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Cost and Treatment Characteristics of Sport-Related Knee Injuries Managed by Athletic Trainers: A Report From the Athletic Training Practice-Based Research Network

Kenneth C. Lam, ScD, ATC*; Ashley N. Marshall, PhD, ATC†; Cailee E. Welch Bacon, PhD, ATC*; Tamara C. Valovich McLeod, PhD, ATC*

*Department of Interdisciplinary Health Sciences, A.T. Still University, Mesa, AZ; †Department of Health and Exercise Science, Appalachian State University, Boone, NC

Context: Knee injuries are common during sport participation. However, little is known about the overall management and estimated direct costs of care associated with these injuries when under the care of athletic trainers.

Objective: To describe the treatment characteristics and direct costs of care for athletic training services provided for patients with knee injuries.

Design: Descriptive study.

Setting: Ninety-five athletic training facilities across 24 states.

Patients or Other Participants: A total of 117 athletic trainers (females = 56.4%, age = 29.4 ± 8.7 years, years certified = 4.7 ± 6.0, years employed at site = 1.6 ± 4.1).

Main Outcome Measure(s): Complete patient cases were identified using International Classification of Disease-10 diagnostic codes between 2009 and 2020. Summary statistics were calculated for patient demographics, treatment characteristics, and direct costs of care. Treatment characteristics included the type of athletic training service, duration, amount (eg, number of visits), and direct costs of care.

Results: A total of 441 patient cases were included. The most common injuries reported were cruciate ligament sprain (18.1%, n = 80), medial collateral ligament sprain (15.4%, n = 68), and knee pain (14.1%, n = 62). Injuries occurred most frequently during football (35.4%, n = 156), basketball (14.7%, n = 65), and soccer (12.7%, n = 56). A total of 8484 athletic training services were recorded over 4254 visits, with therapeutic exercise (29.8%, n = 2530), hot or cold pack (25.8%, n = 2189), and therapeutic activities (11.2%, n = 954) being the most frequently reported services. The median duration of care was 23 days and number of visits was 8. The median total cost of care was $564 per injury and $73 per visit.

Conclusions: Patients with knee injuries demonstrated greater time loss than those with other lower extremity injuries. Thus, it is unsurprising that knee injuries were associated with a longer duration and higher cost of care than other lower extremity injuries such as ankle sprains. Future researchers should examine the effectiveness of common treatment strategies and aim to identify treatments that can reduce costs and improve patient outcomes.

Key Words: value, worth, quality, patient care, point of care

Key Points

- When compared with ankle sprains, knee injuries typically required larger amount of care, longer duration of care, and higher direct costs.
- After a knee injury, the median estimated cost over the duration of care was $564 (mode = $160, interquartile range = $267–$1080, range = $0–$2160).
- Future investigators should assess the effectiveness of common treatment strategies and seek to identify treatments that can decrease costs and enhance patient outcomes.

Knee injuries are common among athletes during sport activities, particularly those that require dynamic movements (eg, cutting and jump stopping) such as football, basketball, and soccer.[1,2] Although the ankle represents the body part injured most frequently during sport activities,[3] the knee accounts for the largest percentage of severe injuries (ie, injuries causing >21-day loss in participation).[4,5] Furthermore, a reported 21% of all sport-related knee injuries required some form of surgical intervention[5] and sport-related knee injuries were associated with short-term and long-term consequences,[6] including osteoarthritis[7] and an increased need for total knee replacement later in life.[8] Due to the frequency and potential consequences of these injuries, it is important to understand how these patients are cared for and managed at the time of injury.

Historically, clinicians and researchers have relied on epidemiologic studies to gain a better understanding of injury characteristics (eg, sport, sex, time of injury, and diagnosis). However, in general, limited information is

available regarding the treatment and management of athletic injuries. Recently, investigators have begun providing insight into treatment characteristics of injuries (eg, type, amount, and duration of care) for different sports[9,10] and body parts.[11–13] For example, Grooms et al[13] stated that the average patient who sustained a knee injury used 12 athletic training services across 4 visits, with therapeutic activities or exercise being the most commonly reported service. Although these findings offer insight into the care and management provided by athletic trainers (ATs) to patients with knee injuries, the available evidence on treatment characteristics is otherwise limited.

Similarly, the evidence related to the estimated direct costs of care for knee injuries under the care of ATs is limited. An understanding of the estimated direct costs of care for services provided by ATs is important for clinicians and the profession as a whole, particularly in the context of demonstrating the worth and value[14–16] of a typical AT. Recently, Marshall et al[11] found that ankle sprains were associated with median costs estimated at $360 per patient case (interquartile range = $145 to $572). However, to our knowledge, no other researchers have described the estimated direct costs of care associated with the care provided by ATs for patients with knee injuries. Therefore, the purpose of our study was to describe treatment characteristics and direct costs of care for services provided by ATs to patients with knee injuries.

METHODS

Design and Setting

We conducted a retrospective analysis of patient records in the Athletic Training Practice-Based Research Network (AT-PBRN).[9,17] The patient records were collected between 2009 and 2020 during routine care by ATs practicing at 95 clinical practice sites (secondary schools = 79, colleges = 11, military = 3, other = 2) across 24 states that represented the South (n = 7), Midwest (n = 6), Northeast (n = 5), West (n = 5), and Pacific (n = 1) regions of the United States as classified by the US Census Bureau.[18]

Participants

A total of 117 ATs worked at these clinical practice sites during the study period. Most ATs were female (56.4%, n = 66); they were 29.4 ± 8.7 years old, certified for 4.7 ± 6.0 years, and employed at their current site for 1.6 ± 4.1 years at the time of treatment. This study was deemed exempt by the university's institutional review board, as it was a retrospective analysis of deidentified patient records.

Procedures

Data were recorded in the AT-PBRN's electronic medical record (EMR) by ATs who completed a training session[17] before data collection. We used data-extraction procedures that were similar to those detailed by Marshall et al,[11] who reported treatment and cost characteristics for ankle sprains. In short, one research team member (A.N.M.), who was responsible for the daily management of the EMR's relational database, completed the data extraction for quality-assurance procedures.[19] Patient cases were first identified by the injured body region (knee) on the injury demographic form. Next, using the unique identifier (ie, injury identification number) associated with each patient case, we identified and extracted the remaining study variables from other EMR forms (ie, injury evaluation, daily treatment, and discharge forms) for analysis. Consistent with Marshall et al, we included only complete patient cases in the EMR to address known challenges related to patient documentation (eg, incomplete records and patients without recorded discharge forms)[12,20–22] and obtain the best estimate of treatment and costs characteristics related to the care of patients with knee injuries.[11] *Complete patient cases* were operationalized as cases that had (1) an injury demographics form, (2) an injury evaluation, (3) daily treatment forms with at least 1 encounter per week for the duration of care, and (4) a discharge form.[11]

Instrumentation

The CORE-AT EMR (www.core-at.com) is a web-based, Health Insurance Portability and Accountability Act–compliant patient-documentation system that features standard documentation forms, an injury-surveillance feature, and patient-oriented outcome forms. In-depth descriptions of the features and functionality of the CORE-AT EMR have been provided.[9,17,23] For the current study, we extracted variables from a variety of forms in the EMR.

Patient characteristic variables were extracted from the demographics form and included sex, sport, activity during injury (ie, practice and competition), mechanism of injury, and diagnosis (International Classification of Disease [ICD] diagnostic codes).[9,11,17] The study period included the transition between versions 9 and 10 of the ICD coding system that occurred in 2015. In the EMR, ICD codes were cross-walked between the 2 coding versions during this transition. Thus, we reported ICD codes as version 10.

Treatment characteristic variables were extracted from the evaluation, discharge forms from the EMR, and encompassed the type of service (Current Procedural Terminology [CPT] code), amount of care (number of visits, number of services per visit, and number of services per patient case), and duration of care (number of days between intake and discharge).[9–11] A *service* was defined as an application of any type of care provided and operationalized by a CPT code.[9–11] A *visit* was defined as 1 encounter in the athletic training clinic.[9–11] The calculations for the number of visits (sum of visits divided by the sum of patient cases), number of services per visit (sum of services divided by the sum of visits), and number of services per patient case (sum of services divided by the sum of patient cases) were based on previous studies[9–13] on the treatment characteristics of injuries managed by ATs.

Cost characteristics were calculated using the CPT codes in the EMR and the direct cost of care values reported by the Centers for Medicare and Medicaid Services (CMS) Physician Fee Schedule.[24] The CPT codes were recorded on the evaluation, daily treatment, and discharge forms of the EMR[11] and reported in 15-minute increments (eg, 8–22 minutes of care = 1 unit of care).[25] The direct cost of care value for each CPT code was identified in the CMS Physician Fee Schedule for nonfacility (ie, nonhospital) organizations.[24] Because the CMS Physician Fee Schedule changes on an annual basis, the direct cost of care values were identified for each year of the study period and used to

Table 1. Current Procedural Terminology (CPT) Codes, Mean Fees, and Fee Ranges for Each Athletic Training Service Recorded for Knee Injuries During the Study Period (2009–2020)

Treatment or Procedure	CPT Code	Service or Time Based	Mean Fee, $	Fee Range, $
Aquatic therapy	97113	Service	40.87	34.26–43.78
Athletic trainer evaluation	97005	Service	76.85	69.97–86.49
Athletic trainer re-evaluation	97006	Service	45.39	37.51–58.74
Electrical stimulation	97014	Service	18.42	16.23–19.40
Gait training	97116	Time	27.41	24.53–28.75
Hot or cold pack	97010	Service	0.00	0.00–0.00
Infrared	97026	Service	5.77	5.05–6.12
Iontophoresis	97033	Time	28.51	22.25–33.06
Manual therapy techniques	97140	Time	28.95	25.97–30.51
Massage	97124	Time	25.33	22.36–26.95
Neuromuscular reeducation	97112	Time	32.36	28.85–34.45
Physical performance test or measurement	97750	Time	32.20	28.85–33.67
Strapping: knee	29530	Service	43.19	28.75–53.76
Therapeutic activities (procedure)	97110	Time	33.66	29.57–35.53
Therapeutic exercises ("ing" code)	97530	Time	31.11	28.13–33.02
Ultrasound	97035	Time	12.45	11.54–12.94
Vasopneumatic devices	97016	Service	18.29	15.15–19.74
Whirlpool	97022	Service	21.94	17.31–24.05

calculate the cost of care estimates based on the year each CPT code was recorded in the EMR. The CPT code, type of service (time based or service based), mean fee, and range of fees for each athletic training service recorded during the study period (2009–2020) are summarized in Table 1. For time-based CPT codes, the cost was calculated by multiplying the number of units of care by the direct cost of care per visit.[26] For service-based CPT codes, only 1 unit of care per visit is permissible for reimbursement, regardless of the time spent on the service. For this study, costs were reported per visit and per patient case.[26]

Analysis

We used frequency counts, percentages, means, and standard deviations to describe demographic variables as appropriate. Normality of data was assessed using the Kolmogorov-Smirnov test and visual inspection of box-plots.[27] Several variables (amount of care, duration of care, and cost of care) revealed skewed distributions. As a result, these variables were summarized using the average (median and mode), interquartile range (IQR), and range of scores. Furthermore, patient cases that exceeded 1.5 times the IQR were identified as *outliers* and removed from the final analysis.[27] We used SPSS (version 26; IBM Corp) for all analyses.

RESULTS

Patient Cases

Between 2009 and 2020, a total of 5643 knee injuries were reported in the AT-PBRN via an injury demographics form. A flow diagram that illustrates how patient cases were identified based on the operationalization of complete knee cases is provided in Figure 1. Based on our inclusion criteria, a total of 533 complete patient cases were identified. After examination for normality and visual inspection of the data, we identified 92 patient cases as outliers and subsequently removed these from the dataset. Thus, a total of 441 patient cases were analyzed.

Patient Characteristics

Our study sample consisted of 300 males (68.0%) and 141 females (32.0%; age = 17.4 ± 3.2 years, height = 173.8 ± 12.5 cm, mass = 79.4 ± 20.7 kg). The most frequently recorded injuries were cruciate ligament sprain (ICD-10 code: S83.509A, n = 80 [18.1%]), medial collateral ligament sprain (ICD-10 code: S83.419A, n = 68 [15.4%]), and knee pain (ICD-10-code: M25.569, n = 62 [14.1%]; Table 2). The injuries occurred most commonly during football (35.4%, n = 156), basketball (14.7%, n = 65), and soccer (12.7%, n = 56; Figure 2). Injury

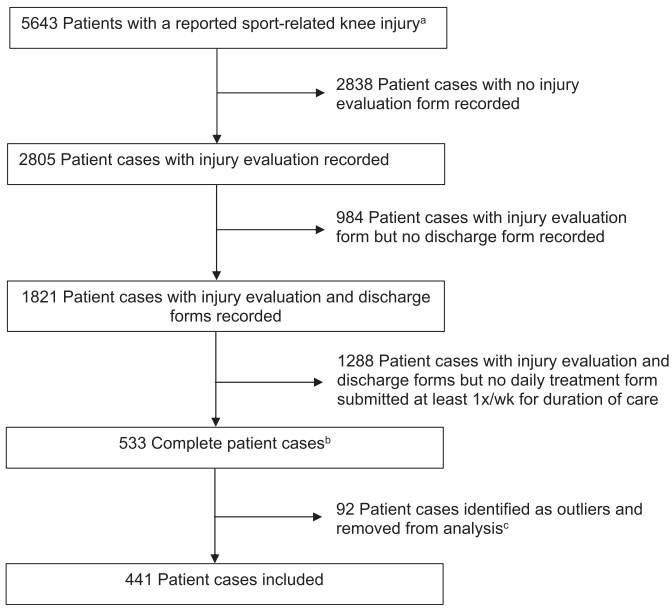

Figure 1. Flow diagram for selection of the study cohort.
[a] Identified by a injury demographics form submitted to the electronic medical record.
[b] Complete patient cases were operationalized as cases that had (1) an injury demographics form, (2) an injury evaluation, (3) daily treatment forms with at least 1 encounter per week for the duration of care, and (4) a discharge form.
[c] *Outliners* were defined as patient cases that exceeded 1.5 times the interquartile range.

Table 2. Knee Injuries by Diagnosis

Diagnosis Type	No. (%)
Ligamentous	
Cruciate sprain	80 (18.1)
Medial collateral sprain	68 (15.4)
Lateral collateral sprain	16 (3.6)
Muscular	
Patellar tendinitis	31 (7.0)
Strain (unspecified)	25 (5.7)
Iliotibial band syndrome	13 (2.9)
Quadriceps strain	8 (1.8)
Quadriceps tendinitis	1 (0.2)
Cartilaginous	
Meniscal tear	51 (11.6)
Articular cartilage lesion	3 (0.7)
Dislocation or subluxation	
Patellar dislocation or subluxation	31 (7.0)
Degenerative or chronic	
Chondromalacia patella	3 (0.7)
Plica	2 (0.5)
Internal derangement	2 (0.5)
Miscellaneous	
Knee pain	62 (14.1)
Contusion	38 (8.6)
Bursitis	4 (0.9)
Osgood-Schlatter syndrome	2 (0.5)
Loose body	1 (0.2)
Total	441 (100.0)

mechanisms were mostly noncontact (67.8% [n = 299] versus 32.2% [n = 142] noncontact).

Treatment Characteristics

A total of 8484 athletic training services were recorded over 4254 visits. The median duration of care was 23 days (mode = 7, IQR = 11–49, range = 1–106), with 19 patient cases lasting more than 90 days (Figure 3). Patients visited the athletic training clinic a median of 2 times per week (mode = 1, IQR = 1–3, range = 1–7) for the duration of care. Patients with knee injuries received a median of 2 athletic training services per visit (mode = 2, IQR = 2–3, range = 1–6), with therapeutic exercises (CPT 97110 = 29.8%), hot or cold pack (CPT 97010 = 25.8%), therapeutic activities (CPT 97530 = 11.2%), AT reevaluation (CPT 97006 = 10.5%), and AT evaluation (CPT 97005 = 5.6%) as the most frequently reported services. A comprehensive list of all reported athletic training services captured during the study period can be found in Figure 4. For each visit, a median of 3 units of service (mode = 2, IQR = 2–3, range = 1–6) were provided to the patient. From intake to discharge, patients with knee injuries received a median total of 16 athletic training services (mode = 5, IQR = 8–27, range = 1–105) over 8 visits to the athletic training clinic (mode = 3, IQR = 5–14, range = 1–27; Figure 5).

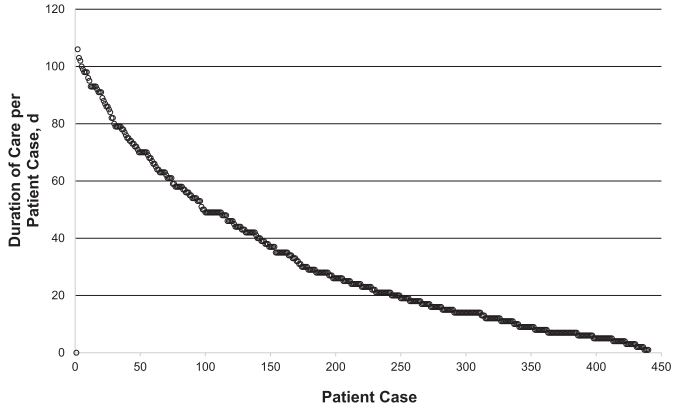

Figure 3. Distribution of duration of care (days) per patient case for sport-related knee injuries under the care of athletic trainers (median = 23, mode = 7, interquartile range = 11–49, range = 1–106 days).

Cost Characteristics

The median estimated direct cost of care per visit was $73 (mode = $53, IQR = $53–$92, range = $0–$171). The median estimated cost of care over the duration of care was $564 (mode = $160, IQR = $267–$1080, range = $0–$2160; Figure 6). The distribution of the estimated direct costs of care by the 10 most commonly reported diagnoses is shown in Table 3.

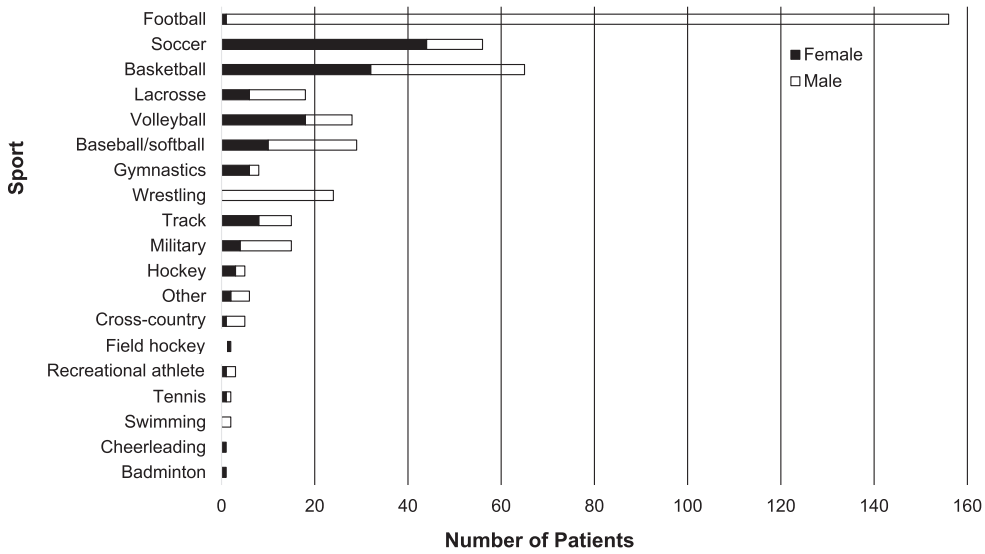

Figure 2. Patients cases by sport and sex.

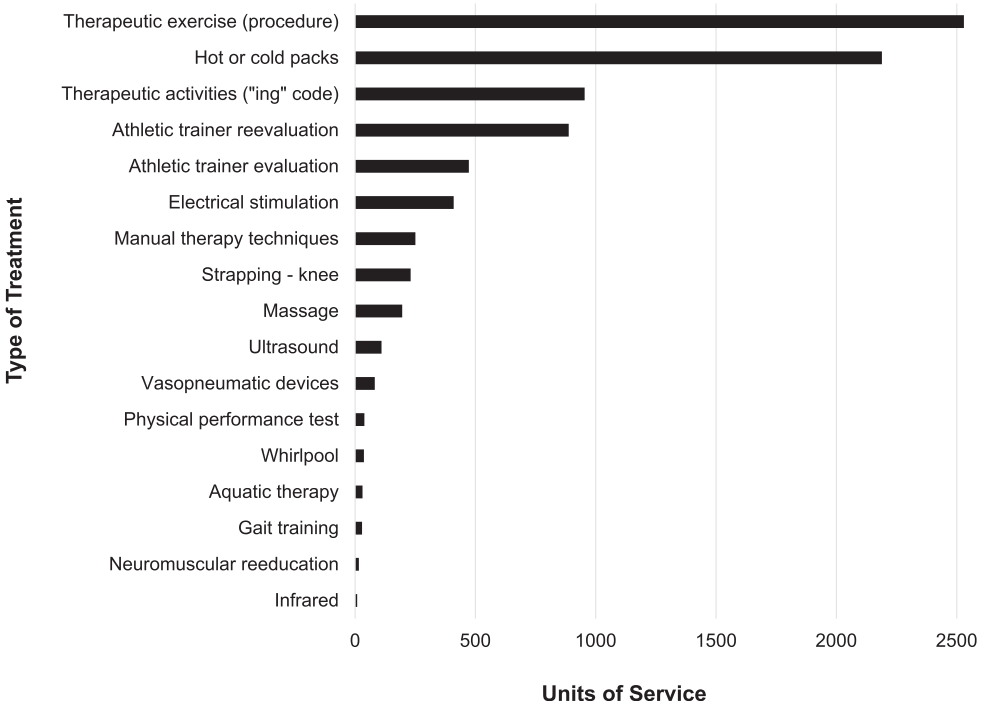

Figure 4. Treatments provided by athletic trainers for sport-related knee injuries.

DISCUSSION

To the best of our knowledge, we are the first researchers to describe patient, treatment, and cost characteristics specific to complete patient cases evaluated and managed by ATs after a knee injury. In our study, patient characteristics were similar to those reported by previous researchers in epidemiologic studies.[27,28] Specifically, patients sustained knee injuries most often during participation in football, soccer, and basketball, and most sport-related knee injuries were diagnosed as ligamentous sprains. Interestingly, we found that knee pain was a frequent diagnosis among patients experiencing a knee injury, which has not been reported by the authors of earlier injury-surveillance investigations.[2,13] This difference may be due to the methods by which diagnoses were recorded in the respective studies. For example, studies from the National Athletic Treatment, Injury and Outcomes Network[13] or High School Reporting Information Online[14] did not appear to have an ICD-10 code for knee pain, which may have instead been captured under the *other* category in those data-collection systems.

In terms of treatment characteristics, therapeutic exercises were reported to be the most common service provided to patients with a sport-related knee injury, which is consistent with previous publications[11–13] on the treatment of sport-related lower extremity injuries and likely highlights the use of rehabilitative techniques by ATs in caring for their patients. In addition, sport-related knee injuries required 8 visits (IQR = 5–14) and 16 (IQR = 8–27) athletic training services per patient care. The variability in these treatment characteristics may be associated with the different types of injuries encountered by the ATs. For example, the treatment and recovery time for a muscular strain is typically shorter than for an anterior collateral ligament sprain. Our results suggested that knee injuries

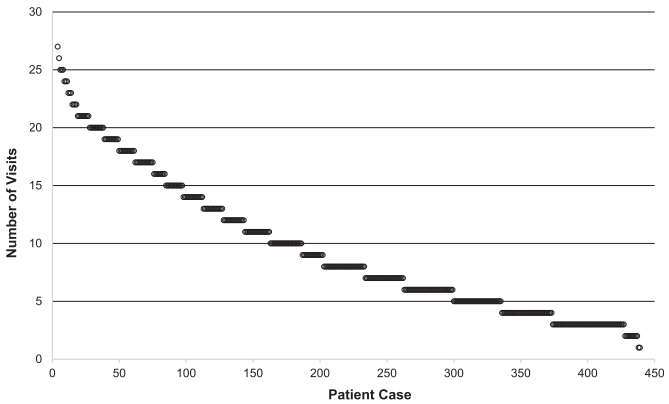

Figure 5. Distribution of visits per patient case for sport-related knee injuries under the care of athletic trainers (median = 8, mode = 3, interquartile range = 5–14, range = 1–27).

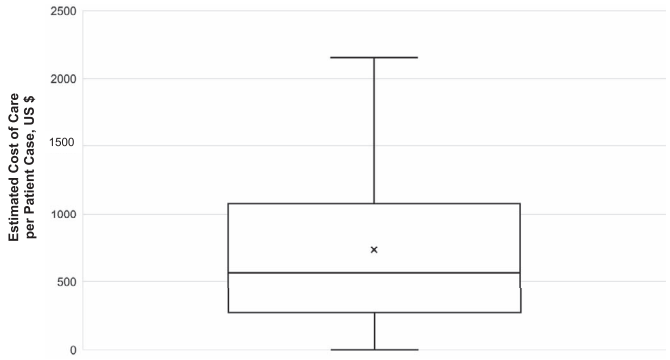

Figure 6. Estimated direct costs of care per patient case for sport-related knee injuries under the care of athletic trainers (mean = $733, median = $564, mode = $160, interquartile range = $267–$1080, range = $0–$2160).

Table 3. Estimated Direct Costs of Care Per Patient Case for the 10 Most Commonly Reported Sport-Related Knee Injury Diagnoses

Diagnosis	No. (%)	$		
		Median Cost	Interquartile Range	Range
Cruciate sprain	80 (18.1)	1176	777–1594	0–2160
Patellar dislocation or subluxation	31 (7.0)	1108	620–1508	178–1982
Meniscal tear	51 (11.6)	638	337–1309	75–1987
Strain (unspecified)	25 (5.7)	453	168–672	75–1807
Patellar tendinitis	31 (7.0)	451	266–1028	75–2027
Knee pain	62 (14.1)	436	202–941	39–1801
Medial collateral ligament sprain	68 (15.4)	434	248–807	75–2001
Lateral collateral ligament sprain	16 (3.6)	335	205–604	108–1643
Iliotibial band syndrome	13 (2.9)	319	240–739	215–960
Contusion	38 (8.6)	239	170–442	75–1790

required, on average, more visits and a longer duration of care than ankle sprains.[11] This discrepancy may reflect the difference in injury severities. For example, previous researchers[4,5] stated that although ankle injuries accounted for most injuries during sports, knee injuries accounted for the largest percentage of severe injuries.

Our findings differ from those of Grooms et al,[13] who observed that patients required an average of 4 visits and 12 athletic training services per patient case. These differences are likely due to differences in methods between our work and that of Grooms et al. For instance, due to known challenges to patient documentation (eg, incomplete records),[12,20–22] we decided to include only complete patient cases (ie, cases with completed injury evaluation, treatment, and discharge forms) because these cases likely reflect the most complete level of care. In contrast, Grooms et al[13] included all patient cases that reported to the athletic training clinic, regardless of whether the patient was lost to follow up or formally discharged from the AT's care. Therefore, we noted a larger number of visits and athletic training services because our data probably included more time-loss injuries than did Grooms et al, who described abrasions and contusions as the most common knee conditions documented by ATs in the high school setting. Despite these differences, both studies provided much needed insight into the treatment and management of patients who are under the care of ATs, which may begin to offer us ways to contextualize the effect of ATs as health care providers.[29]

Understanding treatment characteristics is important from a clinical perspective, as it allows clinicians to better estimate the overall demands of injuries and sports.[28,30] The NATA "Appropriate Medical Coverage of Intercollegiate Athletics"[31] and "Appropriate Medical Coverage for Secondary Schools"[30,32] documents recommended that medical coverage should be determined by a number of variables, including the overall demands of injuries and sport. We highlight the importance of understanding the intricate variations in treatment characteristics based on injury diagnosis. That is, even though ankle injuries are most common, knee injuries likely result in a greater time burden because they require more visits and longer durations of care. Researchers need to better understand how patients with different injuries are specifically treated. Additionally, future investigators should aim to describe the treatment characteristics for a wide range of injuries ATs encounter during routine clinical practice to further illustrate the AT's effect on the global health care system.

Limited evidence is available regarding the costs associated with sport-related knee injuries. de In 2000, Loes et al[33] reported that the estimated mean cost of caring for sport-related knee injuries was about $1100 per patient case (or $1650 per patient case in 2020 when adjusted for inflation). These estimates are almost 3 times higher than the median value of $564 we identified for the duration of care. The disparity between our results and those of de Loes et al is likely due to different methods. For example, de Loes et al addressed injuries that required physician care, which were generally more severe (eg, complete ligament ruptures and complete meniscal tears) than the ones we included. Furthermore, de Loes et al conducted their study in a different country (Switzerland) with a different health care infrastructure, which likely had different rules for cost calculations. These disparities also highlight the importance of understanding that reimbursement rules vary among organizations (eg, third-party payers) and institutions (eg, CMS and American Medical Association), even within the same country.[26] For example, we followed cost estimate rules from the American Medical Association, which allow calculations to be based on each time-based service. Thus, if service A took 10 minutes to complete and service B took 10 minutes to complete, then 2 units of service can be reported.[26] In contrast, cost estimates under CMS rules would be based on the total time to complete all services.[25] Hence, if service A took 10 minutes to complete and service B took 10 minutes to complete, then only 1 unit of service can be reported because the total time of 20 minutes falls within the 1-unit range based on time (1 unit = 8–23 minutes). As a result, one should be cognizant of these differences in rules and consider them before making head-to-head comparisons in cost estimates between investigations.

The cost estimates we reported here provide insight that has otherwise been limited in athletic training and align with current initiatives to describe the role of the AT as a health care professional.[14,15] Specifically, efforts have focused on demonstrating the worth (ie, "the monetary value of service") and value (ie, "the extent to which a service's worth is perceived") of ATs in providing care to athletes.[14,15] These guiding documents for secondary[14] and college or university[15] ATs also emphasize the general message that services provided by ATs are not free. Thus, although it is essential to collect and track monetary-based services to demonstrate worth and value, it can be argued that services supplied without an inherent monetary benefit (eg, CMS guidelines) should also be collected and tracked to

provide a more comprehensive description of all services provided by ATs at their clinical practice sites. For instance, commonly used treatment modalities by ATs are not reimbursable per CMS guidelines.[20,30] In particular, the use of hot and cold packs is not reimbursable, which explains why the lowest value of the direct costs of care per visit in our study was $0. As the profession aims to demonstrate the overall role of ATs, it is important to capture all services provided by ATs, even if some are not reimbursable per CMS guidelines. In terms of cost estimates, although we offered preliminary insight into the costs associated with sport-related knee injuries, researchers need to obtain better cost estimates and perhaps estimates for specific injury diagnoses. Furthermore, to demonstrate value, both cost and quality need to be assessed.[14,15] As a result, assessment of the clinical outcomes of patient care provided by ATs, particularly patient-reported outcomes,[34] is needed to determine the quality of care.

This study was not without limitations. We relied on ICD codes that, at times, were general. For example, we were unable to separate anterior and posterior cruciate ligament injuries because the ICD coding system only provides a cruciate ligament option. Similarly, some CPT codes, such as the code for therapeutic exercises, did not offer the clinician a way to describe the specific exercises supplied. Also, we could not account for patients who may have been receiving treatment from other health care providers (eg, physical therapist) outside the school setting. However, because our aim was to estimate the costs associated with the services provided by ATs, we believe our findings reflect the practical nature of routine athletic training clinical practice. Furthermore, due to the lack of documentation and billing standards in athletic training,[20,35] comparisons between our findings and those in other health care fields may be limited. The direct relationship between patient documentation (eg, CPT codes) and reimbursement of services offers inherent controls related to data collection in other health care fields that do not exist in athletic training. To address the challenges associated with patient documentation in our dataset (eg, missing data), we decided to include only complete patient cases to optimize data quality. This approach resulted in the exclusion of many patient cases recorded in the EMR, which may reduce the generalizability of our findings. However, we believe that our findings likely reflect the most complete level of care provided by ATs, and we offer meaningful insight to athletic training practice that has otherwise been limited in the literature. In addition, our use of different measures of central tendency should provide a broader perspective on the estimated costs related to the management of knee injuries, and readers should use these measures when interpreting our results.

CONCLUSIONS

We supplied additional information on the injury and treatment characteristics of patients after sport-related injuries, and to our knowledge, we are the first researchers to obtain estimates of the direct costs of care for patients being treated by ATs. When compared with ankle sprains, knee injuries typically require a larger amount of care, a longer duration of care, and higher direct costs of care. These differences are likely due to variations in the severity of injury for a typical ankle sprain versus a typical knee sprain.

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Address correspondence to Kenneth C. Lam, ScD, ATC, Department of Interdisciplinary Health Sciences, A.T. Still University, 5850 E. Still Circle, Mesa, AZ 85206. Address email to klam@atsu.edu.