Chronic Lack of Sleep is Associated With Increased Sports Injuries in Adolescent Athletes

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Background: Much attention has been given to the relationship between various training factors and athletic injuries, but no study has examined the impact of sleep deprivation on injury rates in young athletes. Information about sleep practices was gathered as part of a study designed to correlate various training practices with the risk of injury in adolescent athletes.

Methods: Informed consent for participation in an online survey of training practices and a review of injury records was obtained from 160 student athletes at a combined middle/high school (grades 7 to 12) and from their parents. Online surveys were completed by 112 adolescent athletes (70% completion rate), including 54 male and 58 female athletes with a mean age of 15 years (SD = 1.5; range, 12 to 18 y). The students' responses were then correlated with data obtained from a retrospective review of injury records maintained by the school's athletic department.

Results: Multivariate analysis showed that hours of sleep per night and the grade in school were the best independent predictors of injury. Athletes who slept on average <8 hours per night were 1.7 times (95% confidence interval, 1.0-3.0; $P = 0.04$) more likely to have had an injury compared with athletes who slept for ≥ 8 hours. For each additional grade in school, the athletes were 1.4 times more likely to have had an injury (95% confidence interval, 1.2-1.6; $P < 0.001$).

Conclusion: Sleep deprivation and increasing grade in school appear to be associated with injuries in an adolescent athletic population. Encouraging young athletes to get optimal amounts of sleep may help protect them against athletic injuries.

Level of Evidence: Level III.

Key Words: sleep, adolescents, sports, injuries

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More than 38 million children and adolescents participate in sports in the United States, and more than 3.5 million children receive medical treatment for sports-related injuries each year.[1] Increased specialization among young athletes and increased participation in year-round sports have been proposed as reasons for a high incidence of injury in this population.[2,3] Previous studies have shown increased injury rates based on number of sports played, number of exposures, and playing year-round.[4–9] Cuff et al[6] found that, even when controlling for increased exposure rate, playing year-round was an independent risk factor for injury.

Little is known about the role that sleep deprivation plays in the risk of injuries in adolescent athletes. Modest sleep loss has been associated with impairment of psychomotor performance in adults[10]; however, little is known about the effects in children. Athletic performance generally has been shown to be affected by sleep patterns,[11–14] and sleep deprivation is known to dampen reaction times and affect mood and cognitive functions, which could increase the risk of injury in adolescent athletes.[15,16]

Our study sought to identify risk factors for injuries in a cohort of adolescent athletes and to determine the relative contributions of each factor to the risk of injury. Risk factors studied included: the number of sports played; time spent participating in sports through school and private club teams; participation in strength training; use of a personal coach for training outside of school; average amount of sleep per night; and subjective assessment of enjoyment in sports.

METHODS

This study was conducted at a combined high school/middle school in a large metropolitan area. The

study was approved by the school's athletic department and administration and by our Institutional Review Board. All student athletes and their families were informed of the study during preseason meetings and were invited to participate. Written informed consent was first obtained from willing parents and then the consent was confirmed with the student athletes. After informed consent was obtained from student athletes and their parents, all consented student athletes were invited by email to take part in the survey. The invitation contained a link to the survey, which consisted of 10 questions:

(1) How many weeks a year do you participate in organized sports?
(2) During the average week, how many hours are spent in sports including training, practice, and competition? (Excluding time spent reviewing films, playbooks, and team meetings.)
(3) Have you had a private coach outside of normal school or club teams?
(4) If so, how many hours per week, on average, are spent in private coaching?
(5) During the season how many hours of sleep, on average, do you get per night?
(6) Do you participate in strength training on a regular basis?
(7) How many times per week do you participate in strength training?
(8) How long is each strength training session?
(9) How many sports do you participate in per year on a school or club level?
(10) How much fun are you having in sports right now on a scale of 1 to 10? (1 would be having no fun and 10 being the most fun possible.)

Eligible participants included any male or female student at the school who was entering grades 7 to 12 who had participated and planned to continue to participate in at least one sport during the previous and upcoming year. Consent of both the student athletes and their parents was required for inclusion in the study. Consent was obtained between May 2011 and February 2012. Age and grade in school were defined at the time of questionnaire completion. Data from student athletes who did not fully respond to the online survey were excluded from the analysis.

Included injuries were defined as any injury that necessitated a visit to the athletic trainer's room for evaluation and/or treatment. The injury log from the school's athletic training room was reviewed for the records of our survey participants over a 21-month period (June 5, 2010 to March 15, 2012). Seven seventh graders were included from their matriculation to the middle school until March 15, 2012 but did not have full 21-month injury data. Injuries were cataloged by anatomic location, activity while injured, and what sport the athlete was participating in.

STATISTICAL ANALYSIS

Survey data were compiled and then compared with the injury log using Stata 12.0 (StataCorp LP, College Station, TX) to perform statistical analyses. The generalized linear model was used to examine predictors of injury versus no injury. Probability of injury (defined as injury vs. no injury) was used as the primary outcome. Possible independent variables included gender, age, grade in school at time of study participation, hours of sleep obtained per night, weeks of participation in sports per year, hours of participation per week (including time spent training, practicing, and competing), number of sports, strength training, private coaching, and subjective assessment of "having fun in sports." Univariate analysis was performed first, followed by multivariate analysis. The multivariate analysis included the variables that were found to be significant in the univariate analysis. Relative risk (RR) of injury was estimated by the Poisson regression with robust error variance, along with standard errors and 95% confidence intervals (CI) for the RR.[17] The significance level was set at $P < 0.05$.

RESULTS

Informed consent for participation in our study was obtained from 160 student athletes and their parents. All consenting students were sent a copy of the survey by school-registered email. Of the 160, 112 student athletes (54 male and 58 female athletes) completed the survey for a 70% participation rate. Average age was 15.2 years (SD = 1.5; range 12 to 18 y). One student athlete only partially completed the survey and their responses and injury data were excluded.

Of the 112 athletes studied, 64 athletes (57%) sustained a total of 205 injuries; 48 athletes (43%) were not injured. Of those who were injured, 42 athletes sustained >1 injury (38%). Table 1 includes a summary of the injuries by anatomic location.

In the univariate analysis (Table 2), the strongest predictor of injury was <8 hours of sleep per night (RR = 2.1; 95% CI, 1.2-3.9; $P = 0.01$) (Table 2). Sixty-five percent of athletes (56/86) who reported sleeping <8 hours per night were injured, compared with 31% of athletes (8/26) who reported sleeping ≥ 8 hours per night. Figure 1 shows the likelihood of injury over the 21-month period of reporting, based on hours of sleep per night.

Increased age (RR = 1.4 per year; 95% CI, 1.2-1.5; $P < 0.001$) and grade in school (RR = 1.4 per grade; 95% CI, 1.2-1.6; $P < 0.001$) were significantly associated with increased likelihood of injury. Strength training was also associated with an increased likelihood of injury (RR = 2.0; 95% CI, 1.3-3.2; $P = 0.003$), as was hours per week of participation in sports (RR = 1.2 per 5 hours; 95% CI, 1.0-1.3; $P = 0.01$). Gender, weeks per year participating in sports, number of sports, private coaching, and subjective assessments of "having fun in sports" were not significantly associated with injury history.

In the multivariate analysis (Table 3), the best model included showed hours of sleep per night and grade in school as the most significant independent risk factors for injury. Athletes who slept on average <8 hours per night had 1.7 times greater risk of being injured than those who slept ≥ 8 hours (95% CI, 1.0-3.0; $P = 0.04$) (Table 3). For

TABLE 1. Injuries by Anatomic Location

Anatomic Injury Location	No. Injuries
Hand/wrist	30
Knee	28
Shoulder	24
Ankle	19
Back	18
Head	17
Quadriceps/hamstring	12
Elbow	11
Hip	11
Shin/calf	11
Foot/toe	7
Neck	7
Rib/chest	4
Face/eye	4
Fatigue/sickness	2
Total	205

each additional grade in school, the risk of injury increased by 1.4 times (95% CI, 1.2-1.6; $P < 0.001$).

DISCUSSION

Our study shows that the amount of sleep per night is associated with the risk of injuries in adolescent athletes. This association was observed even after accounting for other factors that might affect injury rates such as grade in school or amount of time spent participating in sports. This finding is not surprising in view of previous research that shows that even modest sleep loss is associated with impairment of psychomotor performance.[10] Sleep deprivation can affect motor function, mood, and cognitive functions, all of which could affect a young student athlete's performance and injury risk.[15,16]

The effect of sleep duration on athletic performance in college-age athletes has been examined previously. Mah et al[12] found that basketball players who increased their sleep to at least 10 hours were able to sprint faster, shoot more accurately, and had improved subjective ratings of physical and mental well-being. Mougin et al[13] found that sleep deprivation negatively affected cardiovascular performance in cyclists, whereas Reilly and Piercy found that submaximal weight lifting was negatively affected by sleep deprivation.[14] We are not aware of any previous study that examined sleep as a risk factor for injury in adolescent athletes.

This study confirms that increasing age is an independent predictor of injury in adolescent student athletes. Others have shown that increasing age is predictive of injury in pediatric and adolescent athletes involved in football, soccer, and gymnastics.[4,18–20] This is not surprising given the physical and mental demands of participation at increasing levels of competition (ie, the progression from freshman to junior varsity to varsity level teams). In addition, older athletes have accumulated more exposure time for potential overuse injuries. Our study did not show an association between weeks of participation per year or number of sports with increased risk of injury but did show an association with hours of participation per week in univariate analysis. This differs slightly from previous studies.[4–9] Cuff et al[6] found a 42% increased risk of injury in high school athletes participating in year-round sports compared with single-season athletes. In the univariate analysis, strength training was also found to be associated with injury history, but the amount of strength training was not found to be associated with injury history. The multivariate analysis did not find strength training to be an independent predictor of injury. One possible reason for this set of findings could be that older athletes were more likely to participate in strength training and it may be difficult to separate the effects of these 2 risk factors in this study.

A strength of this study is that it involves a cohort of adolescent student athletes subject to similar sets of academic, psychological, and physical stresses. This cohort had a dedicated certified athletic training staff available at all times during their athletic participation, including both game and practice situations. Training room facilities were available if injuries occurred during sporting activities, and the certified athletic training staff kept records of every injury encounter reported by the athletes including those sustained during school-sponsored athletic events and practices along with injuries sustained in the community and then reported to the staff by the athlete before being allowed to return to school-sponsored athletics. The injured and noninjured student athletes in this cohort were well matched.

TABLE 2. Results of Univariate Analysis

Risk Factor	Relative Risk	SE	95% CI	*P*
Male	1.0	0.2	0.7, 1.4	0.96
Age (y)	1.4	0.1	1.2, 1.5	< 0.001
Grade in school	1.4	0.1	1.2, 1.6	< 0.001
Sleep (h/night)	0.8	0.1	0.7, 0.9	0.006
< 8 h/night sleep	2.1	0.6	1.2, 3.9	0.01
Weeks/year of sports (5 wk increments)	1.1	0.1	1.0, 1.2	0.17
Hours/week of sports (5 h increments)	1.2	0.1	1.0, 1.3	0.01
No. sports	1.0	0.1	0.8, 1.2	0.97
Strength training	2.0	0.5	1.3, 3.2	0.003
Private coaching	1.2	0.2	0.9, 1.6	0.30
"Fun in sports"	1.0	0.04	0.9, 1.1	0.49

CI indicates confidence interval.

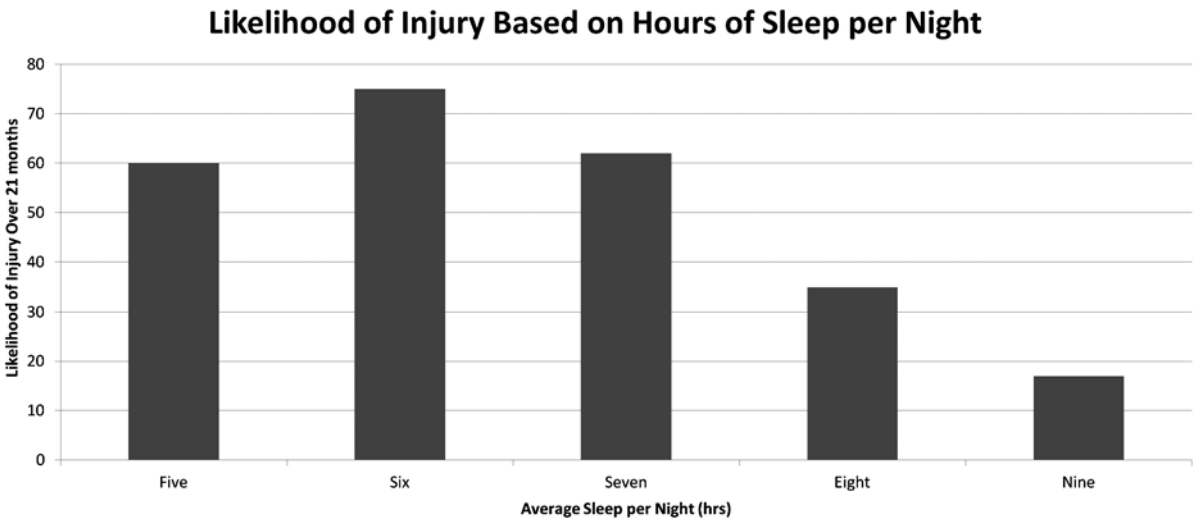

FIGURE 1. Likelihood of injury over 21-month period based on hours of sleep per night. Used with permission from Children's Orthopaedic Center at Children's Hospital, Los Angeles. Adaptations are themselves works protected by copyright. So in order to publish this adaptation, authorization must be obtained both from the owner of the copyright in the original work and from the owner of copyright in the translation or adaptation.

Despite the fairly small cohort, reported hours of sleep in these adolescents were similar to those reported in the literature. The Centers for Disease Control recently reviewed over 14,000 adolescents' responses to health questionnaires including questions about their sleep patterns and found that 68.9% reported ≤ 7 hours of sleep per night.[21] They found that only 23.5% reported 8 hours of sleep and only 7.6% reported "optimal sleep" of ≥ 9 hours per night. In our cohort, 76.7% of adolescents reported ≤ 7 hours of sleep per night, showing a similar or slightly greater lack of sleep in the adolescents studied here compared with national data. Lack of sleep in adolescents appears to be an issue in both this cohort and nationally. No formal guidelines for necessary sleep exist for adolescents, but the National Sleep Foundation defines < 8 hours as insufficient, 8 hours as borderline, and ≥ 9 hours as optimal for high school age students.[21]

The estimated injury rate for the athletes who participated in this study (based on the average reported weeks/year and hours/week of participation) was approximately 1.7 injuries per 1000 hours of participation. This rate is comparable with that found in larger studies performed by others. Caine et al[5] reviewed 31 articles and found that injury rates ranged from 0.5 to 34.4 injuries per 1000 hours of participation.

A limitation of this study was that it was conducted at a single academically demanding, urban, private, combined middle school/high school, and the findings may not be generalizable to other populations in different geographic, socioeconomic, and educational settings. Further, the data are based on the self-reported survey responses of adolescents. Another possible limitation is that this study examines the adolescents' reported chronic sleep deprivation. Acute sleep deprivation, such as getting minimal sleep on a more limited basis, may also put the athlete at increased risk of injury but would not have been captured by this survey as the average amount of sleep might be sufficient. In addition, the athletes were not asked about their dietary intake or specific medications, which may have an effect on their sleep or injury risk. We also did not account for napping in this population as a source of additional sleep. Several authors have shown that daytime napping can improve performance of both athletic and cognitive tasks.[22,23] Future studies to examine the prevalence and utility of napping in adolescent athletes may enhance our understanding of its value in the prevention of injuries. It is possible that some injuries were not captured by the athletic trainers' reports, particularly those that occurred away from school or in sports activities not affiliated with the school. We believe that the great majority of injuries were likely to have been captured because student athletes are required by school policy to report all injuries to the athletic training staff.

In conclusion, lack of sleep and increasing grade in school appear to be associated with increased injury risk in an adolescent athletic population. Encouraging young athletes to get optimal amounts of sleep may help protect them against athletic injuries.

TABLE 3. Multivariate Analysis

Risk Factor	Relative Risk	SE	95% CI	*P*
Grade in school	1.4	0.1	1.2, 1.6	< 0.001
< 8 h/night sleep	1.7	0.5	1.0, 3.0	0.04

CI indicates confidence interval.

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