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Original Research

Geographic Disparity in Distance to Trauma Care in Secondary Schools Across the United States

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Context: Geographic disparities exist in trauma care (ie, "trauma center desert") within the United States. An athletic trainer (AT) on site at secondary schools (SSs) may help enhance collaboration with emergency medical systems and potentially lead to better outcomes after catastrophic injuries. However, access to AT services relative to the location of level I or II (ie, tertiary) trauma centers remains unknown.

Objectives: To visualize and describe the distance between SSs and trauma centers and compare access to AT services across the United States.

Design: Cross-sectional study.

Setting: Public and private SSs with interscholastic athletics programs in the United States.

Patients or Other Participants: Survey data obtained through the Athletic Training Locations and Services (ATLAS) project database between September 2019 and April 2023.

Main Outcome Measure(s): The minimum distance from each SS to a tertiary trauma center was calculated on Tableau Desktop by geocoding with longitude and latitude. The status and level of AT employment were obtained from the ATLAS project database. The odds and percentages of access to AT services were examined by distance ranges.

Results: A total of 18 244 SSs were included in the analyses. Of these, 75% (n = 13 613) were located within 50 miles (81 km) of a tertiary trauma center. The odds of access to AT services were 2.74 (95% CI = 2.56, 2.93) times greater in SSs situated within 50 miles of a tertiary trauma center ($P < .001$). Additionally, SSs located more than 60 miles (97 km) from a tertiary trauma center had decreased access to AT services ($R^2 = 0.9192$).

Conclusion: This study highlighted the geographic disparities in distance to trauma care for SSs in the United States. Those SSs located more than 60 miles from trauma centers had reduced odds of access to AT services. Identification of geographic trends of AT services relative to the location of tertiary trauma centers is a critical first step in preventing fatal consequences of catastrophic injuries.

Key Words: emergency medical system, athletic trainer, sports safety, rurality

Key Points

- We provided the first map of the distance from secondary schools (SSs) to the closest tertiary trauma center.
- A total of 75% of SSs (n = 13 613) were located within 50 miles of the closest tertiary trauma center across the United States. The odds of access to athletic trainer (AT) services were 2.7 times greater in SSs located within 50 miles of those trauma centers.
- Secondary schools located more than 60 miles from the closest tertiary trauma center had decreased access to AT services.

The term *trauma center desert* is defined as a medically underserved area in which the population lacks access to a trauma center.[1] Although most US residents have access to a level I or II trauma center within 1 hour via ground or air transport, almost 30 million people (approximately 12% of the US population) live in trauma center deserts.[2,3] This highlights the geographic disparities that exist in access to trauma care within the United States.[3] Level I or II trauma centers are considered tertiary or definitive care centers, which offer the most comprehensive care for severely injured patients, and they accept patients from nontertiary centers (ie, levels III, IV, and V) in the region.[4] Previous researchers described an inverse relationship between access to trauma centers and trauma-related mortality.[5–7] Furthermore, in the pediatric population, every 10% increase in access to level I or II trauma centers was associated with a reduction in the mortality rate by up to 5.4 deaths per 100 000.[7] Thus, it is crucial to have access to tertiary trauma centers in a time of emergency.

Access to trauma centers among US adult populations has been studied; however, access to trauma centers among adolescent populations, specifically secondary school (SS) athletes, remains unclear. Injury is an inherent risk of sport participation, and catastrophic injuries in SS athletes occur

despite mitigation efforts. The National Center for Catastrophic Sports Injury Research reported 56 catastrophic injuries, including both direct and indirect causes, in SS and college organized sport participants in the 2020–2021 academic school year alone.[8] Of those incidents, the majority of sport-related catastrophic events (85.7%; n = 48) occurred at the SS level, and approximately 1 in 3 injuries were fatal or caused permanent severe functional disabilities. The National Center for Catastrophic Sports Injury Research has also indicated that the number of overall catastrophic injuries has remained fairly consistent and most catastrophic events occur in the SS sport setting.[8] This emphasizes the importance of ensuring access to proper trauma care to address the risks associated with sport participation in the SS setting.

To reduce the effect of geographic disparities, an athletic trainer (AT) on site at each SS would be essential for prevention, evaluation, treatment, and prehospital emergency care for athletes in emergency situations. Best practices in athletic training emergency care ensure collaboration with local emergency medical systems and can lead to better outcomes by limiting the extent of an injury and preventing any injury sequelae in the prehospital settings.[9] Although access to AT services is associated with geographic locales,[10] AT employment status and the level of SS AT services relative to the distance to tertiary trauma centers remain unknown. Therefore, the purpose of our study was to visualize and describe the distance between US SSs with access to AT services and tertiary trauma centers.

METHODS

Participants

Secondary school data were collected through the Athletic Training Locations and Services (ATLAS) project developed by the Korey Stringer Institute and the National Athletic Trainers' Association (NATA). A description of the development of the ATLAS Project database can be found in the article by Huggins et al.[11] Geographic information (ie, addresses) of 21 248 SSs were extracted from the ATLAS project database. Of those SSs, 18 244 SSs, which completed or updated their surveys between September 2019 and April 2023, were included in the analyses. If the survey had not been updated by an SS AT for more than 3 years, the AT information was removed and changed to *unknown* status. Schools with unknown AT employment status (n = 3004) were excluded from analyses. Additionally, US level I or II trauma centers (N = 452; level I = 199, level II = 253), including both American College of Surgeons (ACS)–verified and state-designated pediatric trauma centers, were identified by using the ACS website and all 51 state and District of Columbia Department of Public Health websites.[12] Trauma center designation is outlined at the state or local level, and categories define national standards for trauma care in hospitals that are unique to adult and pediatric facilities. Trauma center verification is completed by the ACS through an evaluation process. It is important to note that the verification process by the trauma center is voluntary, and certification lasts for 3 years. We included only deidentifiable information from the ATLAS project database and publicly available data from the ACS website and each Department of Public Health website. Thus, approval of this study by the institutional research board was not required due to the nature of the data.

Procedures

All SSs in the ATLAS project database with completed and updated surveys and level I or II trauma centers were geocoded with longitude and latitude. Due to the large number of US hospitals and trauma centers and our focus on catastrophic sport injuries, we opted to include only level I and level II trauma centers because of their commitment, readiness, resources, policies, and patient care as determined by the ACS. To visualize the minimal distance from each SS to the closest tertiary trauma center, we uploaded and mapped the geographic information on Tableau Desktop (version 2022.2; Salesforce, Inc). The following formula was entered in the calculated field to estimate the radial distance from an SS to the closest tertiary trauma center:

$$\begin{aligned} &3959 * \mathrm{ACOS}(\sin[\mathrm{radians}(\mathrm{latitude})]) \\ &\quad * \sin(\mathrm{radians}[\mathrm{latitude}(\mathrm{trauma\ center})]) \\ &\quad + \cos(\mathrm{radians}[\mathrm{latitude}]) \\ &\quad * \cos(\mathrm{radians}[\mathrm{latitude}(\mathrm{trauma\ center})]) \\ &\quad * \cos(\mathrm{radians}[\mathrm{longitude}(\mathrm{trauma\ center})]) \\ &\quad - \mathrm{radians}(\mathrm{longitude}). \end{aligned}$$

Using the formula in the calculated field, Tableau Desktop automatically calculated the radial distance based on the latitude and longitude. To provide a visualization of distance to tertiary trauma centers in the SS setting, each SS was color coded based on the minimum distance from the closest tertiary trauma center. Schools located ≤50 miles (81 km) from a trauma center were color coded in blue, whereas the rest of the schools located >50 miles from a trauma center were color coded between light orange and dark orange, which approximated trauma center deserts. We selected the cutoffs of less than and greater than 50 miles to approximate ground transportation, as *trauma center deserts* have been defined as being more than 1 hour away via transport. After creating the map on Tableau Desktop, we extracted the distance data and grouped them into 4 categories based on distance: distance 1 ≤ 50 miles, distance 2 ≥ 50 to 100 miles (81 to 161 km), distance 3 ≥ 100 to 150 miles (161 to 241 km), and distance 4 ≥150 miles. These mileage cutoffs were established in order to visualize and color code all the SSs from the ATLAS database on the map, so the actual transport time from each SS was not calculated due to the immense number of schools, trauma centers, and variability (ie, traffic conditions) for each data point. To achieve our goal of visualizing the geographic relationship between each SS and the closest tertiary trauma center, we used the minimum distance instead of transport time, which may be affected by multiple confounding factors such as ambulance speed, traffic, and the level of rurality in the area. The total number and percentage of each distance category by NATA district can be found in Table 1. Additionally, the status of SS AT employment (*yes* or *no*) and the level of AT service (*full time* or *part time*) were extracted from the ATLAS project database. To report detailed changes in the percentage of access to AT services and the level of AT service, we divided the data into 10- to 20-mile increments (0 to 150 miles) and >150 miles.

Data Analysis

All statistical analyses were completed using SPSS (version 29; IBM Corp). The minimum distance between each SS and a tertiary trauma center was described as the median

Table 1. Secondary Schools by Distance Range and by National Athletic Trainers' Association District

District	Secondary Schools, No.	Distance, Miles, Median [Interquartile Range]	Distance Range(s), No. (%)				
			1 (≤50 miles)	2 (>50 to 100 miles)	3 (>100 to 150 miles)	4 (>150 miles)	2 to 4
1	933	13.7 [5.5, 27.4]	879 (94.2)	39 (4.2)	10 (1.1)	5 (0.5)	54 (5.8)
2	1953	8.8 [3.3, 23.0]	1837 (94.1)	115 (5.9)	1 (0.1)	0 (0.0)	116 (5.9)
3	1605	19.8 [8.2, 38.2]	1366 (85.1)	237 (14.8)	2 (0.1)	0 (0.0)	239 (14.9)
4	1802	20.3 [7.3, 36.8]	1564 (86.8)	153 (8.5)	62 (3.4)	23 (1.3)	238 (13.2)
5	2231	47.4 [21.6, 74.6]	1176 (52.7)	821 (36.8)	225 (10.1)	9 (0.4)	1055 (47.3)
6	1642	37.8 [12.2, 73.6]	980 (59.7)	427 (26.0)	207 (12.6)	28 (1.7)	662 (40.3)
7	897	31.0 [8.3, 88.5]	519 (57.9)	201 (22.4)	158 (17.6)	19 (2.1)	378 (42.1)
8	1723	7.5 [3.7, 21.6]	1542 (89.5)	135 (7.8)	18 (1.0)	28 (1.6)	181 (10.5)
9	2799	26.6 [18.7, 52.8]	2048 (73.2)	638 (22.8)	113 (4.0)	0 (0.0)	751 (26.8)
10	1099	89.4 [20.6, 167.2]	416 (37.9)	176 (16.0)	181 (16.5)	326 (29.7)	683 (62.1)
11	1560	19.2 [5.2, 39.8]	1286 (82.4)	258 (16.5)	15 (1.0)	1 (0.1)	274 (17.6)
Overall	18 244	21.9 [7.0, 50.7]	13 613 (74.6)	3200 (17.5)	992 (5.4)	433 (2.4)	4631 (25.4)

(interquartile range) for each NATA district. The coefficient of determination (R^2) indicated the reliability of the trendlines. Pearson χ^2 tests and odds ratios (ORs) with 95% CIs were calculated to determine the relationship between the status of AT employment and the minimum distance from the closest tertiary trauma center using the following formula: OR = $(A/C)/(B/D)$. Here, A represents the number of schools with an AT employment status of *no* in distances 2 to 4; B, the number of schools with an AT employment status of *no* in distance 1; C, the number of schools with an AT employment status of *yes* in distances 2 to 4; and D, the number of schools with an AT employment status of *yes* in distance 1. Significance was set a priori at $P \leq .05$.

RESULTS

In total, 18 244 SSs and 452 tertiary trauma centers (level I: n = 199, level II: n = 253) were included in the analyses. The map of the distance to the tertiary trauma centers is displayed in Figure 1. Each dot represents 1 SS with the color code based on the distance to the closest tertiary trauma center. The number and percentage of SSs by

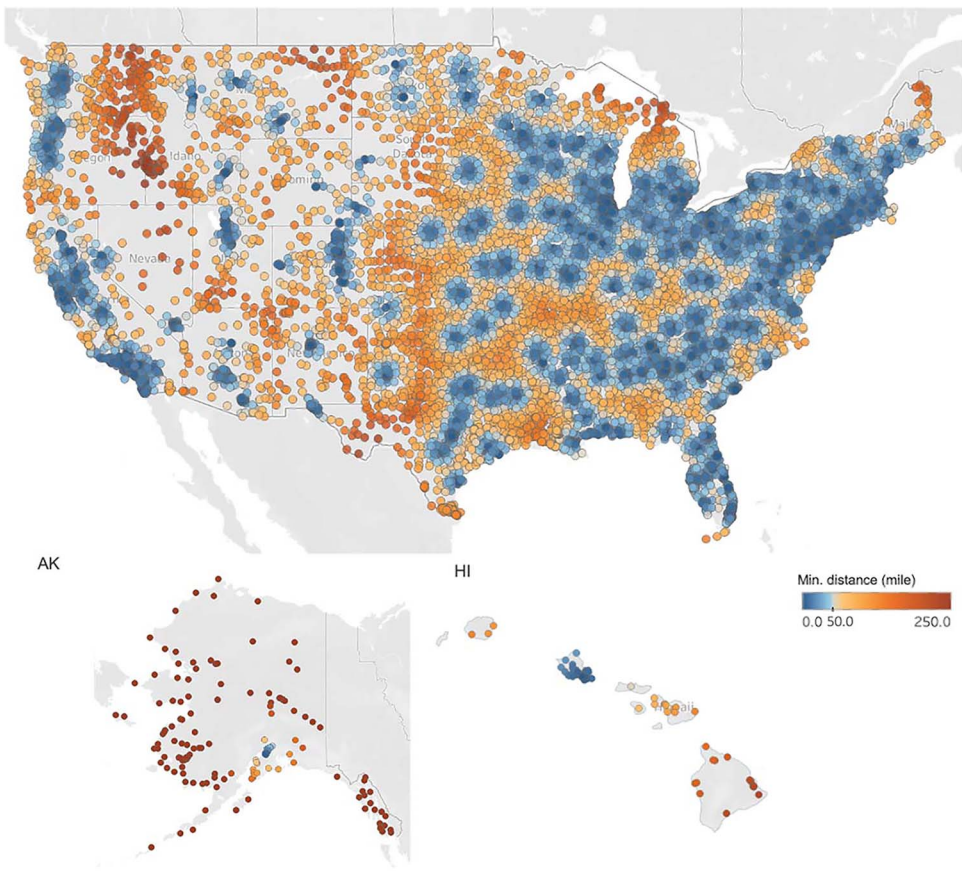

Figure 1. Trauma center desert map in US secondary schools.

Table 2. Athletic Trainer Employment Status in Each Trauma Center Distance Range

Distance(s)	Athletic Trainer Employment, No. (%)		χ^2 Value	*P* Value	Odds Ratio (95% CI)
	Yes	No			
1 (≤50 miles)	9116 (67.0)	4497 (33.0)	–	–	
2 (>50 to 100 miles)	1462 (45.7)	1738 (54.3)	502.767	<.001[a]	2.410 (2.229, 2.606)
3 (>100 to 150 miles)	396 (39.9)	596 (60.1)	297.803	<.001[a]	3.051 (2.674, 3.481)
4 (>150 miles)	112 (25.5)	327 (74.5)	324.154	<.001[a]	5.918 (4.761, 7.357)
2 to 4	1970 (42.5)	2661 (57.5)	864.742	<.001[a]	2.738 (2.557, 2.932)

[a] Indicates a difference from distance 1.

distance ranges and by NATA district are shown in Table 1. Seventy-five percent of SSs (n = 13 613) were located within 50 miles of the closest US tertiary trauma center, whereas 25.4% of SSs (n = 4631) were located outside of a 50-mile radius. The percentage of SSs ≥50 miles from a tertiary trauma center was higher in Districts 5, 6, 7, 9, and 10 (47.3%, 40.3%, 42.1%, 26.8%, and 62.1%, respectively) than the overall mean percentage observed in 11 NATA districts (25.4%). Moreover, Districts 5 and 10 showed notably larger median distances from the closest tertiary trauma center (47 miles and 89 miles [76 and 144 km], respectively) than the overall median distance across all 11 NATA districts (22 miles [35 km]). Athletic trainer employment status in each distance range is shown in Table 2. The odds of access to AT services were 2.74 (95% CI = 2.56, 2.93) times greater in distance 1 than in distances 2, 3, and 4 ($P < .001$). The odds of not having access to AT services increased as the distance range moved farther from distance 2 to distance 4. The percentage of access to AT services was also significantly greater in distance 1 than in the other 3 distance ranges ($P < .001$). Sixty-seven percent of SSs in distance 1 had an AT, whereas only 42.5% of SSs in distances 2, 3, and 4 had access to AT services. Moreover, further analysis of the changes in access to AT services based on the smaller distance increments was provided in Figure 2. A trend ($R^2 = 0.9192$) indicated that SSs located >60 miles (97 km) from a tertiary trauma center had decreased access to AT services. Additionally, SSs located >40 miles (64 km) from a tertiary trauma center had decreased access to full-time AT services ($R^2 = 0.9192$).

DISCUSSION

The primary purpose of our study was to visualize and describe the distance between SSs and tertiary trauma centers and the access to AT services based on these distance

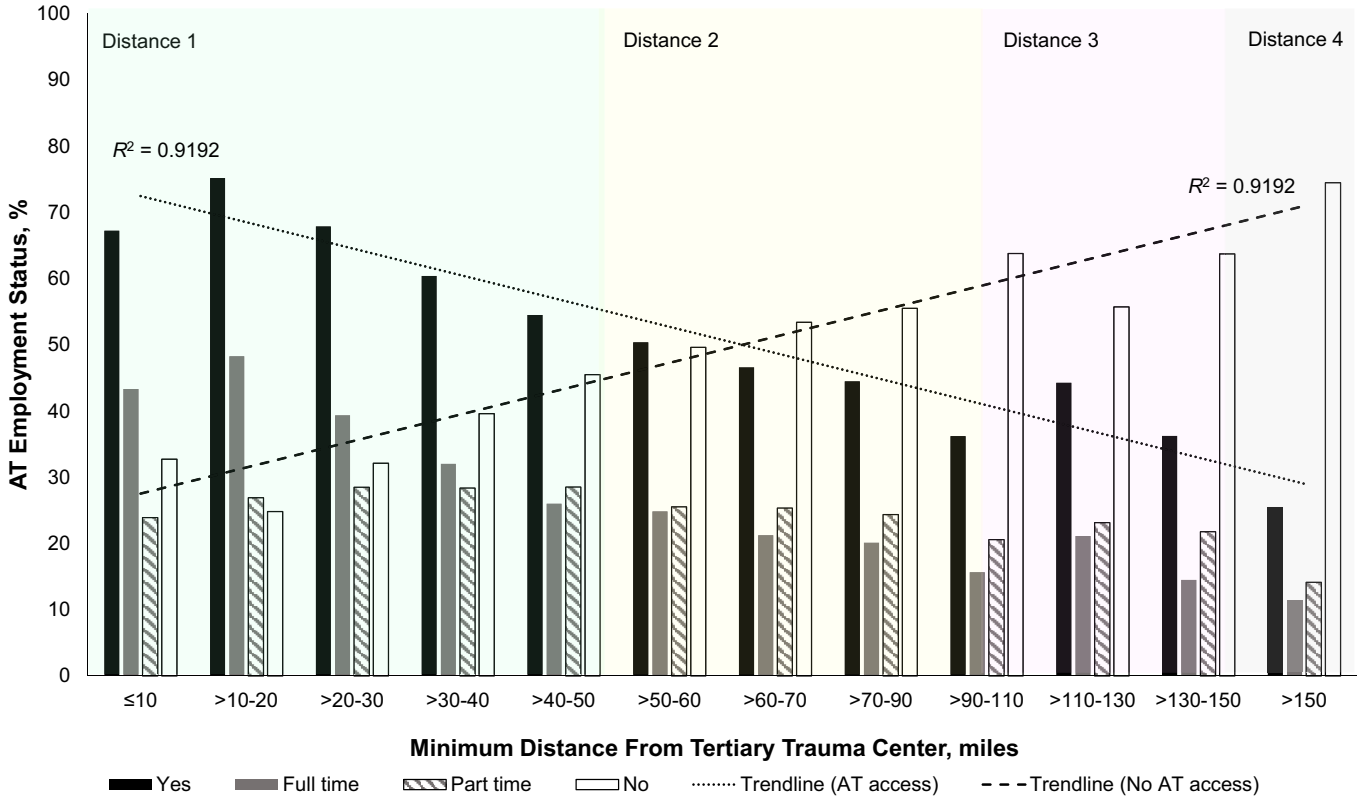

Figure 2. Changes in access to athletic trainer (AT) services based on the distance from the closest tertiary trauma center.

ranges across the United States. Greater distances to tertiary trauma centers could reflect health care disparities. To our knowledge, we are the first to provide a visualization of possible trauma center deserts in the SS setting across the United States by calculating the distance between SSs and the closest tertiary trauma centers. We hope that this visualization will help highlight disparities in trauma care access for SS athletes across the country and provide valuable data when advocating for increasing access to AT services.

One-quarter of SSs were located >50 miles from a tertiary trauma center, which was consistent with similar disparities found previously: 71.5% of pediatric patients had access to verified pediatric trauma centers within 1 hour by ground or air transport.[5] Although 88.3% of Americans had access to tertiary trauma centers within 1 hour,[1] our results showed that pediatric patients, potentially including SS athletes, may have less access to tertiary trauma centers than adult or elderly populations because of the distance from these trauma centers. It is important to note that we examined the distance between each SS and a tertiary trauma center rather than calculating the approximated transport times. Therefore, comparisons of our findings with those from earlier research using estimated ground transport time must be viewed critically.[2,5–7,13] Carr et al[3] concluded that access to tertiary trauma centers was not equal throughout the country because of geographic, demographic, and socioeconomic disparities. Tertiary trauma centers tend to be located in urban areas, whereas nontertiary trauma centers provide care to underserved populations in rural areas.[14] The rurality of an area is a strong indicator of outcomes after catastrophic injury.[14,15] As opposed to urban areas, rural areas experience a scarcity of medical services, a lack of trained physicians, insufficient public transport, and poor availability of online services (eg, telehealth).[16] Financial constraints compound these problems, making it difficult to establish sustainable medical services in rural areas. Prior investigators showed that budget limitations were the greatest barrier to hiring ATs.[17] The same financial and budget challenges that affect access to tertiary trauma centers in rural areas also seem to affect access to AT services and may help explain our findings of lower odds of access to AT services in SSs that were farther from those trauma centers. This likely represents a greater national issue specific to health care disparities in areas of lower economic status.[18–20]

Furthermore, the odds and percentages of access to AT services were greater in distance 1 than in the other 3 distance ranges. Secondary schools in distance 1 were more likely in urbanized areas, where more ATs were available. Regional differences in access to AT services have also been reported in distances 2 to 4, which are more rural and have less access to tertiary facilities. When examining AT services by regional NATA districts, Huggins et al[11] found that only 40% to 58% of SSs had access to AT services in Districts 5, 6, 7, 9, and 10, whereas the national average was 66%.[11] These districts also tended to be more remote and less populated. The authors observed that 57% of SS ATs were employed by medical facilities, such as hospitals, clinics, or universities in the United States.[11] For instance, the majority of SS ATs (72%) in District 5 were employed by medical or university facilities. Additionally, 7 states (Alaska, Hawaii, Idaho, Montana, North Dakota, South Dakota, and Wyoming) did not have a level I trauma center. Of those, 5 states (Alaska, Idaho, Montana, North Dakota, and South Dakota) are in District 5 or 10. Because medical or university facilities are the predominant employment model for the provision of AT services in the United States, some regions may have fewer opportunities to hire an AT from a medical or university facility if the schools are located farther from those facilities.[11,21] Therefore, this might explain the relationship we demonstrated between the odds of access to AT services and the distance from tertiary trauma centers.

Closer examination of smaller-distance categories revealed a proportional inverse relationship between access to AT services and distance from a tertiary trauma center. The percentage of access to AT services (*yes* or *no*) changed in SSs located >60 miles away and decreased as the distance from the closest tertiary trauma center increased. Additionally, access to full-time AT services changed in SSs located >40 miles from the closest tertiary trauma center. Thus, SSs located farther from tertiary trauma centers had less access to AT services. This result is concerning because it could indicate that SSs farther from tertiary trauma centers may be more likely to experience poor consequences of catastrophic injuries due to the lack of proper onsite emergency care in the form of AT services. Common sense would tell us that these areas farthest from access to a tertiary trauma center should be afforded more access to AT services to help reduce the disparity in trauma care. Therefore, community-based or state-funded programs as well as educational programs directed toward school administrators on the importance of onsite medical care would need to be developed to provide appropriate onsite trauma care to student-athletes and minimize the risk of sport-related injuries and illnesses. Although these rural communities have financial challenges to employing full-time AT services, perhaps other entities in the town, such as police, fire, or other municipalities paid for by the taxpayers, could also benefit from the services of the AT. Outside-the-box thinking and models will bring ATs and their services to more rural and less urban communities.[22]

Limitations

In this study, we included only level I or II trauma centers in the analyses. However, more nontertiary trauma centers than tertiary trauma centers exist across the United States.[12] In general, patients with direct and indirect causes of catastrophic injury would be transported to the closest nontertiary trauma center first for initial evaluation and stabilization before being transferred to level I or II trauma centers as necessary. Across the United States, access to trauma care within 60 minutes increased by 4.6% when level III trauma centers were considered.[2] Previous researchers found that mortality rates were lower for patients transferred to tertiary trauma centers from nontertiary trauma centers than for those remaining at nontertiary trauma centers.[4] Although we did not address nontertiary trauma centers, collaboration within the trauma care system would result in better patient care outcomes.

In addition, we selected a 50-mile radius as the cutoff to approximate trauma center deserts, encompassing medically underserved areas in which the population has a lack of access to a tertiary trauma center. Although other authors used shorter distance cutoffs (eg, 5 miles [8 km], 5 km) at the city or state level to assess mortality, our mileage cutoff allowed us to visualize the lack of access to trauma care on a larger scale across the United States.[23,24] Future examinations would benefit from assessments of transport times at a more granular level to better

demonstrate the effect of geographic disparity in access to tertiary trauma centers on mortality and subsequent consequences associated with catastrophic injuries in SS settings. Another limitation was that we did not account for air transport. In emergencies, air transport by a medical helicopter or aircraft may be used when the patient is in a rural or remote area or when ground transport is challenging.[25] Prior investigators determined that simultaneously dispatched air transport was faster at distances greater than 10 miles (16 km), and nonsimultaneously dispatched helicopter transport was still faster than ground transport if the distance was greater than 45 miles (72 km) from the hospital.[26] Thus, air transport may be activated depending on the severity of the patient's injuries or illnesses and accessibility to a tertiary trauma center in trauma center deserts (ie, distances 2 to 4). Although we should weigh the benefits and risks associated with air transport, in-hospital mortality was reduced with the use of helicopter emergency medical services.[27] Therefore, we should consider both the levels of trauma centers and the types of transportation to create a more comprehensive trauma center desert map in the future.

Future Directions

Based on the map of the current distance to a tertiary trauma center, SS ATs should know the distance from the closest tertiary trauma center to prepare for emergency situations and help prevent fatal consequences of catastrophic injuries and illnesses. More deaths were reported within 24 hours for injured patients who were transported from rural areas than for those transported from urban areas because of higher interfacility transfer rates and longer transfer distances.[28] To enhance SS AT employment, especially in areas far from tertiary trauma centers, clarifying the advantages of having an SS AT on site and comparing the average emergency medical services activation time by the level of AT service (ie, full time versus part time) would be informative. This is a critical first step in encouraging AT employment by SSs located in likely trauma center deserts and providing proper trauma care for all SS athletes.

CONCLUSIONS

This was the first study to identify geographic disparities in access to tertiary trauma centers in SSs across the United States. Twenty-five percent of SSs were located outside of a 50-mile radius of a tertiary trauma center. Specifically, SSs located >60 miles from a trauma center had decreased access to both AT services and tertiary trauma centers. Access to full-time AT services decreased in SSs located >40 miles from a trauma center. Identifying SSs in trauma center deserts and the status of access to AT services are critical first steps in promoting improved access to prehospital trauma care in SS athletes and prevention of fatal consequences of catastrophic injuries in the future.

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