Reflection of Coverage Technique in Player Movement

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Introduction

In the NFL, pass defense is one of the most important components of the game. While post-snap coverage technique is often analyzed, good technique and positioning post-throw (when the ball is in the air) are also necessary. To highlight effective techniques and positioning/movement post-throw, leading to pass breakups (PBUs), I focused on plays where defenders force PBUs.

Several variables shape what the proper technique and movement post-throw is to force PBUs, especially the defender's coverage role and the route they're guarding. The goal of this project is to analyze commonalities in post-throw technique and movement characteristics of defenders who forced PBUs across different coverage roles and routes defended. To evaluate the ways these defenders move post-throw, based on coverage and route, I created five movement metrics: vertical displacement, horizontal displacement, breaking point, speed variance, and angle change. These represent the factors that characterize how defenders move post-throw. Using these metrics, I evaluated defender movement paths post-throw, to show how PBU-forcing defenders move based on their coverage responsibility and route their guarding.

Research

I had to ensure I properly evaluated players' post-throw movements within the context of their coverage responsibilities against certain routes. Through conversations with college football coaches, I learned how defenders are taught to play, and move, against certain routes and in certain coverages. There are three main coverage roles and route types dictating how players should play a pass.

Considering that I am analyzing successful PBUs, it may be expected that these players' movement post-throw reflects the proper techniques and movements described in the table

below. Therefore, these eight coverage vs. route scenarios are crucial to understanding how defenders are *supposed* to move post-throw when evaluating their *actual* movements post-throw on PBUs. Analyzing the components of defenders' movements post-throw on PBUs within the context of how they're supposed to move post-throw based on coverage and route can help evaluate if the movements result from following proper technique.

Proper Technique by Coverage and Route

	Vertical Routes (Go, Post, Wheel)	Horizontal Routes (Crosser, Slant)	Breaking Routes (In, Out, Hitch, Corner, Angle)
Underneath Zone (Hole, Hook, Flat)	- If in Zone Match, run with route - If in Spot Drop Zone, run to where QB's eyes are	- Sit in Zone - Break to where QB's eyes are	- Sit in Zone - Undercut routes behind - Jump routes in front
Deep Zone (Half, Third, Quarter)	- Run with route - Push receiver towards inside help or sideline		- Break on where QB's eyes are
Man	- Run with route - Push receiver towards inside help or sideline	- Stay In-phase - Trail just behind OR - Mirror step-by-step	- If In-phase after break, stay just behind - If out of phase after break, recover to ball

Data and Methods

Data

I incorporated 3 datasets: 2023 NFL regular season play-level data from nflfastr, the post-throw tracking data provided, and SumerSports public supplemental data. The nflfastr data gave me the plays where PBUs were forced, and the player(s) who forced them, so I could filter the post-throw tracking data to include the relevant player paths. Within the tracking data, for each PBU forced, I found the frame-by-frame location coordinates of the PBU-forcing defender(s) post-throw, and the route type that was thrown to. SumerSports supplemental data added in player-level coverage responsibilities for each play.

Interpretability

Defenders' post-throw movement paths needed to be interpretable for analysis, so the raw tracking data, for several reasons, had to be adjusted. Plays had differing starting points, directions, and frame counts, so players' paths were not on a common locational scale or timeline. To put the defender paths on a common locational scale, I made two adjustments to player coordinates. I flipped x/y coordinates so all plays went to the right, and standardized x/y coordinates so all plays were on the same yardline and hash, and all routes were to the same sideline. To put defender paths on a common timeline, I resampled each defender path to 10 frames using linear interpolation and extrapolation.

Defender paths were also difficult to visualize because they were jagged from noise in the coordinates between frames, making patterns in the movement paths hard to identify. Therefore, I smoothed the player paths using general additive modeling. This modeled smoothed player coordinates for each resampled frame, forming more curved player paths. This provided more interpretable post-throw defender paths, while still visually capturing breaks and transitions.

Clustering

The way defenders move post-throw is contingent on their coverage responsibility and the route they're guarding. However, defenders' movements post-throw also vary within these combinations. For example, the way a deep zone defender guarding a vertical route moves post-throw will differ based on what kind of deep zone they're playing and what kind of vertical they're guarding. To analyze differences in post-throw defender movements between and within coverage and route combinations, I used clustering, a way to group defender paths within each coverage and route combination, based on similar "movement characteristics". These "movement characteristics" needed to capture football movements like distance covered in coverage, speed, and sudden changes in direction. I calculated five characteristics that did this. Vertical Displacement and Horizontal Displacement,

Responsibility x Route Cluster Sizes

Plays with a PBU - 2023 Season

responsibility_type	route_type	cluster_1_size	cluster_2_size	cluster_3_size
DEEP ZONE	BREAKER	6	168	61
DEEP ZONE	VERTICAL	34	62	84
MAN	BREAKER	124	50	35
MAN	HORIZONTAL	90	10	34
MAN	VERTICAL	70	68	43
UNDERNEATH ZONE	BREAKER	11	185	65
UNDERNEATH ZONE	HORIZONTAL	91	3	24
UNDERNEATH ZONE	VERTICAL	18	17	44

the changes in a defender's vertical and horizontal positions while the ball is in the air, quantify how much the defender moved post-throw. Total Angle Change, the absolute sum of a defender's angle change across frames, captures how much the defender's direction changes along their path. Breaking Point shows at what point in time along their post-throw path the defender makes their sharpest change in direction, which is often when they break on the ball. Lastly, Speed Variance captures if the defender is moving at a constant pace or stop-starting.

All post-throw defender paths within each coverage responsibility and targeted route combination were grouped into three clusters based on their movement characteristic values, making twenty-four clusters across eight combinations. For each cluster, I also calculated the mean of all characteristics and averaged the smoothed x/y coordinates at each frame to find the mean post-throw defender path.

Analysis

Visual Analysis

To visually analyze the post-throw paths of PBU-forcing defenders, based on coverage responsibility and the targeted route type, I plotted the three mean cluster defender paths within each coverage and route combination. I also created a dynamic dashboard, allowing me to choose three coverage vs. route plots to view simultaneously. To ensure visual analysis would be in a football context, I defined each mean cluster path based on the defender's technique, the specific kind of coverage role the defender plays within their coverage responsibility type, and the specific kind of route within the route type that was targeted. I achieved this through film study of plays within each cluster, identifying similarities in the PBU-forcing defenders' techniques, coverage roles, and defended routes.

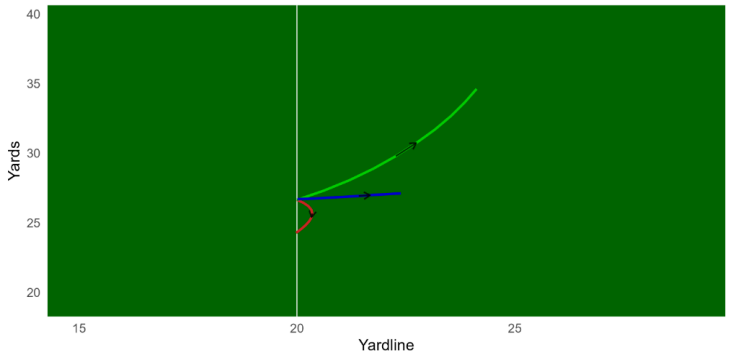
Defined Cluster Names

coverage_route_combo	cluster_1_name	cluster_2_name	cluster_3_name
Deep Zone vs. Breaker	Jump from Great Depth	Jump From Minimal Depth (No Transition)	Break from Minimal Depth (Transition)
Deep Zone vs. Vertical	Inside Helper on Vert	Carry Vertical w/ Sideline Help	Carry Seam w/ Inside Help
Man vs. Breaker	Recovery	In-Phase on In/Out Breaker	In-Phase on Stop Routes
Man vs. Horizontal	Mirror	Undercut	Trail
Man vs. Vertical	Squeeze to Bottom Sideline	In-Phase, No Squeeze	Squeeze to Top Sideline
Underneath Zone vs. Breaker	Hook/Curl Flat w/Vertical Break	Hook/Curl Flat, w/ Horizontal Break	Ball Thrown Right to Zone
Underneath Zone vs. Horizontal	Zone Drop from LOS	Play Flat Zone	Cut Off Crosser
Underneath Zone vs. Vertical	Hook/Curl Flat Carry Seam	Hook/Curl Flat Carry Vert	Hole Drop

Mean Cluster Defender Paths in Man Coverage

Clustered Mean Defender Paths on PBUs Man vs. Breaker Routes

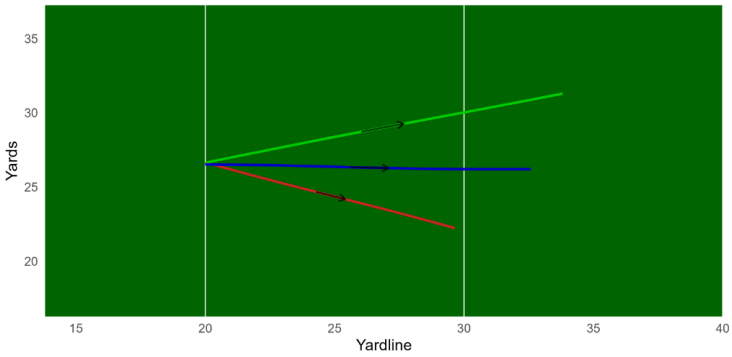
2023 NFL Regular Season | Paths Smoothed using GAM | Silhouette = 0.317



Cluster — In-Phase on In/Out Breaker (124) — Recovery (50) — In-Phase on Stop Routes (35)

Clustered Mean Defender Paths on PBUs Man vs. Vertical Routes

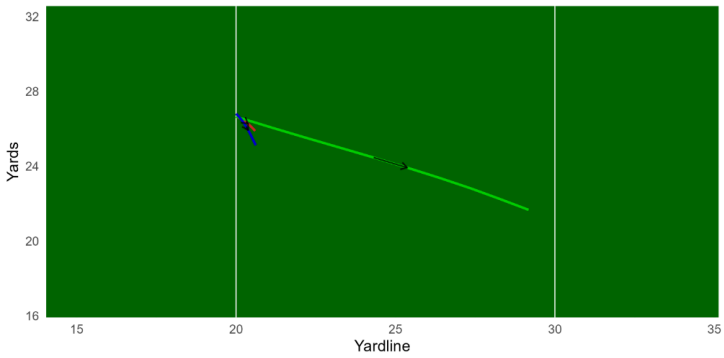
2023 NFL Regular Season | Paths Smoothed using GAM | Silhouette = 0.249



Cluster — Squeeze to Bottom SL (70) — Squeeze to Top SL (68) — In-Phase, No Squeeze (43)

Clustered Mean Defender Paths on PBUs Man vs. Horizontal Routes

2023 NFL Regular Season | Paths Smoothed using GAM | Silhouette = 0.419



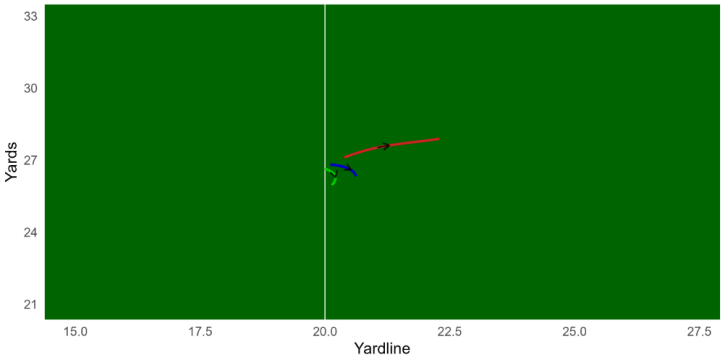
Cluster — Mirror (90) — Undercut (10) — Trail (34)

Source: NFL, nflfastr, SumerSports

Mean Cluster Defender Paths in Underneath Zones

Clustered Mean Defender Paths on PBUs Underneath Zone vs. Breaker Routes

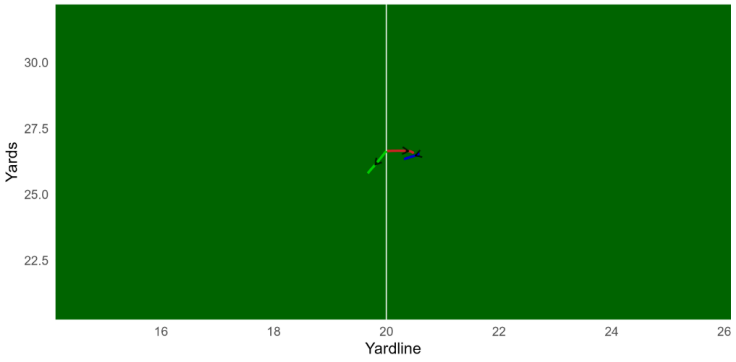
2023 NFL Regular Season | Paths Smoothed using GAM | Silhouette = 0.344



Cluster — Hook/Curl Flat, w/ Horizontal Break (11) — Hook/Curl Flat w/Vertical Break (185) — Ball Thrown Right to Zone (65)

Clustered Mean Defender Paths on PBUs Underneath Zone vs. Horizontal Routes

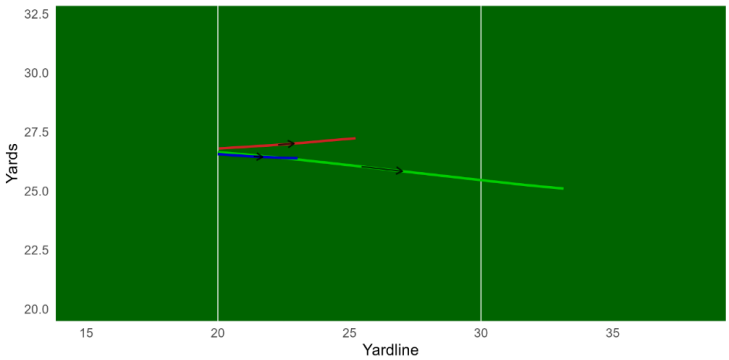
2023 NFL Regular Season | Paths Smoothed using GAM | Silhouette = 0.403



Cluster — Cut Off Crosser (91) — Play Flat Zone (3) — Zone Drop from LOS (24)

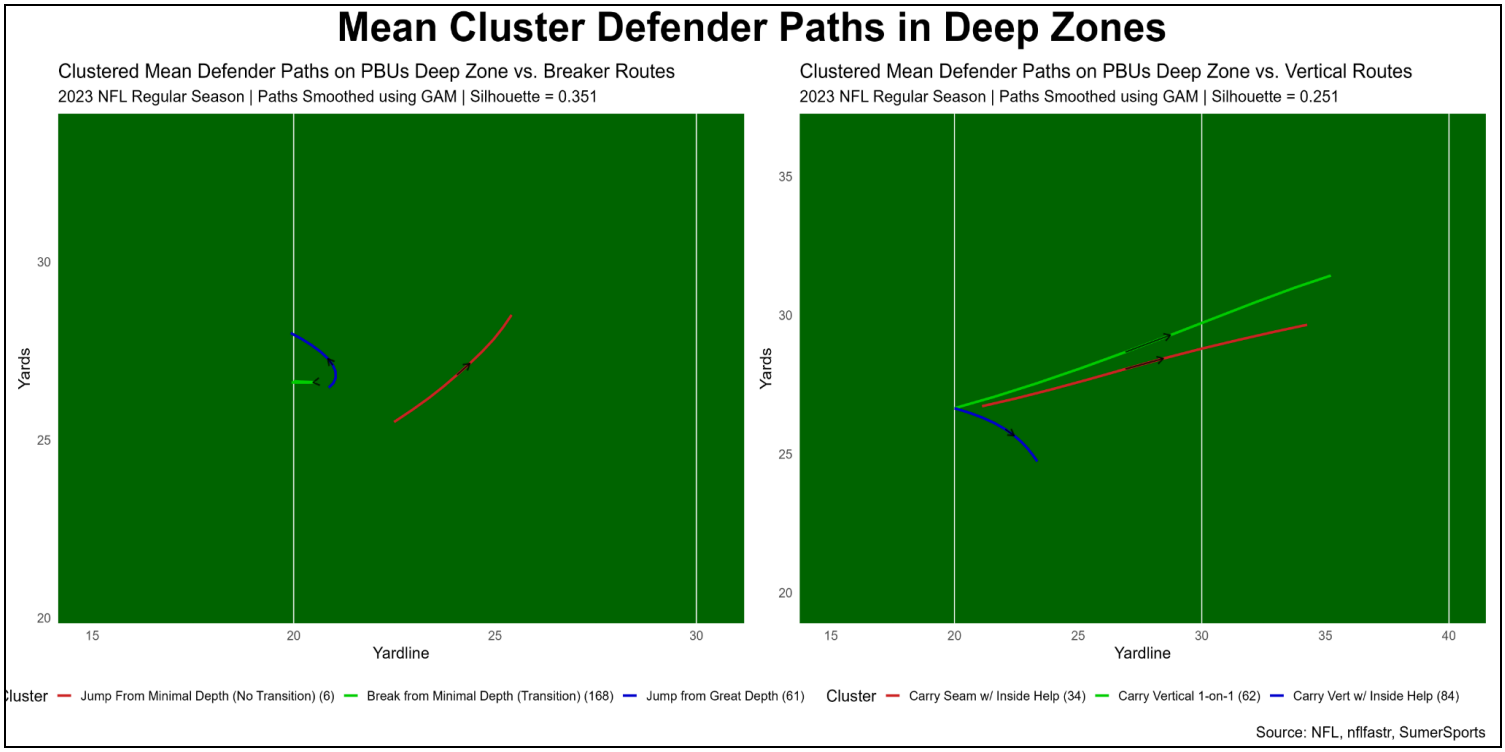
Clustered Mean Defender Paths on PBUs Underneath Zone vs. Vertical Routes

2023 NFL Regular Season | Paths Smoothed using GAM | Silhouette = 0.283



Cluster — Hole Drop (18) — Hook/Curl Flat Carry Vert (17) — Hook/Curl Flat Carry Seam (44)

Source: NFL, nflfastr, SumerSports



Snapshots - Defender Paths Visuals

Several patterns within defenders' post-throw paths can be surmised from these visuals. Across coverage and route combinations, there's one key similarity in defenders' post-throw player paths based on coverage responsibility, and one key similarity based on the route type targeted.

Similarities Based on Coverage Responsibility

Man: *defender post-throw paths cover more ground vertically and horizontally*

Football Explanation: defenders are following routes to stay in-phase, therefore covering more ground

Underneath Zone: *defender post-throw paths are shorter, with more horizontal displacement than vertical*

Football Explanation: underneath defenders don't need depth to play their zone, and are often breaking sideways to the ball

Deep Zone: *defender post-throw paths are shorter than in man, with more vertical displacement than horizontal*

Football Explanation: deep defenders have to gain depth to play their zone, and break downward on the throw

Similarities Based on Route Targeted

Breakers: *defender post-throw paths move upwards before changing directions to move downwards*

Football Explanation: defenders are gaining depth on the stem of the route, and at the break of it, breaking down on the ball

Verticals *defender post-throw paths are aiming downfield, gaining significant horizontal and vertical displacement*

Football Explanation: defenders are running downfield with the route, and are squeezing receivers to the sideline

Horizontals: *defender post-throw paths are short, but still gain horizontal displacement*

Football Explanation: defenders have to gain width to undercut or cut off the route

These patterns signify that PBU-forcing defenders tended to follow proper technique based on coverage and route. Verticals are being squeezed towards help in man and zone coverage, and on breaking and horizontal routes, man defenders stay in-phase, while zone defenders make good breaks from their spots. However, these visual findings are only based on player displacement, and to make solid conclusions, all aspects of that movement need to be analyzed.

Quantitative Analysis

I quantitatively analyzed the mean movement characteristics within each cluster to identify post-throw movement trends that I was unable to evaluate visually, to more clearly tell if PBU-forcing defenders' post-throw movements aligned with proper technique. My quantitative analysis had three intentions: 1) Confirm or deny my visual findings on defenders’ displacement

post-throw, 2) Identify movement trends in non-displacement characteristics to evaluate how defenders' speed and changes in direction alter based on coverage and route, and 3) use the findings of the first 2 to determine if PBU-forcing defenders' movement post-throw is a reflection of proper technique.

The numerical differences in the amount of ground defenders cover based on coverage and route match those in the visuals. Regardless of route, man defenders are covering a lot of ground, averaging 4-13 yards of horizontal movement and 2-7 of vertical movement across 6 of 9 clusters. Similarly, underneath zone defenders are not covering as much ground, but are getting more width than depth, averaging more horizontal than vertical displacement in 8 of 9 clusters, while deep zone defenders are gaining much more depth than width, averaging more vertical than horizontal displacement on all non-vertical route clusters, where horizontal displacement is especially high across coverages. Speaking of which, visual findings about displacement based on route type are very evident on vertical routes. The largest average horizontal displacement values all come from vertical route clusters, and while the average vertical displacement on vertical routes is not as extreme, ranging from .16 to 4.7 yards, it's still relatively higher than when guarding other routes.

Evaluating average breaking points, speed variance, and angle change across coverages and route types revealed several patterns in defenders' speed and change in direction. PBU-forcing defenders' variance in speed is particularly constant when playing any type of zone, varies up to 0.004 frames/second against non-verticals, whereas in man, speed varies up to 0.009 frames/second.

Man Mean Paths Characteristics by Cluster

Plays with a PBU - 2023 Season

cluster	route_type	vertical_disp	horizontal_disp	breaking_point	speed_var	total_angle_change
1	BREAKER	-2.369	-0.020	4	0.000	1.017
2	BREAKER	7.971	4.123	3	0.003	0.476
3	BREAKER	0.408	2.373	10	0.009	0.159
1	HORIZONTAL	-0.762	0.600	4	0.000	0.449
2	HORIZONTAL	-4.983	9.173	9	0.004	0.132
3	HORIZONTAL	-1.687	0.617	3	0.000	0.225
1	VERTICAL	-4.420	9.653	9	0.003	0.063
2	VERTICAL	4.648	13.798	5	0.007	0.032
3	VERTICAL	-0.320	12.574	8	0.005	0.078

Underneath Zone Mean Paths Characteristics by Cluster

Plays with a PBU - 2023 Season

cluster	route_type	vertical_disp	horizontal_disp	breaking_point	speed_var	total_angle_change
1	BREAKER	0.784	1.913	6	0.002	0.457
2	BREAKER	-0.697	0.138	5	0.000	1.182
3	BREAKER	-0.494	0.513	6	0.000	1.148
1	HORIZONTAL	-0.098	0.466	10	0.001	1.386
2	HORIZONTAL	-0.850	-0.330	10	0.000	0.129
3	HORIZONTAL	-0.218	-0.239	4	0.000	1.971
1	VERTICAL	0.430	5.200	7	0.001	0.051
2	VERTICAL	-1.545	13.137	10	0.015	0.057
3	VERTICAL	-0.169	3.033	10	0.000	0.053

Deep Zone Mean Paths Characteristics by Cluster

Plays with a PBU - 2023 Season

cluster	route_type	vertical_disp	horizontal_disp	breaking_point	speed_var	total_angle_change
1	BREAKER	3.009	2.919	9	0.003	0.380
2	BREAKER	-0.038	-0.055	10	0.004	3.131
3	BREAKER	1.537	-0.945	4	0.004	1.749
1	VERTICAL	2.937	13.150	3	0.005	0.101
2	VERTICAL	4.783	15.224	10	0.019	0.123
3	VERTICAL	-1.919	3.349	8	0.014	0.638

Units: yards, yards, frames, frames/sec, degrees; higher is red, lower is green

The increased speed variance in man coverage reflects how man defenders cover another player and must continuously match their speed, leading to more variance. Contrastingly, zone defenders are playing a spot, and they mainly move to play the ball, which is at a constant speed, unless carrying verticals. As for angle changes, zone defenders have higher total angle changes than man defenders, except on vertical routes. Man defenders typically move backwards to gain cushion and then in the direction their man runs their route, so their direction only changes once. Zone defenders, however, unless carrying vertical, move based on the QB's eyes, causing more directional shifts based on where the quarterback looks. Lastly, man defenders have slightly earlier breaking points than zone defenders, which is a reflection of positioning. Man defenders stay close to the receiver, breaking when the receiver looks for the ball, whereas zone defenders need to stay within their spot and wait a tick longer to see the ball come out before fully breaking. The only time this isn't the case is on breaking routes, where zone defenders can jump routes similar to man defenders.

My analysis reveals many movement trends, and breaking them down in a football context shows that they reflect "proper technique" for the given coverage and route. Man defenders are taught to run with the route and stay in-phase, squeeze towards help if the route is vertical, and play from behind on the ball on breakers and crossers. Movement trends reflect this, with man defenders matching the speed and direction of the route runner, having extreme horizontal displacement vs. verticals, from squeezing, and breaking early on defenders' hands on breakers and crossers. Likewise, zone defenders are taught to carry vertical routes and otherwise read the QB's eyes and break on them. Similarly, their movement shows they have the most displacement vs. verticals, where they have to carry the route downfield, and on non-vertical routes, they change direction more, by following the QB's eyes while sat in their zone until the last second to break on the ball. Given such, there are clear signs that the PBU-forcing defenders move post-throw in a way that reflects proper technique.