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Injury patterns and healthcare utilisation by runners of the New York City Marathon

Todd Michael McGrath,[1] Mark Alan Fontana,[2] Brett Gregory Toresdahl[3]

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[1]Department of Primary Sports Medicine, Hospital for Special Surgery, New York, New York, USA
[2]Center for Analytics, Modeling and Performance, Hospital for Special Surgery, New York, New York, USA
[3]Department of Orthopaedics, University of Utah Health, Salt Lake City, Utah, USA

Correspondence to
Dr Todd Michael McGrath; mcgratht@hss.edu

ABSTRACT

Objectives The purpose of this study was to describe injury patterns and healthcare utilisation of marathon runners.

Methods This was a previously reported 16-week prospective observational study of runners training for the New York City Marathon. Runners completed a baseline survey including demographics, running experience and marathon goal. Injury surveys were collected every 4 weeks during training, as well as 1 week before and 1 week after the race. Injury details collected included anatomic location, diagnosis, onset, and treatment received.

Results A total of 1049 runners were enrolled. Injuries were reported by 398 (38.4%) during training and 128 (14.1%) during the marathon. The overall prevalence of injury was 447/1049 (42.6%). Foot, knee and hip injuries were most common during training, whereas knee, thigh and foot injuries were most common during the race. The most frequent tissue type affected was the category of muscle, tendon/fascia and bursa. The prevalence of overuse injuries increased, while acute injuries remained constant throughout training. Hamstring injuries had the highest prevalence of diagnosis with 38/564 injuries (6.7%). Of the 447 runners who reported an injury, 224 (50.1%) received medical care. Physical therapy was the most common medical care received with 115/1037 (11.1%) runners during training and 44/907 (4.9%) postrace.

Conclusion Runners training and participating in a marathon commonly experience injuries, especially of the foot and knee, which often are overuse soft tissue injuries. Half of the injured runners sought out medical care for their injury. Understanding the patterns of injuries affecting marathon runners could help guide future injury prevention efforts.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Training for and participating in a half or full marathon have been associated with a high risk of running-related injury (RRI) with a prevalence of 29%–44% during training.

⇒ RRIs can result in training time lost, failure to complete a race and a financial burden on the athlete and medical system.

WHAT THIS STUDY ADDS

⇒ Among runners who were injured while training for and participating in a marathon, the most affected tissue type was soft tissue (muscle, tendon/fascia and bursa), and the most common anatomic locations of injury were the foot and knee.

⇒ While the most common medical service used by marathon runners for their injuries was physical therapy, 1 in 23 had an MRI before or after the race. For a large marathon like the New York City Marathon, this equates to over 2000 MRIs for injuries associated with training or participating in the marathon.

⇒ Overall incidence and pattern of injury were consistent in age groups.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Understanding the types of injuries affecting marathon runners could help guide future injury prevention programmes.

⇒ Understanding the healthcare utilisation among marathon runners throughout training and racing can help clinicians better prepare for, evaluate and treat these injuries.

INTRODUCTION

Running is one of the most common forms of exercise worldwide. Running race participation has increased by 57% over the past decade, with approximately 1.1 million people finishing a marathon worldwide each year.[1 2] Running-related injuries (RRIs) are common among recreational runners with an incidence ranging from 4.0 to 6.3/1000 training hours in varied populations of runners.[3–5] RRIs are often presumed to be multifactorial as risk factors are broad and include a history of RRI, inexperience, strength deficits, training errors, biomechanics and orthotics use.[6–10] Training for and participating in a half or full marathon have also been shown to be associated with an increased risk of RRI.[6 8] In the lead-up to a marathon or half marathon, the prevalence of RRI ranges between 29.2% and 43.5%.[11] RRIs can result in training time lost, failure to complete a race and a financial burden on the athlete and medical system.[12] RRIs have been shown to prevent nearly 10%

of runners from reaching the starting line of their goal marathon and account for 35% of prerace dropouts.[13] Healthcare utilisation associated with RRIs can be a financial burden on athletes and the medical system, despite a relatively low amount of time loss from work.[14]

Understanding why runners get injured is essential when creating injury prevention programmes. To date, few interventions have resulted in a measurable decrease in injuries among runners.[15–18] Foundational to understanding *why* runners get injured is understanding *how* runners get injured. There are little data available for marathon runners throughout training and racing to determine when runners are more likely to experience injuries, what those injuries are (eg, anatomic location and tissue type), the effect of age on injury patterns and runners' healthcare utilisation for these injuries.[19]

A more robust understanding of the patterns, types and timing of injuries would allow researchers and sports medicine professionals to better understand why marathon runners get injured. This could lead to more precise identification of modifiable risk factors, which could in turn lead to the development of methods for effective injury prevention for runners. The purpose of this study is to describe the distribution and types of injuries experienced by a cohort of marathon runners and measure healthcare utilisation for these injuries, which can add a financial burden to runners and healthcare systems.

METHODS

This was a secondary analysis of a previously reported 16-week observational study of runners training for the 2019 New York City Marathon.[20] Eligibility criteria included marathon registrants, age 18 years and older, English-speaking and without a current injury. A study recruitment email was sent by New York Road Runners to all registrants 20 weeks before the marathon.

Data collection

Data were collected and managed using Research Electronic Data Capture (REDCap), which is a secure web platform for online databases and surveys that is supported by the Weill Cornell Medicine Clinical and Translational Science Center and subsidised by National Institutes of Health (NIH) grant UL1 TR0002384 from the National Center for Advancing Translational Sciences of the NIH. The recruitment email included a link to an electronic consent form and a baseline survey (online supplemental appendix A), which asked about age, sex, race, ethnicity, height, weight, marathon goal, current running patterns (average runs/week and distance/week in the past month), running race experience (number of completed half and full marathon and fastest finishing times) and other forms of exercise.

The 16 weeks before the marathon were divided into four training quarters (TQ), numbered TQ1–TQ4. A survey was administered at the end of each TQ to inquire if the runner was still planning to participate in the marathon and whether the runner had sustained an injury (online supplemental appendix B). For those who were no longer planning to participate in the marathon, runners were asked to provide a primary reason. One week after the marathon, a final survey (online supplemental appendix C) was administered that asked if the runner started the marathon, finished the marathon (if not, the primary reason why not), finishing time and if their finishing time was affected by an injury.

Runners who reported an injury were also asked how the injury affected training or the marathon itself, as well as the location of the injury, any specific diagnosis (if known) and what medical care had been received for the injury (if any). Injuries during training were defined as those that limited training frequency, distance or pace. Pain while training (without an associated impact on training) was not considered an injury for this study. An injury associated with the race was recorded if it was the primary reason for a finishing time being slower than the runner's goal or if the runner received medical care for it in the week after the marathon.

Injured runners were asked to select the anatomic location primarily affected: low back, hip, thigh, knee, leg, ankle, foot or others. Runners then selected a diagnosis to the best of their knowledge (table 1). Diagnoses were classified by tissue type by the investigators as one of the following: (1) muscle, tendon/fascia, bursa, (2) joint, (3) bone or (4) nerve. For the onset of injury, runners selected one of the following: (1) 'acute injury, such as a twisted ankle'; (2) 'rapid onset of an overuse injury, such as a pulled muscle'; and (3) 'gradual onset of an overuse injury, such as shin splints, iliotibial (IT) band syndrome or plantar fasciitis'. All questions also included 'other' and 'don't know' as options. At any point, if a runner experienced more than one injury, the runner was asked to report only the most severe injury.

Statistical analysis

Runners were included in the current analysis if they completed at least one injury survey (TQ1–TQ4 or postrace). Descriptive statistics were used to analyse baseline characteristics, which included means and SD for normally distributed data and medians and IQRs for non-normally distributed data. χ^2 tests were used to compare the prevalence of injury between the TQs, as well as tissue types by age group. For runners who had previously reported that they intended to participate in the marathon but reported in the postrace survey that they did not start the marathon due to injury, the injuries were classified as 'prerace' and were included in TQ4. For runners who reported multiple injuries, a subsequent report of an injury of the same anatomic location was considered the same injury. For runners who reported an injury of the same anatomic location on more than one survey, the final diagnosis reported on the last survey was used.

RESULTS

A total of 1082 runners enrolled and participated in the study.[20] 1049 runners met the inclusion criteria for the

Table 1 Running injury diagnoses and tissue type affected by anatomic location

Anatomic location	Diagnosis	Tissue type
Low back	Muscle strain	Muscle, tendon/fascia, bursa
	Pinched nerve/sciatica	Nerve
Hip	Hip flexor tendinitis or iliopsoas bursitis	Muscle, tendon/fascia, bursa
	Abductor tendinitis or trochanteric bursitis	Muscle, tendon/fascia, bursa
	Groin pull	Muscle, tendon/fascia, bursa
	Osteoarthritis	Joint
	Labral tear or impingement syndrome	Joint
	IT band syndrome at the hip	Muscle, tendon/fascia, bursa
	Stress fracture or stress reaction	Bone
Thigh	Quad strain	Muscle, tendon/fascia, bursa
	Hamstring strain/tear	Muscle, tendon/fascia, bursa
	Stress fracture or stress reaction	Bone
Knee	IT band syndrome at the knee	Muscle, tendon/fascia, bursa
	Patellar tendinitis	Muscle, tendon/fascia, bursa
	Patellofemoral syndrome or chondromalacia patella	Joint
	Osteoarthritis	Joint
	Meniscus tear	Joint
Leg	Medial tibial stress syndrome	Bone
	Calf strain/tear	Muscle, tendon/fascia, bursa
	Stress fracture or stress reaction	Bone
Ankle	Achilles tendinitis	Muscle, tendon/fascia, bursa
	Peroneal tendinitis	Muscle, tendon/fascia, bursa
	Posterior tibial tendinitis	Muscle, tendon/fascia, bursa
	Osteoarthritis	Joint
	Stress fracture or stress reaction	Bone
Foot	Plantar fasciitis	Muscle, tendon/fascia, bursa
	Neuroma	Nerve
	Osteoarthritis	Joint
	Stress fracture or stress reaction	Bone

Table 2 Demographics and baseline running information

Characteristics	Value
Age (years), mean (SD)	41.8 (10.8)
Sex, female (%)	510 (48.6%)
Body mass index, mean (SD)	23.7 (3.4)
Race, n (%)	
American Indian or Alaska Native	2 (0.2%)
Asian	90 (8.5%)
Black or African American	31 (3.0%)
White	820 (79.0%)
Other	56 (5.3%)
More than one race	22 (2.1%)
Prefer not to answer	19 (1.8%)
Ethnicity, n (%)	
Hispanic or Latino	151 (14.4%)
Not Hispanic or Latino	710 (67.7%)
Other ethnicity	155 (14.8%)
Prefer not to answer	33 (3.1%)
Marathon goal, n (%)	
Get a personal record	411 (39.2%)
Finish the race	222 (21.2%)
Have fun	208 (19.8%)
Run the whole time	77 (7.3%)
Not get injured	40 (3.8%)
Get healthy/lose weight	23 (2.2%)
Raise money for a charity	18 (1.7%)
Assist another runner	10 (1.0%)
Other	40 (3.8%)
Marathon finishing time goal (minutes), mean (SD)	245.1 (48.1)
Running distance/week in the month before the study (miles), median (IQR)	21 (15, 31)
Running days/week in the month before the study, median (IQR)	4 (3, 5))
Number of half marathons completed, median (IQR)	9 (4, 15))
Number of marathons completed, median (IQR)	3 (1, 7)

current analysis (the remainder opted out or became injured prior to the start of the observation period and were excluded). Table 2 shows summaries of their demographics and running experiences. During the study period, 142 runners stopped training because of reasons unrelated to injury or were lost to follow-up. Given that the 1049 runners were sent 5 surveys each, a total of 5245 surveys were distributed, among which 4792 (91.4%) were completed. There were 907 runners (86.5% of runners enrolled) that started the marathon and 896 that completed it (85.4% of runners, 98.8% among those who started). The mean time to finish the marathon was 4 hours and 26 min (SD 60 min).

Specific to the runners included in this analysis, injuries were reported by 398/1037 (38.4%) during training. Of the 907 runners who participated in the marathon, 128 (14.1%) reported an injury that either affected their

Table 3 Injury prevalence and overall incidence by anatomic location, tissue type and onset

	TQ1 prevalence (n=977) n (%)	TQ2 prevalence (n=991) n (%)	TQ3 prevalence (n=961) n (%)	TQ4 prevalence (n=956) n (%)	Training incidence* (n=1037) n (%)	Race incidence (n=907) n (%)	Overall incidence* (n=1049) n (%)
Runners reporting an injury	111 (11.4)	181 (18.3)	204 (21.2)	215 (22.5)	398 (38.4)	128 (14.1)	447 (42.6)
Anatomic location							
Low back	6 (0.6)	9 (0.9)	11 (1.1)	12 (1.3)	29 (2.8)	4 (0.4)	32 (3.1)
Hip	21 (2.1)	23 (2.3)	27 (2.8)	36 (3.8)	73 (7.0)	22 (2.4)	89 (8.5)
Thigh	13 (1.3)	18 (1.8)	29 (3.0)	22 (2.3)	56 (5.4)	25 (2.8)	71 (6.8)
Knee	20 (2.0)	36 (3.6)	35 (3.6)	41 (4.3)	87 (8.4)	26 (2.9)	101 (9.6)
Leg	13 (1.3)	24 (2.4)	27 (2.8)	34 (3.6)	64 (6.2)	10 (1.1)	70 (6.7)
Ankle	18 (1.8)	24 (2.4)	24 (2.5)	25 (2.6)	57 (5.5)	14 (1.5)	66 (6.3)
Foot	17 (1.7)	37 (3.7)	42 (4.4)	43 (4.5)	93 (9.0)	23 (2.5)	108 (10.3)
Other	3 (0.3)	10 (1.0)	9 (0.9)	6 (0.6)	24 (2.3)	4 (0.4)	27 (2.6)
Tissue type							
Muscle, tendon/fascia, bursa	46 (4.7)	69 (7)	88 (9.2)	97 (10.1)	190 (18.3)	62 (6.8)	217 (20.7)
Bone	14 (1.4)	14 (1.4)	23 (2.4)	25 (2.6)	46 (4.4)	12 (1.3)	54 (5.1)
Joint	4 (0.4)	15 (1.5)	12 (1.2)	15 (1.6)	35 (3.4)	7 (0.8)	38 (3.6)
Nerve	1 (0.1)	6 (0.6)	5 (0.5)	5 (0.5)	13 (1.3)	2 (0.2)	14 (1.3)
Other	25 (2.6)	36 (3.6)	44 (4.6)	40 (4.2)	114 (11)	22 (2.4)	128 (12.2)
Don't know	21 (2.1)	41 (4.1)	32 (3.3)	33 (3.5)	78 (7.5)	23 (2.5)	90 (8.6)
Onset							
Gradual onset of an overuse injury	53 (5.4)	94 (9.5)	108 (11.2)	134 (14)	236 (22.8)	66 (7.3)	257 (24.5)
Rapid onset of an overuse injury	25 (2.6)	40 (4.0)	64 (6.7)	52 (5.4)	133 (12.8)	43 (4.7)	168 (16.0)
Acute injury	19 (1.9)	38 (3.8)	25 (2.6)	21 (2.2)	76 (7.3)	17 (1.9)	91 (8.7)
Other	2 (0.2)	0	2 (0.2)	1 (0.1)	4 (0.4)	0	4 (0.4)
Don't know	12 (1.2)	9 (0.9)	5 (0.5)	11 (1.2)	30 (2.9)	2 (0.2)	32 (3.1)

*The cumulative training incidences and overall incidences do not equal the incidence of any location as different injuries/locations could be reported at each survey.
TQ, training quarter.

finishing time or required medical care after the race. The overall prevalence of injury during both training and the race was 42.6% (447/1049). The prevalence at each TQ and the overall incidence of injuries by anatomical location, tissue type and onset are shown in table 3. There was a statistically significant increase in injury prevalence from TQ1 to TQ4 (X^2 p<0.001).

The specific diagnoses (as best understood and reported by the runner) are listed in table 4.

The tissue type injured by age group is shown in table 5. Although the proportion of joint injuries was slightly higher among runners age ≥50 years (compared with the younger age groups), it was not statistically significant (X^2 p=0.38).

There were 224 runners who reported receiving medical care for their injuries during training and after the marathon, equating to 21.4% of all runners (n=1049) and 50.1% of those reporting an injury (n=447). The specific healthcare utilisation during training and after the race is shown in table 6.

DISCUSSION

In this large cohort of runners who we were prospectively following while training for and participating in the New York City Marathon, we showed a propensity during training for foot (93/1037, 9.0%), knee (87, 8.4%) and hip (73, 7.0%) injuries, whereas during the race, knee (26/907, 2.9%), thigh (25, 2.8%) and foot (23, 2.5%) injuries were the most reported. Injuries of the muscle, tendon/fascia and bursa category were the most frequent tissue type injured at each time point in this study. As expected, overuse injuries were more common than acute injuries with the prevalence of overuse injuries having steadily increased throughout training, while the prevalence of acute injuries remained more consistent. Gradual onset of an overuse injury was the most common form of symptom onset during each TQ as well as during the marathon. As for self-reported diagnoses, hamstring strain/tear had the highest incidence. The incidence of injury by age group was similar, but there was an increased

Table 4 Diagnosis by location

Anatomic location	Diagnosis	Proportion of reported injuries (n=564) n (%)
Low back	Muscle strain	14 (2.5)
	Pinched nerve/sciatica	11 (2.0)
	Other	4 (0.7)
	Don't know	3 (0.5)
Hip	Hip flexor tendinitis or iliopsoas bursitis	15 (2.7)
	Groin pull	13 (2.3)
	Abductor tendinitis or trochanteric bursitis	8 (1.4)
	IT band syndrome at the hip	8 (1.4)
	Labral tear or impingement syndrome	5 (0.9)
	Stress fracture or stress reaction	4 (0.7)
	Other	19 (3.4)
	Don't know	17 (3.0)
Thigh	Hamstring strain/tear	38 (6.7)
	Quad strain	15 (2.7)
	Stress fracture or stress reaction	5 (0.9)
	Other	11 (2)
	Don't know	2 (0.4)
Knee	IT band syndrome at the knee	25 (4.4)
	Patellofemoral syndrome or chondromalacia patella	14 (2.5)
	Patellar tendinitis	7 (1.2)
	Meniscus tear	5 (0.9)
	Osteoarthritis	5 (0.9)
	Stress fracture or stress reaction	4 (0.7)
	Other	24 (4.3)
	Don't know	17 (3)
Leg	Calf strain/tear	31 (5.5)
	Medial tibial stress syndrome	16 (2.8)
	Stress fracture or stress reaction	4 (0.7)
	Other	7 (1.2)
	Don't know	12 (2.1)
Ankle	Achilles tendinitis	23 (4.1)
	Posterior tibial tendinitis	8 (1.4)
	Stress fracture or stress reaction	7 (1.2)
	Osteoarthritis	2 (0.4)
	Peroneal tendinitis	1 (0.2)
	Other	14 (2.5)
	Don't know	11 (2.0)
Foot	Plantar fasciitis	27 (4.8)
	Stress fracture or stress reaction	14 (2.5)
	Neuroma	3 (0.5)
	Osteoarthritis	1 (0.2)
	Other	43 (7.6)
	Don't know	20 (3.5)
Other	N/A	27 (4.8)

incidence of joint injuries in older runners. Physical therapy was the most used form of medical treatment.

The predominance of knee and foot injuries has been reported in multiple studies of marathon runners.[19 21–26] In terms of knee diagnoses, IT band syndrome and patellofemoral pain/chondromalacia patella were most common in our cohort of marathon runners, which is consistent with a literature review of the epidemiology and aetiology of injuries in marathon runners by Fredericson *et al*.[27] As for diagnoses of the foot and ankle, our data support prior RRI evidence that Achilles tendinosis and plantar fasciitis are the most common injuries to those anatomic locations. Di Caprio *et al* observed 166 runners over 4 years and reported that the most common injuries were plantar fasciitis (31%) and Achilles tendinopathy (24%).[28] The pattern of knee and foot injuries was also described by Lopes *et al*, in a systematic review of ultramarathon runners where the rates of patellofemoral pain and Achilles tendinopathy were higher than any other anatomic location.[29] Additionally, a high rate of hamstring injuries among marathon runners was reported by Longo *et al*, who collected injury questionnaires from 700 runners of the 2019 Rome Marathon.[30] Within our cohort, thigh injuries were the second most common race injury location, of which the majority (54%) were attributed to hamstring injuries.

The overall incidence of injury was consistent between age groups, as was the distribution of injuries by tissue type affected. The prevalence of lower extremity joint injury in the two older age groups (5.0% and 6.7%) in this study was less than the prevalence of knee osteoarthritis in the general population of 55–60-year-olds (almost 10%).[31 32] Despite perceptions about the negative impact of running on knee health,[33] several recent systematic reviews suggest no difference in rates of knee osteoarthritis, progression of knee arthritis symptoms, patient-reported outcomes or radiologic progression of knee osteoarthritis in populations of runners compared with non-runners.[34 35] Further research is needed to determine the true effect of running on knee osteoarthritis.

The information presented here can help refine other analyses of risk factors for injury. Our previous analysis of training patterns associated with injury from this cohort of runners showed that rapid increases in training as measured by the acute to chronic workload ratio were associated with increased injuries.[20] However, this analysis of training patterns did not differentiate acute versus overuse injuries or soft tissue versus bone/joint. If a larger cohort of runners can be similarly measured, by involving multiple marathons or multiple years, the training patterns associated with injury could be identified for specific injury onset patterns and tissue types. Additionally, a better understanding of the type and onset of injury may help inform future injury prevention programmes for runners by identifying potentially preventable injuries. Specifically, training modifications may prevent overuse injuries in general, whereas strength

Table 5 Injury tissue type by age

Tissue type	≥18 and <30 (n=174) n (%)	≥30 and <40 (n=313) n (%)	≥40 and <50 (n=303) n (%)	≥50 and <60 (n=199) n (%)	≥60 (n=60) n (%)
Any tissue type	76 (43.7)	136 (43.5)	126 (41.6)	83 (41.7)	26 (43.3)
Muscle, tendon/fascia, bursa	35 (20.1)	67 (21.4)	62 (20.5)	43 (21.6)	10 (16.7)
Bone	11 (6.3)	18 (5.8)	14 (4.6)	10 (5.0)	1 (1.7)
Joint	7 (4.0)	8 (2.6)	9 (3.0)	10 (5.0)	4 (6.7)
Nerve	1 (0.6)	4 (1.3)	2 (0.7)	5 (2.5)	2 (3.3)
Other	24 (13.8)	31 (9.9)	37 (12.2)	29 (14.6)	7 (11.7)
Don't know	16 (9.2)	20 (6.4)	32 (10.6)	14 (7.0)	8 (13.3)

training interventions may prevent soft tissue (muscle, tendon/fascia, and bursa) injuries. This estimate of potentially preventable injuries is needed to accurately power future interventional studies.

More than half of the injured runners in our study (50.1%) reported receiving some form of medical care with the most common being physical therapy, which was similarly observed in a cohort of 1696 novice runners by Smits *et al*.[14] Wayner *et al* also showed that the use of rehab services was the predominant form of medical utilisation when looking at bone stress injuries in cross-country runners (168 bone stress injuries generating 1764 athletic training services and 117 physician encounters).[36] For the purpose of this study, seeking out physician services, physical therapy or other medical services was weighted equally whether that entailed one visit or several. While X-ray was the most used imaging modality, the use of MRI was notable. We found that 1 in 23 marathon runners get at least one MRI during training or in the week following a marathon. If this cohort was representative of all registrants of the 2019 New York City Marathon, which had 54 205 starters, this translates to over 2300 MRIs performed for injuries related to training for the marathon before accounting for those that were unable to start the race due to injury. This represents a significant use of healthcare resources and costs stemming from marathon running.[37] Future directions may evaluate whether this cost is offset by any potential reduction in the financial burden of chronic disease that may be reduced from running. In addition, future directions may look into the injury patterns of the 49.9% of runners who did not seek medical care and how they compare with those who did seek medical care.

Table 6 Healthcare utilisation

Type of medical care	Training (n=1037) n (%)	Postrace (n=907) n (%)	Overall (n=1049) n (%)
Any medical care	193 (18.6)	71 (7.8)	224 (21.4)
Physical therapy	115 (11.1)	44 (4.9)	138 (13.2)
MD or DO evaluation	91 (8.8)	27 (3)	107 (10.2)
Massage therapy	74 (7.1)	30 (3.3)	88 (8.4)
X-ray	62 (6.0)	17 (1.9)	73 (7.0)
MRI	41 (4.0)	8 (0.9)	45 (4.3)
Chiropractic care	38 (3.7)	14 (1.5)	44 (4.2)
Acupuncture	36 (3.5)	10 (1.1)	39 (3.7)
Prescription medication	26 (2.5)	10 (1.1)	32 (3.1)
Podiatrist evaluation	19 (1.8)	9 (1.0)	25 (2.4)
Ultrasound	15 (1.4)	7 (0.8)	20 (1.9)
Orthotics	17 (1.6)	6 (0.7)	19 (1.8)
Brace	15 (1.4)	6 (0.7)	18 (1.7)
Injection	14 (1.4)	3 (0.3)	16 (1.5)
CT scan	4 (0.4)	1 (0.1)	5 (0.5)
Other	16 (1.5)	6 (0.7)	21 (2.0)

DO, Doctor of Osteopathic Medicine; MD, Doctor of Medicine.

Strengths and limitations

This study included a large cohort of runners training for the same event, with frequent injury surveillance surveys and a high response rate. This robust dataset allows for a better understanding of the types of injuries experienced by marathon runners, the timing of when injuries occur and the medical care received. By using a self-reported survey, we captured injury data from runners who received care during the race as well as those who did not receive medical care until after the race. Given that an injury in this study was defined as having affected training or marathon participation, pain or dysfunction that does not limit training was not captured in this study. With an injury defined as having affected training or marathon participation, runners who elect to run through an injury/pain may go unreported. Diagnoses were self-reported and hence not extracted from medical records or recorded by clinicians directly. This may lead to misclassification of both the specific diagnoses and the tissue type. Our study participants may have a stronger bias towards seeking medical care, limiting the translation of our results to the overall collection of marathon runners. Further limitations include the large time frame of each TQ. Evaluation on a more frequent basis with smaller sections of the training time in between may help to further elicit when/how injuries occur relative to training.

CONCLUSION

This study analysed injury data from 1049 runners from a single marathon and demonstrated an overall injury prevalence of 43%. We found that knee (with 8.4% during training and 2.9% during race) and foot injuries (with 9.0% during training and 2.5% during race) were the most common conditions at all time points and increased as the training cycle progressed. Hamstring injuries were the most common diagnosis. Older runners have similar overall incidence of injury and distribution of affected tissue types. Half of the runners who reported an injury received medical care, predominantly physical therapy services.

Twitter Todd Michael McGrath @mcgrathtodd and Brett Gregory Toresdahl @bretttoresdahl

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ORCID iD

Todd Michael McGrath http://orcid.org/0009-0000-4973-9947

REFERENCES

1 Hulteen RM, Smith JJ, Morgan PJ, *et al*. Global participation in sport and leisure-time physical activities: A systematic review and meta-analysis. *Prev Med* 2017;95:14–25.
2 Anderson JJ. The state of running 2019. 2023. Available: https://runrepeat.com/state-of-running
3 Chandran A, Morris SN, Boltz AJ, *et al*. Epidemiology of injuries in national collegiate athletic Association women's cross-country: 2014-2015 through 2018-2019. *J Athl Train* 2021;56:622–8.
4 Chandran A, Morris SN, Boltz AJ, *et al*. Epidemiology of injuries in national collegiate athletic Association men's cross-country: 2014-2015 through 2018-2019. *J Athl Train* 2021;56:629–35.
5 Mann RH, McKay CD, Clift BC, *et al*. Injuries and training practices in competitive adolescent distance runners: A retrospective cross-sectional study. *Front Sports Act Living* 2021;3:664632.
6 Fokkema T, Varkevisser N, de Vos R-J, *et al*. Factors associated with running-related injuries in recreational runners with a history of running injuries. *Clin J Sport Med* 2023;33:61–6.
7 Rasmussen CH, Nielsen RO, Juul MS, *et al*. Weekly running volume and risk of running-related injuries among Marathon runners. *Int J Sports Phys Ther* 2013;8:111–20.
8 van der Worp MP, ten Haaf DSM, van Cingel R, *et al*. Injuries in runners; a systematic review on risk factors and sex differences. *PLoS One* 2015;10:e0114937.
9 Mohseni MM, Filmalter SE, Taylor WC, *et al*. Factors associated with Half- and full-Marathon race-related injuries: A 3-year review. *Clin J Sport Med* 2021;31:e277–86.
10 Damsted C, Parner ET, Sørensen H, *et al*. Projectrun21: do running experience and running pace influence the risk of running injury-A 14-week prospective cohort study. *J Sci Med Sport* 2019;22:281–7.
11 Franke TPC, Backx FJG, Huisstede BMA. Running themselves into the ground? incidence, prevalence, and impact of injury and illness in runners preparing for a half or full Marathon. *J Orthop Sports Phys Ther* 2019;49:518–28.
12 Hespanhol Junior LC, Huisstede BMA, Smits D-W, *et al*. The NIstart2Run study: economic burden of running-related injuries in novice runners participating in a novice running program. *J Sci Med Sport* 2016;19:800–4.
13 Clough PJ, Shepherd J, Maughan RJ. Marathon Finishers and pre-race drop-outs. *Br J Sports Med* 1989;23:97–101.
14 Smits D-W, Huisstede B, Verhagen E, *et al*. Short-term absenteeism and health care utilization due to lower extremity injuries among novice runners: A prospective cohort study. *Clin J Sport Med* 2016;26:502–9.
15 Cloosterman KLA, Fokkema T, de Vos R-J, *et al*. Educational online prevention programme (the SPRINT study) has no effect on the number of running-related injuries in recreational runners: a randomised-controlled trial. *Br J Sports Med* 2022;56:676–82.
16 Alexander JLN, Culvenor AG, Johnston RRT, *et al*. Strategies to prevent and manage running-related knee injuries: a systematic review of randomised controlled trials. *Br J Sports Med* 2022;56:1307–19.
17 Relph N, Greaves H, Armstrong R, *et al*. Running shoes for preventing lower limb running injuries in adults. *Cochrane Database Syst Rev* 2022;8:CD013368.
18 Anderson LM, Martin JF, Barton CJ, *et al*. What is the effect of changing running step rate on injury, performance and Biomechanics? A systematic review and meta-analysis. *Sports Med Open* 2022;8:112.
19 Kakouris N, Yener N, Fong DTP. A systematic review of running-related musculoskeletal injuries in runners. *J Sport Health Sci* 2021;10:513–22.
20 Toresdahl BG, Metzl JD, Kinderknecht J, *et al*. Training patterns associated with injury in New York City Marathon runners. *Br J Sports Med* 2023;57:146–52.
21 van Gent RN, Siem D, van Middelkoop M, *et al*. Incidence and determinants of lower extremity running injuries in long distance runners: a systematic review. *Br J Sports Med* 2007;41:469–80;
22 Lysholm J, Wiklander J. Injuries in runners. *Am J Sports Med* 1987;15:168–71.
23 Hsu C-L, Yang C-H, Wang J-H, *et al*. Common running musculoskeletal injuries and associated factors among recreational gorge Marathon runners: an investigation from 2013 to 2018 Taroko gorge Marathons. *Int J Environ Res Public Health* 2020;17:8101.
24 Vitez L, Zupet P, Zadnik V, *et al*. Running injuries in the participants of Ljubljana Marathon. *Zdr Varst* 2017;56:196–202.
25 Desai P, Jungmalm J, Börjesson M, *et al*. Recreational runners with a history of injury are twice as likely to sustain a running-related injury as runners with no history of injury: A 1-year prospective cohort study. *J Orthop Sports Phys Ther* 2021;51:144–50.
26 Maughan RJ, Miller JD. Incidence of training-related injuries among Marathon runners. *Br J Sports Med* 1983;17:162–5.
27 Fredericson M, Misra AK. Epidemiology and Aetiology of Marathon running injuries. *Sports Med* 2007;37:437–9.
28 Di Caprio F, Buda R, Mosca M, *et al*. Foot and lower limb diseases in runners: assessment of risk factors. *J Sports Sci Med* 2010;9:587–96.

29 Lopes AD, Hespanhol Júnior LC, Yeung SS, *et al*. What are the main running-related musculoskeletal injuries. *Sports Med* 2012;42:891–905.
30 Longo UG, Stelitano G, Berton A, *et al*. Rome Marathon, hamstring injuries in long distance runners: influence of age, gender, weight, height, number of Marathons and impact profile. *J Sports Med Phys Fitness* 2019;61:1653–60.
31 Peat G, McCarney R, Croft P. Knee pain and osteoarthritis in older adults: a review of community burden and current use of primary health care. *Ann Rheum Dis* 2001;60:91–7.
32 Losina E, Weinstein AM, Reichmann WM, *et al*. Lifetime risk and age at diagnosis of symptomatic knee osteoarthritis in the US. *Arthritis Care Res (Hoboken)* 2013;65:703–11.
33 Esculier J-F, Besomi M, Silva D de O, *et al*. Do the general public and health care professionals think that running is bad for the knees? A cross-sectional International Multilanguage online survey. *Orthop J Sports Med* 2022;10:23259671221124141.
34 Burfield M, Sayers M, Buhmann R. The association between running volume and knee osteoarthritis prevalence: A systematic review and meta-analysis. *Phys Ther Sport* 2023;61:1–10.
35 Dhillon J, Kraeutler MJ, Belk JW, *et al*. Effects of running on the development of knee osteoarthritis: an updated systematic review at short-term follow-up. *Orthop J Sports Med* 2023;11:23259671231152900.
36 Wayner RA, Brown CN, Bovbjerg VE, *et al*. Epidemiology of bone stress injuries and Healthcare utilization in PAC-12 cross-country athletes. *J Athl Train* July 18, 2023.
37 NYRR. By the Numbers: 2019 TCS New York City Marathon Becomes World's Largest Marathon, Available: https://www.nyrr.org/media-center/press-release/20191105_tcsnycmbythenumbers