How Common is Subsequent Posterior Tibial Tendon Dysfunction or Tarsal Tunnel Syndrome After Ankle Sprain Injury?

Kaitlyn S. Foster, DPT[1] Tina A. Greenlee, PhD[1] Jodi L. Young, DPT[2] Cory F. Janney, MD[3] Daniel I. Rhon, DPT, DSc, PhD[1,4]

[1] Department of Rehabilitation Medicine, Brooke Army Medical Center, San Antonio, Texas
[2] Doctor of Science Program in Physical Therapy, Bellin College, Green Bay, Wisconsin
[3] Naval Medical Center San Diego, San Diego, California
[4] Department of Rehabilitation Medicine, School of Medicine, Uniformed Services University of the Health Sciences, Bethesda, Maryland

Address for correspondence Kaitlyn Foster, DPT, Department of Rehabilitation Medicine, Brooke Army Medical Center, 3551 Roger Brooke Drive, San Antonio, TX 78234 (e-mail: kaitlyn.s.foster.ctr@mail.mil).

J Knee Surg 2022;35:1181–1191.

Abstract

Posterior tibial tendon dysfunction (PTTD) and tarsal tunnel syndrome (TTS) are debilitating conditions reported to occur after ankle sprain due to their proximity to the ankle complex. The objective of this study was to investigate the incidence of PTTD and TTS in the 2 years following an ankle sprain and which variables are associated with its onset. In total, 22,966 individuals in the Military Health System diagnosed with ankle sprain between 2010 and 2011 were followed for 2 years. The incidence of PTTD and TTS after ankle sprain was identified. Binary logistic regression was used to identify potential demographic or medical history factors associated with PTTD or TTS. In total, 617 (2.7%) received a PTTD diagnosis and 127 (0.6%) received a TTS diagnosis. Active-duty status (odds ratio [OR] 2.18, 95% confidence interval [CI] 1.70–2.79), increasing age (OR 1.03, 95% CI 1.02–1.04), female sex (OR 1.58, 95% CI 1.28–1.95), and if the sprain location was specified by the diagnosis (versus unspecified location) and did not include a fracture contributed to significantly higher ($p < 0.001$) risk of developing PTTD. Greater age (OR 1.06, 95% CI 1.03–1.09), female sex (OR 2.73, 95% CI 1.74–4.29), history of metabolic syndrome (OR 1.73, 95% CI 1.03–2.89), and active-duty status (OR 2.28, 95% CI 1.38–3.77) also significantly increased the odds of developing TTS, while sustaining a concurrent ankle fracture with the initial ankle sprain (OR 0.45, 95% CI 0.28–0.70) significantly decreased the odds. PTTD and TTS were not common after ankle sprain. However, they still merit consideration as postinjury sequelae, especially in patients with persistent symptoms. Increasing age, type of sprain, female sex, metabolic syndrome, and active-duty status were all significantly associated with the development of one or both subsequent injuries. This work provides normative data for incidence rates of these subsequent injuries and can help increase awareness of these conditions, leading to improved management of refractory ankle sprain injuries.

Keywords
- ankle
- sprain
- posterior tibial tendon
- tarsal tunnel syndrome
- odds ratio

received
January 30, 2022
accepted after revision
May 23, 2022
published online
August 9, 2022

Thieme Medical Publishers, Inc., 333 Seventh Avenue, 18th Floor, New York, NY 10001, USA

DOI https://doi.org/10.1055/s-0042-1751246.
ISSN 1538-8506.

Posterior tibial tendon dysfunction (PTTD) is an acquired, progressive, and debilitating condition of the foot and ankle that is caused by an eventual insufficiency of the posterior tibialis myotendinous complex, limiting mobility and causing pain and weakness.[1,2] The proposed mechanism of injury results from the inability of the posterior tibialis tendon (PTT) to stabilize the foot and ankle complex. With decreased muscle activity, the medial arch of the foot collapses over time, causing the subtalar joint to evert, the heel to drift into valgus, the forefoot to abduct at the talonavicular joint, and the tibia to internally rotate leading to knee pain and cartilage damage.[3–5] This is often accompanied by tendonitis of the PTT. The posterior tibial nerve runs in close proximity to the PTT, posterior and inferior to the medial malleolus.[6] Entrapment of this nerve or its branches within the tarsal tunnel often leads to tarsal tunnel syndrome (TTS). There are many causes of TTS, ranging from osteophytes, tendinopathies, space-occupying lesions, direct trauma, footwear, foot posture, or systemic inflammation to all around the medial ankle complex.[7] While it is unknown whether ankle sprain is a risk factor for the onset of PTTD or TTS, they both are potential clinically relevant impairments as a sequelae of an ankle sprain given their mechanisms of injury and proximity to the ankle structure.

Ankle sprains are one of the most common injuries sustained in the U.S. armed services, with military members being five times more likely to experience a sprain over civilian populations.[8] Often viewed as an innocuous injury, the majority of acute sprains do not receive medical treatment and are instead self-managed.[9] Beyond the acute phase of self-managed healing, 34% of individuals will experience recurring sprains after the initial injury and 40% will develop chronic ankle instability.[10–12] Individuals also demonstrate altered muscle activation patterns, gait deviations, decreased mobility, sensory deficits, balance deficits, and increased time to stabilization.[13–21] These impairments can lead to other conditions which have received less attention in the literature, such as PTTD and TTS.

While these subsequent injuries are noticed anecdotally in the clinic, there is a dearth of evidence to describe their relationship to ankle sprains and associated burden. Because ankle sprains and chronic foot and ankle injury continue to be a prevalent problem,[8,22,23] the purpose of this study was to investigate the incidence of PTTD and TTS following an ankle sprain and determine which factors might be associated with their onset.

Methods

Study Design

This was a retrospective assessment of a consecutive cohort of beneficiaries in the Military Health System who sought care for an ankle sprain between 2010 and 2011. Ethics and regulatory approval were granted by the Institutional Review Board of the U.S. Army Regional Health Command-Central in San Antonio, Texas, United States. The reporting of studies conducted using observational routinely collected health data statement was used to guide reporting in this study.[24]

Data Source

Electronic medical records and claims data were pulled from the U.S. Military Health System Data Repository (MDR), a centralized medical database that captures Defense Health Agency health care data for all active and retired military service members, their families, and other beneficiaries worldwide.[25] The repository contains person-level data for all outpatient and inpatient medical visits, clinical procedures, and medication prescriptions provided to all beneficiaries in both military and civilian health care settings.

Participants

Patients diagnosed with an ankle injury present in their electronic medical records (International Classification of Disease, 9th revision [ICD-9] codes 845.00, 845.01, 845.02, 845.03, 845.09, 824.00, 824.10, 824.20, 824.30, 824.40, 824.50, 824.60, 824.70, 824.80, 824.90) in the Military Health System between January 1, 2010 and December 31, 2011 were included in the analyses.

Study Variables

Age, sex, branch of service, rank as a surrogate for socioeconomic status (i.e., junior enlisted, senior enlisted, junior officer, senior officer, and cadet), and beneficiary status were entered as demographic predictor variables. Ankle sprain injury subgroup (concurrent ankle fracture, medial and lateral sprain without fracture, medial ankle sprain without fracture, lateral ankle sprain without fracture, and unspecified without fracture) and medical history variables shown to have an association with PTTD or TTS[26] (specifically metabolic syndromes identified with a diagnosis of obesity, diabetes and hypertension, or cardiovascular disease) were also identified as predictors and assessed descriptively across the cohort. The presence of metabolic syndrome (250.x0 and 250.x2; 272.0–272.4 and 272.7; 278.0x) or cardiovascular disease (348.2, 401.xx-405.xx, 410.xx-414.xx, 420.xx-429.xx) was based on at least two separate visits with a relevant ICD-9 diagnosis code in the 12 months prior to initial ankle sprain diagnosis where “x” indicated any integer 0 to 9. Rank and branch of service were based on the sponsor (active-duty family member) at the time of initial injury. Unspecified injuries included all the other categories, as well as high ankle sprains. Subsequent incidence of PTTD and TTS was determined by the presence of a future medical visit with the relevant diagnosis code (355.50, 726.72, and 726.79), in any setting where TRICARE was the payer. Cases of PTTD or TTS were only included in our counts when the patient had no history of these diagnoses in the 1 year prior to their ankle sprain, to ensure that these were new episodes of care and not issues present prior to ankle sprain. Finally, injury-related costs and visits for the entire 2-year period after the initial ankle sprain were calculated and reported for each group (ankle sprain alone or combined with PTTD and/or TTS).

Data Analysis

Descriptive and demographic statistics were reported across the entire cohort and for respective injury subgroups (PTTD and TTS). Incidence rates for each injury type were calculated. To better understand what factors might increase the risk for these subsequent injuries, separate hierarchical binary logistic regression models were conducted for each condition in two blocks. In the first block, age, female sex, and cardiometabolic conditions were included based on relationships reported previously in the literature.[26–31] Block 2 included ankle sprain type and military sponsor's demographics, as additional variables of clinical relevance that were unique to our sample. This model was chosen because it allows for the management of a large number of predictor variables and can help determine how much a dependent variable can be explained beyond variance already explained by other variables.[32] Individual β coefficients and 95% confidence intervals (CIs) were reported, and the level of significance was set at $p < 0.05$.

Generalized linear models (GLMs) were used to examine secondary outcomes of cost and ankle–foot-related visits to determine differences in burden (health care costs and visit counts) among injury groups (i.e., ankle sprain only, PTTD only, TTS only, or both PTTD and TTS). We fit a GLM using a log-link with a gamma distribution family for the cost data due to heavy skewness and nonzero characteristic associated with cost data.[33,34] We fit a GLM using a negative binomial distribution family for visits because it represents a count variable and is also skewed. We included the comorbidities of metabolic syndrome and cardiovascular disease in the model as these can influence both visits and costs. We reported estimated marginal means with 95% CIs and also removed any extreme outlier cases (z-scores > 3.29).[35,36]

Results

There were 289,680 individuals identified in the MDR with any ankle–foot injury with benefits eligibility during the study period. Then, 39,348 unique individuals remained after selecting only those with an ankle sprain, with 22,966 individuals meeting the full-time period eligibility criteria (►**Fig. 1**). The mean age was 31.49 (SD 0.06) years, and the majority were male (60.9%, $n = 13{,}992$), with the sponsor that was junior enlisted (59.6%, $n = 13{,}697$), active-duty member (53.2%, $n = 12{,}211$), and in the Army (39.7%, $n = 9{,}112$). Additional descriptive statistics can be found in ►**Table 1**. Of the total cohort, 617 (2.7%) were diagnosed with PTTD, with a median of 252 (IQR 110,410) days after the initial ankle sprain. Further, 127 (0.6%) were diagnosed with TTS, with a median of 355 (IQR 177,579) days after the initial ankle sprain (see ►**Fig. 2**).

The factors that significantly increased the odds of a PTTD diagnosis were increasing age (OR 1.03, 95% CI 1.02–1.04), female sex (OR 1.58, 95% CI 1.28–1.95), military active duty (OR 2.18, 95% CI 1.70–2.79) or reservist (OR 1.55, 95% CI 1.08–2.21), if the initial ankle sprain involved both the medial and lateral sides (OR 3.20, 95% CI 1.26–8.09), was

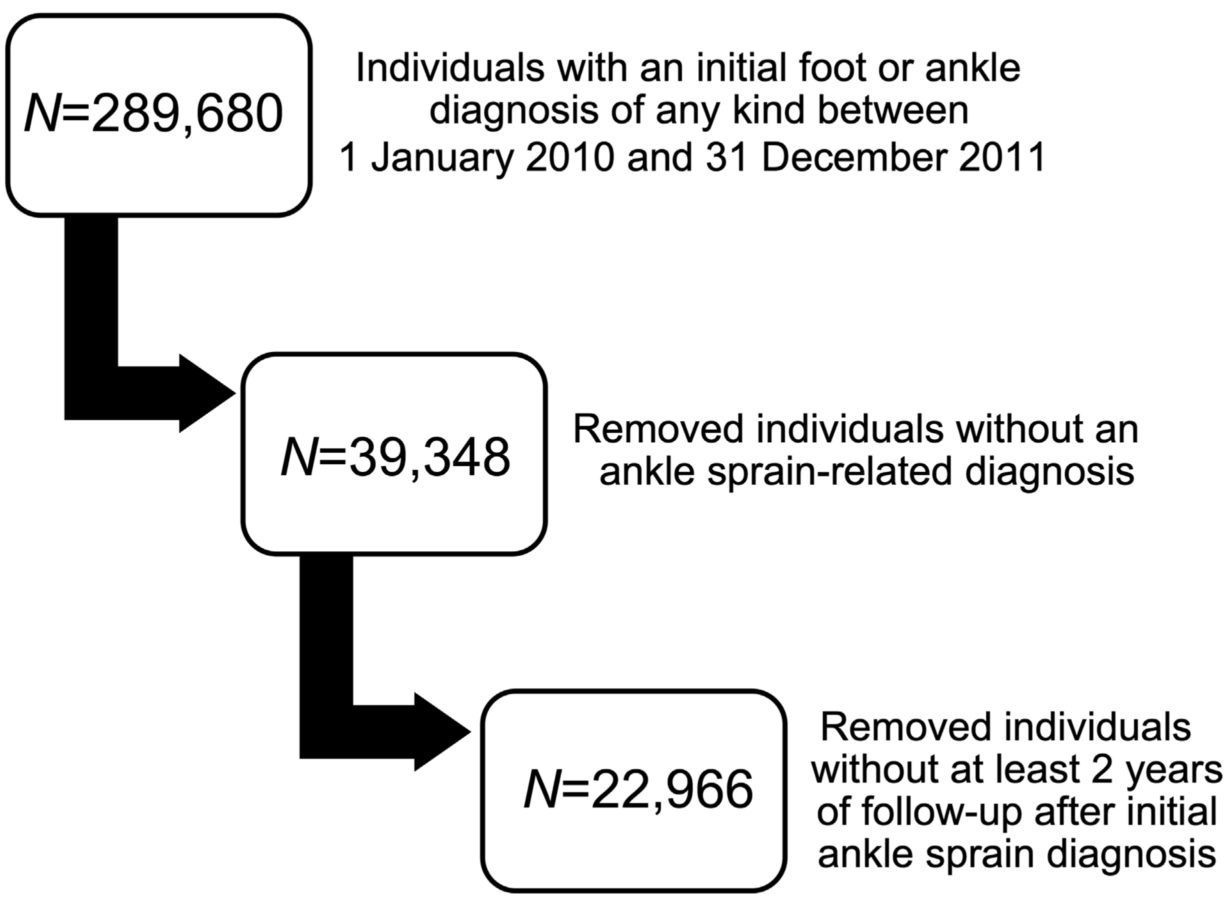

Fig. 1 Flow of cohort selection.

Table 1 Patient demographics

Demographics	Full cohort n = 22,966	PTTD within 2 y n = 617	TTS within 2 y n = 127
Age—Mean (Standard deviation)	31.49 (0.06)	32.90 (0.36)	35.83 (0.82)
Days to secondary Dx—Median (IQR)		252 (110,410)	355 (177,579)
Female sex[a]	8,623 (37.5%)	251 (40.7%)	73 (57.5%)
Cardiovascular Dx 12 mo prior[b]	1,320 (5.7%)	50 (8.1%)	18 (14.2%)
Metabolic syndrome 12 mo prior[b]	1,727 (7.5%)	56 (9.1%)	23 (18.1%)
Sponsor's branch of service			
Army	9,112 (39.7%)	226 (36.6%)	58 (45.7%)
Coast Guard	822 (3.6%)	25 (4.1%)	4 (3.1%)
Air Force	6,493 (28.3%)	176 (28.5%)	40 (31.5%)
Marines	2,055 (8.9%)	61 (9.9%)	9 (7.1%)
Navy	4,080 (17.8%)	121 (19.7%)	15 (11.8%)
Other	53 (0.2%)	2 (0.3%)	1 (0.8%)
Sponsor's socioeconomic status			
Junior enlisted	13,697 (59.6%)	369 (59.8%)	71 (55.9%)
Senior enlisted	4,986 (21.7%)	131 (21.2%)	30 (23.6%)
Junior officer	1,785 (7.8%)	49 (7.9%)	7 (5.5%)
Senior officer	1,981 (8.6%)	57 (9.2%)	19 (15%)
Cadet	166 (0.7%)	5 (0.8%)	0 (0%)
Other	351 (1.5%)	6 (1.0%)	0 (0%)
Beneficiary status			
Active duty	12,211 (53.2%)	377 (61.1%)	64 (50.4%)
Dependent/family member	7,426 (32.3%)	162 (26.3%)	48 (37.8%)
Retiree	1,263 (5.5%)	25 (4.1%)	6 (4.7%)
Reservist	1,709 (7.4%)	47 (7.6%)	9 (7.1%)
Other/unknown	6 (0%)	0 (0%)	0 (0%)

Abbreviations: 12 mo, 12-month period prior to initial ankle sprain; Dx, diagnosis; IQR, interquartile range; PTTD, posterior tibial tendon dysfunction; TTS, tarsal tunnel syndrome.
Note: Values represent frequency (%) unless otherwise specified.
[a]Includes 13,992 male and 351 unknown sexes.
[b]533 individuals had both cardiovascular and metabolic diagnoses.

isolated to only the medial side (OR 4.01, 95% CI 2.69–5.99), or was isolated to the lateral side (OR 1.42, 95% CI 1.05–1.94) compared with being a military dependent or having an unspecified ankle sprain diagnosis. Finally, an ankle fracture that occurred with the initial sprain made it less likely that the patient was going to receive a PTTD diagnosis in the 2 years following the initial injury (OR 0.71, 95% CI 0.59–0.86) compared with those who sustained an unspecified sprain without a fracture. The sponsor's rank did not contribute to the model (see ►**Table 2**).

Factors that increased the odds of receiving a TTS diagnosis included increasing age (OR 1.06, 95% CI 1.03–1.09), female sex (OR 2.73, 95% CI 1.74–4.29), and having a metabolic syndrome diagnosis (OR 1.73, 95% CI 1.03–2.89). Being an active-duty military member increased the risk of TTS (OR 2.28, 95% CI 1.38–3.77) compared with being a dependent. An ankle fracture that occurred with the initial sprain made it less likely that the patient was going to receive a TTS diagnosis in the 2 years following the initial injury (OR 0.45, 95% CI 0.28–0.70) compared with those who sustained an unspecified sprain without a fracture. The sponsor's rank did not significantly contribute to this model (see ►**Table 3**).

For those with available cost and visit data ($n = 22,256$), the mean 2-year ankle-related costs were significantly different among groups: $2,388.35 (95% CI $2,281.89, $2,499.78) for those with an isolated ankle sprain, $4,299.09 (95% CI $3,957.11, $4671.71) for those with a PTTD diagnosis, $4,746.99 (95% CI $3,880.10, $5,807.55) for those with a TTS diagnosis, and $6,636.65 (95% CI $5,243.70, $8,399.63) for those with both PTTD and TTS combined. Further, mean 2-year ankle-foot-related visit counts also differed significantly: 10.72 (95% CI 10.35, 11.09) for isolated ankle sprains, 20.51 (95% CI 19.19, 21.91) for individuals diagnosed with PTTD, 22.74 (95% CI 19.50, 26.51) for

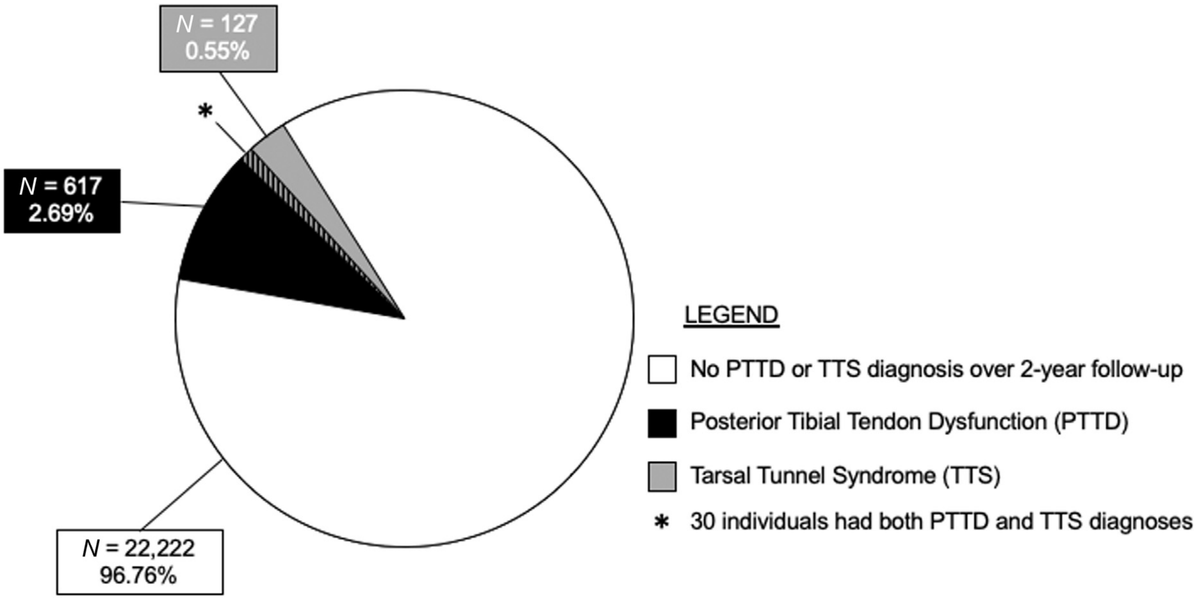

Fig. 2 Incidence of PTTD and TTS in 2 years following ankle sprain in the U.S. Military ($n = 22{,}966$).

Table 2 Hierarchical binary logistic regression: likelihood of PTTD 2 years postankle sprain

Variable group	Variable	β	Odds ratio	95% CI		*p*-Value	Group *p*-Value
				LL	UL		
	Age	0.03	1.03	1.02	1.04	<0.001	
Sex (RS: male)	Female sex	0.46	1.58	1.28	1.95	<0.001	
Cardiovascular Dx (RS: ≤1 visit)	2+ visits 12 mo prior	0.29	1.33	0.96	1.85	0.086	
Metabolic syndrome (RS: ≤1 visit)	2+ visits 12 mo prior	0.05	1.05	0.77	1.43	0.757	
Ankle sprain type[a] (RS: unspecified without fracture)	Concurrent fracture	−0.35	0.71	0.59	0.86	<0.001	<0.001
	Medial and lateral	1.16	3.20	1.26	8.09	0.014	
	Medial	1.39	4.01	2.69	5.99	<0.001	
	Lateral	0.35	1.42	1.05	1.94	0.025	
Status[a] (RS: dependent)	Active duty	0.78	2.18	1.70	2.79	<0.001	<0.001
	Retiree	−0.10	0.90	0.57	1.44	0.668	
	Reservist	0.44	1.55	1.08	2.21	0.018	
Sponsor's rank[a] (RS: junior enlisted)	Senior enlisted	−0.08	0.92	0.73	1.16	0.494	0.966
	Junior officer	−0.06	0.94	0.70	1.28	0.713	
	Senior officer	−0.04	0.97	0.71	1.31	0.824	
	Cadet	0.10	1.10	0.45	2.73	0.832	
	Constant	−5.07	0.01			<0.001	

Abbreviations: 12 mo, 12-month period prior to initial ankle sprain; CI, confidence interval; Dx, diagnosis; LL/UL, lower/upper limit; PTTD, posterior tibial tendon dysfunction; RS, reference standard.
[a]Entered in Step 2.

Table 3 Hierarchical binary logistic regression: likelihood of TTS 2 years postankle sprain

Variable group	Variable	B	Odds ratio	95% CI		*p-Value*	Group *p*-Value
				LL	UL		
	Age	0.06	1.06	1.03	1.09	<0.001	
Sex (RS: male)	Female sex	1.00	2.73	1.74	4.29	<0.001	
Cardiovascular Dx (RS: ≤ 1 visit)	2+ visits 12 mo prior	0.45	1.57	0.89	2.77	0.118	
Metabolic syndrome (RS: ≤ 1 visit)	2+ visits 12 mo prior	0.55	1.73	1.03	2.89	0.037	
Ankle sprain type[a] (RS: unspecified without fracture[b])	Concurrent fracture	−0.81	0.45	0.28	0.70	0.001	0.005
	Medial	0.45	1.57	0.49	5.01	0.448	
	Lateral	0.25	1.28	0.66	2.49	0.458	
Status[a] (RS: dependent)	Active duty	0.83	2.28	1.38	3.77	0.001	0.013
	Retiree	−0.17	0.85	0.34	2.13	0.724	
	Reservist	0.33	1.39	0.65	2.99	0.396	
Sponsor's rank[a] (RS: junior enlisted[c])	Senior enlisted	−0.27	0.76	0.47	1.23	0.268	0.454
	Junior officer	−0.44	0.65	0.30	1.41	0.274	
	Senior officer	0.19	1.21	0.69	2.11	0.513	
	Constant	−7.86	0.000			<0.001	

Abbreviations: 12 mo, 12-month period prior to initial ankle sprain; CI, confidence interval; Dx, diagnosis; LL/UL, lower/upper limit; RS, reference standard; TTS, tarsal tunnel syndrome.
[a]Entered in Step 2.
[b]No individuals with combined medial and lateral sprain.
[c]No cadets.

individuals diagnosed with TTS, and 30.60 (95% CI 24.98, 37.49) for individuals with both PTTD and TTS. Costs and visits were adjusted for the presence of cardiovascular and metabolic syndrome comorbidities.

Discussion

The aim of the study was to evaluate the incidence of PTTD and TTS in the 2 years following an ankle sprain. Of those who experienced an ankle sprain, 617 (2.7%) developed PTTD and 127 (0.06%) developed TTS during this period of time. These values reflect a low proportion of these specific injuries after an ankle sprain. However, it is worth considering because ankle sprains are one of the most common injuries sustained in this setting and are a leading cause of injury-related limited duty status in service members.[37] Even though the proportional rate of PTTD and TTS may be low after ankle sprain, it does not necessarily mean these injuries are rare or occur infrequently. Despite their relative infrequency, these diagnoses carry significant financial burden. We identified almost a two-fold greater utilization of health care resources for individuals with secondary diagnoses of PTTD and TTS (20.51 and 22.74 visits, respectively) compared with 10.72 visits for those with an isolated ankle sprain. This was also reflected by greater costs for individuals with PTTD ($4,299.09) or TTS ($4,746.99) relative to those with only an ankle sprain ($2,388.35), and these values were all adjusted for the presence of comorbidities. The risk factors for developing PTTD and TTS were essentially identical (age, female sex, not having a concurrent fracture with the ankle sprain, being on active duty rather than a dependent or retiree, and copresence of metabolic syndrome). The median time between the original ankle sprain was 252 days for the diagnosis of PTTD and 355 days for TTS, reflecting a likely onset of these conditions within 1 year. This timeframe resembles the typical duration of ligament healing following ankle sprain,[38] as patients continue to demonstrate laxity as well as subjective reports of ankle instability 1-year post-injury.[39] It is unknown how long individuals had symptoms before deciding to seek care for them.

It is estimated that 2 million ankle sprains occur annually in the United States.[40] With a sprain, patients regularly demonstrate altered muscle activation patterns, gait deviations, decreased mobility, sensory deficits, and balance deficits.[13–21,41] These impairments lead to compensatory movement patterns that result in mechanical overload of surrounding tissues, one of those surrounding tissues being the PTT. Our results showed that having a specific ankle sprain diagnosis (medial, lateral, or combined) increased the odds of a subsequent diagnosis of PTTD, using unspecified ankle sprains as a reference standard. However, this finding is limited in its possible conclusions as an unspecified diagnosis makes up the largest subgroup in our dataset and could reflect any type of ankle sprain injury. Future studies may benefit by including only specific diagnoses, which are likely better represented with ICD-10 codes, to allow for more specific examination of sprain type[42] as a predictor of PTTD. In the cases with subsequent injury, compensatory movement patterns described previously and the pressure to return to work despite ongoing ankle dysfunction could be relevant factors. The overload of these tissues (PTT and tarsal tunnel structure) due to an unstable ankle, if not addressed properly, has the potential to lead to flatfoot deformity and eventual disability.[43,44] Further, the patterns of strength deficits seen in those who have experienced an ankle sprain have been found in patients with PTTD, specifically ankle plantarflexion, ankle eversion, hip extension, and hip abduction strength, indicating a natural progression from sprain to dysfunction.[14,45–48] In our model, even though isolated medial ankle sprain had the lowest incidence it was the strongest predictor of developing PTTD compared with the other ankle sprain injury subgroups. This is likely due to the mechanism of the sprain and involvement of the deltoid ligament (►**Fig. 3**).[49] With an eversion injury, the tendon undergoes a quick stretch that can cause it to become inflamed or torn, although the incidence of acute rupture is relatively rare.[50–53]

It was found that ankle sprains with concurrent fractures had a significantly reduced the risk of developing PTTD. It is likely that patients who have sustained a fracture are expected to have residual pain or dysfunction in the months following the injury and therefore do not explore other diagnoses or alternate explanations as to why they are unable to return to activity.[54] Meanwhile, those with ankle sprains (without concurrent fractures) may seek additional care and additional diagnoses may be considered when pain persists. Even still, this finding was somewhat surprising given that muscular atrophy that often occurs when patients immobilize or unload the joint completely for 4 to 8 weeks for bone healing postfracture[55,56] could predispose them to overuse injury.[57,58] However, this short period of immobilization can support the healing of surrounding tissues[39,59,60] and is typically followed by a return-to-activity protocol from a physical therapist[57,58,61] possibly leading to fewer instances of PTTD. Ankle sprains, on the contrary, are often thought of as self-limiting injuries which leads to underestimating the value of rehabilitation for proper recovery. Many service members may not be able access to rehabilitation, due to deployment or training requirements, evidenced by the fact that 72.6% of all individuals sustaining an ankle sprain in the MHS over a 2-year period did not receive any exercise therapy.[62,63] In the military health care setting, it is conceivable that individuals with ankle fractures were directed toward physical therapy by orthopedic specialists who managed their care, while individuals with acute sprains were more likely to receive initial evaluation from a Primary Care Manager, medic or Independent Duty Corpsman for whom physical therapy referral would be less habitual. Further, fear-avoidance beliefs following a fracture may prevent several patients from resuming or attempting to resume their normal activities.[64] If such beliefs led to an extended period of modified activity, it could also help explain the lower likelihood of PTTD development. Consistent with other studies, most of the patients with PTTD in this study were older females.[26–28] Lastly, it is likely that the increased incidence of these injuries in active-duty military members is due to the reality that they are often required to return to high levels of physical activity shortly after injury.[27,52,65]

TTS is a condition that often goes underdiagnosed as symptoms typically mimic other lower limb conditions

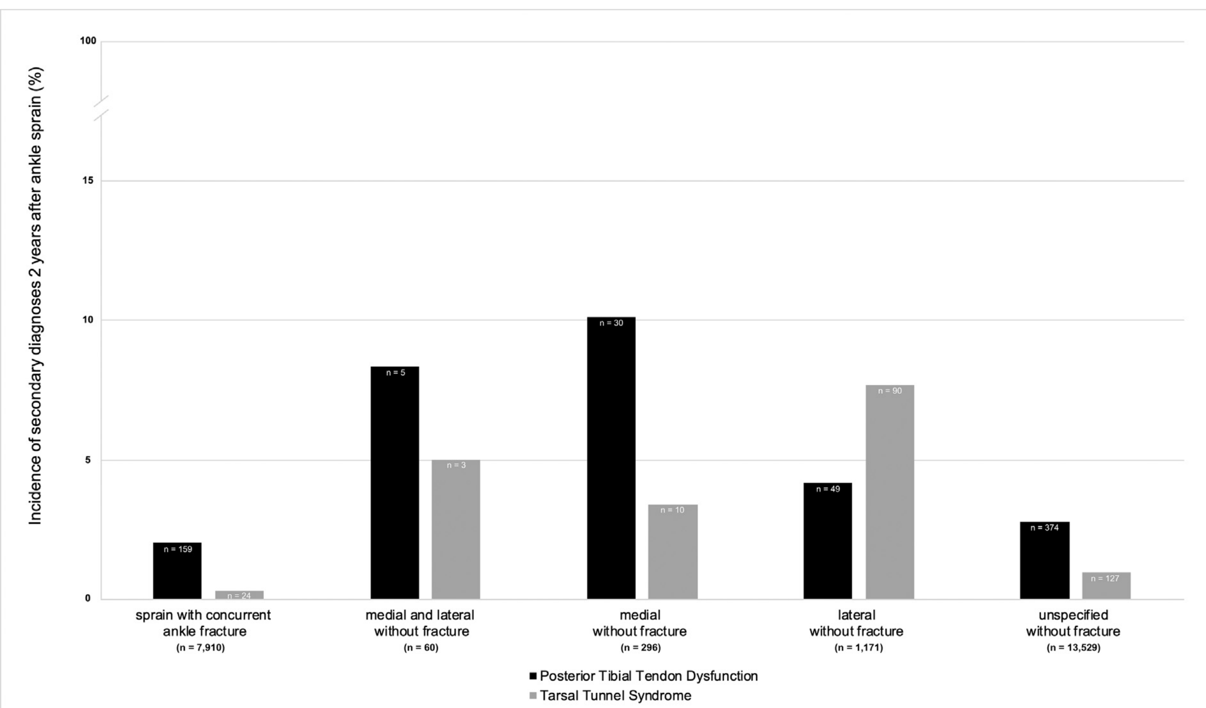

Fig. 3 Incidence of PTTD and TTS by the initial ankle sprain type.

and diagnostic tests can be inconclusive.[7,66,67] It is associated with traumatic inflammatory etiologies, or conditions that result in significant swelling, creating space occupying lesions that encroach on the nerve.[6,29,30,68,69] It may be that metabolic syndrome diagnoses are predictive of developing TTS as it contributes to the multifactorial nature of inflammation, increased stress reactions, and delayed tissue healing.[70–72] These patients could require higher frequency of appointments with their provider to manage their existing condition, allowing the opportunity for additional diagnoses such as TTS. Due to the rarity of the diagnosis, there is limited high-quality evidence to guide treatment.[69] Therefore, identifying patients at risk for the development of TTS could be an important step for improving care. This is especially true in patients that require surgical decompression to prevent nerve fibrosis and atrophy, where early intervention substantially influences patient outcomes.[7] Similar to PTTD, it was found that patients who sustained an ankle fracture along with the initial sprain were at a reduced risk of developing TTS. The literature suggests that females have an increased risk of developing TTS, although it is unclear why this is the case.[29,30] Lastly, the group least likely to receive a diagnosis of TTS was retirees. This is likely due to the fact that ankle injuries, and subsequent trauma-induced secondary injuries, are more common in younger active populations,[73] and active-duty service members have higher physical demands to return to following injury, so they may be more likely to seek care for them.

Recognition and early intervention for PTTD and TTS may prevent progression and prolonged disability.[29,74] Understanding which factors increase the likelihood of each condition, allows for better-informed treatment, which may lead to better patient outcomes and reduce secondary postinjury sequelae.[75–77] Preexisting literature has cited relationships between posterior tibial tendon health and cardiometabolic disorders,[26] leading us to include them as predictors in this model. These comorbid conditions may relate to ankle health due to their impact on peripheral nerve function,[78] inflammation,[79] and tendon integrity.[80,81] Metabolic disorders, which have been previously associated with overall healing potential,[82] were expectedly predictive of secondary TTS diagnosis following ankle sprain in our sample. However, our findings did not indicate that cardiovascular comorbidities significantly increased the risk of PTTD or TTS diagnoses secondary to ankle sprain, possibly due low prevalence of these conditions in this population. Perhaps risk factors associated with athletic populations such as strenuous sporting activity (sprinting and jumping),[83] altered foot posture,[84,85] and abnormal foot-ankle mechanics[86,87] following a sprain that would better predict these secondary diagnoses. Future research should also investigate other contributing factors to these subsequent injuries, such as the role of chronic ankle instability, comorbid conditions such as chronic pain or lumbar radiculopathy,[88,89] physical activity and work behavior, recovery time, provider type, and patterns of care in the likelihood of diagnosing these conditions. More specifically, work should be conducted to further explore the relationship between postankle sprain sequelae onset and the influence of appropriate and timely rehabilitation, as contributing deficits in mobility and strength are correctable with proper care.[75,90,91]

Strengths and Limitations

The key strength of this study is that the data are from a large population-level sample. The data source is a single-payer, closed government system, where individuals receive all of their care in the same system, at no additional cost or copay for all beneficiaries. This provides a uniquely complete snapshot of health care utilization and chronology of patient diagnoses following ankle sprains. This study also fills a knowledge gap by providing a military-specific incidence of PTTD and TTS following ankle sprain. There are also limitations to consider which include lack of detail surrounding the mechanisms of injury, injury severity, and patient-reported outcomes of pain, function, disability, and post-injury physical activity behavior. While our understanding of the timing to the onset of these disorders has improved, a surveillance period of 2 years may be too short to capture all chronic onset cases of PTTD or TTS. There was also an inability to determine the laterality of injury based on the nature of the diagnosis codes available. Many clinicians utilized the generic ankle sprain code (unspecified), which limits the specificity of the conclusions. Encouraging clinicians to code with greater specificity will improve the future use of these data to guide clinical and policy decisions. Only health-seeking injuries were identified, and therefore, it is possible that individuals developed PTTD or TTS, but instead self-managed and did not seek care. Or conversely, because these diagnoses can be elusive, a higher number of individuals could have sustained true PTTD or TTS, but the diagnosis was missed, overlooked, or given a different label by their medical team. Costs should not be compared between direct and purchased care settings. In purchased care, they represent claims, and in direct care, they represent values assigned to establish operational budgets, since no actual money is exchanged for the latter in this single-payer system. Many individuals in this cohort received care in both settings and if one type of condition or treatment was more common in one setting compared with the other, it could have influenced the costs. A more formal cost analysis is recommended to determine a more conclusive cost burden. Finally, these findings may not generalize to other health systems or settings.

Conclusions

PTTD and TTS should be considered as a possible postankle sprain sequelae, especially in patients with both persistent symptoms and any of the identified risk factors. Increased age, female sex, not having a concurrent fracture with the ankle sprain, being on active duty rather than a dependent, and metabolic syndromes increase the risk that a patient would receive a diagnosis of PTTD and TTS after the initial ankle sprain. This work has the potential to help increase awareness of these conditions as a potential consequence of ankle sprain.

Disclaimer

The view(s) expressed herein are those of the author(s) and do not necessarily reflect the official policy or position of Brooke Army Medical Center, the U.S. Army Office of the Surgeon General, the Department of the Army, the Department of the Navy, the Uniformed Services University, the Defense Health Agency, the Department of Defense, nor the U.S. Government.

Funding

This research was supported by the Department of Defense Clinical Rehabilitation Medical Research Program (CRMRP) Award #W81XWH-18-1-0788, under program number W81XWH-17-DMRDP-CRMRP-NMSIRRA

Conflict of Interest

None declared.

References

1 Knapp PW, Constant D. Posterior tibial tendon dysfunction. In: StatPearls. Treasure Island, FL: StatPearls Publishing; 2021
2 Geideman WM, Johnson JE. Posterior tibial tendon dysfunction. J Orthop Sports Phys Ther 2000;30(02):68–77
3 Gross KD, Felson DT, Niu J, et al. Association of flat feet with knee pain and cartilage damage in older adults. Arthritis Care Res (Hoboken) 2011;63(07):937–944
4 Conley T, Davenport J II. Pes Planus (Flat Feet) in Relation to Knee Pain. Published online 2018. Accessed October 20, 2021 at: https://digitalcommons.usm.maine.edu/thinking_matters/140/
5 Myerson M. Adult acquired flat foot deformity. Foot Ankle Clin 2003;8(03):xiii–xiv
6 Cancilleri F, Ippolito M, Amato C, Denaro V. Tarsal tunnel syndrome: four uncommon cases. Foot Ankle Surg 2007;13(04): 214–217
7 Ahmad M, Tsang K, Mackenney PJ, Adedapo AO. Tarsal tunnel syndrome: a literature review. Foot Ankle Surg 2012;18(03): 149–152
8 Cameron KL, Owens BD, DeBerardino TM. Incidence of ankle sprains among active-duty members of the United States Armed Services from 1998 through 2006. J Athl Train 2010;45 (01):29–38
9 Hubbard-Turner T. Lack of medical treatment from a medical professional after an ankle sprain. J Athl Train 2019;54(06): 671–675
10 McKay GD, Goldie PA, Payne WR, Oakes BW. Ankle injuries in basketball: injury rate and risk factors. Br J Sports Med 2001;35 (02):103–108
11 Doherty C, Bleakley C, Hertel J, Caulfield B, Ryan J, Delahunt E. Recovery from a first-time lateral ankle sprain and the predictors of chronic ankle instability: a prospective cohort analysis. Am J Sports Med 2016;44(04):995–1003
12 van Rijn RM, van Os AG, Bernsen RMD, Luijsterburg PA, Koes BW, Bierma-Zeinstra SMA. What is the clinical course of acute ankle sprains? A systematic literature review. Am J Med 2008;121(04): 324–331.e6
13 Feger MA, Donovan L, Hart JM, Hertel J. Lower extremity muscle activation during functional exercises in patients with and without chronic ankle instability. PM R 2014;6(07):602–611, quiz 611
14 Fatima S, Bhati P, Singla D, Choudhary S, Hussain ME. Electromyographic activity of hip musculature during functional exercises in participants with and without chronic ankle instability. J Chiropr Med 2020;19(01):82–90
15 Doherty C, Bleakley C, Hertel J, Caulfield B, Ryan J, Delahunt E. Single-leg drop landing movement strategies 6 months following first-time acute lateral ankle sprain injury. Scand J Med Sci Sports 2015;25(06):806–817
16 Herb CC, Grossman K, Feger MA, Donovan L, Hertel J. Lower extremity biomechanics during a drop-vertical jump in participants with or without chronic ankle instability. J Athl Train 2018; 53(04):364–371
17 Theisen A, Day J. Chronic ankle instability leads to lower extremity kinematic changes during landing tasks: a systematic review. Int J Exerc Sci 2019;12(01):24–33
18 Koldenhoven RM, Feger MA, Fraser JJ, Saliba S, Hertel J. Surface electromyography and plantar pressure during walking in young adults with chronic ankle instability. Knee Surg Sports Traumatol Arthrosc 2016;24(04):1060–1070
19 Lehr ME, Pettineo SJ, Fink ML, Meyr AJ. Closed chain dorsiflexion and the regional interdependence implications on fundamental movement patterns in collegiate athletes. Foot 2021;49:101835
20 Bullock-Saxton JE. Local sensation changes and altered hip muscle function following severe ankle sprain. Phys Ther 1994;74(01): 17–28, discussion 28–31
21 Doherty C, Bleakley C, Hertel J, Caulfield B, Ryan J, Delahunt E. Dynamic balance deficits in individuals with chronic ankle instability compared to ankle sprain copers 1 year after a first-time lateral ankle sprain injury. Knee Surg Sports Traumatol Arthrosc 2016;24(04):1086–1095
22 Gerber JP, Williams GN, Scoville CR, Arciero RA, Taylor DC. Persistent disability associated with ankle sprains: a prospective examination of an athletic population. Foot Ankle Int 1998;19 (10):653–660
23 Shah S, Thomas AC, Noone JM, Blanchette CM, Wikstrom EA. Incidence and cost of ankle sprains in United States emergency departments. Sports Health 2016;8(06):547–552
24 Benchimol EI, Smeeth L, Guttmann A, et al; RECORD Working Committee. The REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) statement. PLoS Med 2015;12(10):e1001885
25 Rhon DI, Clewley D, Young JL, Sissel CD, Cook CE. Leveraging healthcare utilization to explore outcomes from musculoskeletal disorders: methodology for defining relevant variables from a health services data repository. BMC Med Inform Decis Mak 2018; 18(01):10
26 Bubra PS, Keighley G, Rateesh S, Carmody D. Posterior tibial tendon dysfunction: an overlooked cause of foot deformity. J Family Med Prim Care 2015;4(01):26–29
27 Edwards MR, Jack C, Singh SK. Tibialis posterior dysfunction. Curr Orthop 2008;22(03):185–192
28 Holmes GB Jr, Mann RA. Possible epidemiological factors associated with rupture of the posterior tibial tendon. Foot Ankle 1992; 13(02):70–79
29 Hudes K. Conservative management of a case of tarsal tunnel syndrome. J Can Chiropr Assoc 2010;54(02):100–106
30 Lau JT, Daniels TR. Tarsal tunnel syndrome: a review of the literature. Foot Ankle Int 1999;20(03):201–209
31 Park S, Lee J, Cho HR, Kim K, Bang YS, Kim YU. The predictive role of the posterior tibial tendon cross-sectional area in early diagnosing posterior tibial tendon dysfunction. Medicine (Baltimore) 2020;99(36):e21823
32 Frey BB. Hierarchical regression. In: The SAGE Encyclopedia of Educational Research, Measurement, and Evaluation. Thousand Oaks, CA: SAGE Publications, Inc; 2018
33 Malehi AS, Pourmotahari F, Angali KA. Statistical models for the analysis of skewed healthcare cost data: a simulation study. Health Econ Rev 2015;5:11
34 Blough DK, Ramsey SD. Using generalized linear models to assess medical care costs. Health Serv Outcomes Res Methodol 2000;1 (02):185–202
35 Verkoeijen PP, Polak MG, Bouwmeester S, Vazire S, Savalei V. A practical illustration of methods to deal with potential outliers: a multiverse outlier analysis of study 3 from Brummelman,

Thomaes, Orobio de Castro, Overbeek, and Bushman. Collabra Psychol 2018;4(01): Accessed July 9, 2022 at: https://online.ucpress.edu/collabra/article-abstract/4/1/30/112965
36 Kannan KS, Manoj K, Arumugam S. Labeling methods for identifying outliers. Stat Inference Stoch Process 2015;10(02):231–238
37 Roy TC, Faller TN, Richardson MD, Taylor KM. Characterization of limited duty neuromusculoskeletal injuries and return to duty times in the U.S. Army during 2017-2018. Mil Med 2022;187(3-4):e368–e376
38 Frank CB. Ligament structure, physiology and function. J Musculoskelet Neuronal Interact 2004;4(02):199–201
39 Hubbard TJ, Hicks-Little CA. Ankle ligament healing after an acute ankle sprain: an evidence-based approach. J Athl Train 2008;43(05):523–529
40 Herzog MM, Kerr ZY, Marshall SW, Wikstrom EA. Epidemiology of ankle sprains and chronic ankle instability. J Athl Train 2019;54(06):603–610
41 de Noronha M, Refshauge KM, Crosbie J, Kilbreath SL. Relationship between functional ankle instability and postural control. J Orthop Sports Phys Ther 2008;38(12):782–789
42 Inscore MC, Gonzales KR, Rennix CP, Jones BH. The effect of transitioning to ICD-10-CM on acute injury surveillance of active duty service members. Inj Epidemiol 2018;5(01):32
43 Kohls-Gatzoulis J, Angel JC, Singh D, Haddad F, Livingstone J, Berry G. Tibialis posterior dysfunction: a common and treatable cause of adult acquired flatfoot. BMJ 2004;329(7478):1328–1333
44 Hopkins JT, Coglianese M, Glasgow P, Reese S, Seeley MK. Alterations in evertor/invertor muscle activation and center of pressure trajectory in participants with functional ankle instability. J Electromyogr Kinesiol 2012;22(02):280–285
45 Kulig K, Popovich JM Jr, Noceti-Dewit LM, Reischl SF, Kim D. Women with posterior tibial tendon dysfunction have diminished ankle and hip muscle performance. J Orthop Sports Phys Ther 2011;41(09):687–694
46 Webster KA, Gribble PA. A comparison of electromyography of gluteus medius and maximus in subjects with and without chronic ankle instability during two functional exercises. Phys Ther Sport 2013;14(01):17–22
47 Feger MA, Donovan L, Hart JM, Hertel J. Lower extremity muscle activation in patients with or without chronic ankle instability during walking. J Athl Train 2015;50(04):350–357
48 Alvarez RG, Marini A, Schmitt C, Saltzman CL. Stage I and II posterior tibial tendon dysfunction treated by a structured nonoperative management protocol: an orthosis and exercise program. Foot Ankle Int 2006;27(01):2–8
49 Smith JT, Bluman EM. Update on stage IV acquired adult flatfoot disorder: when the deltoid ligament becomes dysfunctional. Foot Ankle Clin 2012;17(02):351–360
50 Vosoughi AR, Ravanbod H, Gilheany M, Erfani MA, Mozaffarian K. Posterior tibialis tendon rupture associated with closed medial malleolus fracture and avulsion of anterior talofibular ligament: a case report and review of the literature. Hong Kong J Emerg Med 2018;25(04):232–235
51 Cataldi C, Bacci N, Colasanti GB, et al. Posterior tibial tendon rupture associated with anterolateral distal tibial and medial malleolar fracture and a novel pattern of tibiofibular syndesmotic injury: a case report and review of the literature. J Foot Ankle Surg 2020;59(05):1066–1071
52 McPhail SM, Dunstan J, Canning J, Haines TP. Life impact of ankle fractures: qualitative analysis of patient and clinician experiences. BMC Musculoskelet Disord 2012;13:224
53 Jackson LT, Dunaway LJ, Lundeen GA. Acute tears of the tibialis posterior tendon following ankle sprain. Foot Ankle Int 2017;38(07):752–759
54 Beckenkamp PR, Lin CWC, Chagpar S, Herbert RD, van der Ploeg HP, Moseley AM. Prognosis of physical function following ankle fracture: a systematic review with meta-analysis. J Orthop Sports Phys Ther 2014;44(11):841–851, B2
55 Swart E, Bezhani H, Greisberg J, Vosseller JT. How long should patients be kept non-weight bearing after ankle fracture fixation? A survey of OTA and AOFAS members. Injury 2015;46(06):1127–1130
56 Kannus R, Jòzsa L, Renström R, et al. The effects of training, immobilization and remobilization on musculoskeletal tissue. Scand J Med Sci Sports 2007;2(03):100–118
57 Vandenborne K, Elliott MA, Walter GA, et al. Longitudinal study of skeletal muscle adaptations during immobilization and rehabilitation. Muscle Nerve 1998;21(08):1006–1012
58 Stevens JE, Pathare NC, Tillman SM, et al. Relative contributions of muscle activation and muscle size to plantarflexor torque during rehabilitation after immobilization. J Orthop Res 2006;24(08):1729–1736
59 Lamb SE, Marsh JL, Hutton JL, Nakash R, Cooke MWCollaborative Ankle Support Trial (CAST Group) Mechanical supports for acute, severe ankle sprain: a pragmatic, multicentre, randomised controlled trial. Lancet 2009;373(9663):575–581
60 Hertel J. Immobilisation for acute severe ankle sprain. Lancet 2009;373(9663):524–526
61 Lin CWC, Donkers NAJ, Refshauge KM, Beckenkamp PR, Khera K, Moseley AM. Rehabilitation for ankle fractures in adults. Cochrane Database Syst Rev 2012;11:CD005595
62 Feger MA, Glaviano NR, Donovan L, et al. Current trends in the management of lateral ankle sprain in the United States. Clin J Sport Med 2017;27(02):145–152
63 Rhon DI, Fraser JJ, Sorensen J, Greenlee TA, Jain T, Cook CE. Delayed rehabilitation is associated with recurrence and higher medical care use after ankle sprain injuries in the United States Military Health System. J Orthop Sports Phys Ther 2021;51(12):619–627
64 Steven JL, Buer N, Samuelsson L, Harms-Ringdahl K. Pain-related fear, catastrophizing and pain in the recovery from a fracture. Scand J Pain 2010;1(01):38–42
65 Beckenkamp PR, Lin CWC, Engelen L, Moseley AM. Reduced Physical activity in people following ankle fractures: a longitudinal study. J Orthop Sports Phys Ther 2016;46(04):235–242
66 Galardi G, Amadio S, Maderna L, et al. Electrophysiologic studies in tarsal tunnel syndrome. Diagnostic reliability of motor distal latency, mixed nerve and sensory nerve conduction studies. Am J Phys Med Rehabil 1994;73(03):193–198
67 Samarawickrama D, Therimadasamy AK, Chan YC, Vijayan J, Wilder-Smith EP. Nerve ultrasound in electrophysiologically verified tarsal tunnel syndrome. Muscle Nerve 2016;53(06):906–912
68 Cimino WR. Tarsal tunnel syndrome: review of the literature. Foot Ankle 1990;11(01):47–52
69 McSweeney SC, Cichero M. Tarsal tunnel syndrome—a narrative literature review. Foot 2015;25(04):244–250
70 Sharma P. Inflammation and the metabolic syndrome. Indian J Clin Biochem 2011;26(04):317–318
71 Wearing SC, Hennig EM, Byrne NM, Steele JR, Hills AP. Musculoskeletal disorders associated with obesity: a biomechanical perspective. Obes Rev 2006;7(03):239–250
72 Monteiro R, Azevedo I. Chronic inflammation in obesity and the metabolic syndrome. Mediators Inflamm 2010;2010;289645
73 Waterman BR, Owens BD, Davey S, Zacchilli MA, Belmont PJ Jr. The epidemiology of ankle sprains in the United States. J Bone Joint Surg Am 2010;92(13):2279–2284
74 Rabbito M, Pohl MB, Humble N, Ferber R. Biomechanical and clinical factors related to stage I posterior tibial tendon dysfunction. J Orthop Sports Phys Ther 2011;41(10):776–784
75 Lin CWC, Hiller CE, de Bie RA. Evidence-based treatment for ankle injuries: a clinical perspective. J Manual Manip Ther 2010;18(01):22–28
76 Chorley JN. Ankle sprain discharge instructions from the emergency department. Pediatr Emerg Care 2005;21(08):498–501

77 Hubbard TJ, Wikstrom EA. Ankle sprain: pathophysiology, predisposing factors, and management strategies. Open Access J Sports Med 2010;1:115–122
78 van der Velde JHPM, Koster A, Strotmeyer ES, et al. Cardiometabolic risk factors as determinants of peripheral nerve function: the Maastricht Study. Diabetologia 2020;63(08):1648–1658
79 Esser N, Paquot N, Scheen AJ. Inflammatory markers and cardiometabolic diseases. Acta Clin Belg 2015;70(03):193–199
80 Applegate KA, Thiese MS, Merryweather AS, et al. Association between cardiovascular disease risk factors and rotator cuff tendinopathy: a cross-sectional study. J Occup Environ Med 2017;59(02):154–160
81 Li K, Deng G, Deng Y, et al. High cholesterol inhibits tendon-related gene expressions in tendon-derived stem cells through reactive oxygen species-activated nuclear factor-κB signaling. J Cell Physiol 2019;234(10):18017–18028
82 Guo S, Dipietro LA. Factors affecting wound healing. J Dent Res 2010;89(03):219–229
83 Kinoshita M, Okuda R, Yasuda T, Abe M. Tarsal tunnel syndrome in athletes. Am J Sports Med 2006;34(08):1307–1312
84 Jackson DL, Haglund B. Tarsal tunnel syndrome in athletes. Case reports and literature review. Am J Sports Med 1991;19(01):61–65
85 Churchill RS, Sferra JJ. Posterior tibial tendon insufficiency. Its Diagnosis, Management, and Treatment. Am J Orthop 1998;27(05):339–347
86 Jackson DL, Haglund BL. Tarsal tunnel syndrome in runners. Sports Med 1992;13(02):146–149
87 Mousavi SH, Hijmans JM, Rajabi R, Diercks R, Zwerver J, van der Worp H. Kinematic risk factors for lower limb tendinopathy in distance runners: A systematic review and meta-analysis. Gait Posture 2019;69:13–24
88 Chodoroff B, Ball RD. Lumbosacral radiculopathy, reflex sympathetic dystrophy and tarsal tunnel syndrome: an unusual presentation. Arch Phys Med Rehabil 1985;66(03):185–187
89 Zheng C, Zhu Y, Jiang J, et al. The prevalence of tarsal tunnel syndrome in patients with lumbosacral radiculopathy. Eur Spine J 2016;25(03):895–905
90 Punt IM, Ziltener JL, Laidet M, Armand S, Allet L. Gait and physical impairments in patients with acute ankle sprains who did not receive physical therapy. PM R 2015;7(01):34–41
91 Kulig K, Reischl SF, Pomrantz AB, et al. Nonsurgical management of posterior tibial tendon dysfunction with orthoses and resistive exercise: a randomized controlled trial. Phys Ther 2009;89(01):26–37

