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# The Impact of the Olympics on Regular Season Team Performance in the National Hockey League

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## Abstract

**Objective:** The Winter Olympics occurs during the NHL regular season, and because many teams send multiple players to the Olympics, the question of whether there is a negative impact of player participation on team performance has been raised. In this paper, we examine the impact of player participation on goal differential for each Winter Olympic Games in the period from 1998 to 2014.

**Methods:** Adjusting for prior team success (whether the team made the playoffs in the previous season), we test for a number of players by time (pre and post-Olympics) interaction in each season the Winter games occurred using mixed effects, growth curve modeling.

**Results:** The results show a negative effect of player participation by time for the 1997-1998 NHL season: Teams with a higher number of players sent had more goals scored against them in the period after the Games than teams that sent fewer players. For the 2012 Winter Games, there is no effect of player participation on post-Games regular reason performance. The remaining seasons in which Olympic Games occurred shows a trend toward statistical significance (p<0.10).

**Conclusion:** Possible explanations for these effects are discussed, as are limitations and future directions for research.



**Keywords**

Ice hockey; Winter Olympics; Fatigue hypothesis; Goal differential; Team performance; Mixed effects modeling


## Introduction

The first time ice hockey was included as part of the Olympics was in the 1920 Summer Games held in Antwerp, Belgium. Organized international ice hockey, the International Ice Hockey Federation (IIHF), had only recently been formed 13 years earlier in 1908 [1,2]. It would be another four years, however, until the first Winter Olympic Games were held in Chamonix, France in 1924 [1]. It was then ice hockey was officially made part of the Winter Games.

At the time of the first modern Olympiad and for the next 71 years, professional athletes were prohibited from competing in the Olympic Games. In the case of ice hockey specifically, it would not be until 1995 that an official agreement was reached between the International Olympic Committee (IOC), the IIHF, the National Hockey League (NHL) and the NHL Players Association (NHLPA), setting the stage for professional hockey players to compete in the Winter Olympics [3]. To accommodate the NHL, the format of the first 1998 Winter Games was altered to include a preliminary round that did not include NHL players, or the top six international teams (Canada, the Czech Republic, Finland, Russia, Sweden and the United States). Following this round, the NHL officially ceased play for the next 17 days to allow participating players to both compete, rest and recover. The positive reaction of NHL Commissioner Gary Bettman in the aftermath of those games foretold what would become a regular practice of allowing NHL players to compete, and the temporary suspension of regular season play for the duration of the games every four years [4].

While many elite, international sport competitions include professional athletes drawn from club teams from individual countries (e.g., FIFA and UEFA), including the Summer Olympics (e.g., NBA players are eligible to compete), the situation with professional ice hockey and the Winter Olympics is unique in that the games occur during the NHL regular season. Competition in the Olympics includes many games played within a condensed schedule, whereby top athletes are asked to represent their countries to the best of their abilities for this highly competitive set of games. For NHL hockey players who participate, this highly intense and emotionally charged contest occurs fully four months into what is already a highly competitive, physically and mentally demanding NHL season. The resultant extra pressure arising from Olympic competition increases the risk for both significant physical and mental strain, which in turn may lead to performance decrements after the games have ended and players return to resume their regular season play. Conversely, for those who do not compete, the Olympics may actually provide a respite opportunity, in the midst of a demanding 82-game long season. Longley [5] refers to this effect as the "fatigue" theory: Players who participate in the Olympics experience post-competition fatigue, which in turn negatively affects performance when the regular season resumes. At the team level, because the rate of participation is not equal (some teams send many players, others less), this fatigue effect means that teams who send more players to the Olympics should experience greater post-Olympic declines in overall team performance, relative to those teams who send fewer or no players to the Olympics. Moreover, the fatigue effect may be exacerbated based on the location of the games. Since the NHL began sending players to the Olympics, the Games have been held outside of North America three times: First in Nagano, Japan in 1998, Turin in Italy in 2006, and most recently in Sochi, Russia (2014). The additional demands of travel, adapting to a different time zone, combined with the intensity of Olympic competition may further affect post-Olympic performance. It is clear that the nature (intensity) of the event, its timing, and the fact that rate of player participation is not equal across teams makes it possible that participation may adversely affect a team's competitiveness post Olympics – and some teams, especially those who have more players participating - may be more adversely

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affected than others. An obvious concern for the NHL therefore is that participation in the Olympics may affect the league's overall competitive balance [5].

Previous studies have explored a number of different predictors of overall team performance in professional hockey. For example, whether or not the team participated in NHL playoffs in the previous year [5], mid-season coaching changes [6,7], the so-called home ice disadvantage [8,9], especially in decisive (e.g., game 7 of Stanley Cup finals) games for established championship teams [10], and the effect of player aggression on team outcomes [11] are all factors that have been explored in the literature. We could find only one study, however, that examined the effect of player participation in the Olympics on pre- and post-Olympic team performance in the NHL. In his analysis of the Winter Olympics from 1998 to 2010, Longley [5] found a negative effect of number of players on post-Olympic regular performance, measured using relative goal differentials (goals for minus goals against) pre- and post-Olympics. According to Longley [5], these results support a fatigue effect, suggesting that teams who send more players to the games are more likely to experience declines in performance when the season re-commences after the conclusion of the Olympics.

There is good reason, however, to re-examine the impact of NHL player participation in the winter Olympics on team performance in the light of the following concerns. First, it is questionable whether Longley [5] has used the best statistical analysis to test the fatigue effect in this context. Specifically, the analysis used in his paper is based on linear regression, where the outcome is measured as the average change in goal differential post-Olympics relative to pre-Olympic performance. The unit of analysis was the team, and the average results for all teams are combined across each of the four seasons in which Winter Olympic Games had occurred (1998 to 2010). A more powerful test of the effect of number of players on team performance outcomes (in this context, also measured as goal differential) are to use a longitudinal, growth curve modeling approach where goal differential is analyzed as a repeated-measures dependent variable, and number of players participating per team is used to predict change in goal differentials over time within a single season. This approach has at least two advantages over that used by Longley [5]. One, growth curve analysis allows us to fully utilize the longitudinal nature of the data, so we can assess change in performance over all 82 regular season games for each team in the same models. It also allows for a more direct test of the fatigue hypothesis, as we can not only directly estimate the main effects for both number of NHL players participating and time (games occurring before and after the Olympics), but also the interaction between these factors. This, we argue, is in fact a more direct test of the fatigue hypothesis, which postulates that team performance outcomes such as goal differential are affected by the total number of players sent to the games, but only in the period preceding the Olympics (a time by number of players interaction).

Second, the approach used by Longley [5] required combining data from different seasons (1998; 2002; 2006; 2010) together, to maximize sample size for the analyses (the resultant sample in his analysis was 116, which is the total number of teams for each season combined). However, the fatigue effect includes the contingency that travelling outside North America may further exacerbate the fatiguing of NHL player participation in the Olympics. Any specific effect of location of the games is masked when data across all Olympics are pooled. In this study, we test to see whether the effect of time by number of participating players on team performance outcomes are unique to specific Olympic games, by estimating separate models for each of the five years in which Winter Olympics involving NHL players have occurred.

Thirdly, a consideration that appears to have been overlooked in Longley's analysis was the fact that not all players in the regular season remain with the same team throughout the season [5]. Indeed, the official trade deadline in the NHL is typically in the month of March, although sometimes it has occurred late in February. Since 1998, the trade-deadline in seasons where the Olympics have occurred has always been after the regular season has resumed post-Olympics (typically in early to mid-March). Therefore, players that played in the Olympics, but are then traded to another team afterwards, should not be counted on the roster for the team that traded them.

Finally, at the time of Longley's analysis [5], the 2014 games had not yet occurred. By including data from the 2013-2014 NHL season, we are able not only to re-test the effect of player fatigue in the same period as Longley [5], but also extend our analysis to include the most recent winter games in Sochi, Russia. Given the potential exacerbating effect of location on fatigue, inclusion of this particular Olympics is of particular importance. In the present study, we address each of these issues using data from each of the Winter Olympic Games from 1998 to 2014.

## Methods and analysis

### Data extraction

A database was constructed to examine goal differential as the performance outcome for each season that NHL players participated in the Winter Games, beginning in 1998 to the most recent in 2014. First, Olympic team rosters were extracted from the official website of the IIHF (http://www.iihf.com/iihf-home/history/past-tournaments/), identifying the all NHL players who participated in the Games [12]. It should be noted, however, as the team rosters in 1998 were not available from the official IIHF website, names of participating players were identified using the online database of Hockey-Reference.com (http://www.hockey-reference.com/) [13]. Second, we extracted team level statistics for all regular season games for each of the teams in all five seasons (26 teams in 1998 and 30 teams in 2002-2014) from the official NHL team websites, building a database that included: home/road game, decision (win or lose), goals for and goals against. The date of each game was also recorded so games pre- and post-Olympics could be identified. Using the official rosters for the Olympics, cross-referenced to the NHL team website, a variable for the number of players sent to the Winter Olympic Games for each team in each season was created. We also made note of the Olympic participants whom were traded between NHL teams within the same season of the Olympic Games. Lastly, included in the database was a variable created to reflect whether the team had made the playoffs in the season immediately prior to the Olympics. In an effort to increase accuracy, all team-level data initially extracted from the NHL team websites were cross-referenced to data from http://www.hockey-reference.com; no differences in the data were found.

### Dependent measure

Consistent with the study by Longley [5], we use goal differential as the dependent variable. Goal differential is a better indicator of team performance outcome than wins and losses because after

2005, the introduction of shootouts makes it possible for teams to secure a point simply by playing to tie, which in turn increases the likelihood that teams may steal an extra point simply by winning the shootout. Therefore, we calculated goal differential (goals for minus goals against) for each game in a season and for each team, which was treated as a continuous variable in statistical analyses.

### Independent variables

Our main independent variables were time, which we created as a binary variable indicating games played pre-Olympics (=0) from those played post Olympics (=1), and number of NHL players participating per team. Number of players was treated as a continuous variable (simple count of all players) in all analyses. We also created an "adjusted" number of NHL players' variable, which excludes those players that were traded between NHL teams within the same season of the Olympic Games (10 in 1998, 13 in 2002, 9 in 2006, 10 in 2010, and 10 in 2014). Finally, we included a binary measure to indicate whether a team had made the post-season in the season immediately prior to the Olympic year (i.e., post season = 1; no post-season play = 0), as an indicator of recent success. Besides time and number of players, previous research has found that recent success (measured as playing in the NHL playoffs in the previous season) was the only other factor related to team performance during an Olympic year [5].

### Statistical analysis

In order to test to see if the number of NHL players from each team that participate in the Olympics negatively impacts post-Olympic NHL team performance outcome, we examine goal differential before and after the Olympic break using mixed-effects general linear modeling [14]. As noted previously, mixed effects models allow us to estimate growth curves – change in goal differential over all 82 games in a season, while taking into account the effect of statistical dependence between repeated observations on parameter estimates. In order to test the fatigue effect, we estimated two models with goal differential as the outcome for each of the five years the Winter Olympics have been played with NHL players (1998; 2002; 2006; 2010; 2014). In the first model, we include main effects for time, number of NHL players, and whether or not the team participated in NHL playoffs in the previous year. This last variable was included as a control given that recent success has been found to impact team performance during an Olympic year [5]. It stands to reason that teams with prior success in the playoffs are likely to be contending teams in the following season, and therefore more likely to have players that will likely be selected for participation in the Olympics. This variable, however, was not included in 2006, as the playoffs were cancelled in 2005 because of the players strike. We also include an interaction term for time by number of NHL players in model 1. This is a specific test of the fatigue hypothesis, as we would expect number of players participating to have a greater impact on team performance outcome post-Olympics, than on play before the games commenced. In the second model, we created an "adjusted" number of players variable, which removed all players who were traded post-Olympics from the analysis. We then re-ran the analysis with the adjusted variable. By comparing the results using the adjusted variable to those with the total number of players sent regardless of post-Olympic trades, we are able to conduct a sensitivity analysis to see if the effect of traded-players impacts goal differential. We stratified all analyses by year of the Olympics, to test to see whether the impact of NHL players (unadjusted and adjusted) by time varied by where the Games were played. All analyses were conducted using the PROC MIXED program in SAS version 9.3 [15].

## Results

Table 1 shows the average, minimum and maximum numbers of NHL players per team participating in each of the Winter Games from 1998 to 2014. Overall, the average number of players per team has remained relatively constant over time. This table also highlights, however, the disparity in participation across teams in each season: Some teams send only 1 or 2 players, while others send 8 to 10.

Table 2 shows the results of the longitudinal data analysis for each of the 5 Olympic Games from 1998 to 2014. With the exception of the 2005-06 season, if a team made the playoffs in the previous season, on average, they had better (positive) goal differential in the subsequent season relative to teams that failed to make the post-season. The effect ranged from 0.51 to 0.84. A higher goal differential suggests that team scored more goals against opponents than had goals scored on them. However, the main variables of interest are time (pre- and post-Olympic Games), number of players and the interaction of time by number of players. As the interaction term represents a specific test of the fatigue hypothesis, we will consider the results testing that interaction in the sections that follow.

The only statistically significant number of players by time interaction was observed in the 1997-98 season: Teams with a higher number of players sent to the Olympics that season was associated with a negative goal differential in the post-Olympic regular season (estimate=-0.14; SE=0.06; $p$=0.012). A similar effect was also observed when player trades were taken into account (see Table 2, Model 2; estimate = -0.12; SE=0.06; $p$=0.03). For the 2001-02, 2005-06 and 2013-2014 seasons, the interaction term for number of players by team showed a trend toward statistical significance ($p$<0.10), the estimates ranging from -0.07 to -0.09 and $p$-values from 0.05 to 0.08. The exception was for the 2009-2010 season, where the interaction effect was very small (estimate=-0.005), and the $p$-value was 0.93. Similar effects were observed in model 2 for each season, suggesting eliminating traded players makes very little difference to the results. Given that the interaction terms are the specific test for the fatigue effect, and also that it is difficult to interpret the main effects of time and number of players in the presence of an interaction, we will not comment on these estimates in this analysis.

In order to better interpret the interaction effect, we used the equation from model 1 in Table 2 for the 1997-98 season to calculate pre- and post-Olympic goal differential by the lowest, average and highest number of players from all NHL teams who sent to the Olympics from the NHL that season (one, four and nine players respectively; see Figure 1). Positive values mean that the team scores more goals on opponents than goals scored against them. From Figure 1, it can be seen that among teams who sent just one player, goal differential actually improves during the post-Olympic period. For teams that sent four players, which is the league average, there is little difference in goal differential over time. Among teams that sent nine players, there is a clear, negative impact to goal differential in the post-Olympic period. Overall though, it is important to note that the absolute differences are all less than one goal. In other words, while there is a significant effect, the size of the effect is small.

Because the effect seems most pronounced for those teams sending nine or more players, we decided to graph the raw results for all teams sending this number of players during the 1997-98 season: The Pittsburgh Penguins and the Colorado Avalanche. We graphed

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**Table 1:** Average Number of NHL Players Participating in the Winter Olympics By Year of Games, 1998 to 2014.

| Year | Location | Mean (SD) | Minimum per Team | Maximum Per Team |
|---|---|---|---|---|
| 1998 | Nagano, Japan | 4.53 (2.08) | 1 | 9 |
| 2002 | Salt Lake City, United States | 4.90 (2.52) | 0 | 11 |
| 2006 | Turin, Italy | 4.90 (2.17) | 1 | 10 |
| 2010 | Vancouver, Canada | 4.73 (1.80) | 1 | 9 |
| 2014 | Sochi, Russia | 4.90 (2.21) | 2 | 10 |

**Table 2:** Growth Curve Modeling of the Impact of Time (pre- and post- Olympics) and Number of Participating NHL Players on Goal Differentials for Each of the Olympic Games Held between 1998 and 2014.

| Variables | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|
| | Estimate | SE | *P*-value | Estimate | SE | *P*-value |
| **1997-98 NHL Season** | | | | | | |
| Intercept | -0.93 | 0.20 | <0.001 | -0.83 | 0.19 | <.001 |
| Time | | | | | | |
| Pre-Olympics | 0.64 | 0.27 | 0.020 | 0.83 | 0.13 | 0.04 |
| Post-Olympics | Ref | | | Ref | | |
| Number of NHL Players | 0.09 | 0.04 | 0.015 | 0.08 | 0.04 | 0.04 |
| Playoffs Last Year | | | | | | |
| Yes | 0.84 | 0.13 | <0.001 | 0.83 | 0.13 | <.001 |
| No | Ref | | | Ref | | |
| Number of NHL Players by Pre-Olympics | -0.14 | 0.06 | 0.012 | -0.12 | 0.06 | 0.03 |
| Covariance Parameter Estimates | | | | | | |
| Intercept | 0.04 | -.03 | 0.08 | 0.04 | 0.03 | 0.07 |
| Residuals | 5.16 | 0.15 | <0.001 | 5.17 | 0.16 | <0.001 |
| **2001-2002 NHL Season** | | | | | | |
| Intercept | -0.76 | 0.14 | <0.001 | -0.74 | 0.13 | <0.001 |
| Time | | | | | | |
| Pre-Olympics | 0.35 | 0.22 | 0.109 | 0.32 | 0.21 | .124 |
| Post-Olympics | Ref | | | Ref | | |
| Number of NHL Players | 0.08 | 0.03 | 0.002 | 0.09 | 0.03 | <0.001 |
| Playoffs Last Year | | | | | | |
| Yes | 0.67 | 0.12 | <0.001 | 0.65 | .12 | <0.001 |
| No | Ref | | | Ref | | |
| Number of NHL Players by Pre-Olympics | -0.07 | 0.04 | 0.07 | -0.07 | 0.04 | 0.08 |
| Covariance Parameter Estimates | | | | | | |
| Intercept | 0.03 | 0.02 | 0.112 | 0.02 | 0.02 | .138 |
| Residuals | 5.00 | 0.14 | <0.001 | 5.00 | 0.14 | <0.001 |
| **2005-2006 NHL Season** | | | | | | |
| Intercept | -0.83 | 0.18 | <0.001 | -0.85 | 0.17 | <0.001 |
| Time | | | | | | |
| Pre-Olympics | 0.41 | 0.26 | 0.116 | 0.39 | 0.25 | 0.12 |
| Post-Olympics | Ref | | | | | |
| Number of NHL Players | 0.10 | .038 | 0.008 | 0.11 | 0.04 | 0.002 |
| Playoffs Last Year[1] | | | | | | |
| Yes | 0.63 | 0.15 | <0.001 | 0.60 | 0.15 | <0.001 |
| No | Ref | | | Ref | | |
| Number of NHL Players by Pre-Olympics | -0.08 | 0.05 | 0.08 | -0,08 | 0.05 | 0.09 |
| Covariance Parameter Estimates | | | | | | |
| Intercept | 0.05 | 0.03 | 0.04 | 0.05 | 0.03 | 0.06 |
| Residuals | 5.72 | 0.16 | <0.001 | 5.72 | 0.16 | <0.001 |
| **2009-2010 NHL Season** | | | | | | |
| Intercept | -0.56 | 0.16 | 0.002 | -0.55 | 0.14 | <0.001 |
| Time | | | | | | |
| Pre-Olympics | 0.02 | 0.31 | 0.94 | 0.09 | 0.27 | 0.73 |
| Post-Olympics | Ref | | | Ref | | |
| Number of NHL Players | 0.06 | 0.03 | 0.08 | 0.07 | 0.03 | 0.04 |
| Playoffs Last Year | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Yes | 0.51 | 0.11 | <0.001 | 0.47 | 0.12 | <0.001 |
| No | Ref | | | Ref | | |
| Number of NHL Players by Pre-Olympics | -0.005 | 0.06 | 0.93 | -0.02 | 0.06 | 0.71 |
| Covariance Parameter Estimates | | | | | | |
| Intercept | 0.01 | 0.02 | 0.33 | 0.01 | 0.02 | 0.35 |
| Residuals | 5.36 | 0.15 | <0.001 | 5.36 | 0.15 | <0.001 |
| **2013-2014 NHL Regular Season** | | | | | | |
| Intercept | -0.65 | 0.15 | <0.001 | -0.66 | 0.14 | <0.001 |
| Time | | | | | | |
| Pre-Olympics | 0.43 | 0.25 | 0.08 | 0.39 | 0.23 | 0.09 |
| Post-Olympics | Ref | | | Ref | | |
| Number of NHL Players | 0.06 | 0.03 | 0.07 | 0.07 | 0.03 | 0.04 |
| Playoffs Last Year | | | | | | |
| Yes | | | | | | |
| No | Ref | | | Ref | | |
| Number of NHL Players by Pre-Olympics | -0.09 | 0.04 | 0.05 | -0.09 | 0.04 | 0.06 |
| Covariance Parameter Estimates | | | | | | |
| Intercept | 0.03 | 0.02 | 0.11 | 0.03 | 0.02 | 0.126 |
| Residuals | 5.12 | 0.14 | <0.001 | 5.12 | 0.14 | <0.001 |

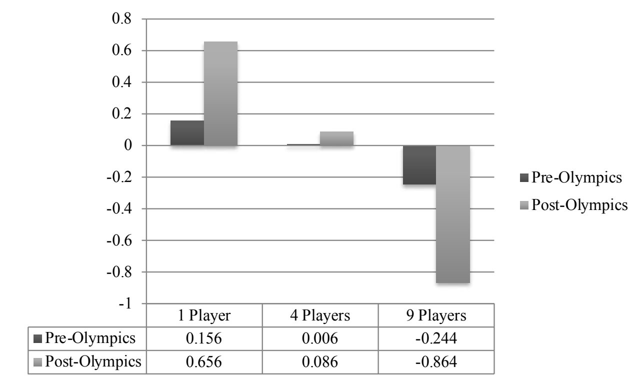


**Figure 1:** Average Goal Differential Pre- and Post-Olympics by Number of NHL Players Sent to the 1998 Winter Olympics in Nagano, Japan.

the goal differential for each of the 82 games in the regular season (see Figures 2A and 2B). The darker bars show goal differential by games prior to the Olympics; the lighter grey bars are games after the Olympics. Visual inspection of the graphs shows that for both teams, there are more goals scored against in the post-Olympic regular season, although the effect appears to be stronger (more grey bars in the negative range on the graph) for the Avalanche.

## Discussion

As the premiere league for elite hockey talent, most NHL teams send multiple players to the Winter Olympics. In the lead up to the 2014 Winter Olympic Games, there was some discussion, at least in the Canadian sports media, about whether sending NHL players to the games would have negative consequences for teams in the post-Olympic period [16]. The issue of NHL participation again became front and centre during the games when John Tavares, one of the premiere players for the New York Islanders received a season-ending knee injury during the opening round of play for team Canada [17]. While an injury of this magnitude has been rare, the general manager of the Islanders made national news headlines in Canada and the US for tweeting his frustration over the injury and asking whether the IOC was prepared to compensate season ticket holders in New York ~~of~~ for the loss of his star player [18]. The cost of sending NHL players, both in relation to travel and in relation to potential impact to the home teams are of obvious concern both to the IOC and the NHL.

In this paper, we examined the impact of sending NHL players to the Olympics on goal-differential, which is a global measure of team performance. Our results only partially confirm those of Longley [5], in that we were able to show a significant effect of number of players sent to the games on team performance post Olympics, but only for the 1998 games. For all the other games except 2010, we found evidence of a trend-level effect ($p<0.10$). It should note that the limited number of games played during the post-Olympic period may mean we are not adequately powered to detect a significant effect. Indeed, there is remarkable consistency in the parameter estimates (size and nature of the effect) for this interaction across each season except for 2009-2010. At the same time, it is important to note that the effects for number of players by time in each season are small.

The very first Winter Olympics in which NHL players were allowed to participate were held in Nagano Japan in 1998. It is interesting that this was the only time where we observed a statistically significant effect for number of players on goal differential in the post-Olympic period. Given both the distance of travel (from North America to Asia), and that much of the organizational and logistical planning was based not on experience but on conjecture, it is not surprising we observed a cost of participation in terms of team performance outcome post-Olympics. In the 2009-2010 season conversely, the only period we did not observe an effect of player participation, the games were held in Vancouver, British Columbia, Canada. Not only would this reduce the travel demands for most NHL players, it was held in a country and a city used to organizing large, hockey events. At the same time, we must be cautious regarding this interpretation. As noted previously, the effect of number of players on goal differential post Olympics in the 2001-02, 2005-06, 2013-2014 seasons just failed to reach statistical significance ($p<0.10$). While three of those games were played outside North America, the 2002 Winter Olympics were held in Salt Lake City, Utah.

We did not examine whether number of players sent negatively impacted post-season play. There are three reasons for this: First, a knockout tournament like the NHL post-season run to the Stanley Cup is more likely to be chance-dominated meaning teams can

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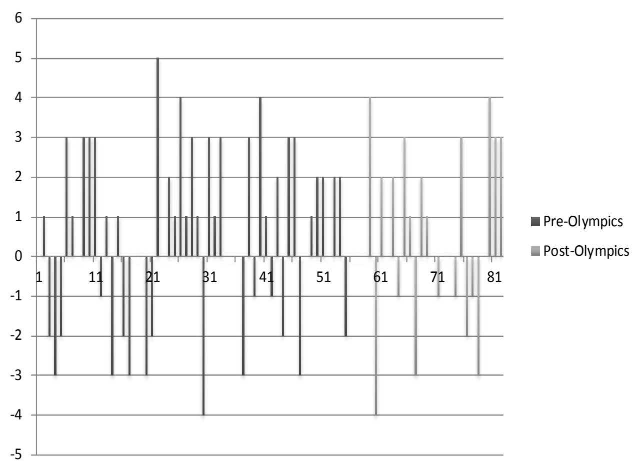


**Figure 2A:** Goal Differential Pre- and Post-Olympics for the Pittsburgh Penguins in the 1997-98 NHL Season.

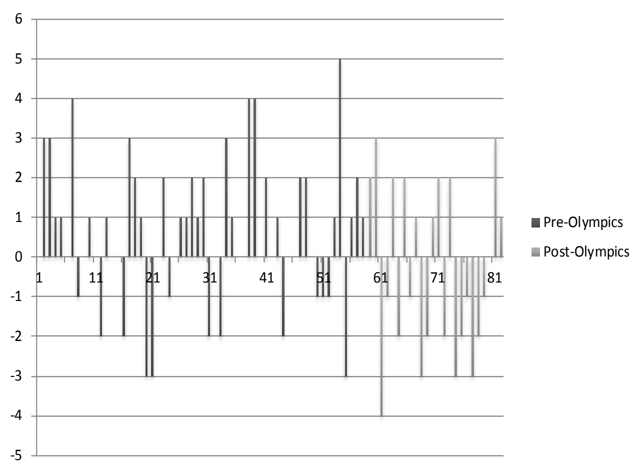


**Figure 2B:** Goal Differential Pre- and Post-Olympics for the Colorado Avalanche in the 1997-98 NHL Season.

achieve success simply due to the structure of the event. Indeed, the awarding of overtime points has increased the chances that even below average performing teams can potentially make it into the first round. There are also fewer games, making it difficult to examine effects. Finally, the playoffs occur significantly after the Olympics, so we would expect the effect of player participation to be weaker.

Practically, our results suggest that while the sending of players to the Olympics does have a negative impact on goal differential (significant in 1998; trend level for 2002, 2006, 2014), the overall impact is small. This lends support to the argument in favor of allowing NHL players to participate in the Games, given that no strong claims can be made that participation negatively impacts performance at the team level to a point that is detrimental to a team's overall success. Given the increasing use of analytics in decision-making in professional sports, analyses of this kind presented in this paper should be used by analysts and statisticians when evaluating the impact of player participation in events outside the regular season on team performance outcomes. Indeed, ice hockey is not the only professional sport where sending players to external competitions raises concerns over impact to league teams when regular season play commences. For example, in Major League Baseball, sending players to the World Baseball Classic (WBC) has raised similar concerns with regard to regular season player (and team) performance. Recent discussions about once again including baseball in the Summer Olympics would further create a situation similar to the one faced by the NHL [19,20]. Mixed-effects, longitudinal modeling can be used to analyze both player and team impact to determine the cost of participation in these events and we recommend this approach to both professional leagues like the NHL and governing bodies such as the International Olympic Committee.

## Limitations and Future Directions

There are some limitations that should be addressed in future work. First, it may be that sample size (i.e., number of games post-Olympics, number of Olympic cycles) is simply not sufficient for examining this effect. It will be important to replicate these results in the future, assuming the NHL agrees to continue to send players. At the same time, given the overall effect sizes (estimates) are not large, power (sample size) may not necessarily be the problem: the effects may simply be weak. In addition, goal differential is not the only possible outcome to examine. Although more difficult to obtain, injury data (including time off due to injury) could be used as a more direct test of player fatigue. Similarly, the fatigue effect could also be tested at the individual-level, with examination of player performance before and after the games. While we examined the effects of the number of players being sent to the Olympic games on team performance outcome, it should be noted that other factors such as team cohesion or confidence in the teams' ability to compete were not tested in the current study. More research examining the complex relationships between psychosocial and physiological determinants of team-based performances are warranted.

Although we found some support for the fatigue hypothesis, as noted above, the effect sizes for player participation were relatively small. This raises the question of why player participation in the Olympics is not that strongly related to post-Olympic team performance outcomes. For example, there may be countervailing effects that work to offset the negative impact of participation. First, it is important to remember that it is only a small proportion of NHL players who actually participate in the Olympics. For the majority of NHL players, cessation of play for the Olympics means a two-week rest period within a long season. Perhaps any negative performance impact for participating players is offset by the recuperation that is provided to the rest of the team. Another explanation may be related to the conditioning of elite players: As professional athletes, players in the NHL are extremely well conditioned meaning the extra demands of Olympic competition may not have as strong a fatigue effect as once posited. It is also important to consider the impact of participation beyond just physical demands. Participation in the Olympics, let alone winning, is an emotionally charged experience for athletes. Perhaps there is an inspirational, experiential element for those participating players, which positively impacts post-Olympic play. Not all players selected are necessarily the top players for their NHL teams. This is particularly true for less competitive international teams such as Germany or Latvia. Professional players representing these teams may not be first or even third line players in the NHL, which means any effect of their participation may be less felt by the team when the regular season resumes. Furthermore, it is not at all clear that the impact of participation is the same for all positions. One final point bears mention in this context. After the 2004-05 lockout, the NHL instituted a salary cap, along the same model as

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the one implemented in the NBA. One impact of a hard cap is that it ensures greater equity in talent distribution across teams, preventing, for example, large market (wealthier) teams from signing all the top-level players out from under smaller market teams. The net effect is greater parody across the league. Such parody may also contribute to the relatively small effects observed in this study for players sent. Further research is required to examine these possible explanations.

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