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A Perfect Storm?: The Association of Vitamin D with Injury Incidence among Acrobatics and Tumbling Athletes

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A Perfect Storm?: The Association of Vitamin D with Injury Incidence among Acrobatics and Tumbling Athletes

Abstract

Purpose: Acrobatics and Tumbling (A&T) is an emerging NCAA sport. Due to the novelty of the sport, limited research on injury incidence and correlates exists. Anecdotal evidence suggests that A&T presents with high injury rates. A relationship between vitamin D and bony injuries exists among athletes, but little is known about soft tissue injuries. Understanding the causes and incidence of injuries, including vitamin D, may assist athletic trainers. Methods: Forty-two A&T athletes (19.69 ± 1.199 years) completed 2 blood draws as part of routine medical care prior to and following fall training period. Results: Average vitamin D at T1 was 47.976 ± 18.874 ng/ml and T2 was 41.883 ± 18.453 ng/ml. Injury variables (i.e., incidence, mechanism) and time loss (TL) were recorded between blood draws. T-tests and ANOVAs assessed differences in injuries and TL based on serum vitamin D. Poisson and logistic regressions were utilized to assess injury and TL odds ratios based on vitamin D. Twenty-eight injuries were sustained and eleven participants suffered TL. Serum vitamin D significantly decreased an average of 6.093 ± 10.973 ng/ml (p

Conclusions: No significant differences in injury status or TL based on vitamin D were identified. Identifiable patterns were found in injuries sustained by participants. Serum vitamin D concentrations showed a significant decrease as volume and intensity of training increased. The significant decrease in vitamin D and high injury incidence indicates a need for further monitoring of biomarkers, such as vitamin D, in these athletes and research to determine injury prevention strategies.

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ABSTRACT

Purpose: Acrobatics and Tumbling (A&T) is an emerging NCAA sport. Due to the novelty of the sport, limited research on injury incidence and correlates exists. Anecdotal evidence suggests that A&T presents with high injury rates. A relationship between vitamin D and bony injuries exists among athletes, but little is known about soft tissue injuries. Understanding the causes and incidence of injuries, including vitamin D, may assist athletic trainers.

Methods: Forty-two A&T athletes (19.69 ± 1.199 years) completed 2 blood draws as part of routine medical care prior to and following fall training period. Results: Average vitamin D at T1 was 47.976 ± 18.874 ng/ml and T2 was 41.883 ± 18.453 ng/ml. Injury variables (i.e., incidence, mechanism) and time loss (TL) were recorded between blood draws. T-tests and ANOVAs assessed differences in injuries and TL based on serum vitamin D. Poisson and logistic regressions were utilized to assess injury and TL odds ratios based on vitamin D. Twenty-eight injuries were sustained and eleven participants suffered TL. Serum vitamin D significantly decreased an average of 6.093 ± 10.973 ng/ml (p<0.001). Conclusions: No significant differences in injury status or TL based on vitamin D were identified. Identifiable patterns were found in injuries sustained by participants. Serum vitamin D concentrations showed a significant decrease as volume and intensity of training increased. The significant decrease in vitamin D and high injury incidence indicates a need for further monitoring of biomarkers, such as vitamin D, in these athletes and research to determine injury prevention strategies.

Keywords: inadequacy, injury descriptive, time loss, injury correlates
INTRODUCTION

To date, more than 490,000 student athletes compete in the National Collegiate Athletic Association (NCAA) in 24 varsity sports. The literature suggests that at least half of NCAA student athletes sustain some type of injury as a result of sport participation. Injuries to collegiate athletes are prevalent and associated with costs related to physician services, imaging, surgical costs and hospitalizations.

Acrobatics and Tumbling (A&T) has historically been managed by the National Collegiate Acrobatics and Tumbling Association (NCATA), but joined the NCAA Emerging Sports for Women program during the 2020-2021 school year. The NCATA defined A&T as “the evolution of different disciplines of gymnastics, which includes the athletic aspects of competitive cheerleading.” A&T consists of multiple events including acrobatic lifts, tumbling, tosses, and pyramids. Within A&T, the demands on each athlete are determined by their position, either a top or base. Both positions participate in tumbling skills, but similar to cheerleading, bases toss, catch, and hold the tops during various skills. At its inception, A&T was proposed to present injury rates similar to women’s soccer (i.e., 8.33 injuries per 1000 athlete exposures (AEs)). To date, research has not identified the actual injury rates that occur through participation. Thus, further insight is needed to assist administrators and health care professionals to gain a better understanding of injuries and cost associated with participation.

Despite comparisons to soccer, injury incidence in A&T may be more similar to cheerleading and/or gymnastics given the nature of activities associated with those sports. Cheerleading and gymnastics studies have found injury rates of 0.57-2.8/1000 AEs and 8.00/1000 AEs, respectively. Lower extremity injuries are the most common among cheerleaders, accounting for 30% of all injuries. The most common mechanisms of injury found in cheerleading include basing (24%), tumbling (15%), and falls (14%). Women’s gymnastics has regularly been found to have the highest injury rate amongst collegiate women’s sports. Strains (16.5%) and sprains (16.4%) accounted for the largest proportion of injuries. Similar to cheerleaders, lower extremity injuries were most common in gymnastics and included knee (13.1%), ankle (12.6%), and foot (12.1%) injuries. In addition, surface contact (35.4%), overuse (20.3%), and noncontact (19.1%) were the most commonly reported mechanisms of injury in women’s gymnastics. Most of these injuries occurred during the floor routine while tumbling. It is also important to note that a significant proportion of injuries sustained in both cheerleading and gymnastics resulted in time loss. In cheerleading, stunt-related injuries averaged time loss of 14 ± 17 days. One study examined cheerleading injuries more broadly and identified 50% of injuries that averaged 2.5 weeks of time lost, while 3% missed the remainder of the season. An epidemiological study of women’s gymnastics found 44.1% of injuries reported a time loss of greater than 1 day, with an average time loss of 23.9 ± 34.1 days.

Vitamin D

Vitamin D inadequacy is a significant issue, with 1 billion people believed to have insufficient serum vitamin D worldwide. Inadequate serum vitamin D can be detrimental because when serum vitamin D is low, calcium is mobilized from the bones to the bloodstream. This response leads to a potential decrease in bone mineral density and increase in injury risk to bony structures. As a result, prolonged vitamin D inadequacy has shown to increase the risk of fracture. In addition to its role in bone metabolism, vitamin D is also proposed to play a role in skeletal muscle function. However, less is known than about this relationship, especially in athletes. To date, there is very little published literature that explores the relationship between vitamin D and its role in soft tissue health and injury.

Vitamin D inadequacy is also well documented among collegiate athletes. There has been a significant debate on the values defining vitamin D insufficiency and deficiency. Vitamin D inadequacy is the term often used to address those that fall below the level of sufficient, incorporating both insufficient and deficient. Many authors have examined serum vitamin D in a variety of different sports and levels of athletes. The proportion of participants with vitamin D deemed inadequate by various authors include 57.1% in professional men’s basketball, 84.2% in soccer, 33.3% in women’s gymnastics, and 80.9% in American football. These authors used a variety of values to define inadequacy that ranged from <20 ng/ml to <32 ng/ml. Despite the high reported prevalence of vitamin D inadequacy in the athletic population, little published research exists on the association between prolonged vitamin D inadequacy and injury among collegiate athletes. As participants in an indoor sport occurring during the winter and spring seasons, A&T student-athletes may be at a higher risk of vitamin D inadequacy. However, further studies are needed to assess the relationship between vitamin D levels and injuries (i.e., soft tissue, bone).

The present study sought to fill gaps in the published literature by identifying the injury incidence and associated factors among a sample of A&T student-athletes. We hypothesized that these athletes would display injury rates similar to those identified in gymnastics and cheerleading due to similar sport demands. We also hypothesized that A&T student athletes would possess inadequate vitamin D levels due to the indoor nature of their training, including a decrease in vitamin D over the course of the fall.
METHODS

Subjects
Athletic trainers at a NCAA division I institution were contacted for recruitment and assented to A&T athletes to participate in the research study. A&T competes during the spring season (February-April). Data collection occurred during the fall semester prior to their competition season. Subjects were recruited from the 51-person roster of the division I A&T team. A recruitment meeting with a member of the research team was held the evening prior to a scheduled routine medical assessment. To reduce a coercive environment, recruitment occurred in a private group setting without the presence of the coaching staff associated with the team. All participants had the opportunity to withdraw from the study at any point without penalty. Data collected up to the point of withdrawal was included in subsequent analyses. Subjects had to be listed as active on the team roster and between 18-30 years of age. Written informed consent was obtained from each participant and approval to conduct the study was granted by the Institutional Review Board for Human Subjects prior to data collection.

Variables

Vitamin D
Vitamin D concentrations were measured at two timepoints, and the change in vitamin D between timepoints was assessed. Serum vitamin D (ng/mL) was assessed via vitamin D (25-OH) ELISA kit (Crystal Chem Inc., Elk Grove Village, IL) from blood samples obtained during routine blood draws.

Injuries
Injuries sustained during the study period were recorded and documented by the team’s athletic training staff. Deidentified injury details were provided to the research team. Information collected is included in table 2. Participants were categorized dependent on if they did or did not sustain an injury during the study period. Number of injuries sustained by each individual was also recorded.

Time Loss
A&T participation includes a variety of activities (e.g., tumbling, acrobatic lifts, tosses) that all may be completed within the same practice session. Due to this variety in activity, participants were not often restricted to complete rest during practice which made recording of time loss difficult. The variable of time loss was categorized per individual if they had sustained a time loss injury or not during the study period. Those who sustained multiple injuries were categorized as sustaining time loss if a minimum of one of their injuries resulted in time loss from activity.

Procedures

Blood Draw
Data was collected at 2 timepoints, before and after completion of A&T’s fall 20-hour period. Blood draws were completed at each time point as part of routine medical care and shared with researchers. Samples were sent to a CDC-certified cell culture lab to evaluate basic biomarkers (complete metabolic profile, lipid profile, ferritin, and complete blood count). Serum samples were allowed to clot for 30 minutes at room temperature, whereas plasma EDTA samples were stored on ice for 30 minutes, followed by centrifugation at 3330 RPM for 10 minutes. All blood samples were aliquoted into 2 mL micro plastic storage tubes. The remainder of the plasma and serum samples were stored in an ultra-low temperature (ULT) freezer at -80°C until all data was collected and ready to be analyzed. Participants were provided with the results of their blood testing and, if necessary, were scheduled appointments with the team physician and/or team dietitian to address inadequacies.

Injury/Time Loss
Injuries were recorded by the team athletic trainer via the electronic medical records (EMR) system utilized by the university’s athletic medicine department. All injuries sustained between the two timepoints were recorded. Variables recorded included extremity, onset, surgery required, mechanism of injury, activity and specific activity. Time loss in days was unable to be tracked by the current EMR utilized by the athletic medicine department. The EMR used at the sponsoring institution at the time of the study did not allow for the recording of athlete exposures. Time loss was recorded by noting if each injury sustained led to any time loss for that participant. The team athletic trainer provided the compiled injury and time loss data to the research team member working within the athletic department responsible for de-identifying all data.

Statistical Analyses
Statistical analysis performed by SPSS version 28 (IBM® SPSS Statistics, IMB GmbH, Munich, Germany). Serum vitamin D concentrations at each time were compared utilizing paired sample t-tests. Serum vitamin D concentrations at each timepoint, and
the change in vitamin D, were compared between injured vs. uninjured and time loss vs. non-time loss groups utilizing independent samples t-tests. Binomial regressions were utilized to assess odds of sustaining injury or time loss based on vitamin D concentrations at time 1, time 2, and change in vitamin D. Poisson regressions were utilized to assess the odds of the number of injuries in relation to vitamin D at all timepoints.

RESULTS
Subjects
Forty-two female division I A&T athletes consented to participate (84% response rate). Demographic information on subjects is found in table 1.

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>19.6 ± 1.2</td>
<td></td>
</tr>
<tr>
<td>Position</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bases</td>
<td>23</td>
<td>45.2</td>
</tr>
<tr>
<td>Tops</td>
<td>19</td>
<td>54.8</td>
</tr>
<tr>
<td>Year in School</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freshman</td>
<td>13</td>
<td>31.0</td>
</tr>
<tr>
<td>Sophomore</td>
<td>8</td>
<td>19.0</td>
</tr>
<tr>
<td>Junior</td>
<td>10</td>
<td>23.8</td>
</tr>
<tr>
<td>Senior</td>
<td>11</td>
<td>26.2</td>
</tr>
</tbody>
</table>

During the study, 28 injuries were sustained by 22 participants. Descriptive information about the injuries sustained is presented in Tables 2 and 3. The right limb and lower extremity occurred most commonly and each constituted 57.1% (n=16) of the total injuries sustained. Only 1 injury required surgery. Fifty percent of the injuries sustained in the study occurred during tumbling activities and 82.1% (23) were soft tissue injuries. Of the 42 participants, 11 (26.2%) sustained a time loss injury over the course of the study. The remaining participants either sustained an injury that did not require time loss or were not injured.
Table 3. Distribution of injuries in sample by specific activity

<table>
<thead>
<tr>
<th>Specific Activity</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tumbling</td>
<td>14</td>
<td>50.0</td>
</tr>
<tr>
<td>Basing</td>
<td>3</td>
<td>10.7</td>
</tr>
<tr>
<td>Topping</td>
<td>1</td>
<td>3.6</td>
</tr>
<tr>
<td>Overuse</td>
<td>5</td>
<td>17.9</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>7.1</td>
</tr>
<tr>
<td>Unknown</td>
<td>3</td>
<td>10.7</td>
</tr>
<tr>
<td>Total</td>
<td>28</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Abbreviation: UE, upper extremity; LE, lower extremity; MOI, mechanism of injury

The mean vitamin D at time 1 (i.e., October) was 47.976 ± 18.874 ng/ml and at time 2 (i.e., December) was 41.883 ± 18.453 ng/ml. The loss of serum Vitamin D was significant (p<.001), with an average loss of 6.093 ± 10.973 ng/ml. On average, at time 1 tops had a higher vitamin D level at 52.846 ng/ml compared to bases of 43.952 ng/ml (p=.130). At time 2 this pattern persisted, with tops averaging 44.873 ng/ml and bases 39.413 ng/ml (p=.346). Over the course of the study, tops lost on average 7.974 ng/ml and bases lost 4.539 ng/ml (p=.319).

Differences in vitamin D at T1 and change in vitamin D were compared between injured vs. not-injured and TL vs. non-TL. Results are below in table 4. No significant differences were found between groups.

Table 4. Vitamin D differences between injured vs. not-injured and TL vs. no TL

<table>
<thead>
<tr>
<th></th>
<th>Injured</th>
<th>Not-Injured</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin D T1</td>
<td>50.139 ± 23.312</td>
<td>45.596 ± 12.517</td>
<td>0.443</td>
</tr>
<tr>
<td>Difference</td>
<td>6.054 ± 11.297</td>
<td>6.135 ± 10.898</td>
<td>0.981</td>
</tr>
<tr>
<td>TL</td>
<td>No TL</td>
<td>p</td>
<td></td>
</tr>
<tr>
<td>Vitamin D T1</td>
<td>49.057 ± 18.084</td>
<td>47.592 ± 19.424</td>
<td>0.828</td>
</tr>
<tr>
<td>Difference</td>
<td>6.393 ± 9.671</td>
<td>5.987 ± 11.548</td>
<td>0.918</td>
</tr>
</tbody>
</table>

Abbreviation: TL = time loss

Logistic regressions were utilized to assess the relationship between vitamin D, time loss status, and vitamin D serum concentrations. The outcome variables in these models were the dichotomous injury variable (i.e., injured vs. not injured) and time loss. Odds ratios were assessed at both timepoints and for the change in vitamin D from T1 to T2 and can be found in table 5. Results revealed consistent patterns, including greater vitamin D at both T1 and T2, which showed decreased odds of sustaining an injury and time loss from activity due to injury, but no significant differences were present.
INJURY AMONG ACROBATICS AND TUMBLING ATHLETES

Table 5. Odds ratios for the relationships between vitamin D and time loss and the dichotomous injury variable (injured vs. not-injured)

<table>
<thead>
<tr>
<th>OR</th>
<th>95% CI</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Loss</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>0.996</td>
<td>0.961, 1.033</td>
</tr>
<tr>
<td>T2</td>
<td>0.997</td>
<td>0.961, 1.034</td>
</tr>
<tr>
<td>Difference</td>
<td>1.003</td>
<td>0.942, 1.069</td>
</tr>
<tr>
<td>Dichotomous Injury</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>0.986</td>
<td>0.952, 1.021</td>
</tr>
<tr>
<td>T2</td>
<td>0.985</td>
<td>0.947, 1.023</td>
</tr>
<tr>
<td>Difference</td>
<td>0.999</td>
<td>0.945, 1.057</td>
</tr>
</tbody>
</table>

Abbreviation: OR = odds ratio

A Poisson regression was used to assess the relationship between vitamin D and the number of injuries sustained by participants. No significant relationship was found at T1 (1.005 [0.987, 1.023]) or T2 (1.003 [0.984, 1.022]). In relation to the difference between T2-T1, no significant differences were identified (0.993 [0.960, 1.027]).

DISCUSSION

Acrobatics and tumbling is a sport consisting of a variety of different skills and activities with no previous research examining its relation to injury. The goal of this study was to examine the injury incidence and covariates, particularly related to serum vitamin D status. A&T was originally promoted to have an injury rate similar to women’s soccer. The calculated injury incidence in the present study was 52.4%. Similar to soccer, the lower extremity was the mostly commonly injured body area in the present study. However, the sports differed in the mechanism of injury most commonly reported. Player contact was the leading mechanism for soccer, accounting for 29.2% of injuries.6 Results in this study found that the most common mechanism was noncontact. Soft tissue injuries accounted for 64.3% of soccer injuries, similar to A&T as the leading type of injury sustained, but A&T led with 82.1% of injuries being soft tissue related. Our study found that the injury patterns of A&T more closely resembled that of cheerleading and gymnastics.

There are some important patterns that are manifested when comparing injury data from cheerleading and women’s gymnastics with our findings on A&T. Similar to both cheerleading (30%) and gymnastics (37.8%), lower extremity injuries represented the greatest proportion of injuries but accounted for 57.1% of injuries sustained by our sample. These percentages were much greater than the proportions of cheerleading and gymnastics injuries.7,8 Injury percentages among A&T athletes were similar to those reported in both gymnastics and cheerleading with soft tissue injuries (e.g., sprains, strains) being the most common types of injuries sustained. However, percentages of soft tissue injuries in our sample of A&T athletes (82.1%) accounted for a significantly larger proportion of injuries when compared to 47.8% in cheerleading and 32.35% in gymnastics.7,8 In terms of mechanism of injury, A&T injuries were mostly comprised of noncontact (42.9%) and surface contact (35.5%) mechanisms. These findings are similar to data reported in women’s gymnastics (20.02% and 34.67% respectively).9 An examination of cheerleading injuries revealed that basing activities were most commonly related to injury.7,20 In contrast, injuries associated with basing only accounted for 10.7% of injuries in our sample. Tumbling was the leading injury activity in gymnastics and A&T, including 50% of the injuries sustained by our sample. As A&T continues to grow as a sport, understanding of this injury descriptive information is important for coaches, athletic trainers, and administrators to understand when evaluating adding A&T to a university athletic department.

Overall, the average vitamin D concentrations of participants was in the acceptable range (T1 = 47.976 ± 18.874 ng/ml and T2 = 41.883 ± 18.453 ng/ml), with values below 20 ng/ml being considered deficient, and 20-32 ng/ml being considered insufficient. Optimal levels are defined as greater than 40 ng/ml.13 Amongst our sample of A&T athletes, at both time points only 1 participant (2.4%) was in the range of deficient (<20 ng/ml) and it was the same participant who remained deficient throughout the study period. At T1, 8 participants (19.1%) were considered insufficient (20-32 ng/ml), while at T2 that number rose to 13 (31.0%). Our results showed that there was a significant loss of vitamin D throughout the study (p<.001). This indicates that throughout the course of the fall training season, our sample of A&T athletes had a significant decrease in serum vitamin D. As the fall season progresses, the volume and intensity of training both increase as athletes begin to increase their development in the weight room and on the mat. If vitamin D concentrations are dropping as this stress on the body is increasing, it raises concern for the potential development of a variety of injuries, particularly bony stress injuries. The proportion of athletes possessing inadequate vitamin D concentrations (19.1% and 33.3%) were similar to the findings of Lovell et al. in their examination of women’s gymnasts.18 There is a known relationship between serum vitamin D and bony injuries, with multiple authors supplying evidence that vitamin D above the threshold for deficiency/insufficiency is associated with a lower risk of bony injury.21 Although there is little to no evidence on...
vitamin D status and prevention of soft tissue injuries, A&T participants sustained primarily soft tissue injuries (82.1%). This may present one reason for the lack of association found between vitamin D concentrations and injuries sustained in this study. Participants with inadequate vitamin D met with the team physician and/or dietitian to discuss interventions to increase their serum vitamin D. Despite these efforts, the number of participants considered insufficient increased between time points. There is no published research on the sport of A&T, and nothing is known on their vitamin D status and its relation to injury. Although education was not one of the initial aims of this study, we found that education as an intervention did not have a positive impact on participants. Therefore, further investigation on intervention strategies for sports medicine and nutrition staffs may be warranted.

The current EMR system utilized by the athletic medicine department was not conducive to tracking injuries and exposures within the sport of A&T. Overall, the system did not track athlete exposures, making calculation of injury rates impossible. Most previous research on injury in sport examined injury rates by tracking athlete exposures, which provides true injury rate values for sports such as women’s soccer (8.33/1000 AEs) and women’s gymnastics (8.00/1000 AEs).6,8 Unfortunately as we were unable to track athlete exposures, only injury incidence could be calculated for our sample of A&T athletes, limiting our ability to compare to volume of injuries. Time loss was also difficult to assess quantitatively, not only due to the lack of athlete exposures collected, but due to the variety of activities done at each practice. For example, a student athlete may be held from all impact activities (e.g., tumbling, topping), but may be able to complete all non-impact activities (e.g., tosses, basing). As the sport of A&T continues to grow, athletic medicine departments and EMR designers should be aware of the unique requirements of injury tracking and documentation of the sport. Data collection occurred during the fall semester, which did not incorporate the competitive season of A&T. This limited data collected to only practice-related injuries. Future research would benefit from exploring injuries sustained during the competitive season. We were limited to the roster size of the university’s A&T team (n=51) for participant recruitment. Future research would benefit from examining injury rates across multiple institutions and divisions to increase understanding. We found a lack of improvement in vitamin D despite educational intervention with the team physician/dietitian and believe that future studies including a true vitamin D intervention may help to improve vitamin D status in athletes. The sport of A&T is a growing sport across all divisions, allowing for an increasing number of women to participate in collegiate athletics from cheerleading and gymnastics backgrounds. Further research on A&T is warranted to increase the understanding of injury patterns and assist in creating prevention strategies to support student athletes’ overall health and wellbeing, as well as athletic performance.

CONCLUSIONS
Despite interventional meetings with the team physician and/or dietitian after the first blood draw, more participants presented with inadequate vitamin D at T2 than T1. Multiple factors may be related including an increase in training volume and intensity (from 8-hour weeks to 20-hour weeks), change in season (from fall to winter), and lack of dietary/lifestyle adjustment based on medical recommendations. The majority of injuries sustained were sprains/strains to soft tissue, as well as occurred in the lower extremity, with the most common activity being related to tumbling. These are all important factors for both coaches and athletic medicine departments to understand when caring for an A&T team and its student athletes. Athletic medicine and sport nutrition staffs can utilize this knowledge in decision making for appropriate screening, education, and supplementation for A&T student athlete.
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