress fractures as a whole, with important findings such as sub-optimal physiological condition (*e.g.* female athlete triad), excessive repetitive training, and abnormal physiological load, there is limited information regarding this for toe phalanx stress fractures [7,8,22,24-26,34]. As discussed previously, the associated deformity is a significant predisposing factor for these fractures, and this should be actively sought and monitored appropriately [8,22,24-26]. Similarly, tight footwear, which exacerbates such deformities, should be avoided [8]. Further research is required to determine optimal methods by which to prevent such injuries in the future [8,22-26].

There are several limitations to this study. These are predominantly based on the limited, heterogeneous data on the topic [8,15-26].

The lack of available literature on toe phalanx fractures has been previously highlighted [5]. This is likely a consequence of most toe phalanx fractures being managed directly from emergency departments, with limited input from orthopedic services [35]. Future collection of data on this subject should be encouraged, through the relevant services, to increase the information on this topic.

Despite this, of the studies retrieved, several of those with high cohort numbers failed to stratify the fractures by toe or phalanx injured, or by treatment type received[16-18]. Such limitations prevent accurate analysis of these datasets and subsequently preclude data synthesis and meta-analysis of the available studies.

As such, it was not possible to draw firm conclusions on the optimal treatment and rehabilitation of these injuries, nor the expected RRS and RTS[8,15-26]. Further more detailed, research on this topic is required, stratifying outcome data by fracture location and a treatment selected.

CONCLUSION

There is limited information on return to sport following toe phalanx fractures. The majority of acute fractures are treated with 'primary conservative management', with overall satisfactory RRS and RTS. 'Primary surgical management' is reserved for significantly displaced fractures or displaced intra-articular fractures and has been found to achieve good RRS and RTS. Conservative management forms the first line of treatment for sport-related, toe phalanx stress fractures. When successful, this can result in appropriate RTS. Surgical management is indicated with associated deformity and delayed union, or with significantly delayed presentation and established non-union. In both instances, good RRS and RTS can be achieved. Further research is required to better define the optimal treatment and rehabilitation of sport-related, toe phalanx fractures.

ARTICLE HIGHLIGHTS

Research background

There is very little evidence available to guide the management of toe phalanx fractures in the athletic population.

Research motivation

This is the first systematic review to assess return to sport following toe phalanx fractures. It provides a comprehensive overview of the available literature, assessing both acute fractures and stress fractures.

Research objectives

To systemically review all studies recording return to sport following toe phalanx fractures (including acute fractures and stress fractures), and to collate information on return rates to sport (RRS) and return times (RTS) to the sport.

Research methods

A systematic search of all relevant scientific databases was performed followed by manual screening of articles according to the eligibility criteria.

Research results

Most toe phalanx fractures were treated conservatively. Surgical management was reserved for displaced or intra-articular acute fractures, as well as symptomatic stress fracture non-unions, and stress fractures with significant underlying deformity. RRS for both acute fractures and stress fractures managed conservatively ranged from 0% to 100%. RRS for both acute fractures and stress fractures managed surgically was 100%. RTS after conservative management ranged from 8.5 d to 6 mo for acute fractures, and 5 wk to 3 mo for stress fractures. RTS after surgical management ranged from 3 to 6 mo for acute fractures, and 10 wk to 4 mo for stress fractures.

Research conclusions

The majority of sport-related toe phalanx fractures (acute and stress) are managed conservatively with overall satisfactory RRS and RTS.

Research perspectives

Currently, the available literature regarding return to sport after toe phalanx fractures is limited, with most studies being low-volume case series. Further research is required to better define the optimal treatment and rehabilitation of sport related toe phalanx fractures.

FOOTNOTES

Author contributions: Robertson GAJ conceived the methodology for the manuscript, performed the literature search and analysis for the study and wrote the manuscript; Sinha A performed the literature search and analysis for the study, and reviewed and edited the manuscript; Hodkinson T advised on the study, and reviewed and edited the manuscript; Koç T advised on the study, and reviewed and edited the manuscript.

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