Increasing NHL Team Performance via Line Changes and Individual Substitutions

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Introduction

Professional sport franchises have seen an increase in using statistical analysis to increase performance of their players as well as teams as a whole. (Miller, 2011) As more information is learned about players and teams, whether they are on a given team or one of its opponents, it allows for better training and game strategies to be developed. One application of this is in ice hockey, where frequent substitutions are necessary to keep fresher players on the ice whenever possible. The frequency at which this is done may vary by a player's position.

In the National Hockey League (NHL), a team is usually comprised of three or four "lines", or groups of players that are on the ice at a given time. It is most common to have four lines for the three forwards (which generally include a center, left wing and right wing) and three lines for the two defensemen. A goalie will typically play an entire game, unless an injury or poor performance makes substituting a better option. When substitutions take place, an entire line is typically switched out, as opposed to an individual player, and it does not require a stoppage in play, as is the case in football, basketball and soccer. Due to hockey being a very fast-paced sport with few breaks in action, it is difficult to develop the stamina to stay on the ice for more than a couple minutes at a time and remain productive.

The objective of this paper is to determine whether substituting an entire line at once or substituting players individually is more effective. This will be determined by analyzing players of the same team and position and seeing if the variation in their playing time has an effect on their team's performance, which is measured by season points. It is reasonable to think that the amount of time spent on the ice that maximizes a player's efficiency, as well as that of their team, may vary. Factors that affect this may include a player's age, ability level, physical fitness, injury status and those of a player's teammates. At the same time, line changes sometimes occur sooner or later than desired, because it's not always feasible to do without disrupting the game. Making individual substitutions may add another layer of difficulty to this.

Data

The data used for this project were collected at Kaggle and they come from a group of 13 datasets called "NHL Game Data". The datasets include data from 2010 to 2019, but this paper only uses data from the 2018-19 season. Not all datasets have useful information, but the ones that do include:

game: home and away teams, how many goals each team scored, was a game decided in regulation or overtime

game_goalie_stats: goalies and which team they play for, time on ice (seconds), shots and saves when team is in power play, full strength or short-haded, win or loss for the team

game_shifts: when (how many seconds into period) shifts started and ended for a given player in a given game

game_skater stats: a player and what team they play for, time on ice (seconds), goals, assists, shots, hits, penalties, faceoffs won and taken, takeaways, giveaways, blocked shots

game_teams_stats: whether team is home or away, whether team won or lost, game settled in regulation or overtime, goals, shots, hits, powerplays and powerplay goals, faceoff win percentage, takeaways, giveaways, blocked shots

player_info: player_id and corresponding name, nationality, position, birthdate, height, weight

team_info: team_id and corresponding team

Additionally, the standings from the 2018-19 NHL season were obtained on the NHL's website and this information was also used for the project. (National Hockey League, 2019) For each team, games played, wins, losses, overtime losses, points, regulation or overtime wins, goals for, goals against, goal differential, home record, away record, shootout record, record over the last 10 games and streak were included. For clarification, a team receives two points for every game they win, whether that is in regulation, overtime or a shootout, and one point for a game that is lost in overtime or a shootout. A team that loses in regulation receives no points.

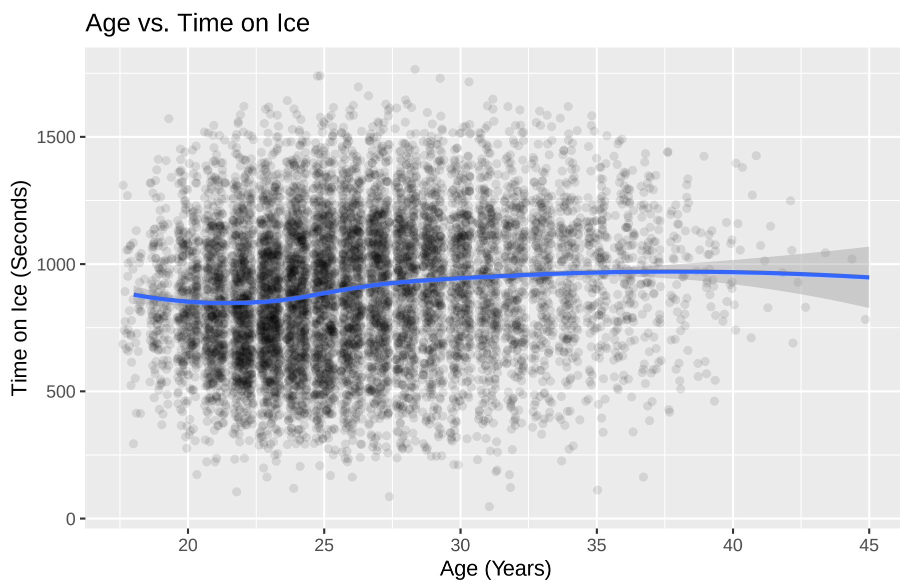


Figure 1: Average time on ice per game for a given player over the course of a season plotted against age.

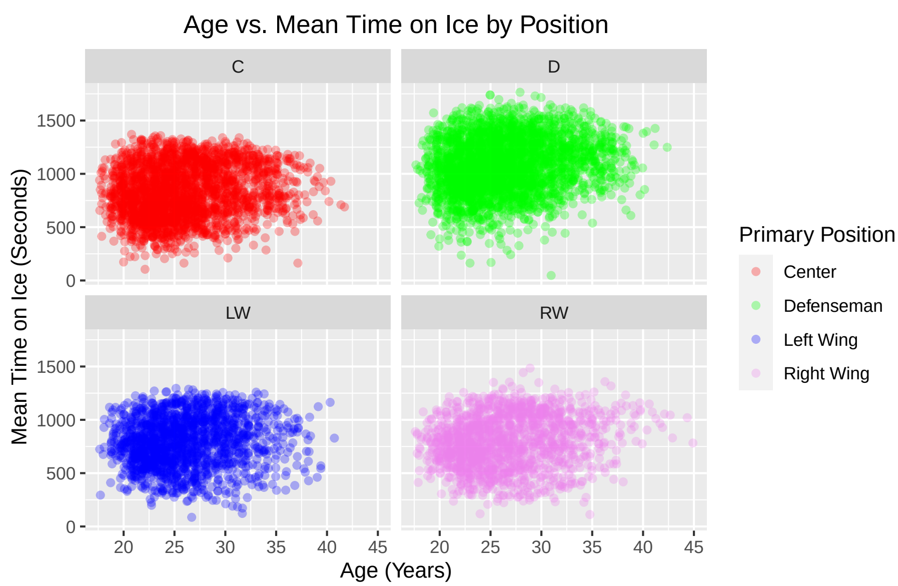


Figure 2: Average time on ice per game for a player plotted against age and sorted by position.

Figure 3: The mean shift lengths for players over an entire season are shown. Players are sorted by position.

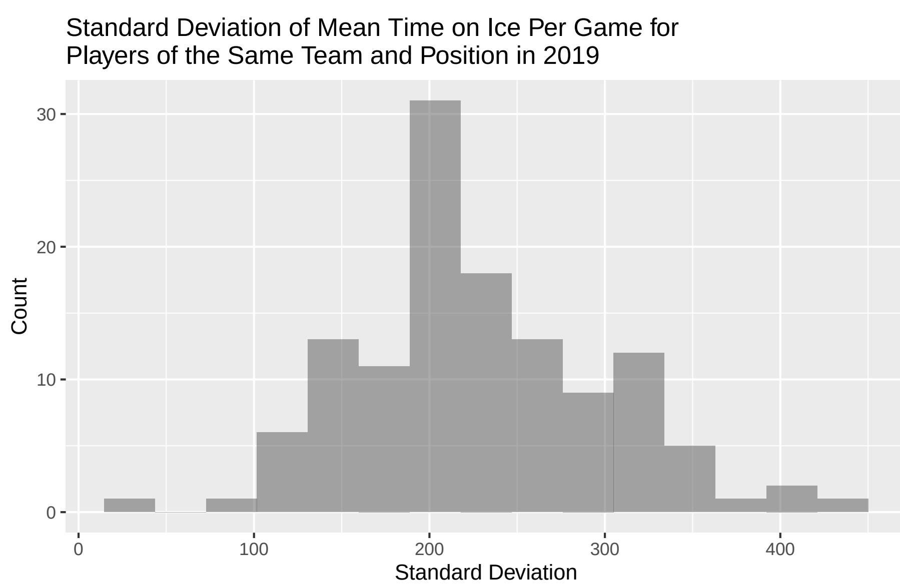


Figure 4: Players are grouped by team and position and the standard deviation of their mean times on ice per game are taken within each group.

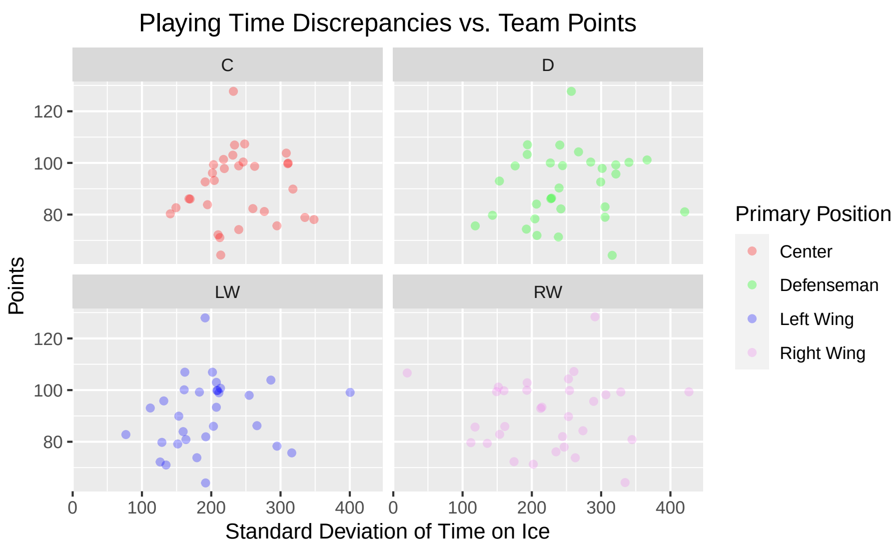


Figure 5: Players are grouped by team and position and the standard deviation of their mean times on ice per game are taken within each group. These are then plotted against total points scored by the corresponding team in the 2018−19 season.

The figures above show three major findings. First, Figure 1 shows that mean time spent on ice does not change much with respect to age. The only trend is a slight increase from around age 23 to age 28, but there are no major changes after age 28 in how much time a player spends on the ice per game. Second, Figures 2 and 3 show that defensemen spend more time on the ice per shift and overall than forwards do. This also appears to be true regardless of age. Third, Figures 4 and 5 show that teams do not always allocate the same playing time, even among players of the same position. The ideal amount of variation in time on ice between players of the same position will be explored in greater detail.

The mean time on ice for each player per game was calculated by adding their shift lengths for each game and dividing by the number of games they appeared in. Hence, the data do not include players who did not appear in a game. The players were then grouped by team and position, which accounts for the fact that some players are traded during the season. The standard deviations of the mean times on ice per game were then taken within each team and position combination. These are the quantities plotted in Figures 4 and 5 and they are used in the models in the next section.

Statistical Procedures

The model deemed to be the most useful is a linear model that can be written as

$TeamPoints_i = B_0 + B_1 * sdTimeOnIce_i + \epsilon_i, \epsilon_i \sim N(0, \sigma^2)$.

B_0 represents the number of points scored by a team that plays all players of a given position, on average, the same amount of time per game. B_1 represents the expected increase in points scored associated with the standard deviation of the playing time per game of a team's players of a given position increasing by one unit. This model was run for each position separately minus goalie.

The correlations between team points and the standard deviation of time on ice per game between players of the same position for centers, left wings, right wings and defensemen, respectively, are given in Table 1. All four of these values are positive, but their magnitudes indicate that the relationship between team points and the standard deviation of time on ice per game may not be strong for any position.

Table 1: Correlations between team points and the standard deviation of time on ice per game.

Position	Correlation
Center	0.0759
Left Wing	0.1739
Right Wing	0.0132

Position	Correlation
Defenseman	0.1135

The models were run separately for each position, because the central question of this paper is whether substituting entire lines or individual players could lead to better team performance. Players who play the same position will rarely if ever play on both an offensive and defensive line. Differences in how long players are on the ice implies that one of two things are true. The first is that different offensive or defensive lines tend to have shifts of different lengths on average. The second is that players are not always substituted with the rest of their line. The latter sometimes happens in the case of a power play. A greater standard deviation in time on ice between players on the same team and position would imply one or both of these things happen more often. It is a possible but not definitive indicator that individual substitutions are more frequent.

Looking at the residual diagnostic plots, which are included in the appendix, the histograms of the residuals are not necessarily normal, but the quantile-quantile plots do have all residuals within the bands, indicating that there is normality. None of the index plots show any clear patterns in residual values with respect to index, which is a reflection of independent residuals. The only potential concern is with the residual vs fitted plots. Ideally, the variance of the residuals does not change with respect to fitted values. However, given that there are only 31 points in each model corresponding to each team (the Kraken did not yet exist), one or two outliers can alter these plots substantially and make them somewhat meaningless and difficult to evaluate. This appears to be the case. In assessing linearity, a similar argument can be made. Although the lines in the residual vs fitted plots generally remain near 0, there are a couple cases where they deviate away from it, particularly in the right wing and defenseman models, but this too seems attributable to a single data point, due to the small data size.

Results

The tables below provide point estimates and 95% confidence intervals for the intercept and playing time parameters for each of the four models.

Table 2: Parameter estimates and 95% confidence intervals for the center model.

Parameter	Point Estimate	95% CI
Intercept	86.1588	(62.7182, 109.5994)
sdTimeonIce	0.0192	(-0.0768, 0.1152)

Table 3: Parameter estimates and 95% confidence intervals for the left wing model.

Parameter	Point Estimate	95% CI
Intercept	83.7074	(67.7661, 99.6488)
sdTimeonIce	0.0359	(-0.0413, 0.1130)

Table 4: Parameter estimates and 95% confidence intervals for the right wing model.

Parameter	Point Estimate	95% CI
Intercept	90.2526	(75.2987, 105.2065)
sdTimeonIce	0.0022	(-0.0605, 0.0648)

Table 5: Parameter estimates and 95% confidence intervals for the center model.

Parameter	Point Estimate	95% CI
Intercept	85.0285	(65.3737, 104.6832)
sdTimeonIce	0.0228	(-0.0529, 0.0984)

The intercept parameter is not of direct interest, because it estimates the mean number of points a team could expect to score if all of its players for a given position averaged the exact same time on ice per game. Given differing skill levels, injuries, power plays and the unpredictable nature of when line changes can be made, this scenario is very unrealistic. Instead, the *sdTimeOnIce* parameter is more useful.

Discussion

For all four positions, the point estimate for *sdTimeOnIce* has a positive value, but its 95% confidence interval includes both positive and negative values. As also indicated by Figure 5, there is not a strong relationship between the standard deviation of the mean time on ice among players of the same team and position versus team points. This is true for all positions. It would indicate that there is no clear advantage to changing players individually as opposed to changing an entire line. Having a confidence interval entirely above 0 for one or more of these models may but doesn't necessarily indicate that individual substitutions may work to a team's advantage. Given that they are not commonly practiced, their effects remain difficult to model at this time.

Because the data used in this analysis came from a single season, this was not a random sample. Inferring these results to other seasons may be difficult, since changes in strategies and fundamentals that take place over time may generate different results if a different season is analyzed. Similarly, causal inference cannot take place, because the coaching staff for each team chooses how much a given player plays, meaning standard deviations in mean playing times are not randomly assigned to teams.

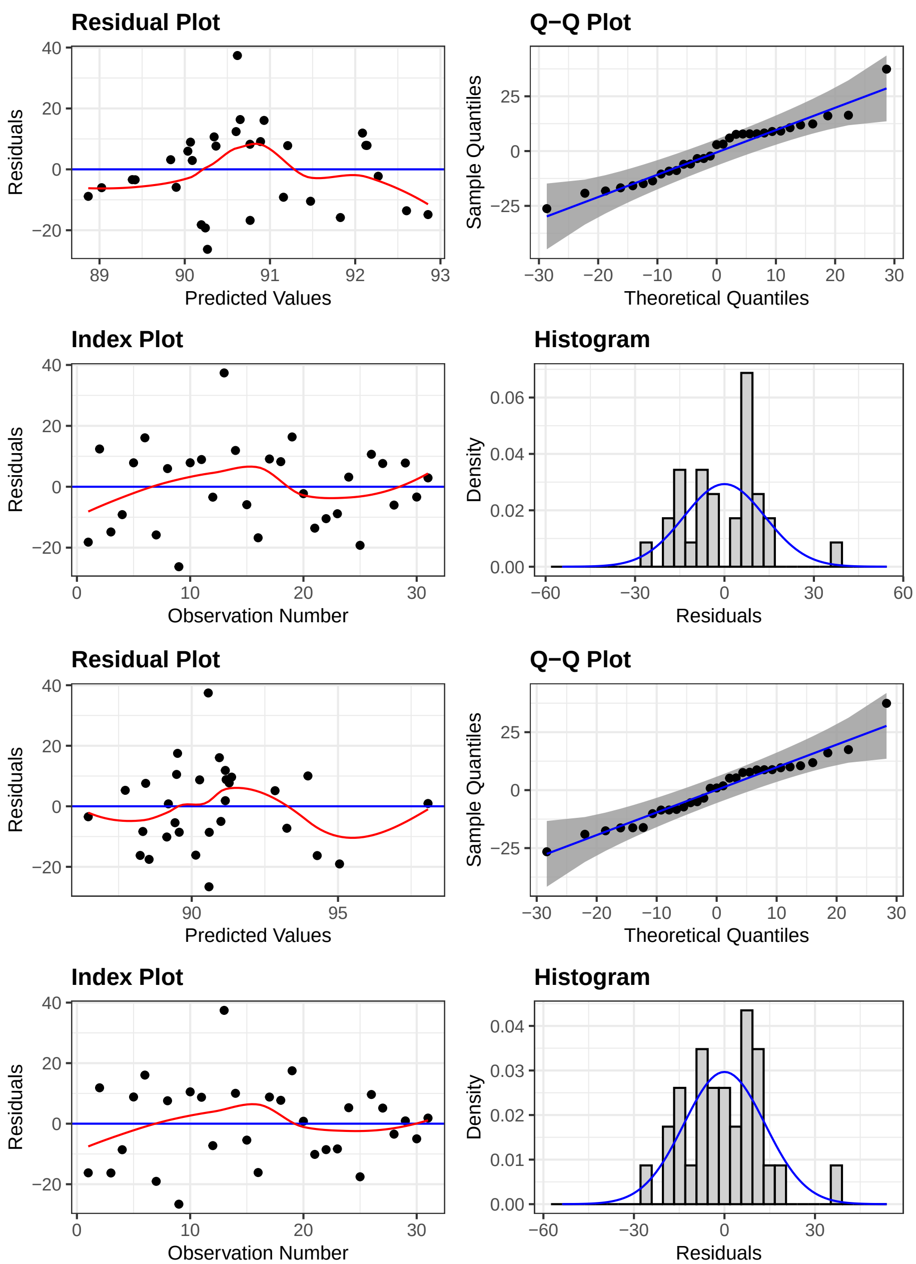
Works Cited

Miller, B. (Director). (2011). *Moneyball*[Film]. Columbia Pictures.

National Hockey League. (2019). *Standings.* https://www.nhl.com/standings/2018/league

Appendix

Residual plots for the center, left wing, right wing and defenseman models, respectively, are shown below.


Residual Plot
Residuals
Predicted Values
Q−Q Plot
Sample Quantiles
Theoretical Quantiles
Index Plot
Residuals
Observation Number
Histogram
Density
Residuals
Residual Plot
Residuals
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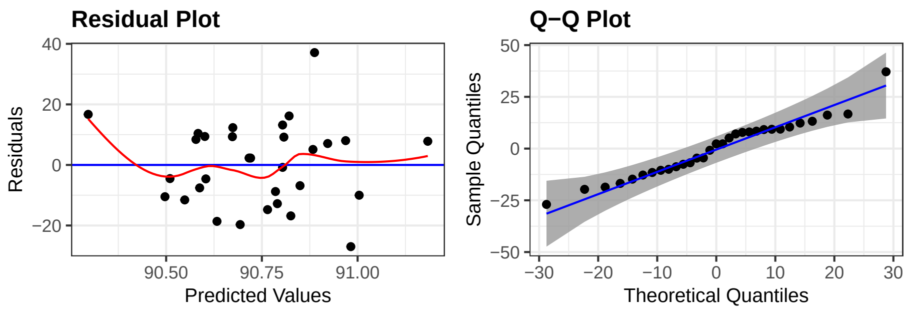
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Residuals
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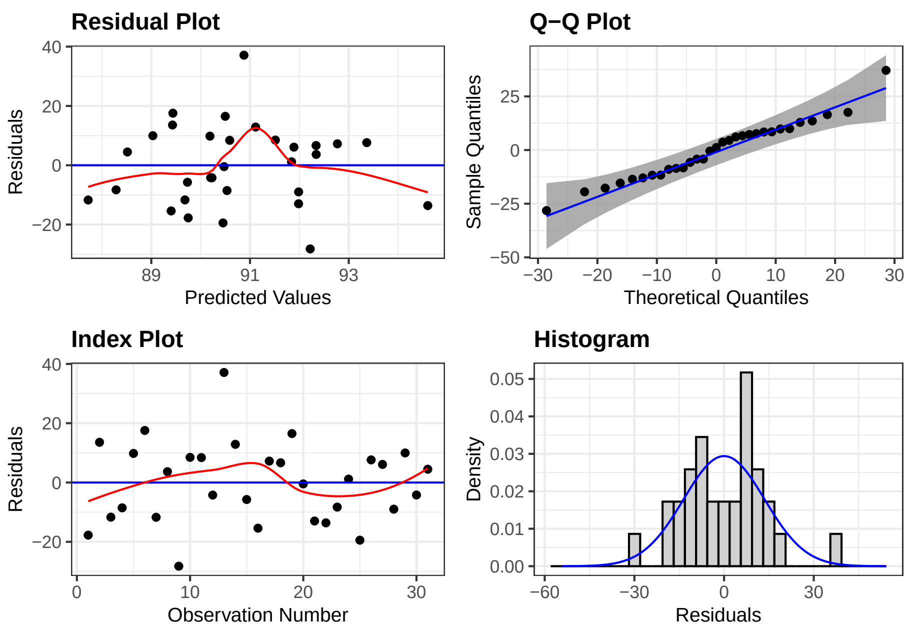
Q−Q Plot
Sample Quantiles
Theoretical Quantiles
Index Plot
Residuals
Observation Number
Histogram
Density
Residuals


Residual Plot
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Predicted Values
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91
93
Q−Q Plot
Sample Quantiles
Theoretical Quantiles
Index Plot
Residuals
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Density
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