Return to Play After Low-Energy Lisfranc Injuries in High-Demand Individuals

A Systematic Review and Meta-Analysis of Athletes and Active Military Personnel

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Background: Although studies are available on high-energy Lisfranc injuries, the evidence for increasingly reported low-energy Lisfranc injuries in active individuals, including athletes and military personnel, remains scarce and mostly retrospective.

Purpose: This meta-analysis aimed to review the return-to-play (RTP) and return-to-duty (RTD) rates with regard to the anatomic type and the management of low-energy Lisfranc injuries in a high-demand, active population.

Study Design: Systematic review; Level of evidence, 4.

Methods: Following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, we searched the MEDLINE (PubMed), EMBASE, Google Scholar, and Cochrane databases through June 2019 to identify studies on low-energy Lisfranc injuries in athletes and military personnel. The primary outcomes were RTP/RTD rates and time to RTP/RTD, and the secondary outcomes were time missed from practice, games missed, time to full recovery, midfoot arthritis rate, and reoperation rate.

Results: Overall, 15 studies (N = 441 patients) were included in the meta-analysis. Of these, 6 studies were of level 3 evidence, 8 studies were level 4 (case series), and 1 study was level 5. Of the 441 subjects, 380 (86.17%) were able to RTP and RTD. There was no statistically significant difference in RTP rates for operative versus nonoperative treatment, ORIF versus PA, or bony versus ligamentous injuries. The mean time missed from practice/duty for operative versus nonoperative treatment was 58.02 days (95% CI, 13.6-102.4 days; $I^2 = 98.03\%$) and 116.4 days (95% CI, 62.4-170.4 days; $I^2 = 99.45\%$), respectively. The mean time missed from practice/duty for bony versus ligamentous injury was 98.9 days (95% CI, 6.1-191.7 days; $I^2 = 99.82\%$) and 76.5 days (95% CI, 37.9-115.02 days; $I^2 = 99.83\%$), respectively, with no statistically significant differences (standardized mean difference = 3.62 days [95% CI: –5.7 to 13 days]; $I^2 = 83.17\%$).

Conclusion: This review indicated an overall excellent RTP/RTD rate for low-energy Lisfranc injuries in high-demand individuals. The time missed from athletic participation/military duty was not affected by injury treatment type, the bony versus ligamentous nature of the injury, or athlete player position. However, the low evidence levels and significant heterogeneity of the included studies precludes making conclusions regarding length of time missed or optimal management. Higher-quality studies on low-energy Lisfranc injuries are needed.

Keywords: return to play; Lisfranc; athletes; military; midfoot sprain; TMT dislocation; ORIF; primary arthrodesis

Lisfranc injuries, or tarsometatarsal (TMT), intercuneiform, and naviculocuneiform joint complex injuries, have been traditionally associated with high-energy trauma. However, a more subtle, low-energy, mostly ligamentous injury is increasingly reported and appreciated in athletes, especially in collision athletes such as football, rugby, and soccer players in whom the plantarflexed foot is axially loaded and forcefully abducted or rotated.[8] It affects 20% of collegiate American football players each year[19] in comparison with 0.2% of fractures in the general population.[11] Despite placing high demands on the TMT joints in the former group, low-energy Lisfranc injuries remain underdiagnosed and inadequately treated. In National Football League (NFL) players, up to 41% had >2-mm residual displacement that affected their athletic performance dramatically and for many seasons.[11,18]

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While there is a relatively large body of studies discussing the high-energy Lisfranc injuries,[10,14] most of the relatively scarce evidence available on low-energy injuries in athletes consists of case series and retrospective cohort studies, often without a comparative control group.[4] The current systematic review and meta-analysis focused on studies of low-energy Lisfranc injuries in athletes and military personnel. Our aim was to report the rates of return to play (RTP) and return to duty (RTD) and times in this population with regard to injury type (bony or ligamentous) and injury management (nonoperative, open reduction and internal fixation [ORIF], or the increasingly debated primary arthrodesis [PA]). To the best of our knowledge, this the first meta-analysis to exclusively report on the RTP rate and time of low-energy Lisfranc injuries.

METHODS

This review was performed following the PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses).[13]

Literature Search

Relevant comparative studies in the English-language literature were identified from database inceptions to June 2019. An electronic search of the MEDLINE (PubMed), Embase, Google Scholar, and Cochrane databases was conducted using the following keywords with their synonyms: ("Lisfranc" AND "athlete" AND "midfoot sprain"). In addition, the reference lists from previous review articles were searched manually to check for eligible studies.

Two investigators (A.A., K.M.) independently reviewed all titles and abstracts and the full text of articles that were potentially eligible based on the abstract review. The eligible studies were selected according to the inclusion and exclusion criteria. Any disagreement was resolved by the senior author (D.F.).

Study Eligibility Criteria

Our primary outcomes were RTP and RTD rates and times. The secondary outcomes were games missed, time missed from practice, midfoot arthritis, and reoperation. For military personnel, the RTP rate was defined as return to active unrestricted military duty (ie, RTD). The research team systematically reviewed published studies according to the following inclusion criteria: studies on Lisfranc or midfoot sprains in athletic high-demand individuals and the outcomes of interest. Studies were excluded if they did not report any of the outcomes of interest or the full text was not available in English. Studies reporting on high-energy Lisfranc injuries or on a population other than athletes and military personnel were excluded as well.

A total of 61 studies were initially identified after removal of duplicates. Of these, 15 were included for further review. Figure 1 shows a flowchart of the study selection process.

Risk-of-Bias Assessment

The Newcastle-Ottawa Scale[20] was used for the quality assessment conducted by 2 independent investigators (Table 1). The scale assesses the quality of the study in 3 domains: selection (4 points), comparability (2 points), and outcome/exposure (3 points). Review Manager (RevMan Version 5.4; Cochrane Collaboration) was used for the risk-of-bias assessment (Figure 2). The level of evidence was assigned according to the Cochrane Book Review Group.[9]

Data Collection

The data retrieved included the following: study characteristics (title, authors, year, level of evidence), patient characteristics (sample size, level of athletic involvement, athlete vs military, field position, and bony vs ligamentous injury), management characteristics, and outcomes measures.

Data Analysis

The data analysis was performed via comprehensive meta-analysis software using a random effect model and SPSS (Version 22; IBM Corp). For continuous variables, the standardized mean difference and 95% CI were calculated. Values of $P < .05$ were considered statistically significant. Heterogeneity was assessed using the Higgins I^2 method. Ranges for interpretation of I^2, according to the *Cochrane Handbook for Systematic Reviews of Interventions*, were 0% to 40% (poor), 30% to 60% (fair), 50% to 90% (moderate), and 75% to 100% (considerable).[9]

RESULTS

The 15 studies that were eligible for the meta-analysis included 441 patients. Six studies were level 3 evidence

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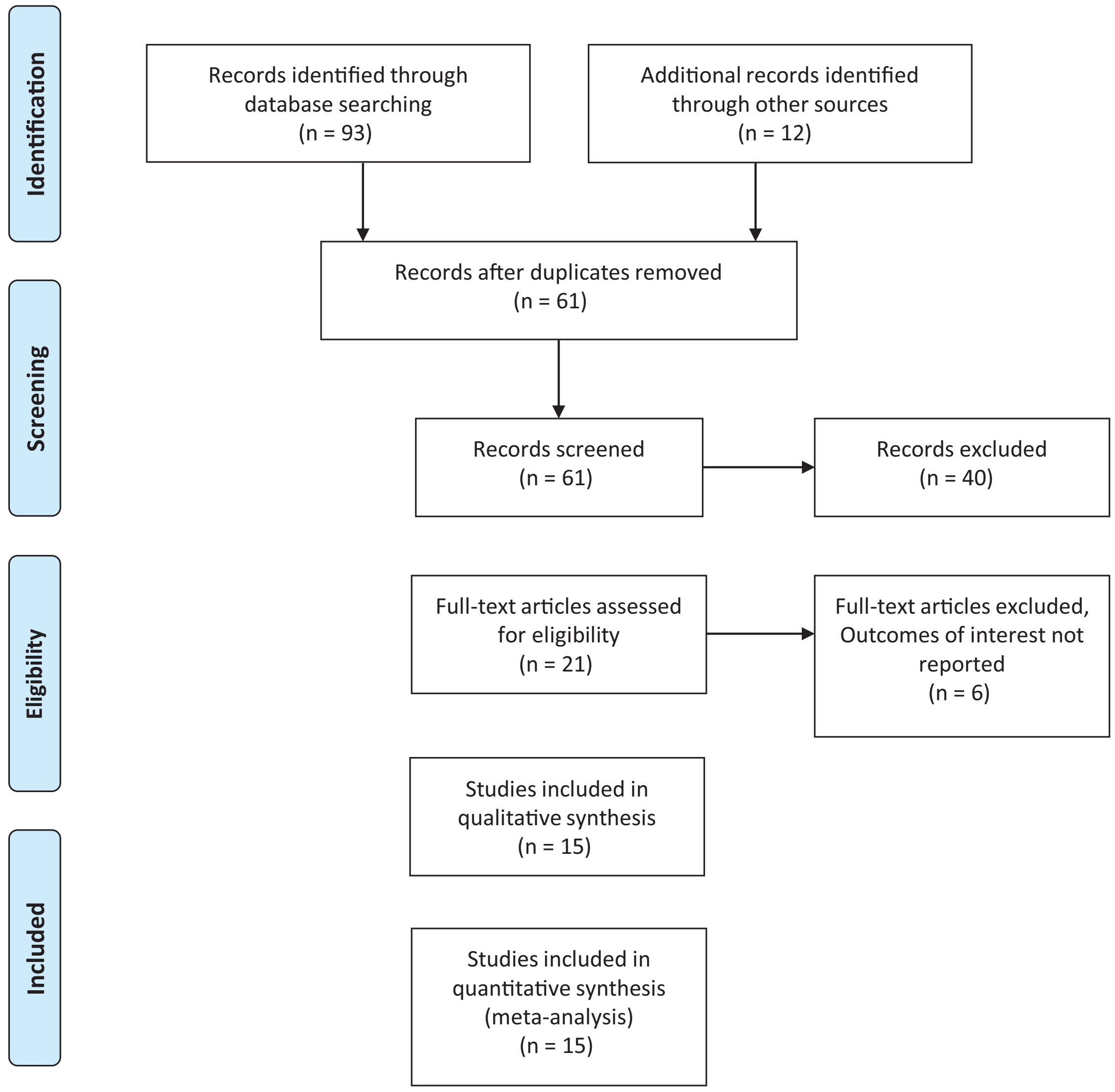

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart.

(4 cohort studies and 2 case-control studies); 8 studies were level 4 evidence (case series); and 1 study had level 5 evidence (technical note and series). Table 2 highlights the characteristics of the included studies.

Heterogeneity Analysis

Table 3 shows the I^2 values for the pooled variables. There was poor heterogeneity (0%-40%) in RTP/RTD within the following groups: nonoperative, operative versus nonoperative, ORIF, PA, ORIF versus PA, bony, ligamentous, and bony versus ligamentous. There was poor heterogeneity in degenerative joint disease (DJD) within non operative group. There was considerable heterogeneity (75%-100%) in time missed from practice/duty, reoperation. There was considerable heterogeneity in DJD within operative group and reoperation within ORIF versus PA group.

RTP/RTD Rate

Of 441 patients, 380 (86.17%) were able to RTP and RTD. The RTP in athletes was 198 of 217 (91.24%), while the RTD in military personnel was 182 of 224 (81.25%), with no statistically significant difference (P = .143). Figure 3 shows the RTP/RTD rates according to injury type and injury management.

RTP/RTD Rate and Injury Type. The pooled RTP rate for bony injury was 82.1% (95% CI, 70.9%-93.4%; $I^2 = 0\%$) in 31 of 39 players, as reported in 5 studies (Figure 3).[5-7,18,19] The pooled RTP rate in ligamentous injury was 95.8% (95% CI, 92.6%-99.1%; $I^2 = 0\%$) in 124 of 132 injuries, as noted in 10 studies (Figure 3).[2,5-7,12,15-19] No difference was found in the RTP rate in a direct comparison between bony and ligamentous injuries (odds ratio [OR], 1.90 [95% CI, 0.64-5.64]; $I^2 = 37\%$), as cited in 5 comparative studies.[5-7,18,19]

TABLE 1
Quality Assessment of Included Studies According to the Newcastle-Ottawa Scale[a]

First Author (Year)	Study Design	Selection	Comparability	Exposure/Outcome
Singh[18] (2018)	Retrospective case series	*	—	*
McHale[11] (2016)	Case-control	****	**	***
Cochran[4] (2017)	Comparative cohort	****	**	***
Hawkinson[8] (2017)	Retrospective comparative series	****	*	***
Balazs[1] (2017)	Retrospective comparative series	***	*	***
Deol[7] (2016)	Case series	*	—	*
Osbahr[16] (2014)	Retrospective cohort	****	*	***
Wagner[19] (2013)	Retrospective case series	*	—	*
Bleazey[2] (2013)	Technical note and case series	*	—	*
Cottom[5] (2008)	Case series	*	—	*
Chilvers[3] (2007)	Case series	*	—	*
Nunley[15] (2002)	Retrospective cohort	****	**	***
Meyer[12] (1994)	Retrospective case series	*	—	*
Shapiro[17] (1994)	Case series	*	—	*
Curtis[6] (1993)	Case series	*	—	*

[a]Each asterisk indicates 1 point on the Newcastle-Ottawa Scale. A dash indicates no points scored.

RTP/RTD Rate and Injury Management. The pooled RTP rate for nonoperative treatment was 94.5% (95% CI, 88.5%-100%; I^2 = 11.88%) in 59 of 64 injuries as reported in 5 studies,[6,12,15,17,18] while the pooled RTP/RTD rate for operative treatment was 90.1% (95% CI, 83.7%-96.6%; I^2 = 63.04%) in 211 of 250 injuries as cited in 11 studies.[2,4-8,15-19] There was no difference in RTP/RTD in a direct comparison between operative and nonoperative treatment (OR, 0.714 [95% CI, 0.17-2.88]; I^2 = 0%) among 4 studies.[6,15,17,18] There was also no difference in RTP/RTD in a direct comparison between ORIF and PA (OR, 0.78 [95% CI, 0.31-1.96]; I^2 = 0%) in 4 studies[1,4,7,8] (Figure 3).

Time Missed From Practice/Duty

Figure 4 shows the time missed from practice/duty according to injury type and management in athletes and military personnel. The pooled mean time missed for nonoperative versus operative treatment was 58.02 days (95% CI, 13.6-102.4 days; I^2 = 98.03%)[12,15-17] versus 116.43 days (95% CI, 62.4-170.4 days; I^2 = 99.45%).[4,7,15,19] The pooled mean time missed for bony versus ligamentous injury was 98.89 days (95% CI, 6.1-191.7 days; I^2 = 99.82%)[7,16,19] versus 76.47 days (95% CI, 37.9-115.0 days; I^2 = 99.83%).[7,12,15-17,19] There was no statistically significant difference in time missed between bony and ligamentous injuries (standardized mean difference, 3.62 days [95% CI, –5.7 to 13 days]; I^2 = 83.17%).[7,16,19]

Games Missed

The number of games missed after operative treatment was 4.3 ± 5.7 (mean ± SD) as reported in 1 study[11] on NFL football players versus 1.6 (95% CI, 0.6-3.8) after nonoperative treatment in 2 studies.[11,12] The number of missed games was 5.3 ± 2.6 games in offensive NFL players versus 4.2 ± 3.6 games in defensive players.[11]

Midfoot Arthritis Rate

Figure 5 shows the percentage of midfoot arthritis with regard to treatment type. The rate of midfoot arthritis was 18.5% (95% CI, 6.2%-30.8%; I^2 = 79.19%) after operative treatment[1,4,6,8,11] versus 11.3% (95% CI, 0.5%-23%; I^2 = 6.81%) after nonoperative treatment;[6,11] there was no statistically significant difference in midfoot arthritis between treatment types (OR, 2.634 [95% CI, 0.69-10]; I^2 = 0%).[6,11] The rate of midfoot arthritis in ORIF in the military subgroup was 20.5% (95% CI, 1.5%-51.5%).

Reoperation Rate

The reoperation rate was 70.7% (95% CI, 62.2%-79.2%) in ORIF[1,8] versus 32.2% (95% CI, 22%-86.4%) in PA.[1,8] However, the difference did not reach statistical significance (OR, 5.69 [95% CI, 0.27-117.9]; I^2 = 75.66%).

DISCUSSION

Lisfranc injuries have been reported to have a detrimental effect on athletic performance. In an analysis of the NFL Scouting Combine (an event where 3% of >100,000 collegiate football players are evaluated by all NFL teams before the NFL draft), players with a history of Lisfranc injury had the worst performance across all NFL variables, including draft position, games played, games missed, and career length over 2 years, ultimately resulting in a lower chance of being drafted.[11]

The RTP rate was excellent in all studies (83%-100%). The RTP rate was marginally higher in those who received nonoperative treatment than in those who underwent surgical stabilization; however, that

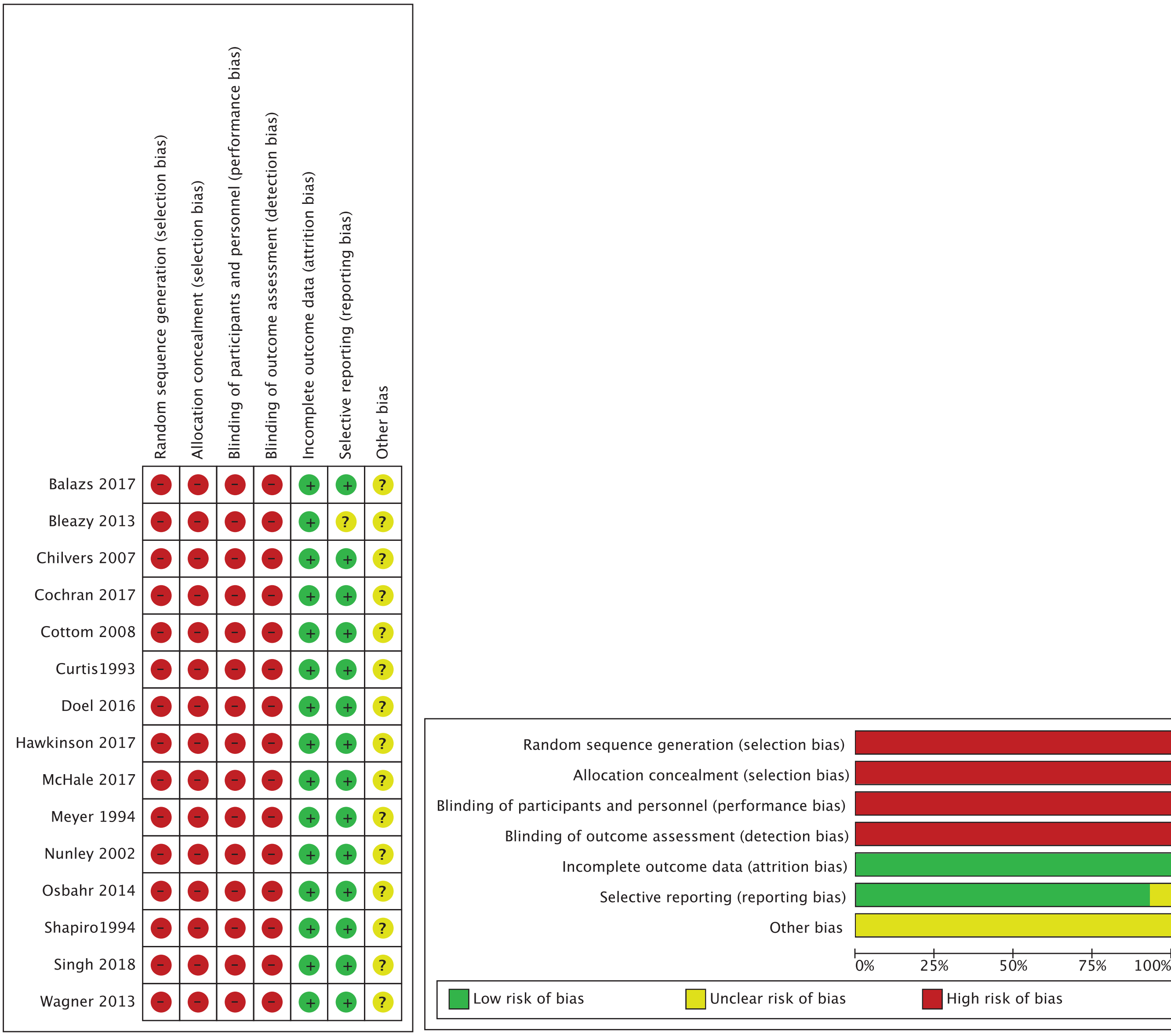

Figure 2. Risk-of-bias assessment of the included studies.

difference was not statistically significant. Our analysis included 4 comparative studies, none of which showed a statistically significant difference in RTP regardless of the intervention.[6,15,17,18] Within the operative treatment group, ORIF and PA had similar outcomes in terms of RTP rate. Four comparative studies[1,4,7,8] demonstrated that PA is a valid option, especially in military personnel with lower rates of reoperation and midfoot DJD. In the military subpopulation, studies[1,4,8] showed satisfactory RTD rates that were comparable to those of athletes. Both procedures resulted in similar pain scores at final follow-up and comparable scores of all components of the Foot and Ankle Ability Measure. PA was superior in terms of time missed and running speed at fitness testing. The PA group returned 2 months sooner and was 29 seconds faster per mile as compared with the ORIF group.[4] This comparison in athletes was not feasible owing to the sample size. The power analysis of 1 study[8] showed that 400 patients were required to allow for the detection of any statistically significant difference in RTD. The sample size available for this comparison in the current study was 144, which was not sufficient to detect differences. Finally, ligamentous and bony Lisfranc injuries had similar RTP rates regardless of the treatment, whether ORIF, PA, or nonoperative. It is important to notice that the differences in outcomes based on the management of an injury might be a surrogate to the severity of the injury. In other words, grades 1 and 2 injuries treated nonoperatively resulted in significantly shorter recovery as compared with grade 3 injuries that were treated surgically.[16] The heterogeneity of the studies with regard to the anatomic classification was

TABLE 2
Characteristics of the Included Studies (N = 441 Patients)[a]

First Author (Year)	LOE	Sport	Management	Injury	Patients, n	RTP/RTD, (%)
Singh[18] (2018)	4	Football, rugby	ORIF, nonoperative	Bony, ligamentous	47	41 (87)
McHale[11] (2016)	3	Football	Operative, nonoperative	Not reported	28	26 (92.9)
Cochran[4] (2017)	3	Military	ORIF, PA	Bony, ligamentous	32	28 (87.5)
Hawkinson[8] (2017)	3	Military	ORIF, PA	Not reported	171	137 (80.1)
Balazs[1] (2017)	3	Military	ORIF, PA	Not reported	21	17 (81)
Deol[7] (2016)	4	Soccer, rugby	ORIF, PA	Bony, ligamentous	17	16 (94.1)
Osbahr[16] (2014)	3	Football	ORIF, nonoperative	Ligamentous only	15	14 (93.3)
Wagner[19] (2013)	4	Soccer, gymnastics, basketball, volleyball	ORIF	Bony, ligamentous	22	22 (100)
Bleazey[2] (2013)	5	Football, baseball, boxing	ORIF	Ligamentous only	13	13 (100)
Cottom[5] (2008)	4	Weight training, basketball	ORIF	Bony, ligamentous	3	3 (100)
Chilvers[3] (2007)	4	Gymnastics	ORIF	Bony, ligamentous	5	1 (20)
Nunley[15] (2002)	3	Football, soccer, baseball	ORIF, nonoperative	Ligamentous only	15	15 (100)
Meyer[12] (1994)	4	Football	Nonoperative	Ligamentous only	24	24 (100)
Shapiro[17] (1994)	4	Gymnastics, football, pole vault, tennis	ORIF, nonoperative	Ligamentous only	9	9 (100)
Curtis[6] (1993)	4	Basketball, running, sailboarding	ORIF, nonoperative	Bony, ligamentous	19	16 (84.2)

[a]LOE, level of evidence; ORIF, open reduction and internal fixation; PA, primary arthrodesis; RTP/RTD return to play/duty.

TABLE 3
Heterogeneity (I^2 Values) of Reported Pooled Variables in the Current Meta-Analysis[a]

	Group						
	Operative	Nonoperative	Operative vs Nonoperative	ORIF vs PA	Bony	Ligamentous	Bony vs Ligamentous
RTP/RTD	63.05	11.88	0	0	0	0	37
Time missed	99.45	98.03	—	—	99.82	99.83	83.17
Reoperation	—	—	—	75.66	—	—	—
Midfoot DJD	79.19	6.81	0	—	—	—	—

[a]All values are %. Dashes indicate not analyzed. DJD, degenerative joint disease; ORIF, open reduction and internal fixation; PA, primary arthrodesis; RTD, return to duty; RTP, return to play.

considerable, and further classification according to severity was not feasible.

Despite the excellent RTP rate, postinjury analysis by Singh et al[18] showed that NFL players experience 20% deterioration of performance in their first season. They continue to have a poorer performance for 2 to 3 seasons before returning to their preinjury level. This concurs with findings of a study[11] on the NFL Scouting Combine that demonstrated a decline in performance for all performance variables. The authors suggested that this may indicate that players are back on the field without adequate recovery.

A few studies commented on the correlation of player position on the field and Lisfranc injuries. According to McHale et al,[11] football players in offensive positions (specifically quarterbacks) had statistically significant higher odds of sustaining a Lisfranc injury. Moreover, offensive football players showed a more substantial decline in performance and required a longer time to regain their preinjury level in comparison with players in defensive positions. Interestingly, this was not the case in a study of professional rugby players, where no difference was found between offense and defense positions.[18] In a 1994 case series, Meyer et al[12] reported in detail on 24 midfoot sprains in collegiate football players treated nonoperatively. They grouped their players by activities performed into skill position (9 players), linemen (8 players), and linebackers (7 players). The mean time missed from practice for each group was 6.3, 15.0, and 22.1 days, respectively, with offensive linemen incurring 29.2% of the injuries. Although it is unclear how each group performed after the injury in comparison with the others, player position might affect the outcomes.

Another sport associated with Lisfranc injury is soccer. Deol et al[7] reported on Lisfranc injuries in elite soccer and rugby players in the English Premier/Championship leagues. All 11 soccer and 6 rugby players returned to competitive participation, except for 1 older rugby player with a ligamentous injury who retired because of constant pain over the midfoot. Interestingly, rugby players had a statistically significant earlier RTP (4 weeks) than did soccer players. Singh et al[18] reported a similar finding, where rugby players returned 2.3 weeks earlier than did their football counterparts. It is worth mentioning that the comparison among sports is clearly limited given the different

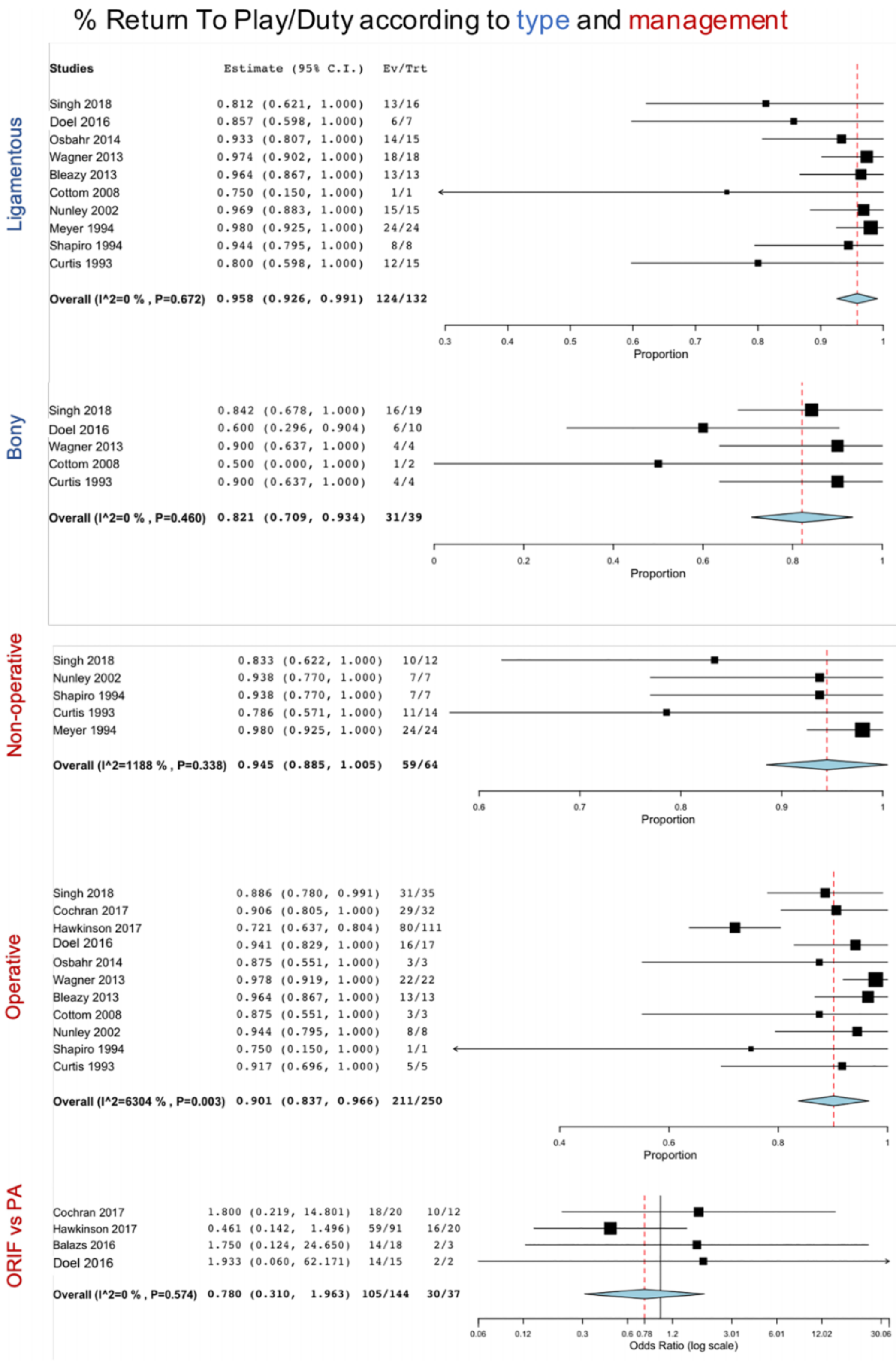

Figure 3. Forest plots of rates of return to play/duty according to injury type and management. C.I., confidence interval; Ev/Trt, events/treatment group number; ORIF, open reduction and internal fixation; PA, primary arthrodesis.

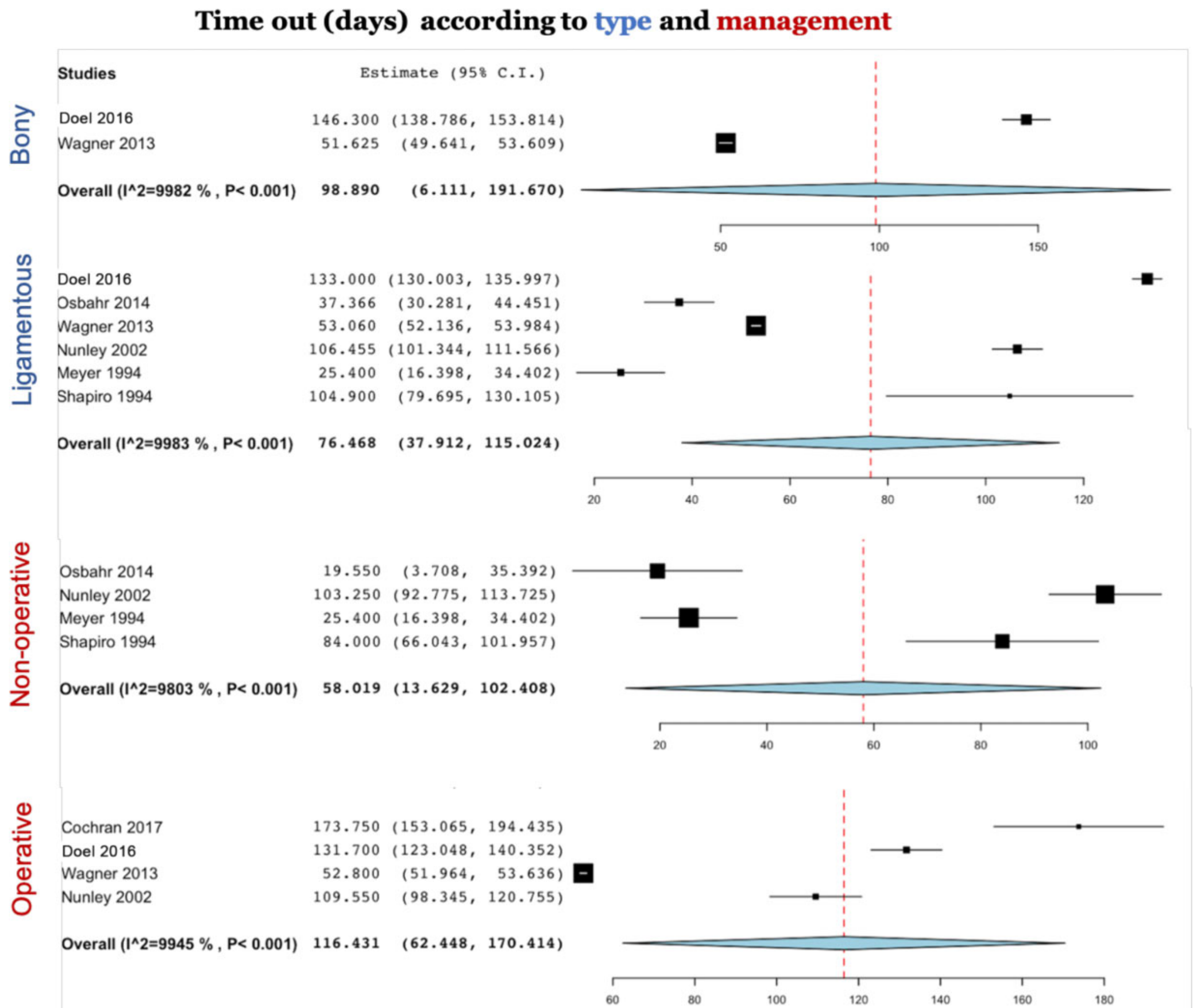

Figure 4. Forest plots of time missed from practice/active duty (expressed in days) according to injury type and management in athletes. C.I., confidence interval; Ev/Trt, events/treatment group number.

body mechanics, playing styles, and performance criteria. However, this may highlight different approaches by orthopaedic surgeons and international differences in the management of this condition.

Although not necessarily a sports injury, Lisfranc injuries in young athletic military personnel share many aspects with those in athletes. They both are low-energy injuries resulting from axial loading of a plantarflexed foot during activities similar to those of athletes. Moreover, military personnel have high functional demands to be able to perform activities such as running, jumping, and general fitness.[1,4,8] For these reasons, this meta-analysis included studies on Lisfranc injuries in young athletic military personnel.

Although the limited and rather heterogeneous literature does not support any differences in RTP rates and time missed based on the anatomic features of the injury or how it was managed, the most critical factor affecting the performance remains the proper reduction of the injury. In an analysis of the NFL Scouting Combine, McHale et al[11] demonstrated that residual displacement >2 mm leads to worse outcomes in comparison with displacement <2 mm. The former group missed more games, started fewer games, and had lower odds of being picked. It is worth mentioning that, unfortunately, >40% of athletes who had Lisfranc injury in this study had residual displacement. Myerson et al[14] and Kuo et al[10] also highlighted the paramount importance of anatomic reduction for performance and functional outcomes.

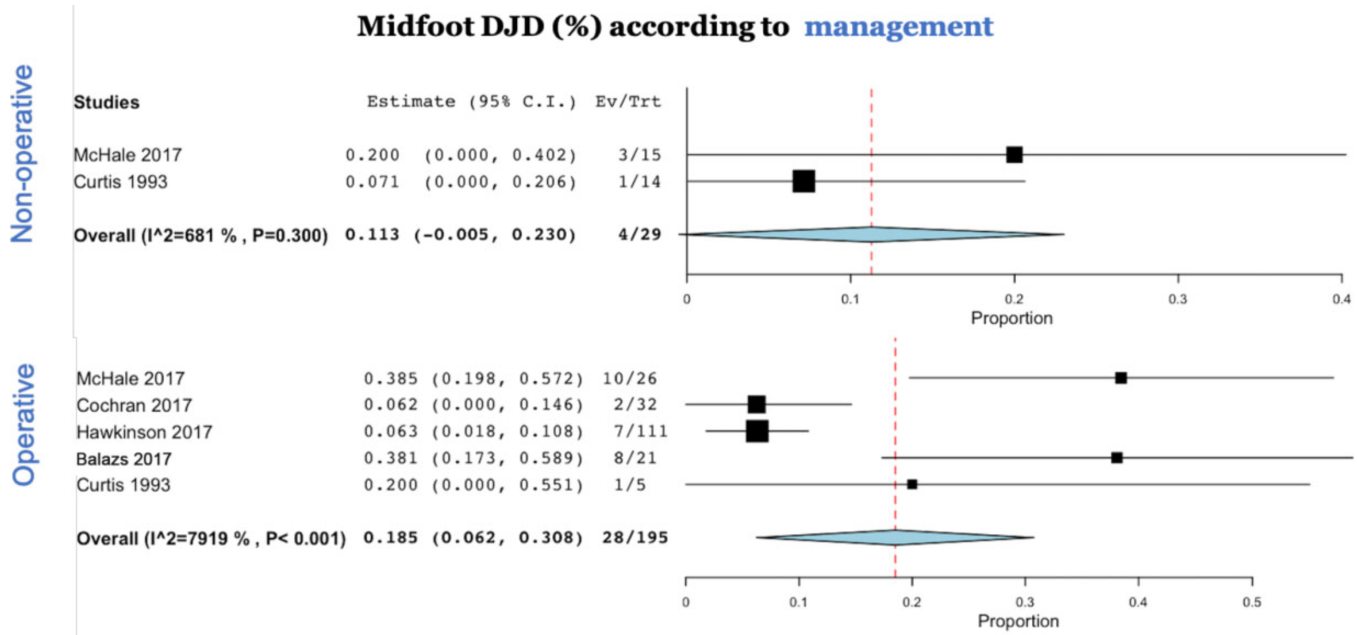

Figure 5. Forest plots of midfoot degenerative joint disease (DJD) percentage with regard to operative versus nonoperative management. C.I., confidence interval; Ev/Trt, events/treatment group number.

Complications: Midfoot DJD and Reoperation

Midfoot degenerative disease and arthritis have been reported to be associated with a nonanatomic reduction of the Lisfranc joint gap. This malreduction and the increased gap have resulted in inferior outcomes in the nonathletic general population[10,14] as well as the athletic and military population.[1,11] There was no statistically significant difference between ORIF and PA in rates of midfoot DJD, which again highlights the importance of reduction rather than fixation technique. Another related complication is reoperation, which was as high as 67% to 71%, especially after ORIF.[1,8] While a proportion of those who underwent ORIF eventually require arthrodesis for late presentation and ensuing midfoot DJD, it is challenging to compare PA with ORIF on the basis of reoperation, as planned hardware removal was routinely done after ORIF, which is not the case with PA.

Deep peroneal nerve (DPN) sensory loss was reported by Deol et al[7] in 3 players (17.6%). It recovered in 2 players at 6 and 12 months, respectively, while it was permanent in 1 player. A similar complication was reported by Cochran et al,[4] where 4 patients (22%) in the ORIF group and 2 in the PA group (14.2%) had permanent DPN sensory changes. Balazs et al[1] reported 1 DPN neuropraxia that resolved within 3 months.

Limitations

The current study is not without limitations, which are similar to those of other meta-analyses, including the significant heterogeneity of studies, the unknown bias in the primary studies, and the inclusion of articles published only in English. Another limitation is that all studies were retrospective and mostly with no control group, except for the studies on the military population, which had the highest level of evidence (level 3).[1,4,8]

We also recognize the potential bias when comparing operative and nonoperative treatment. The decision to treat an injury might be a reflection of its severity, as discussed earlier. Moreover, the studies were unable to control for the military personnel's motivation and satisfaction with military life as a factor affecting RTD.

Finally, time to RTP was not uniformly reported. Some of the studies provided data on time missed from practice and time until full recovery, while others expressed this time in games missed. This limitation may have affected the power of the study. However, we believe that this did not affect the outcomes. The time to RTP, regardless of the term used, showed no statistically significant difference between cohorts (bony vs ligamentous, operative vs nonoperative, and ORIF vs PA) when each interval was analyzed separately.

CONCLUSION

Our meta-analysis on low-energy Lisfranc injuries in high-demand individuals found an overall excellent RTP/RTD rate. The time missed from athletic participation/military duty was not affected by the management or bony or ligamentous nature of the injury or the player's position. However, we believe that this did not affect the outcomes. The time to RTP, regardless of the term used, showed no statistically significant difference between cohorts (bony vs ligamentous, operative vs nonoperative, and ORIF vs PA) when each interval was analyzed separately. Higher-quality studies on low-energy Lisfranc are needed.

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