Decreased Sleep Is an Independent Predictor of In-Season Injury in Male Collegiate Basketball Players

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Background: Although decreased sleep has been associated with decreased performance, increased illness risk, and impaired well-being in athletes, the relationship between sleep and injury risk in collegiate athletes is unknown.

Purpose/Hypothesis: To evaluate the independent effects of sleep duration and subjective well-being on in-season injury in male collegiate basketball athletes. We hypothesized that decreased sleep would be associated with an increased risk of in-season injury.

Study Design: Cohort study; Level of evidence, 2.

Methods: During 2 consecutive seasons, 19 male National Collegiate Athletic Association Division I basketball players reported mood, fatigue, stress, soreness, sleep duration (hours), and previous day's training load every morning. Well-being measures were recorded on a scale from 0 (worst) to 5 (best), and all time-loss injuries were recorded by the team athletic trainer. Separate mixed-effects logistic regression models were used to evaluate the effects of sleep and subjective well-being on in-season injury, with adjustment for same-day training load and individual repeated measures. To determine the independence of sleep and well-being as predictors of injury, each well-being variable was included in a separate mixed-effects logistic regression model, with sleep and training load as covariates.

Results: During the study period, 32 injuries were recorded. In the initial separate prediction models, in-season injury was significantly predicted by mood (odds ratio [OR], 0.50; 95% CI, 0.37-0.66), fatigue (OR, 0.44; 95% CI, 0.33-0.59), stress (OR, 0.57; 95% CI, 0.42-0.76), soreness (OR, 0.41; 95% CI, 0.32-0.54), and sleep duration (OR, 0.57; 95% CI, 0.49-0.66) ($P < .001$ for all). In the multivariable models, sleep duration remained a significant, independent predictor in each of the subsequent multivariable models (OR, 0.52-0.69; $P < .001$ for all) as did soreness (OR, 0.65; 95% CI, 0.44-0.95; $P = .024$), whereas mood (OR, 1.2; 95% CI, 0.76-1.9; $P = .43$), fatigue (OR, 1.1; 95% CI, 0.65-1.9; $P = .68$), and stress (OR, 1.1; 95% CI, 0.75-1.5; $P = .69$) were no longer significant.

Conclusion: Increased sleep duration is independently associated with a reduced risk of in-season injury in male collegiate basketball players, even after adjustment for training load and subjective well-being. The effects of mood, fatigue, and stress on injury were no longer evident after adjustment for the effect of sleep duration.

Keywords: athletes; training load; well-being; sleep; injury

Although the benefits of exercise are considerable, sport participation is also associated with an increased risk of injury.[13] In an epidemiologic study over 15 seasons between 1988 and 2004, male collegiate basketball athletes were found to have an injury incidence of 9.9 and 4.3 injuries per 1000 hours during games and practices, respectively.[6] A more recent 5-year study of 78 men's collegiate basketball programs found a similar overall injury incidence of 7.97 per 1000 hours.[24] In both studies, the majority of injuries were noncontact, with the ankle and knee being the most commonly involved body parts and National Collegiate Athletic Association Division I athletes having higher injury rates than did their Division II and III counterparts.[24] This incidence of injuries represents a significant health burden for these athletes and a threat to athletic success.[7] Consequently, the identification of risk factors in athletes that can be modified before or during the athletic season can potentially reduce in-season injury in athletes.

It has been suggested that in addition to affecting athletic performance, decreased sleep may be a risk factor for injury in athletes. Decreased sleep has been shown to increase fatigue, reduce reaction time, and influence

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cognitive performance, all of which may increase the risk for injury.[14,21] In a retrospective study of middle and high school athletes, Milewski et al[15] surveyed athletes to estimate their average number of hours of sleep during the preceding season and integrated this information with injuries reported to an athletic trainer during the previous 21 months. After adjustment for other covariates, decreased sleep duration was found to be an independent risk factor for injury, with a significantly higher injury risk found among those athletes who slept <8 hours per night on average. A more recent study of 496 adolescent athletes from a variety of sports also found that a decrease in self-reported sleep duration increased the risk for injury, especially when training loads concomitantly increased.[21] In contrast, a prospective study of 22 adult Australian football players using wrist actigraphy over a single season found no significant effect of sleep duration or efficiency on injury risk.[5] As a result, it remains unclear whether impairments in sleep influence injury risk, particularly among adult athletes.

Several recent studies have suggested that impairments in subjective well-being may increase the risk for in-season injury in athletes.[7,14,23] Although a recent study of adult team sport athletes found that perceived recovery and stress were predictive of in-season injury,[19] the study evaluated stress monthly, and more frequent monitoring may be necessary to provide actionable information to coaching and athletic training staff. In a study of adolescent female soccer players over a single season, however, decreased daily mood was found to be an independent predictor of increased injury risk, even after adjustment for the effects of training load.[23] Subjective well-being measures have also been found to be strongly and negatively affected by increases in acute training load and to be more sensitive to training load changes than are objective measures.[17] It has been suggested, therefore, that changes in subjective well-being may represent sensitive markers of acute fatigue or early overtraining and warning signs of an increased risk of subsequent injury.

The independent effects of sleep and well-being on injury are unclear, as alterations in sleep can also have significant effects on mood, fatigue, and stress as well as physical symptoms, such as soreness in athletes.[23] In a longitudinal study of adolescent soccer athletes, increases in sleep were found to have significant, positive, dose-dependent effects on subjective well-being. In addition, a significant portion of the negative effects of increased training load on subjective well-being were found to be mediated by the effects of training load on sleep.[22] This seems to suggest that sleep and subjective well-being are strongly related and may interact to influence injury risk in athletes.

Although previous research has evaluated the predictive ability of data that are collected or aggregated on a weekly or monthly basis,[7] the identification of injury risk on a daily basis may allow for a more timely intervention to promote athlete health. For example, although acute increases in training load can negatively affect sleep and well-being,[17,23] short-term reductions in training load or increases in sleep can restore these measures, potentially averting the increased injury risk.[10,12] Nonetheless, there remains a paucity of prospective data in adult athletes regarding the relationship among sleep, subjective well-being, and injury. In addition, the interaction between sleep and well-being potentially confounds their relationships with injury, and we are aware of no research that has attempted to evaluate the independence of these relationships in athletes. Therefore, the purpose of this study was to determine whether sleep and subjective well-being are independent predictors of injury in male collegiate basketball players. We hypothesized that both sleep and subjective well-being would be related to subsequent injury but only sleep duration would exert an independent effect on injury risk the following day.

METHODS

Study Design

A total of 19 male National Collegiate Athletic Association Division I basketball athletes provided self-reported training load, sleep, and well-being data throughout 2 consecutive 6-month seasons. Each morning during the study period, before any basketball events, athletes were asked to provide ratings of fatigue, mood, soreness, stress, and sleep quality on a 0 (worst) to 5 (best) Likert scale with descriptive text prompts, as well as sleep duration in hours, using an online software program (metrifit.com). As mentioned, subjective measures of well-being and sleep quality, such as these, more accurately reflect changes in training load than do objective measures and have been shown to be predictors of injury in various populations.[17,19,20,23] In addition, sleep quality evaluation through self-report has been suggested as an appropriate measure in team sports athletes, even when compared with objective measures, such as wrist actigraphy.[4] Finally, self-reported sleep duration is a commonly used, low-cost metric that has been found to be highly correlated with objective measures of sleep duration in athletes.[3] Immediately after all physical activity during this period, participants provided the duration (minutes) and subjective intensity (1 [very light] to 10 [maximal]) for all activities, which were multiplied to yield a session

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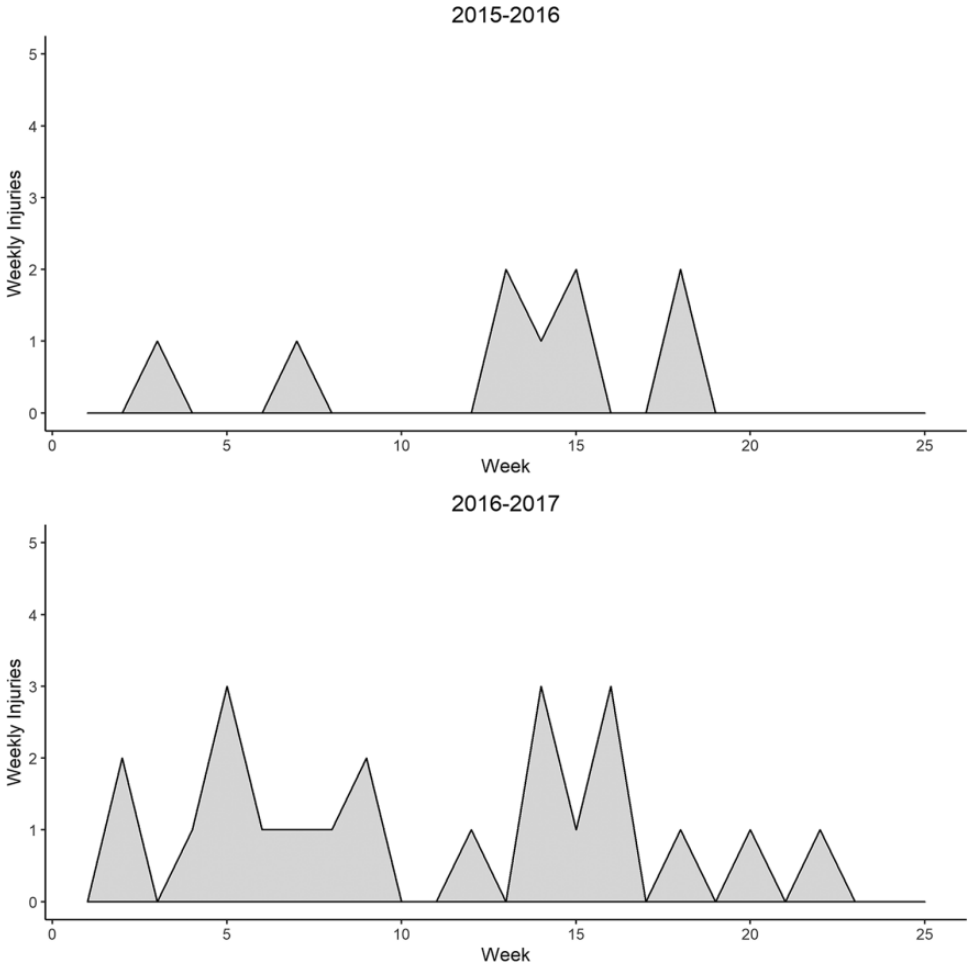

Figure 1. Number of weekly injuries during 2 consecutive seasons among male collegiate basketball athletes.

rating of perceived exertion value as a measure of internal training load.[8,9] All procedures were approved by an institutional review board. Because the data were collected as part of the standard athlete monitoring practices of the teams involved and analyzed retrospectively, informed consent was not deemed necessary for inclusion in this retrospective analysis.

Throughout the study period, injuries that resulted in time loss were recorded by the team athletic trainer. Acute injuries were defined as those with a sudden onset during an identifiable event, whereas overuse injuries were defined as having a gradual onset and unrelated to a specific event. Both first-time and repeat injuries were included if they were believed to represent new injuries based on resolution of symptoms and return to full participation between time-loss injuries. Compliance with the completion of daily training load and well-being ratings was encouraged periodically throughout the study period by coaching staff.

Statistical Analysis

Data were initially evaluated for normality using descriptive statistics and histogram analysis. Injuries per 1000 hours were calculated for days preceded by different amounts of sleep (<6, 6-7, 7-8, and >8 hours). Previous night's sleep and subjective well-being measures from before the basketball events were compared between days with and without an injury using least-squares means from mixed-effects linear regression models to adjust for individual repeated measures. For sleep duration and each subjective well-being measure (mood, fatigue, soreness, stress), separate mixed-effects logistic regression models were used to evaluate their association with in-season injury by including the variable and same-day training load as fixed effects and the individual as random effect. In other words, this tested the relative ability of each variable reported in the morning to predict the likelihood of injury later that day while accounting for the training load that day. To determine the independence of sleep and well-being as predictors, each well-being variable (mood, fatigue, soreness, stress) was included in a separate mixed-effects logistic regression model with sleep duration and same-day training load as covariates. Significance level was determined a priori at the .05 level, and all tests were 2-tailed. All statistical analyses were performed in R.[16]

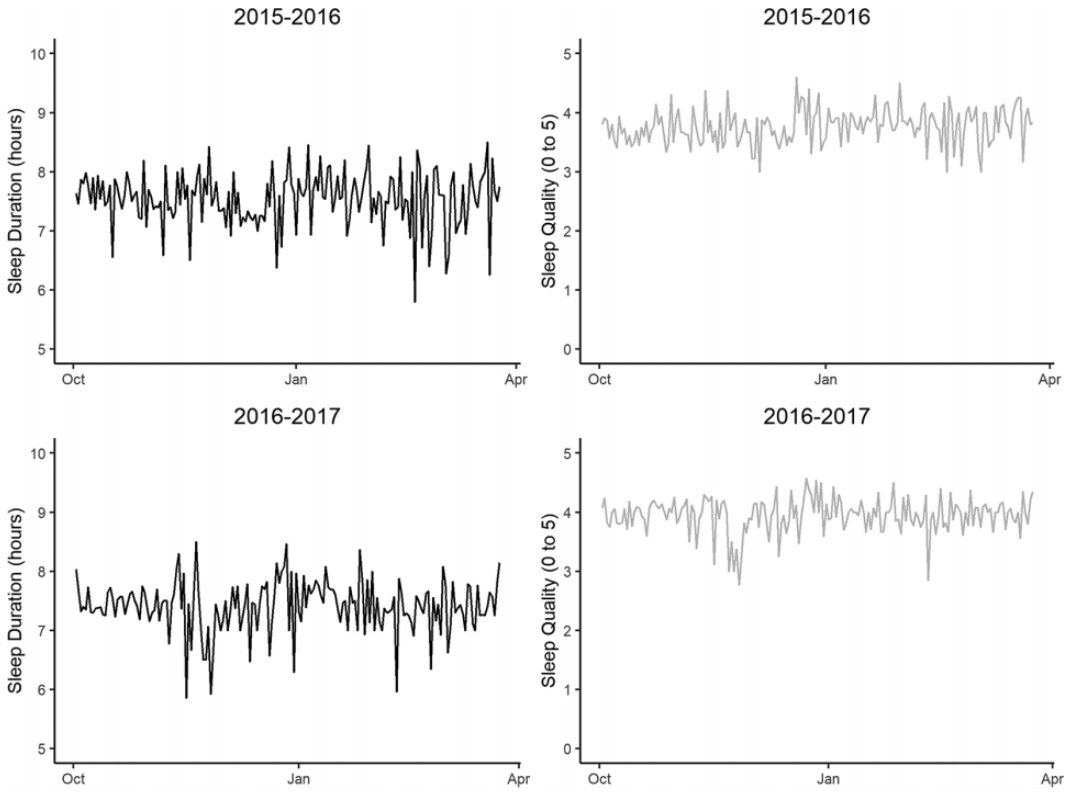

Figure 2. Average nightly, self-reported sleep duration (black) and sleep quality (gray) during 2 consecutive seasons among male collegiate basketball athletes. Sleep duration is shown in hours, whereas sleep quality is measured from 0 (worst) to 5 (best).

RESULTS

We identified 32 injuries occurring on 29 days in 12 individual athletes. The distribution of weekly injuries throughout the study period is shown in Figure 1. The mean sleep duration during the study period was 7.44 ± 1.2 hours, and 83% of the athletes averaged <8 hours of sleep per night. Average nightly sleep duration and quality are shown in Figure 2.

Injuries per 1000 hours decreased dramatically as the preceding night's sleep duration increased (Figure 3). Compared with days without a reported injury, days on which an injury occurred were found to have significantly lower (worse) mood, fatigue, stress, soreness, sleep quality, and sleep duration before the injury (Figure 4).

Sleep duration was found to be significantly related to each of the subjective well-being measures the following morning (Table 1). Daily mood, fatigue, stress, soreness, and sleep quality were all found to be significant predictors of injury in the separate mixed-effects logistic regression analysis, but after inclusion with sleep duration in the multivariable models, only sleep duration and soreness remained significant, independent predictors of injury (Table 2).

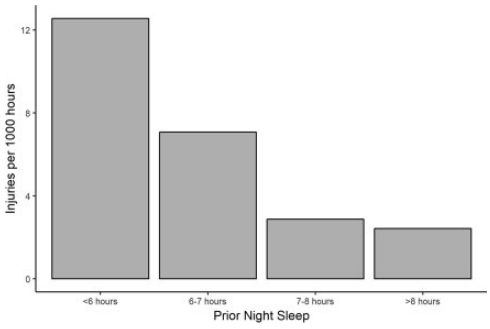

Figure 3. Number of injuries per 1000 hours after nights with different amounts of sleep among male collegiate basketball athletes. Days from both seasons were grouped according to prior night sleep duration, and injuries per 1000 hours were calculated for each group.

DISCUSSION

The primary finding of this study was that increased sleep duration is associated with a decreased risk of in-season injury in male collegiate basketball players even after adjustment for training load. Specifically, we found that a 1-hour increase in sleep duration was associated with a 43% decrease in injury risk the following day. This is consistent with previous studies of youth athletes that have similarly found that decreases in self-reported sleep duration were associated with an increased risk of injury.[15,21] In both of these previous studies, however, sleep and injuries were aggregated during the same time periods,

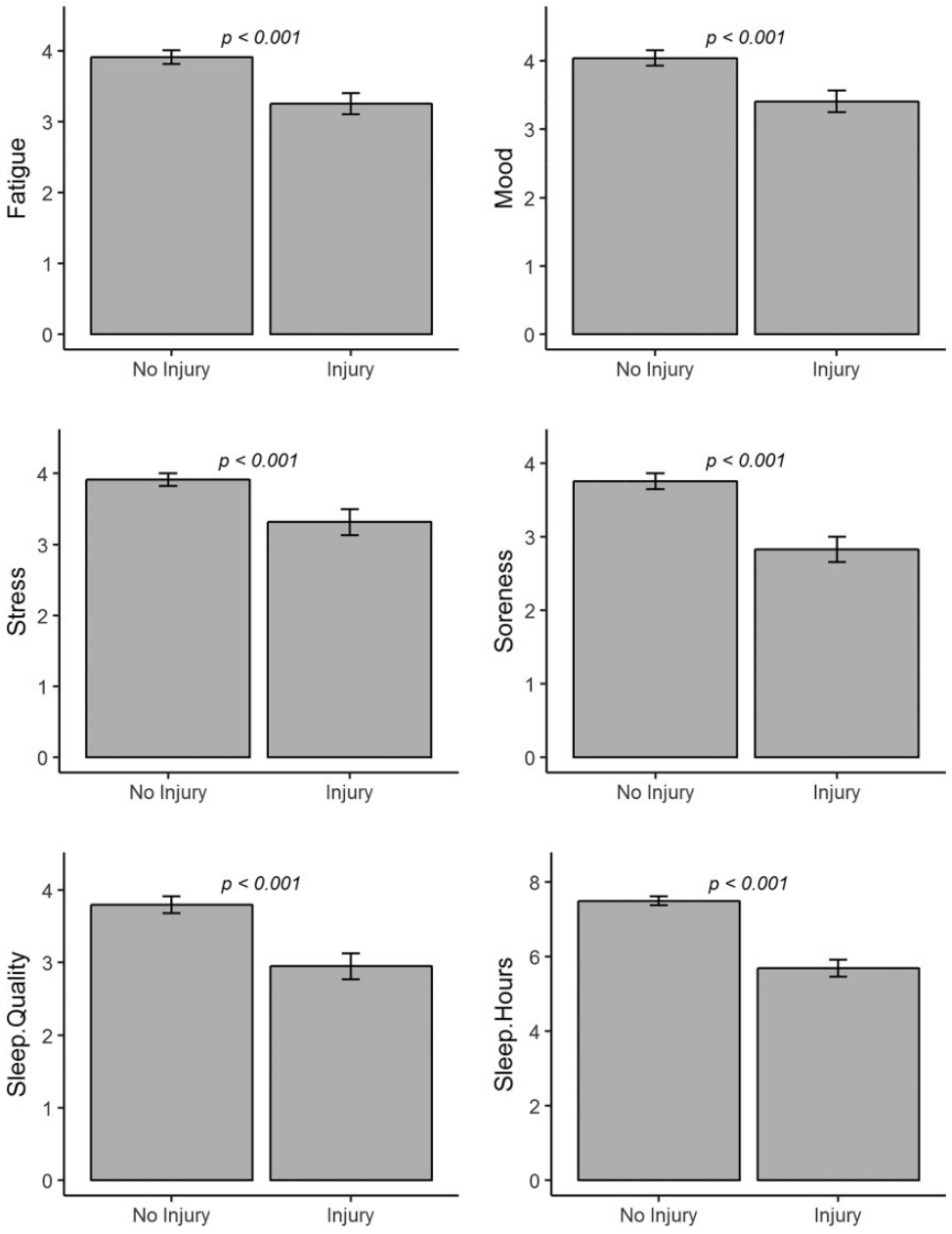

Figure 4. Average daily subjective well-being, sleep duration, and sleep quality immediately before days with and without injuries during 2 consecutive seasons among male collegiate basketball athletes.

making it impossible to know whether decreased sleep preceded the reported injuries or whether the injury itself resulted in subsequent impairments in sleep. A recent study of 22 adult Australian football athletes, however, did not identify a relationship between sleep and injury.[5] Because that study included only a single season with 9 injuries, it may have been insufficiently powered to fully evaluate the relationship. In the current study, we evaluated the effects of the previous night's sleep on the risk of injury the following day on an individual level, better allowing us to speculate about a causal relationship between sleep and injury. The mechanism by which sleep might influence injury is beyond the scope of the current study, but it is reasonable to speculate that decreased sleep may result in reduced reaction time, increased fatigue, and/or reduced cognitive speed, which could predispose athletes to injury.

We also found that all of our measures of subjective well-being were predictive of in-season injury. Although previous studies have found that measures of well-being can predict injury risk, these have not adjusted for training load, which is a predictor of injury and can influence subjective well-being itself.[11,15] Two previous studies of adolescent athletes found that overreached players

TABLE 1
Spearman Correlation Coefficients Between Sleep Duration and Subjective Well-Being Measures the Following Day

	Mood	Fatigue	Soreness	Stress
Sleep duration (h)	0.22[a]	0.35[a]	0.19[a]	0.14[a]

[a]$P < .001$.

TABLE 2
Separate Mixed-Effects Logistic Regression Models to Identify Predictors of In-Season Injury in Male Collegiate Basketball Players

	Odds Ratio	Lower 95% CI	Upper 95% CI	*P* Value[a]
Univariable[b]				
Mood	0.50	0.37	0.66	**<.001**
Fatigue	0.44	0.33	0.59	**<.001**
Soreness	0.41	0.32	0.54	**<.001**
Stress	0.57	0.42	0.76	**<.001**
Sleep quality	0.44	0.33	0.59	**<.001**
Sleep duration[c]	0.57	0.49	0.66	**<.001**
Multivariable[d]				
Mood	1.2	0.76	1.9	.42
Sleep duration	0.52	0.4	0.68	**<.001**
Fatigue	1.1	0.65	1.9	.68
Sleep duration	0.54	0.4	0.73	**<.001**
Soreness	0.65	0.44	0.95	**.024**
Sleep duration	0.69	0.56	0.85	**<.001**
Stress	1.1	0.75	1.5	.69
Sleep duration	0.55	0.44	0.69	**<.001**
Sleep quality	1.0	0.69	1.7	.93
Sleep duration	0.56	0.42	0.76	**<.001**

[a]Boldface values indicate statistical significance ($P < .05$).
[b]Separate mixed-effects logistic regression models were used to predict injury; morning well-being or previous night sleep measure and same-day training load were fixed effects, and individual was a random effect.
[c]Sleep duration was measured in hours in this study.
[d]Separate mixed-effects logistic regression models were used to predict injury, including both sleep duration and the listed well-being variable as fixed effects and individual as a random effect.

demonstrated impairments in several measures of psychosocial well-being compared with controls up to 2 months before the diagnosis of overreaching.[2,18] In a similar study of adolescent male soccer players, however, Brink et al[1] did not demonstrate the ability of these measures to predict injury. In these studies, stress and recovery were measured every 3 weeks,[2] monthly,[1] or only at the time of diagnosis of overreaching.[18] Mood, fatigue, and stress may fluctuate significantly on a much shorter timeline, and previous research has demonstrated the influence of acute training load on several measures of well-being.[22] With that in mind, in the present study, we found that daily measures of mood, fatigue, stress, and soreness were all predictors of injury during the season.

Sleep, training load, and subjective well-being interact considerably, and we sought to evaluate the independent effects of sleep and subjective well-being while accounting for the influences of training load. Specifically, sleep can have a significant influence on subjective well-being the following day,[22] and in this study, we found that the effects of mood, fatigue, and stress on injury were no longer evident after adjustment for the effect of sleep duration. This seems to suggest that the relationship between well-being and injury may be due to the fact that sleep duration influences both well-being and injury, and any influence of well-being on injury is attributable to the underlying effects of sleep. In other words, decreased sleep duration appeared to both increase injury risk and impair subjective well-being, but mood, stress, and fatigue did not demonstrate an independent effect on injury. Soreness, on the other hand, remained an independent predictor of injury after adjustment for the influence of sleep. The effect of soreness was reduced after adjustment for sleep, however, suggesting that a portion of the effect of soreness on injury was also due to the effect of sleep duration on soreness.

This study has several limitations. Although we achieved relatively high compliance, we did have missing data. This was believed to be random within the data set, however, and imputation of missing training load, sleep, and well-being data did not result in a substantive change in the results of our analyses. Our analysis did not account for additional risk factors for injury, such as anatomic differences, body composition, fitness level, or previous injury. In addition, a larger sample size in future studies will allow for the evaluation of additional risk factors and their interactions as well as separate prediction models for contact and noncontact injuries. Finally, this study was conducted among a group of elite, male basketball players and may not be generalizable to other populations. For example, relationships between sleep and injury may differ between sports with high rates of acute versus chronic injuries or between contact and noncontact sports. Additional research is necessary in other populations of athletes to determine whether these relationships are reproducible and whether more generalized or sport-specific recommendations can be made.

CONCLUSION

This study demonstrated that increased sleep duration and improved sleep quality were associated with a decreased risk of injury among male collegiate basketball athletes. Although we also found that several subjective well-being measures were predictors of injury risk, the effects of mood, fatigue, and stress were no longer evident after adjustment for the influence of sleep duration. This seems to suggest that sleep duration may be an important predictor of both well-being and injury risk, whereas the relationship between

well-being and injury is incidental. Efforts to promote proper sleep may reduce the risk of in-season injury among this population of athletes, particularly at times when sleep is threatened, such as during periods of high training loads or before competition. Although the majority of previous research has evaluated the predictive ability of data that are collected or aggregated on a weekly or monthly basis,[7] these results suggest that proactive monitoring of sleep on a daily basis may facilitate identification of individuals or groups at risk for injury. Finally, additional research in other sports is important to allow for the identification of independent, modifiable, sport- and sex-specific risk factors that can be used to guide interventions to improve athlete health.

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