# Introduction

A common refrain from coaches in press conferences and sideline interviews after poor performances is some variation on “we need to return to the fundamentals” to improve. This analytics project quantifies the fundamental elements of sound tackling at a play level so that each fundamental can be independently evaluated on a tackle and can be combined into an overall “score” metric that allows teams and coaches to incorporate personalized preference/weighting for each.

The proposed purpose of the component-level and overall metrics developed here is for a first-pass analysis before more detailed film study and grading, used for in-season game retrospectives and scouting/player evaluation for roster construction. A first pass filtering analysis like this would identify plays and players of interest that may warrant further investigation, returning time back to team analysts and scouts. There are micro-level details like tackling form and tackle types that can’t be measured in the tracking data and can only be graded through watching film.

# Tackle Fundamentals/Components

The phases of an ideal tackle can be broken up into three phases: moving into position/approach for contact, wrapping up the ball carrier, and driving through the tackle to the ground.

## Approach for Contact

A vital component of tackling is identifying the offensive play quickly and moving into the right position on the field to contact and tackle the ball carrier. For this analysis, this component is graded by looking at path efficiency, defined as:

<< insert formula and variable definitions here>>

The contact frameId definition is described in Section XX.

Since many plays in this dataset include less than 3 seconds of data leading up to tackle, and some plays the runner goes to the tackler with little tackler movement, the following rules are applied:

* If the contact frameId is less than 20 or <variable here> is less than 3 yards, use the median <variable here> for all plays, as there is not enough time or distance traveled to properly evaluate path efficiency.
* In all other scenarios, calculate <variable here> between the contact frameId and 3 seconds (30 frames) before contact. Start at frameId = 1 if contact frameId <= 30.

## Wrap Up the Ball Carrier

Wrapping up the ball carrier is important to impede the ball carrier’s movement, either forcing them to the ground or allowing time for teammates to arrive and complete the tackle. The “wrap-up” component is quantified by looking at the distance between the ball carrier and tackler at the “tackle” event frameId:

<formula here>

Looking at the distance at the time of the tackle is a way to confirm the wrap up is maintained through the tackle, as not maintaining a wrap increases the chance of a broken tackle and should be graded lower.

## Drive through the Tackle

A major differentiator for grading tackles is how well the tackler changes the ball carrier’s momentum towards the end zone to minimize yards gained. This change in downfield momentum through the process of the tackle is the metric for driving through the tackle:

<formula definition here>

A neutral/baseline velocity is used as a standardization factor for player weights and downfield velocity at contact of each tackle scenario. From a physics standpoint, a bottled-up Austin Eckler (200 lb) hit by Dexter Lawrence (342 lb) is not equivalent to Travis Kelce (260 lb) running full speed into Tyrann Mathieu (190 lb), so grading the defender’s momentum transfer through the tackle must be compared against a “neutral” outcome specific to that play’s tackle scenario. This neutral outcome velocity is defined as:

<formula for v\_neutral>

This formula is the simplified equation of a fully inelastic collision in physics where the defender has no initial momentum, and only looking along the downfield axis. In practice, this is equivalent to the downfield velocity of the ball carrier immediately after he runs into a flat-footed (non-bracing) defender and the defender wraps up/sticks to the ball carrier.

Looking at the actual ball carrier velocity after the process of the tackle relative to this neutral velocity helps determine who “wins” the interaction, and to what extent.

## Supporting Definition: Contact FrameId

The contact frameId is determined with the following rules:

1. If the tackler is within 3 yards of the defender during the “first\_contact” event frame, use that frameId. 3 yards is used as a generous threshold to account for unknown (unpublished) sensor position error; the main purpose of this rule to eliminate any situation where the “first\_contact” event is triggered far earlier in the play by a different player than the eventual tackler.
2. If any of the first rule’s conditions are not met, set the contact frame as the first frameId where the tackler is within 1.8 yards or reaches the minimum distance to the ball carrier, whichever is larger. 1.8 yards is selected to account for the sensor error mentioned above and is the approximate distance for a 6’2” player’s shoulder pads to their feet. The comparison with the minimum distance is a failsafe in case the 1.8-yard threshold is not loose enough (like a hypothetical high-speed, high-angle trip tackle), as the minimum distance can be assumed to be the contact point.

The contact frameId logic intentionally errs on the early side since the involved metrics (approach and drive-through) are most dependent on play characteristics before and after the tackle interaction, rather than dependent on precise identification of the contact moment.

# Overall Tackle Grade/Metric

## Metric Components

If applicable, the metrics are passed through a transfer function to ensure a value between 0 and 1 for more transparent application of component weightings on the result, where higher values are better.

The “vision metric” <insert name here> is between 0 and 1 by definition.

The “wrap up metric” <insert name here> is scaled using the following transfer function:

< function here>

A value of 1.2 yards or less translates to an ideal tackle. 1.2 yards was chosen because that is approximately the distance between the ball carrier’s shoulder pads (sensor location) to mid-thigh when laying on the ground, which would equate to the defender tackling from the knees or above and maintaining the wrap to the ground. The value scales linearly to 0 at a 2-yard gap, roughly an ankle tackle with wrap. Any gap larger than 2 yards likely means the tackler does not maintain a wrap on the ball carrier through the tackle.

The “drive through the tackle” metric <insert name here> uses a standard min-max scaler using the limits of <name here> from all solo tackles in the Week 1-9 dataset, then subtracted from 1 because lower/negative is a better result:

<formula here>

## Overall Metric Definition

From the metric components above, weights can be applied to the 0-1 scaled component metrics to account for coach preference:

<formula here>

For demonstration purposes, the rest of this analysis will assume equal weighting:

<formula here>

## Metric Validation

To sanity check the results, extensive spot checking was performed on individual plays to validate a high or low score fits with the animation of the play. For brevity, the highest and lowest scores for proactive solo tackle situations (defined in Section XX) are shown below.

Best play: gameId = 2022100901, playId = 735. Cameron Heyward tackles Josh Allen.

Vision: 0.958

Wrap Up: 1.00

Drive Through: 0.959

Overall Score: 0.973

In this play, Cameron Heyward performs all tackle fundamentals well: efficient path to the contact point, wraps Allen up, and drives Allen backwards after contact even though Allen was moving downfield immediately prior to contact. This is a high-quality tackle, and the overall score reflects that assessment.

Worst play: gameId = 2022102000, playId = 2657. Alontae Taylor tackles Keaontay Ingram.

Vision: 0.551

Wrap Up: 0.00

Drive Through: 0.208

Overall Metric: 0.253

In this play, Taylor makes a tackle to prevent Ingram from getting a touchdown (after review), but the fundamentals are poor. Taylor is out of position, as he does not recognize Ingram bouncing outside early enough, reflected in his vision score by sliding towards the middle before reversing course to cover outside. Taylor does not wrap up Ingram, as he maintains his direction towards the sideline while Taylor goes an additional 5 yards downfield past the contact before going down. Taylor does not dampen or reverse the downfield velocity of Ingram after contact around Frame 60, seen visually in the animation and reflected in the low Drive Through score. Taylor made the tackle, but the fundamentals were poor.

# Case Study: Proactive Solo Tackles

Proactive solo tackles are defined in this analysis as tackles where the defender is taking a more aggressive path to stop the ball carrier, only one player is credited with the tackle (no assists), and it is an inbounds tackle with contact (not out of bounds or QB slides). This is an applicable scenario to look at because it is a higher risk-reward tackle situation, so better fundamentals provide a higher chance of success on average.

## Defining Proactive Solo Tackles

This is defined as plays where the tackler’s downfield velocity component of 0.5 yds/sec or less at the contact frameId (towards the offensive backfield is negative), there is a distinct tackle event (not out of bounds or yielding like a QB slide), and no other player is credited with an assist. In general, this will capture decisive path decisions and is sufficient to demonstrate the metrics.

## Team Results

Aggregation of the tackling overall metric by defending team is shown in the figure below. The best-rated team is New England with an average value of 0.783, and the worst team is Carolina at 0.724.

<figure here>

## Position Results

Aggregation of the tackling metrics by individual defenders is shown in the tables below, separated by position group. The thresholds for inclusion in the tables are 5 proactive tackles for defensive linemen, 10 for linebackers, and 15 for defensive backs. These thresholds were selected to include a reasonable amount of players per position group for the provided tracking data.

### Results: Defensive Linemen

<table here>

### Results: Linebackers

<table here>

### Results: Defensive Backs

<table here>

# Conclusions and Future Work

In general, the metrics proposed here for the Approach for Contact, Wrap up the Ball Carrier, and Drive Through the Tackle phases of tackling line up well with the theory of good tackling and match how good tackles should look during play animations. The overall metric also has the flexibility to allow coaches to embed their own philosophy on tackling component relative importance into the metric output. These tackling component metrics are simple to implement and easy to show and explain, which can aid adoption and acceptance of the proposed tackling metrics.

This analysis looks at the fundamentals of tackling on actual recorded tackles. It is worth noting that any tackle is much more valuable than missing tackles or not being in position to attempt a tackle, so a low score is isolated to the physical fundamentals of that tackle and are not a reflection of the play-level value of the tackle.

The vision metric could be improved to grade the tackler’s ability to identify the play in a timely manner rather than assuming 3 seconds before contact, and also account for the effect of blockers on the tackler’s path.

The metrics could be expanded to accommodate grading of all tackle opportunities, as this would add an additional aspect of a player’s tackling ability from a positioning perspective instead of only tackle mechanics.