A Statistical Analysis of Penalty Kill Performance in AHL Games

Sean Chua Ryan Dajani Daniel Lee Rohan Kundu

January 26, 2025

This paper examines the effectiveness of penalty-killing strategies in hockey using a convex hull-based coverage metric. With this metric, dynamics within a given penalty kill are measured for better analysis and evaluation of penalty kill performance. These results show comprehensive analysis using both qualitative and quantitative domains of thought processes in the evaluation of a given special teams sequence. Better understanding the dynamics of odd-man situations allows for nuanced team and player strategies and analysis, while also contributing to a deeper overall understanding of one of the most vital aspects of hockey.

Introduction

Penalty killing effectiveness can significantly influence team success in the NHL. For example, the 2024 Stanley Cup champion Florida Panthers boasted a penalty kill ranked sixth in the league during the regular season. This underscores the critical importance of an effective penalty kill, especially given that penalties are a constant factor in NHL games. This raises an essential question: what defines an effective penalty kill?

While the mechanics of a successful power play are well understood — primarily creating movement to disrupt the penalty killers' structure using the widely adopted 1-3-1 formation — the penalty kill lacks a universal system. Depending on strategy, teams often employ various formations such as the diamond or either a small or large box structure. Given this variability, we aimed to leverage tracking data to analyze patterns and identify what tactics contribute to successful or unsuccessful penalty kills.

By analyzing various penalty-killing approaches — aggressive forechecking, passive box formations, and hybrid systems — this study evaluates their influence on minimizing scoring opportunities and regaining puck possession. Using statistical models, video analysis, and player performance data, we identify key factors that contribute to successful penalty kills, including positioning, communication, and adaptability to opposing power-play tactics. These results hope to provide more information of special teams success beyond the raw numbers, helping teams towards more optimal decision making in penalty kill player deployment and positioning dynamics.

Data

Overview

Data was obtained from the Big Data Cup 2025 GitHub Repository consisting of 3 anonymized AHL games from the 2024-2025 season. More specifically, player shift data, events data, and tracking data were made available for each game. The Tracking data contained data on both the puck and player location in all collected frames over a game, with events data covering all on-ice events (ex. shots, goals, zone-entries), and shifts data containing information about the lengths of each shift for each player.

Methodology

This analysis seeks to evaluate penalty kill effectiveness using convex hulls. By constructing polygons that encompass the positions of players from both teams, the overlapping area of these hulls serves as a measure of penalty kill effectiveness, with a larger overlap indicating a larger area of coverage by the defenders in question.

To establish a clear understanding of Coverage%, it is essential to first define a key principle of effective in-zone defensive coverage: the proximity of defenders to offensive players directly reduces the available space for the offense, limiting their ability to make impactful plays. Thus, by maintaining close proximity to offensive players — both those with and without the puck — good defensive zonal coverage aims to restrict space and create favorable defensive situations. This approach ultimately disrupts the attacking team's ability to execute their strategy effectively.

We define the **Coverage%** of a given frame as:

$$\text{Coverage\%} = \mathit{Area}(\text{ConvHull}(K) \cap \text{ConvHull}(P)) \,/\, \mathit{Area}(\text{ConvHull}(P))$$

Here, ConvHull(K) is the convex hull of the penalty killers. ConvHull(P) is the convex hull of the power play players, and area computes the area of the respective shapes.

Where P and K represent the sets of power-play and penalty-kill players, respectively, and ConvHull(X) denotes the convex hull of a given set X. Convex hulls are defined as the smallest set such that all of the set of points in question is contained within a convex polygon. By retaining convexity, these shapes help us consistently measure the zonal setups, especially in their positioning on the ice at a given moment. Our formulation was inspired by similar work done on analysing zonal setups in the NBA in a blog post by Justin Jacobs, as many of the in-zone situations we wished to measure mirrored that of a NBA half-court situation (Jacobs, 2015).

By calculating Coverage% over the total number of frames within a given penalty kill, we assess the extent to which the power-play players positioned on the boundary of their convex hull are effectively covered by the penalty-kill players on their own convex hull boundary. By definition, Coverage% measures how well the space of the power play players are taken away by the penalty killers, especially for players in close proximity to the penalty killers.

This approach aims to provide deeper insights into the consistency and overall effectiveness of penalty-kill performance throughout a penalty-killing sequence. Additionally, it allows for further analysis

to distinguish the influence of player quality from the strategic setup of the penalty kill, with coverage % that differs based on player deployment and initial positioning.

Discussion

Composition of Effective Penalty Kills

We analyzed power play attempts across all three games that were provided to be able to draw conclusions and paint general trends that are able to help explore the different strategies for defending a power play. Figure 1 shows an example of a successful penalty kill formation.

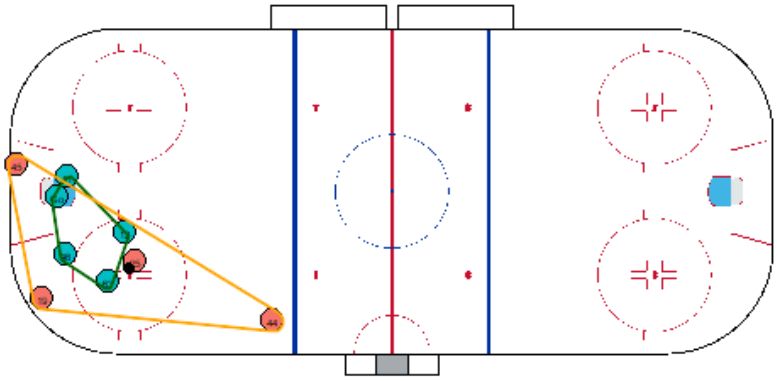

Figure 1: Compact Defensive Structure with Good Closeout Towards the Point

In Figure 1, we have penalty kill formation which demonstrates effective defensive strategies. The setup is a variation of the "box plus one" or "diamond" formation. Several factors contribute to the success of this formation in neutralizing the power-play offense and are outlined below:

Compact Defensive Shape
The penalty killers maintain a tight, structured unit, focusing on high-danger areas of the ice, particularly around the slot and primary shooting lanes. This minimizes opportunities for the attacking team to generate high-quality scoring chances.

Disruption of Passing Lanes
The defenders actively use their sticks to obstruct passing lanes, reducing the power-play team's ability to execute lateral puck movement. By limiting cross-ice passes, the formation mitigates the risk of one-timer opportunities.

Pressure on the Puck Carrier
The penalty killers efficiently rotate to apply consistent pressure on the puck carrier. This defensive pressure forces the power-play unit into rushed decisions, increasing the likelihood of turnovers

Net-Front Protection
Two defenders focus on neutralizing offensive players near the crease, thereby preventing rebound opportunities and tap-ins. This protective approach ensures the goaltender faces fewer high-percentage scoring attempts.

Dynamic Rotations
The penalty killers exhibit coordinated movements, maintaining structural integrity while adapting to puck movement. These rotations ensure continuous coverage of key areas while minimizing defensive gaps.

Perimeter Shot Limitation
The formation's positioning forces the attacking team to take low-percentage shots from the perimeter. This strategic approach favors the defending team, as the likelihood of scoring from such positions is significantly reduced.

Coverage %
The average coverage % on this play is approximately 80%, which means that on average 80% of the possible lanes are covered by the penalty killers, so this is yet another reason as to why this singular play results in such effective penalty killing.

Overall, this penalty kill formation is effective due to its combination of structural discipline, active disruption of offensive plays, and strategic adaptability. By forcing the power-play unit into less favorable positions and reducing high-quality scoring chances, the defenders significantly increase the probability of a successful penalty kill.

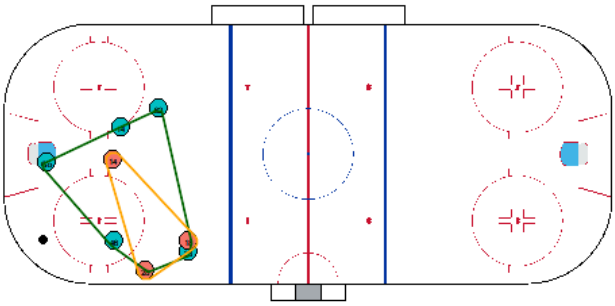

Figure 2: All Penalty Killers Converge towards Puck Carrier

Figure 2 showcases an unsuccessful penalty-killing strategy due to several key issues present in the defensive setup and execution. The following elements illustrate how the defensive team (orange circles) struggles against the attacking team (green circles):

Poor Defensive Positioning:
The penalty-killing unit does not maintain a compact, effective formation. The defenders are too far apart, creating open passing lanes for the attacking team to exploit. The triangle formation is loose, allowing the puck to move easily through the high-danger areas.

Ineffective Pressure on the Puck Carrier:
Figure 2 shows the attacking team moving the puck efficiently, suggesting that the penalty killers are not applying enough pressure. This allows the attackers time and space to execute a well-structured passing sequence, leading to a high-quality scoring chance.

Exposed Passing and Shooting Lanes
The gaps in player coverage result in the attacking team being able to pass the puck freely with little to no resistance, which ends up leading to a scoring chance in the slot area.

Slow Reactions and Coverage Gaps
The defense reacts late to puck movement, and the offense's ability to complete multiple passes suggests that defenders are not anticipating plays or moving quickly enough to block or intercept passes.

Lack of Coordination
The penalty-killing unit appears disjointed, with players failing to work together to contain the attack. The lack of synchronized movement allows the attacking team to manipulate the defensive structure and create scoring opportunities from prime locations.

Coverage %
The average coverage rate for this play is approximately 40%, suggesting that penalty killers are doing a poor job at defending the area that the power play unit is surrounding, thereby opening up a slot shot.

Overall, Figure 2 showcases an ineffective penalty kill, where defensive weaknesses such as improper positioning, lack of pressure, and poor coordination allow the attacking team to generate a dangerous scoring opportunity.

Action Points

Based on our statistical analysis of penalty-killing metrics, the following action points provide practical insights to enhance penalty kill performance and strategic deployment:

1. **Optimize Defensive Formations**
   Teams should focus on refining their penalty kill formations, such as the diamond and box structures, to maximize defensive coverage. The convex hull analysis indicates that compact formations with high Coverage% values (e.g., 80%) are more effective in limiting power-play opportunities. Coaching staff should emphasize maintaining tight defensive spacing and adjusting formations dynamically based on the power play's movement patterns.
2. **Increase Pressure on Puck Carriers**
   Effective penalty kills apply consistent pressure on puck carriers to force turnovers and rushed decisions. Training drills should incorporate aggressive forechecking and rotational strategies to disrupt offensive plays while ensuring defensive integrity. Emphasis should be placed on swift, coordinated rotations to cover gaps left by pressuring players.

Conclusion and Future Research

At the premise of this project, we hoped to discover more inference about penalty kill strategies using both innate detailing of positional assignments of the penalty kill players and by using a metric that we hoped encompassed more of what should be defined as “strategic success”, allowing us to analyse positioning quality in detail.

Future research could explore and analyze each type of man-advantage scenario as a distinct case. Strategies on the penalty kill can vary significantly depending on the number of players penalized, such as a standard 5-on-4 situation versus a more challenging 5-on-3 disadvantage. By isolating and studying these scenarios separately, we can better understand the tactical adjustments teams make and how these adaptations influence penalty kill effectiveness. This approach will provide a more nuanced analysis of team strategies under different conditions and contribute to the development of more targeted insights into penalty kill performance.

Our Coverage% metric could be used to track penalty kill coverage success for certain penalty killing strategies against power play strategies, allowing for more effective strategic formulation in both pre-game and in-game situations. By tracking changes in Coverage% through time, temporal analysis of the effect of longer penalty kills could also be quantified, allowing for additional valuations of the longevity of penalty kill shifts, allowing teams to make more informed decisions with regards to when they should sub off certain players or penalty killing groups. Adding onto this last point, the isolation of certain players and their impacts could be measured by adding/removing individual players from penalty killing groups to measure their “impact” on the coverage, allowing for more inference on whether or not a player or the strategy may be the main culprit of bad coverage situations.

Limitations

A potential limitation of this study lies in the inherent constraints of the Coverage% metric, which does not account for the positioning of inner defenders within the convex hulls. This oversight becomes significant in situations where penalty killers leave inner power-play players unmarked within the defined convex hulls. For instance, consider an extreme scenario where two power-play players are positioned on each side of the offensive zone, forming a convex quadrilateral. If all four penalty killers are stationed directly on these players, the Coverage% metric would approach 1 regardless of the positioning of the fifth power-play player. This situation highlights the metric's inability to reflect the true defensive risk, as it only evaluates the external shell of coverage players and their proximity to their respective marks.

Additionally, although the tracking data provides precise player positions, it does not account for the actual space occupied by defensive coverage, particularly due to the unknown positioning of players' sticks. Since players often use their sticks to block passing lanes and shots, more so than their bodies, the true Coverage% may be higher than the calculated values. This gap suggests that without full information of stick positions, the metric, while effective in most scenarios, may lack accuracy in evaluating true defensive coverage.

Acknowledgements

We would like to thank Shamar Phillips for creating the baseline animation for us to use for our code, which can be found in the following GitHub link: https://github.com/uwaggs/Uwaggs_demos

References

Jacobs, J. (2015, November 8). *Building NBA defenses using the convex hull*. Squared Statistics: Understanding Basketball Analytics. https://squared2020.com/2015/11/08/building-nba-defenses-using-the-convex-hull/