Game Spacing and Density in Relation to the Risk of Injuries in the National Hockey League

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Background: Ice hockey has significant workload demands. Research of other sports has suggested that decreased rest between games as well as an increased workload may increase the risk of injuries.

Purpose: To evaluate whether condensed game schedules increase the frequency and severity of injuries in the National Hockey League (NHL).

Study Design: Descriptive epidemiology study.

Methods: Data were obtained from publicly available online sources on game schedules and injuries for all NHL teams for the 2005-2006 through 2018-2019 seasons. Injury rates (per team per game) and the proportion of severe and nonsevere injuries were determined. The game-spacing analysis assessed the risk of injuries in relation to the number of days between games played (range, 0-$\geq$6 days). The game-density analysis assessed the risk of injuries in relation to the number of games played within 7 days (range, 1-5 games). Results were assessed by analysis of variance, the post hoc Tukey test, and the chi-square test of distribution.

Results: The game-spacing analysis included 33,170 games and 7224 injuries, and a significant group difference was found ($P = 1.44 \times 10^{-5}$), with the post hoc test demonstrating an increased risk of injuries when games were spaced with <1 day of rest. There was no significant difference in the ratio of severe to nonsevere injuries. The game-density analysis included 33,592 games and 10,752 injuries, and a significant group difference was found ($P = 8.22 \times 10^{-48}$), demonstrating an increased risk of injuries with an increased number of games in all conditions except for the comparison between 4 versus 5 games in 7 days. There was also a significant difference in injury severity ($P = .008$), indicating that the least dense condition had a higher ratio of severe to nonsevere injuries compared with the other game-density conditions. Finally, the game-density analysis was repeated after excluding games played with <1 day of rest, and the finding of increased injury rates with increasingly condensed schedules remained significant ($P = 9.52 \times 10^{-46}$), with significant differences between all groups except for the comparison between 1 versus 2 games in 7 days.

Conclusion: We found that a condensed schedule and <1 day of rest between games were associated with an increased rate of injuries in the NHL. These findings may help in the design of future game schedules.

Keywords: hockey; injuries; game schedule; epidemiology; back-to-back games; condensed schedule

Ice hockey is a high-speed, high-skill, full-contact sport that places significant workload demands on players at elite levels.[1] The physical nature of the sport has a significant impact on injuries, as body checking is the most common mechanism of injury in the National Hockey League (NHL).[13] Research on hockey injuries has been hampered by a lack of consistent definitions of injuries and how to best report injury rates.[5] This is problematic, as injuries can have major consequences, particularly at the professional level. In the NHL, varying injuries have been shown to have both short-[21] and long-term[3,12,18] impairments on player performance after return to play. For individual players, injuries can result in a reduction in games played and decreased financial compensation.[14,15] The most serious injuries can be career-threatening and in fact have longer term health implications for the athlete. Therefore, a better understanding of the risk factors contributing to injuries at the professional level is crucial.

Research on injuries in sports has explored measures of fatigue and workload, with a working hypothesis that an increase in the acute- to chronic-workload ratio significantly increases the risk of injuries.[8] In this regard, concern has been expressed that condensed game schedules and inadequate rest may be significant contributors to the injury risk. This has been the subject of research in different sports but with varying results.[2,4,6,16,20,22] Moreover, this has been a source of concern for those in the NHL, with periods of condensed schedules being blamed for a perceived increase in injuries.[10,23]

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This study sought to examine whether condensed game schedules have an impact on injuries in the NHL. It was hypothesized that increasingly condensed game schedules would increase the frequency and severity of injuries. Overall, 2 separate analyses were designed to look at this question in different but related ways to attempt to gain insight into the relevant issues of concern and to decrease the chance of bias. The game-spacing analysis focused on the risk of injuries in a game based on how many days off had transpired since the prior game. The game-density analysis looked at whether there was an increased risk of injuries during a 7-day period based on how many games were played during that time. The assessment of severity was designed to identify whether there was a disproportionate increase in the severity of injuries as game schedules increased, such that there would be a greater ratio of severe to nonsevere injuries.

METHODS

Data were collected from publicly available online resources covering all NHL regular-season games from the 2005-2006 through 2018-2019 seasons. We accessed www.hockeyreference.com for season schedules. This was manually checked with season schedules from www.nhl.com for the entirety of the 2018-2019 schedule to confirm the validity of the source. This study was deemed exempt from institutional review board approval.

When NHL players have a medical condition that may limit participation in game action, the team makes a public statement, which is reported by multiple media organizations that disclose the medical issue and date of occurrence. We accessed www.prosportstransactions.com for player injury data, as this is the only website with a full archive of injury data for the seasons that we were examining. All listed medical conditions were screened, and we excluded medical conditions that were not felt to constitute an injury that could relate to the question of the impact of game schedules, such as infectious diseases (eg, flu) and longer term medical problems (eg, heart surgery or multiple sclerosis) (see online Supplemental Material for a list of included and excluded diagnoses).

Injury Severity

The length of time that a player missed games was used as a proxy for injury severity. Importantly, 2 weeks was used as the cutoff for greater and lesser severity of the injury. This time frame was chosen based on a visual inspection of the variance of the injury data when plotted graphically and the finding that this was a rough median as well as our belief that this provided a clinically relevant time frame. Injuries occurring during the final 2 weeks of the regular-season schedules were excluded from this analysis because of the uncertain duration, as precise data on return from injuries outside of the regular season were unavailable. We performed an analysis looking at the risk of severe injuries per team per game and another analysis that compared the ratio of severe with nonsevere injuries. A secondary analysis was performed using 60 days as the cutoff for greater and lesser severity of injuries.

Game-Spacing Analysis

Each team's schedule was analyzed to identify the number of days between games within the season. The injury rate in the subsequent game was then determined. The first game of each season for each team was excluded from this analysis because of the lack of data on preseason schedules.

Game-Density Analysis

In this analysis, the independent variable was the number of games occurring within a 7-day period. The dependent variable was injuries occurring during the same time period, not necessarily only on game days. This was done to include all injuries, both to be certain that we did not lose injury data to errors in reporting dates and to purposefully include injuries that may have occurred during practices to fully understand how denser game schedules may influence the players' overall risk of injuries. Games would be counted only once during each analysis; however, the same games and injuries could potentially fulfill other game-density criteria based on this method.

Statistical Analysis

The hypothesis of game spacing was tested by a regression analysis comparing the number of days between games to the injury rate per team per game and with 1-way analysis of variance (ANOVA) to assess differences between groups for a smaller subset of game intervals with a larger sample size. The game-density analysis was also conducted by ANOVA comparing the different density conditions. When a significant effect was detected by ANOVA in either analysis, a post hoc analysis was carried out using the Tukey test. Comparisons of severe with nonsevere injuries were assessed by the chi-square test of difference. Significance was accepted at $P < .05$.

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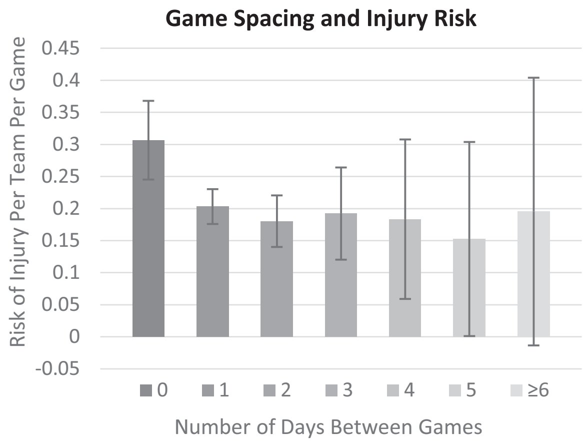


Figure 1. Risk of injuries in relation to the number of days between games. Results are reported as mean ± SD. Analysis of variance demonstrated a significant group difference, $F(6, 217) = 5.744$; $P = 1.44\times10^{-5}$, with the post hoc Tukey test demonstrating that the injury rate was significantly higher when there were 0 days between games than for all other game intervals. All other comparisons between groups were not significant.

RESULTS

Game Spacing

There were 33,170 games and 7224 injuries included in the analysis. The regression for the primary hypothesis that the risk of injuries per team per game would increase as the interval between games decreased was statistically significant ($F = 71.225$; $P = 3.32\times10^{-17}$; $R^2 = 0.002$), but the R^2 value was low. A visual inspection of the data suggested that the effect was being driven by an increased risk of injuries occurring with <1 day of rest between games compared with the other game-spacing intervals. To assess this, we excluded the games with <1 day of rest and repeated the regression on the remaining sample of 27,196 games and found that the results were no longer significant as expected ($P = .344$). We calculated the risk of injuries per team per game and then obtained a mean (±SD) for each game-spacing interval with a sufficient sample size (Figure 1). The group difference was significant, $F(6, 217) = 5.744$; $P = 1.44\times10^{-5}$, with the post hoc test demonstrating that <1 day of rest between games had a higher rate of injuries than all other groups (alpha = .01).

The mean injury risk was also significantly higher when comparing <1 day of rest (0.31 ± 0.06) with all other game-spacing conditions (0.20 ± 0.02) (Z test of means: $Z = 9.48$; $P < .00001$) (Figure 2).

The severity analysis included 30,286 games and 6453 injuries. The mean risk of severe injuries was significantly higher when comparing <1 day of rest (0.12 ± 0.03) with all other game-spacing conditions (0.07 ± 0.01) (Z test of means: $Z = 7.62$; $P = 2.64\times10^{-14}$) (Figure 3).

ANOVA demonstrated a significant group difference, $F(6, 217) = 3.523$; $P = .002$, with the post hoc test demonstrating that <1 day of rest between games had a higher rate of injuries compared with both 4 and 5 days between games (Figure 4).

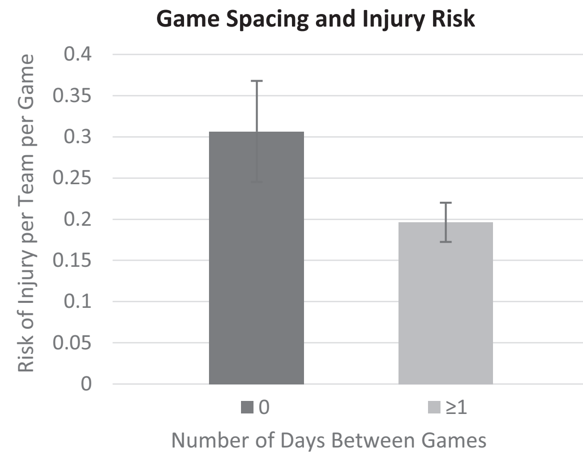


Figure 2. Risk of injuries in relation to the number of days between games: 0 versus ≥1 days. Results are reported as mean ± SD. The injury rate was significantly higher when games were played with 0 days between games compared to ≥1 days (Z test of means: $Z = 9.48$; $P < .00001$).

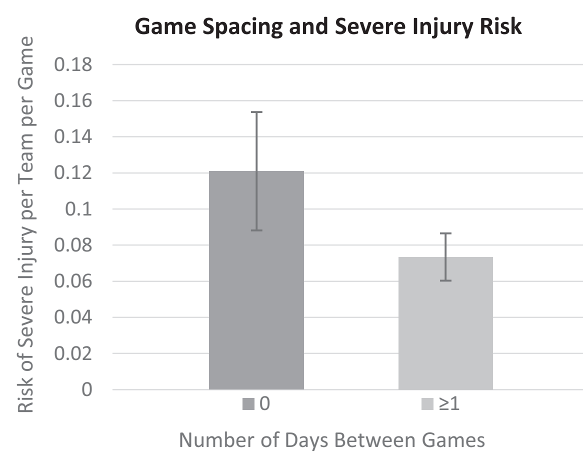


Figure 3. Risk of severe injuries in relation to the number of days between games. Results are reported as mean ± SD. The injury rate was significantly higher when games were played with 0 days between games compared with ≥1 days (Z test of means: $Z = 7.62$; $P = 2.64\times10^{-14}$).

There was no significant difference in the ratio of severe to nonsevere injuries across the different game-spacing conditions ($P = .075$) (Figure 5), nor was this significant when comparing <1 day of rest with all other conditions ($P = .060$). A secondary analysis showed that there was also no difference in the proportion of severe injuries when 60 days was used as the cutoff ($P = .124$) (Figure 6).

Game Density

The game-density analysis included 33,592 games and 10,752 injuries. Season schedules were partitioned to find situations that met our criteria for a specified number of games within a 7-day period, and the rate of injuries per team per game was then determined within that period. The number of games meeting the criteria in each group, in ascending order from 1 game in 7 days (1 in 7) to 5 games in 7 days (5 in 7), was 1653, 11,490, 31,450, 25,146, and 739 games, respectively. The mean rate of injuries increased as game density increased (0.025 ± 0.024, 0.082 ± 0.015, 0.209 ± 0.029, 0.300 ± 0.039, and 0.338 ± 0.141, respectively). There was a significant difference between groups, $F(4, 155) = 126.751$; $P = 8.22\times10^{-48}$ (Figure 7). The post hoc test demonstrated significant differences between all the groups for alpha = .01 except for the comparison between the 4-in-7 and 5-in-7 conditions, which was not significant.

The risk of severe injuries per team per game was analyzed, showing a similar trend. There was a significant difference between groups, $F(4, 155) = 45.476$; $P = 3.17\times10^{-25}$ (Figure 8). The post hoc test demonstrated significant differences between all the groups except for the comparisons between the 1-in-7 versus 2-in-7 and the 4-in-7 versus 5-in-7 conditions. All group differences reached significance for alpha = .01 except for the comparison between the 3-in-7 and 4-in-7 conditions, which was significant at alpha = .05.

The chi-square test of distribution was performed comparing severe with nonsevere injuries and showed a significant difference (P = .008), suggesting that the 1-in-7 condition had a higher ratio of severe to nonsevere injuries than the other conditions (Figure 9).

A secondary analysis demonstrated the same results using 60 days as a cutoff for greater or lesser severity of injuries, with the 1-in-7 condition again having a higher proportion of severe injuries than the other game-density conditions (P = .004) (Figure 10).

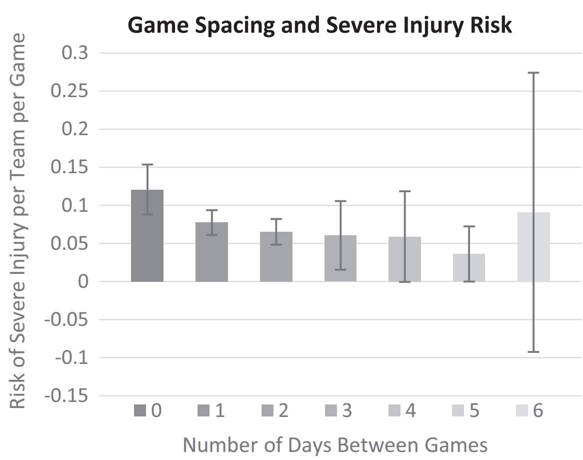
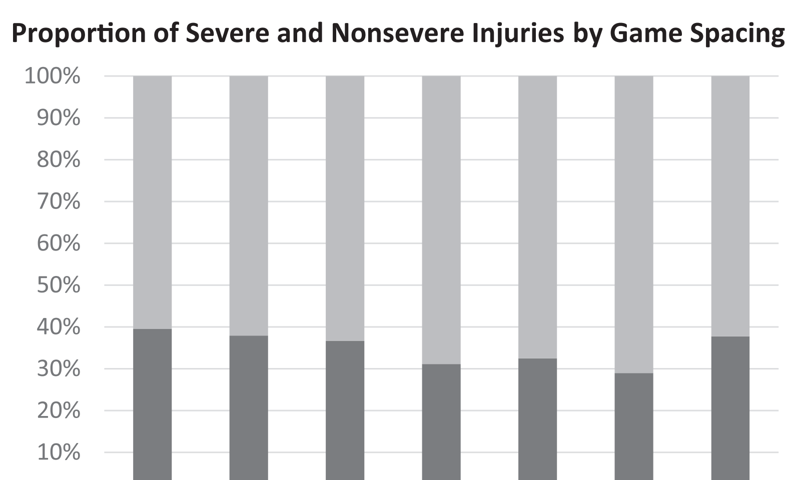


Figure 4. Risk of severe injuries in relation to the number of days between games. Results are reported as mean ± SD. Analysis of variance demonstrated a significant group difference, $F(6, 217) = 3.523$; P = .002, with the post hoc Tukey test demonstrating a higher injury rate with 0 days of rest between games than with 4 and 5 days between games. All other comparisons between groups were not significant.

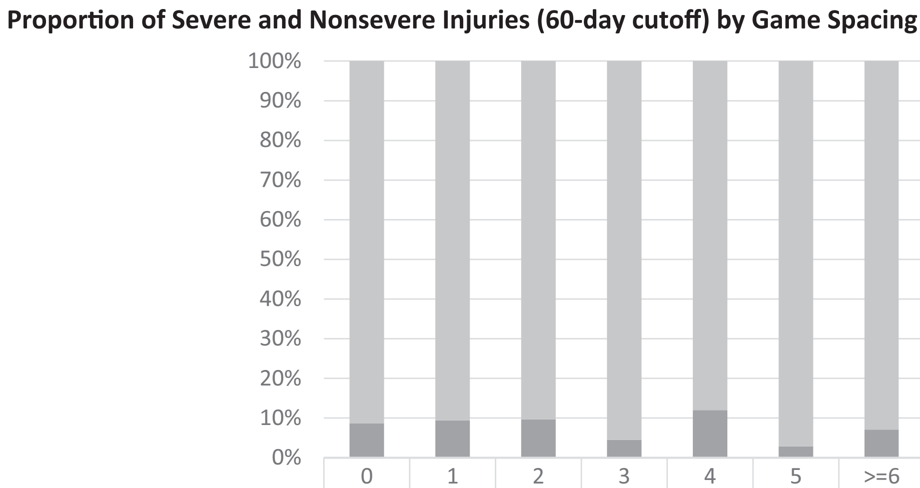
Comparing Game Density and Games With <1 Day of Rest

In reviewing our findings, we questioned whether the increased rate of injuries with denser game schedules could be explained by the increased percentage of games played



	0	1	2	3	4	5	>=6
Non-Severe Injuries	997	2003	672	213	79	27	33
Severe Injuries	653	1223	388	96	38	11	20

Figure 5. Comparison of severe and nonsevere injuries in relation to the number of days between games (0-≥6). Results are expressed as percentages, with the number of injuries reported in the table. There were no significant differences between the groups (P = .075).



	0	1	2	3	4	5	>=6
Non-severe injuries (60 days)	1061	1989	708	232	88	34	26
Severe Injuries (60 days)	100	208	76	11	12	1	2

Figure 6. Comparison of severe and nonsevere injuries in relation to the number of days between games (0-≥6) using 60 days missed as the cutoff for severe injuries. Results are expressed as percentages, with the number of injuries reported in the table. There were no significant differences between the groups (P = .124).

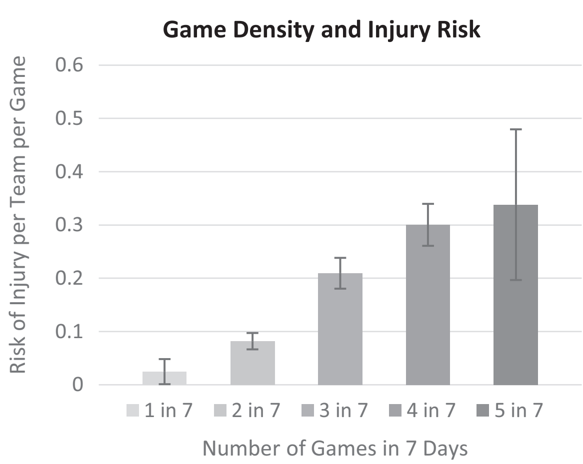


Figure 7. Comparison of the risk of injuries in relation to the number of games played within 7 days. Results are reported as mean ± SD. Analysis of variance demonstrated a significant group difference, $F(4, 155) = 126.751$; $P = 8.22\times10^{-48}$. The post hoc Tukey test demonstrated that all group comparisons were significantly different except for the comparison between 4 games in 7 days and 5 games in 7 days, which was not significant.

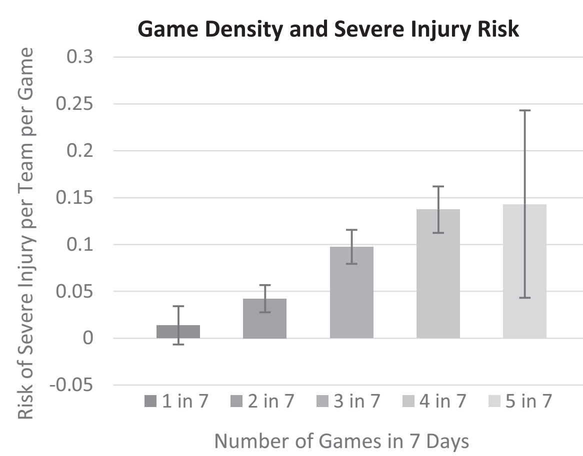
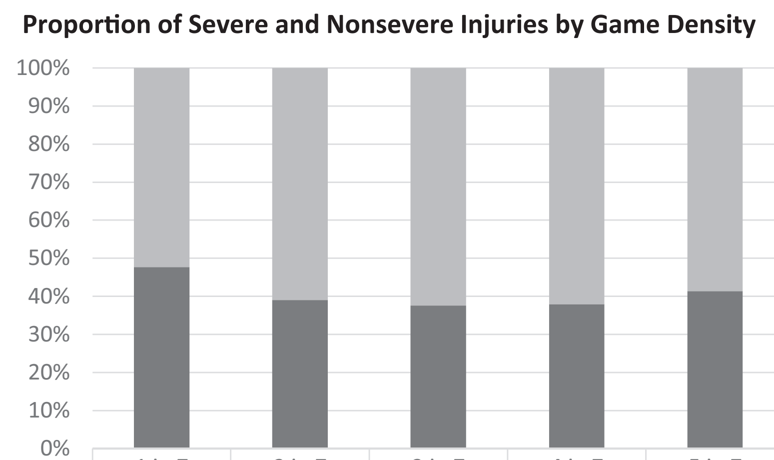


Figure 8. Comparison of the risk of severe injuries in relation to the number of games played within 7 days. Results are reported as mean ± SD. Analysis of variance demonstrated a significant difference between groups, $F(4, 155) = 45.476$; $P = 3.17\times10^{-25}$. The post hoc Tukey test demonstrated significant differences between all the groups except for the comparison between 1 game in 7 days and 2 games in 7 days and the comparison between 4 games in 7 days and 5 games in 7 days. All group differences reached significance for alpha = .01 except for the comparison between 3 games in 7 days and 4 games in 7 days, which was significant at alpha = .05.

with <1 day of rest seen in the denser schedules. To test this new hypothesis, we repeated the game-density analysis but excluded all games that were played with <1 day of rest (Figure 11). This analysis demonstrated that the increased risk of injuries with increased game density remained significant, $F(4, 155) = 116.868$; $P = 9.52\times10^{-46}$. The post hoc test revealed significant differences between all groups for alpha = .01 except for the comparison between the 1-in-7 and 2-in-7 conditions, which was not significant.

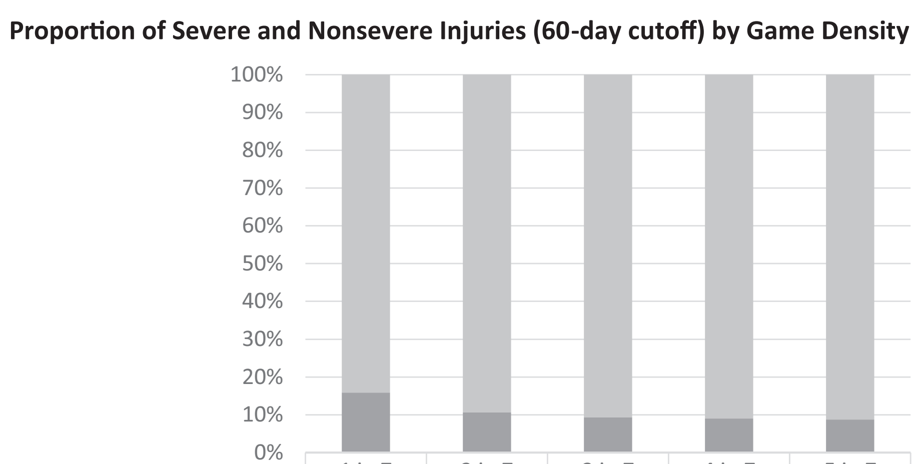
DISCUSSION

This study was designed to assess the effects of the spacing and density of games in the regular season on the risk of injuries in the NHL. We found an increased risk of injuries



	1 in 7	2 in 7	3 in 7	4 in 7	5 in 7
Non-Severe Injuries	157	1275	3819	3083	95
Severe Injuries	143	816	2301	1887	67

Figure 9. Comparison of severe and nonsevere injuries in relation to the number of games played within 7 days. Results are expressed as percentages, with the number of injuries reported in the table. The chi-square test revealed a significant difference between groups ($P = .008$), suggesting an increased risk of severe injuries in the 1 game in 7 days condition.



	1 in 7	2 in 7	3 in 7	4 in 7	5 in 7
Non-severe injuries (60 days)	223	1522	3984	3051	84
Severe injuries (60 days)	42	180	413	302	8

Figure 10. Comparison of severe and nonsevere injuries in relation to the number of games played within 7 days using 60 days missed as the cutoff for severe injuries. Results are expressed as percentages, with the number of injuries reported in the table. The chi-square test revealed a significant difference between groups ($P = .004$), suggesting an increased risk of severe injuries in the 1 game in 7 days condition.

with <1 day of rest between games and that the injury risk increased as the number of games played in 7 days increased.

In investigating the effect of game spacing, our initial hypothesis was that the rate of injuries would decrease as the interval between games increased. However, our findings suggest that this is incorrect. Instead, we found that the risk of injuries increased when there was <1 day of rest between games (ie, the second game of back-to-back games) compared with all longer intervals between games. Our results are in partial agreement with findings in the National Basketball Association in which results have been mixed. Teramoto et al[20] demonstrated an increased risk of injuries in back-to-back games played on the road but not at home, whereas Lewis[11] showed a decrease in the injury risk for each day of rest, although the number of days analyzed

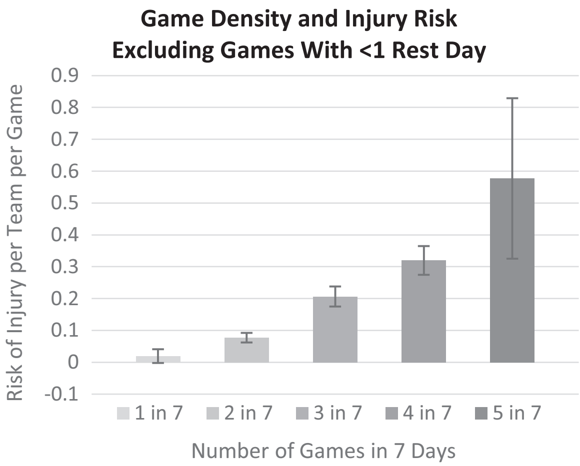


Figure 11. Risk of injuries in relation to the number of games played within 7 days after excluding games played with <1 day of rest. Results are reported as mean ± SD. Analysis of variance demonstrated a significant group difference, $F(4, 155) = 116.868$; $P = 9.52\times10^{-46}$. The post hoc Tukey test revealed significant differences between all groups except for the comparison between 1 game in 7 days and 2 games in 7 days, which was not significant.

was not specified. This could suggest that the failure to find a significant difference in the injury risk in home games was because of the smaller sample size in the Teramoto et al study and would thus suggest converging evidence among different sports for an increased risk of injuries in games played without 1 day of rest between them. We did not investigate whether there was an impact of home- versus away-game locations in ice hockey, but it is also possible that games with <1 day of rest pose a greater risk for injuries in hockey than in basketball, as hockey involves greater amounts of contact between players and there is less opportunity for player rotation compared with basketball in which not all players play in each game.

Our results suggest that when considering individual game spacing alone, there is no additional risk of injuries as long as there is at least 1 day of rest between games. This is in agreement with data from the National Football League in which shortened rest, but still at least 3 days between games, did not result in an increased rate of injuries,[2,16] and indeed, there was a statistically significant decrease in the injury rate for the games with shorter rest. This does not necessarily imply a complete physical recovery or the ability to perform optimally, as there is evidence that soccer players demonstrate decreased measures of physical performance and increased biomarkers of muscle fatigue/inflammation, such as elevated creatine kinase, for up to 72 hours after a game.[7,19] However, we do not see evidence that these altered parameters significantly affect the risk of injuries severe enough to result in missing game time.

An increased density of game schedules was found to be associated with an increased risk of injuries. This is in overall agreement with work in other sports. In rugby, there was a linear increase in the injury risk for increased matches within the preceding 1 month and a nonlinear increase in the risk for playing greater than 35 matches in the preceding 12 months.[22] In soccer, Dupont et al[6] found that athletes playing in 2 matches within 4 days had an increased rate of injuries compared with those playing in 1 game per week. Dellal et al[4] found an increased risk of game injuries during congested compared with noncongested fixtures but interestingly found no overall increase in injuries when analyzing injuries occurring in both games and practices. We did not have data on whether injuries occurred in games or practices, so we were unable to separate these variables; however, we do not expect that this would have altered our results, as we looked at the total increase in injuries occurring within the time frame in question. Prior epidemiological work has suggested that up to 90% of NHL injuries occurred during games.[13] Our analysis identified a higher proportion of injuries than expected that did not appear during our game-spacing analysis, which could suggest an increased rate of nongame injuries. However, as discussed further below, this could also suggest a degree of reporting errors, such that injuries caused by game action were not officially reported until a later date and were thus missed in our game-spacing methods. Regardless of the cause, we do not have data on injuries within practices or the frequency and intensity of practices during these periods in this study. The work of Dellal et al[4] suggests that this may be an important variable for future investigations.

Game density may correlate with an increased workload, which has been assessed as a risk for injuries in other sports. Increased workloads have been associated with increased rates of injuries in basketball[11] and cricket bowlers[9] but not in baseball starting pitchers.[17] We question whether these discrepant findings may relate to the decreased density of game action for baseball starting pitchers compared with these other sports, suggesting that a certain amount of rest may be protective against workload demands, which could be a subject of further study.

Our game-density analysis showed significant differences between all groups except when group 4-in-7 was compared to group 5-in-7. This may most likely be attributed to the high variability in the less common 5-in-7 condition, suggesting that a larger sample of these games may have shown a significant difference. However, it may also suggest that there is no additional increase in the injury risk with additional games played beyond playing in 4 games in 7 days.

In reviewing our initial results, we questioned whether the significant increase in injury rates as game density increased could be caused by the increased proportion of games played with <1 day of rest in those samples, given our findings from the game-spacing analysis. We therefore repeated the game-density analysis and then excluded these games. The retained significance suggests that the increase in injury rates with denser schedules cannot be attributed solely to the inadequate recovery involved in playing games with <1 day of rest in between but instead suggests that an effect of overall increased workloads during the 7 days is indeed present. The lack of a significant difference between the 1-in-7 and 2-in-7 conditions may relate to the decreased sample size, but it could also suggest that there is not an increased risk of injury from playing 2 games in 7 days unless those games are played with <1 day of rest between them.

Our analysis of injury severity suggested that the incidence of severe injuries, as defined by the length of time that players were unable to participate in games, followed the same trends as overall injuries. Severe injuries were more likely to occur when players had <1 day of rest between games than with larger spaced intervals, and the risk of severe injuries increased as game schedules became more condensed for the most common game-density conditions. This is important from a practical perspective, as it suggests that the increased risk of injuries with condensed schedules being investigated in this article can indeed have a more profound impact on players and teams, at least as measured by time lost to an injury.

We were interested in investigating whether condensed game schedules may produce conditions that would result in a disproportionate increase in the severity of injuries, as this may elucidate the mechanisms by which workloads may relate to injuries. To assess this, we compared the ratio of severe to nonsevere injuries for the varying game-scheduling conditions. These analysis results were largely negative. There was no significant effect of game spacing on the ratio of severe to nonsevere injuries. There was a significant group difference in the game-density analysis, driven by an increased proportion of severe injuries in the 1-in-7 condition compared with denser schedules. This could potentially suggest an increased risk of the severity of injuries related to relative inaction in the surrounding schedule, which, in contrast to the other findings of our study about the increased risk of greater game density, may suggest that a certain degree of workload is protective. However, we caution that this statistically significant finding may be spurious, given the much smaller sample size that we have for this condition.

For all of the injury analyses, it is possible that the lack of association between injury severity and game schedules may relate to our methods. We did not have access to medical records, so we did not know the details of diagnoses or the medical severity. We did, however, have data on the length of time that players were listed as injured, so we attempted to use games missed as a proxy for injury severity. There are several ways that this assumption could fall short. Decisions to place NHL players on injured lists and when to reactivate them are not solely medical decisions but can also depend on team needs, and thus, injury time may not correspond to the particular medical severity. When teams are not under strain for players, a player may also be kept out of the lineup when he is not able to play at his physical peak performance, given the high demands and competitiveness of NHL play. As such, a player may stay out of the lineup with a comparatively minor injury for 2 weeks, which can be counted the same as a severe season-ending injury by the methods of our primary analysis. It is encouraging that our secondary analysis, which used a higher severity cutoff, produced the same results. Therefore, within the limitations of our data, we think that we made a reasonable assumption in using 2 weeks as a cutoff based on both the variance of our time-lost-to-injury data and the clinical meaningfulness of that time interval. Overall, our work suggests that while there was an increased risk of injuries with <1 day of rest between games and with greater game density, and while this increased risk of injuries did include severe injuries, we did not find evidence that condensed schedules increased the risk that injuries incurred would be more likely to be severe. This may suggest that the mechanism of severe injuries is not specifically related to fatigue or overuse. Future research with access to medical records can help to clarify this question.

There are several limitations to our study related to our reliance on publicly available data. First and foremost, we do not have a way of independently verifying the process of the collection of injury data and whether this is precise and accurate. The NHL does publicly announce injuries and dates of injuries to the media on a daily basis during the regular season. We believe that the opportunity for accurate data collection exists, but we are unable to verify this process or estimate a potential error rate in this reporting. There are several additional limitations related to the public dataset used. Public reporting in a transaction database required that players be removed from the game or miss subsequent games, so we cannot comment on the rate of injuries within games that did not limit game participation but may have impacted health, on-ice performance, or time on ice. The lack of medical details available, in addition to limiting our assessment of injury severity as above, was problematic for appropriate determinations of inclusion. We intended to exclude listed reasons for missing games if they were not felt to be an injury related to the research question of game schedules, such as infectious diseases or longer term medical problems. We attempted to be conservative to minimize inappropriate exclusions, given the lack of direct medical information available. For example, we included headaches, dizziness, and blurry vision, as these may all be signs that a concussion had occurred. However, it is possible that we may have erred on both sides of selection.

The dataset was also a significant limitation with regard to the publicly reported timing of injuries. We did not have a way to independently verify our large dataset on whether the day that the injury was officially reported was the same day that the injury occurred and whether this occurred in a game or practice. One way that we tried to address this limitation was by performing the differing analyses on game spacing and density. The game-spacing analysis may have accidentally excluded injuries that occurred during a game but were not officially reported until a later date. The game-density analysis was able to capture these injuries by including all injuries occurring within the 7-day time window, but it also includes injuries that may have occurred in practice, potentially overestimating injuries directly related to game schedules. Given the opposing directions of errors but the converging results, as well as the lack of bias for why reporting errors would correlate with game schedules, we do not expect that this significantly altered our findings.

Although the large sample size of our study is a significant strength, it does come with inherent limitations. Our methods did not allow for player-level data to be factored into the analyses. The most concerning omission would be that we were unable to look at individual player workloads in relation to injury rates, as has been performed in other studies. We hope to evaluate this level of detail in future research, and we propose that an appropriate assessment of workloads will need to include factors addressing playing style such as relative exposure to contact rather than time on ice alone.

When considering comparisons to other studies, it is important to note that we have reported injury rates per team per game, which are the most accurate in representing the methods used in this study. The risk of injuries is more commonly calculated by athletic exposure, but this can be difficult to estimate for ice hockey when detailed time-on-ice data are unavailable, and the size of our sample made this impractical to obtain. Different groups have used our methods and attempted to convert game-level data into risk per athletic exposure, but this can produce estimates that have a significant error rate from a direct time-on-ice assessment.[5] Player game hour exposure is a more accurate estimate but still requires several assumptions about player exposure over time. To assist with comparisons to other studies, we note that in our game-spacing analysis, the risk of injuries in games with <1 day of rest was 51.67 compared to 32.93 for other game-spacing conditions per 1000 athletic game hour exposures, and in the game-density analysis, injury rates varied from 4.13 to 58.41 per 1000 athletic game hour exposures.

The finding of an increased risk of injuries with condensed schedules raises important questions about the impact on players and teams in the NHL. Our findings should be regarded as preliminary and confirmed using a primary data source. It is difficult to extrapolate the magnitude of the impact from theoretical schedule changes using our data, as any changes would likely impact the workload in both the acute and chronic settings. For example, a lower density schedule may significantly increase the duration of the season, which could also have an impact on player health and the injury risk. A primary data source with direct medical information would also be helpful in better weighing the risk of injuries against other measures of importance including financial considerations and fan engagement, as a modest increase in nonsevere injuries, which do not have long-term consequences for athletes, may be tolerable. In a high-risk setting, minimizing games with <1 day of rest would likely be a promising intervention; however, our analysis shows that this may not offset the increased risk of injuries from an otherwise condensed schedule. Further research would be needed before any firm conclusions supporting interventions can be drawn.

CONCLUSION

This study assessed the impact of game spacing and density on the risk of injuries in NHL players. Our large sample size produced clear results that there was an increased risk of injuries with increasingly condensed schedules and with <1 day of rest between games (ie, playing the second game of back-to-back games). These risk factors did not increase the likelihood that injuries would be severe, as the ratio of severe to nonsevere injuries did not worsen. The absolute increase in injuries was modest but meaningful to the teams and players of the NHL. These risk factors are among many variables that influence the risk of injuries, so no firm conclusions about interventions can be drawn, but these findings may inform considerations in designing schedules that can minimize the risk of injuries to NHL players.

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