Recruiting Analytics™

Technology That Wins

The how and the why to gaining a competitive advantage using tracking data from computer vision for objective talent evaluation and advanced scouting

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Abstract

Each year 67% of professional, collegiate and high school athletes are misevaluated by sports teams, costing an estimated $18 billion in salaries, scholarships, and financial aid. Talent evaluation has proven to be historically difficult, and is getting more complex and challenging in today's data proliferation era. Despite the increased availability of advanced performance data, talent evaluation remains an inexact science due to the subjective nature of film evaluations, the inability to measure intangibles, and the nonpredictive nature of traditional evaluation metrics.

Throughout this paper we will explore various player tracking technologies from companies like Recruiting Analytics (RA), Zebra Technologies and Catapult. We will examine the athleticism data generated from each technology, and how coaches and evaluators are gaining a competitive advantage and valuable insights from tracking data that is objective, verified, predictive, and actionable. The results from Recruiting Analytics' study show that coaches can improve their hit-rate up to three times with the proper application of tracking data.

High school prospects above the median Recruiting Analytics' Score of 86.6 proved to be high-ceiling players with a favorable NFL trajectory.

These players went on to:

- *Start 73% of games played collegiately*
- *98% earned All-Conference honors*
- *50% earned All-American honors*
- *95% were drafted by the NFL*

Professionally, these players went on to:

- *Start 71% of games played*
- *42% were voted to the Pro Bowl*
- *31% earned All-Pro honors within an average of two seasons*

What is Player Tracking Data?

Quantitative evaluation of football prospects has traditionally been based on measurables, athletic testing and box score statistics. Such evaluations have proven not to be predictive of future success as evident by the National Football League's (NFL's) and National Collegiate Athletic Association (NCAA) football's low hit-rate of 32%[1], and 24%[2] respectively because a weak relationship exists between traditional evaluation metrics and football success. Coaches and scouts continue to rely heavily on known metrics such as height, weight and timed speed. However, the most important aspects of a player's ability such as play speed, change of direction, acceleration, and deceleration are less quantifiable. A player's in-game athleticism is typically evaluated qualitatively, informed by institutional knowledge and intuition of a coach or scout who has spent a significant amount of time watching the player's film. This distinction between quantifiable and non-quantifiable player skills may be on the verge of disappearing.

Advancements in technology and machine learning algorithms unlocking data containing the exact locations of every player, has made player tracking data the hottest commodity in sports, representing a revolutionary new data source for player evaluations. For readability purposes, this paper refers to player tracking data as 'tracking data'. Under a general definition, tracking data is the measurement in which virtually every aspect of a player's performance is tracked and analyzed, numerically. These datasets are extremely complex, rich, and robust. For example, tracking systems can capture thousands of data points per second per player, such as location, max speed, acceleration, and change of direction.

Tracking data is the measurement in which virtually every aspect of a player's performance is tracked and analyzed numerically

Tracking Data Use Cases

The use of tracking data varies by teams and leagues, each unique in the purpose, collection and/or utilization of the data. The most common use case is for player performance for the purposes of evaluation and scouting, as well as optimizing training, player health, wellness monitoring, and an emerging trend of game planning. This paper will focus on the use of tracking data for the purposes of player evaluations and scouting.

Talent acquisition is considered to be the lifeblood of sports teams. Talent acquisition is the process of identifying, evaluating, recruiting, and acquiring skilled prospects to meet team needs. At the apex of talent acquisition is the player evaluation process. Each year NFL teams collectively spend an estimated $320 million on evaluating NFL draft picks[3], with a premium placed on assessing athleticism. Athleticism is the ability to repeatedly perform a range of movements with precision and confidence in a variety of environments, which require competent levels of motor skills, strength, power, speed, agility, balance, coordination, and endurance[4]. The value of tracking data is in the insights gleaned from measuring athleticism during practices and/or games, virtually eliminating the guesswork of projecting traditional athletic metrics (collected at combines and/or pro days) to on-field production. For example, play speed is known to translate to on-field production. Armed with tracking data such as max speed, evaluators have a metric tied directly to play speed, reducing their dependency on using the 40-yard dash as a proxy. Table 1 outlines examples of the traditional metrics used by evaluators to measure athletic critical factors during combines and/or pro days, versus metrics generated from tracking data that can be used to measure the same critical factors.

In most cases (with the exception of the bench press test), tracking data can measure the same critical factors of athleticism as traditional combine testing. However, tracking data has a few clear and distinct advantages over combine testing when measuring athleticism.

1. Tracking data measures athleticism in a live environment (e.g. during games) and/or in a semi-live environment (e.g. during practices), making it easier for evaluators to project talent to the next level.
2. Tracking data measures position-specific athleticism in the context of executing position-required movements repeatedly during a game or practice.
3. Tracking data can be customized to track and measure a specific athletic trait deemed important by a coach or scout.
4. Tracking data can provide trending analysis useful to quantify the impact of age or injury on athletic performance.

For these reasons and more, RA contends that tracking data provides invaluable insights that helps evaluators project with more accuracy to improve their hit-rate.

Table 1: Traditional metrics vs. tracking data used to measure the critical factors of athleticism

Athleticism critical factor	Traditional metric(s)	Tracking data metric(s)	Unit of measure	Tracking data definition
Play speed	40-yard dash	Max speed	Miles per hour	The highest rate of speed an athlete attained during a game, practice or event
		Max speed in first 5, 10, and 15 yards	Miles per hour	The highest rate of speed an athlete reaches in the first 5, 10, and/or 15 yards of a play
		Closing speed	Yards per second	Time it takes a defender to close the separation between him and the ball carrier or receiver.
		Sack time	Seconds	Time that elapses from the snap of the ball, to the moment the defender sacks the QB
		Speed off the line of scrimmage	Miles per hour	The highest rate of speed an athlete achieved from the snap of the ball to a sack, tackle, or user defined distance
Initial speed	10-yard split	Acceleration (time to max speed)	Seconds	How quickly an athlete can accelerate to max speed
Speed endurance	20-yard split	Max speed distance maintained	Yards	The distanced an athlete sustained max speed range (within 5% of max speed)
Change of direction	3-cone drill; 20-yard shuttle	Transition time	Seconds	The time it takes an athlete to transition from the last step in one direction to the first step in any new direction
Explosiveness	Vertical jump; Broad jump	Closing time*	Seconds	The time it takes a defender to close the separation between him and the ball carrier or receiver.
		Yards after catch (YAC)*	Yards	Yards gained after the receiver catches the ball
		Sack time*	Seconds	Time that elapses from the snap of the ball, to the moment the defender sacks the QB

**Position-specific explosiveness metric: DB & LB – closing time; WR – yards after catch; EDGE – sack time*

Practical Application and Importance of Tracking Data

In football, teams don't win because they have a size, skill, and/or athletic advantage over the opposing team. Teams win because they are able to successfully exploit one, some, or all of those advantages. Tracking data can give teams the competitive advantage needed to win, by identifying personnel matchup advantages and disadvantages. Coaches who leverage tracking data to understand the athletic ability of the opposing team's personnel, will be able to devise a game plan to maximize matchup advantages and minimize matchup disadvantages. For instance, let's say the offensive coordinator (OC) knows which cornerback has the slowest transition time. The OC can match the cornerback up with the receiver with the fastest transition time through formation and/or motion, and call designed in or out-breaking routes resulting in greater separation, a larger target window for the quarterback, and a higher completion percentage. On the flip side, a defensive coordinator (DC) privy to the same information can scheme to provide safety help over top, so the corner can play trail technique ready to trigger on short or intermediate routes.

Football coaches have a saying that is indicative of their evaluation philosophy, "the eye in the sky don't lie". Most NFL coaches will tell you that player evaluation is 90% what's seen on film, and 10% combine measurables and interviews[5]. Technological advancements powering tracking data has allowed coaches to quantify the critical factors (athletic ability, functional speed, functional strength, and instincts) they look for when they turn on the tape. Armed with tracking data, coaches can review the numbers to verify their film evaluations.

Player evaluations are retrospective by nature. Coaches and personnel executives draw on productive players from the past to compare current players and prospects. Imagine being able to go back in time to track the max speed of Bo Jackson, the closing speed of Deion Sanders, or the time it takes Jerry Rice to get in and out his breaks. The power of computer vision (CV) technology is its ability to produce tracking data from film of successful players in the recent past. Historical tracking data goes beyond combine measurables, providing evaluators with deeper insights into the critical factor(s) that made great players special. Equipped with this knowledge, coaches and personnel executives can establish the right performance thresholds to evaluate and compare prospects.

Tracking data can give teams the competitive advantage needed to win, by identifying personnel matchup advantages and disadvantages

Proper roster management requires a talent review process that is anchored in objectivity. As teams seek to upgrade the talent on their roster, pairing production with tracking data on current players and free agents provides the needed insights for proper context for comparisons. Evaluators can 'zoom in' on similar players and look beyond dated combine measurables and utilize tracking data to get a practical read on the players' current athletic status. Additionally, answers to questions regarding the players' athletic trajectory can be found by analyzing year-over-year trends in performance metrics like play speed, acceleration time, closing speed, and yards of separation. Of course, age plays a role, but a trajectory analysis on players similarly aged can help personnel executives identify and sign the player with the higher ceiling.

Utilizing tracking data to verify play speed, the speed at which an athlete plays the game, has proven to add significant value to coaches and scouts. NFL teams and top college football programs are leveraging tracking data from computer vision to gain deeper insights into the critical factors of play speed. More specifically, evaluators are able to determine:

1. How quickly an athlete can increase velocity in motion (acceleration)
2. The highest rate of speed an athlete can attain (max speed)
3. The rate of reduction in maximum speed (deceleration)

As teams seek to upgrade the talent on their roster, pairing production with tracking data on current players and free agents provides the needed insights for proper context for comparisons.

Recruiting Analytics applied their player tracking technology to breakdown and explain how DK Metcalf was able to close 20-yards of separation in 8.6 seconds during Metcalf's epic chase down of Budda Baker.

DK Metcalf vs. Budda Baker Acceleration Comparison

DK Metcalf

Metcalf's 5-yard max speed was ~14.6mph (~65% of his max speed)

Budda Baker

Baker's 5-yard max speed was ~14.0mph (~66% of his max speed)

Metcalf's 10-yard max speed was ~17.0mph (~76% of his max speed)

Baker's 10-yard max speed was ~16.5mph (~78% of his max speed)

Metcalf's 15-yard max speed was ~18.9mph (~84% of his max speed)

Baker's 15-yard max speed was ~18.1mph (~85% of his max speed)

DK Metcalf vs. Budda Baker Max Speed Comparison

DK Metcalf

Metcalf reached 95% of his max speed (~21.4 mph) in ~3.5 seconds or ~30 yards

Metcalf accelerated to a max speed of ~22.5 mph in ~6.9 seconds or ~51 yards. 22.5 mph equals ~11 yards/second

Metcalf maintained at least 95% of his max speed for ~4.2 seconds or ~53 yards

Budda Baker

Baker reached 95% of his max speed (~20.1 mph) in ~3.0 seconds or ~25 yards

Baker accelerated to a max speed of ~21.2 mph in ~6.4 seconds or ~46 yards. 21.2 mph equals ~10.4 yards/second

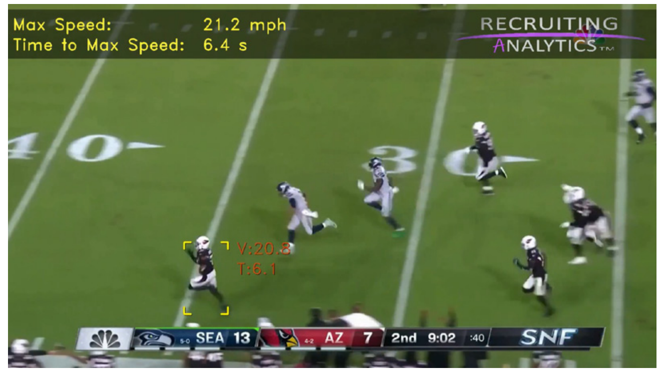
Baker maintained at least 95% of his max speed for ~4.8 seconds or ~48 yards

Budda Baker's Speed Relative to DK Metcalf's Max Speed

DK Metcalf

Metcalf reached 95% of his max speed (~21.4 mph) in ~3.5 seconds or ~30 yards

Budda Baker



Baker was at a max speed of ~20.4 mph (96% of his max speed) at the same point in time

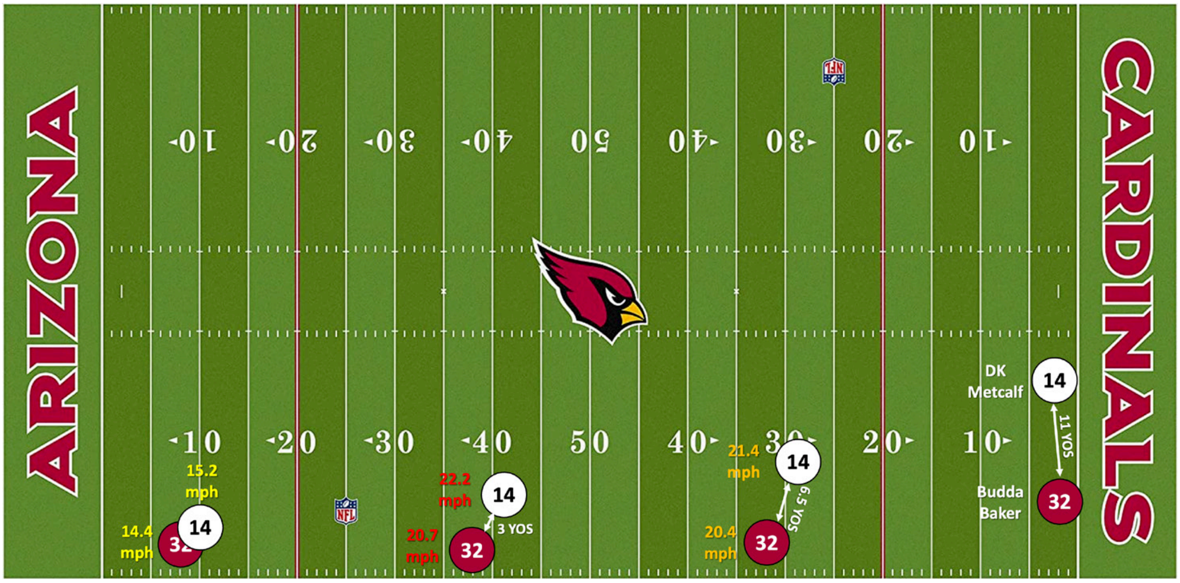
Metcalf continued to accelerate from ~21.4 mph to ~22.5 mph (+5%), over the next 21 yards

Baker continued to accelerate from ~20.4 mph to ~21.1 mph (+3%), but at a slower rate vs. Metcalf

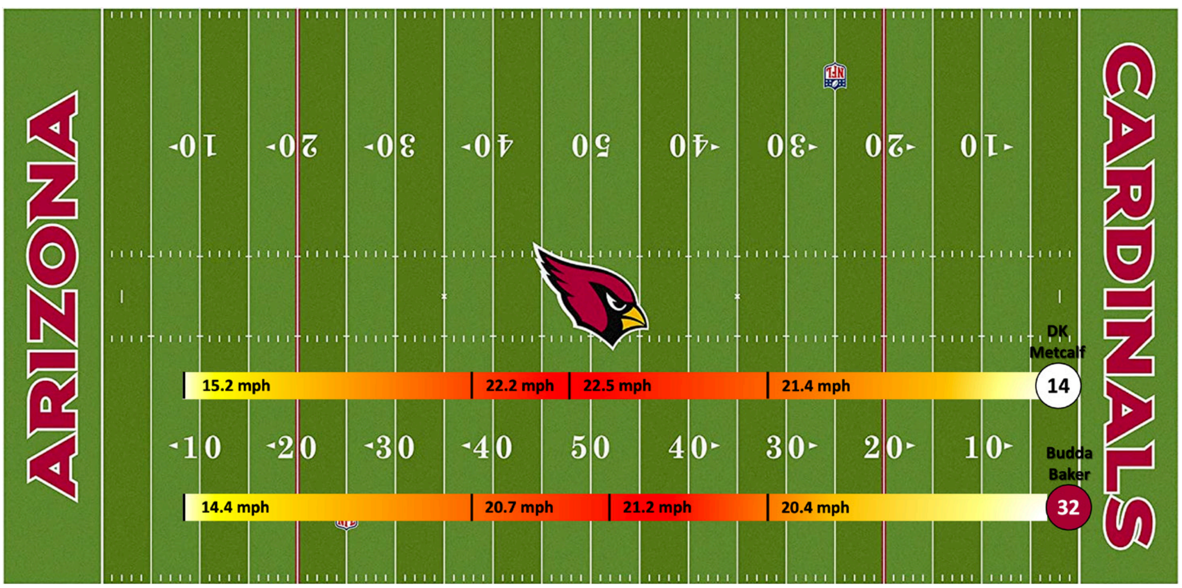
Metcalf maintained at least 95% of his max speed for ~4.2 seconds or ~53 yards

Baker decelerated at a faster rate to ~20.0 mph (94% of his max speed)

DK Metcalf's Distance and Closing Speed



Metcalf and Baker's speed and yards of separation throughout the play



Metcalf and Baker's max speed throughout the play

In summary, DK Metcalf chased down Budda Baker at a closing speed of ~1.1 yards/second. Winning all three sprint phases (acceleration, max speed, and deceleration) enabled Metcalf to close ~11 yards of separation (YOS) in ~9.7 seconds. During the acceleration phase (1^{st} 30 yards), Metcalf closed within ~6.5 YOS reaching ~21.4 mph vs. Baker's ~20.4 mph. Metcalf closed within ~3 YOS during the max speed phase (2^{nd} 30 yards), hitting a max speed of ~22.5 mph compared to Baker's 21.2 mph. Finally, during the deceleration phase (last 30 yards), Metcalf decelerated to 15.2 mph while Baker decelerated to 14.4 mph.

Next, we will explore some of the popular player tracking technologies used to measure athletic performance.

Global Positioning Service (GPS) Player Tracking

Hundreds of sporting organizations use GPS player tracking systems during training and games by companies such as Catapult Sports and STATSports Technologies. GPS tracking devices are worn by athletes on the upper back in an elasticated bra and communicate with GPS satellites in low earth orbit. These satellites triangulate the position of the athlete in the field to monitor changes in athlete position over time. This allows these units to calculate athlete speed, acceleration, and distance covered. This technology was born out of the Australian Institute of Sport in 2004 with the first device collecting data at a frequency of 5 hertz (Hz), meaning it was collecting 5 data points per second. However, as wearable technology has evolved and the reliance on GPS has increased, devices such as the GPEXE Pro^2 by GPEXE now collects data at 18 Hz, ensuring high speed movements are captured.[6]

In more recent years, GPS companies have added accelerometers to their devices to give deeper insights into actions which happen on the court or the field. Accelerometers have become crucial, especially to those involved in indoor sports such as basketball where a clear path to satellites signal is impossible. They are also able to collect data at much higher frequencies and allow practitioners to drill down even further into an athlete's locomotion, not just identifying how far or how fast they ran but what each foot strike looked like.[7]

Examples of GPS tracking from STATSports Technologies.

GPS industry leaders include:

- Catapult Sports (Owns GPSports and PlayrTek)
- STATSports
- Mclloyd Sports
- Sonda Sports

Camera-Based Systems

Optical tracking technology is a camera-based system that collects data 25 times per second, enabling real-time performance of players. Typically used in the NBA, the camera-based system captures the X/Y coordinates and references of all the players in a game to track their movements. The system also uses 3D coordinates of the ball through recognizing of visual signals from lines on the court to reflections of flashing billboards to track ball movement. The measurement accuracy of camera-based systems has already been scientifically evaluated, shown to have a margin of error of 3%.[8] The disadvantages of video recordings are the extensive use of hardware and limited mobility, as cameras are permanently installed.

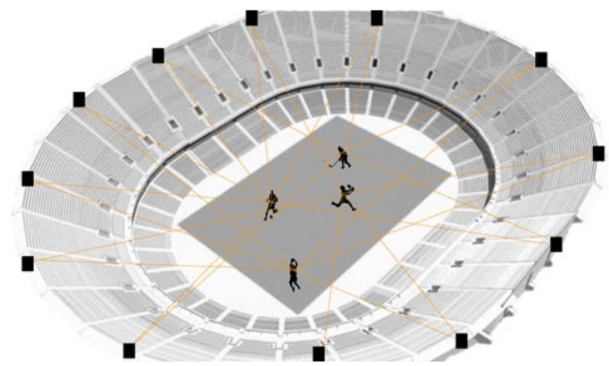
Camera-based tracking system

Camera-Based Systems Leader:

- SportsVU

Location Positioning System (LPS) Player Tracking

GPS systems do not work indoors. Therefore, companies such as KINEXON, Catapult and STATSports have developed their own LPS to track athletes indoors. Local positioning systems remove the reliance on satellite constellations by installing receivers that communicate with the units instead. LPS allows higher sampling rates, greater accuracy, and smaller units. These systems tend to have a higher accuracy with real-time data.



Examples of LPS player pracking

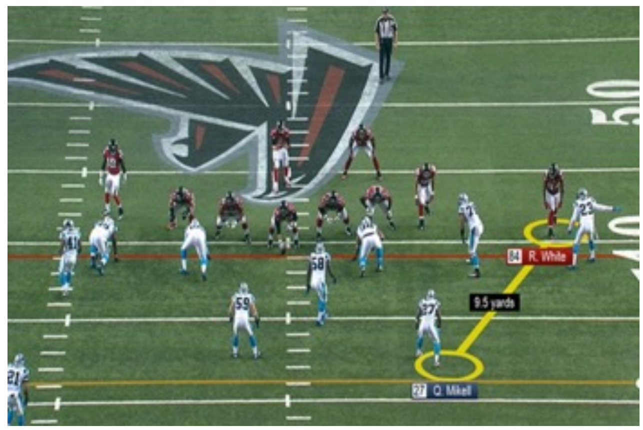
Leaders in the market:

- Kinexon
- Catapult Sports
  (Owns GPSports and PlayrTek)
- STATSports

Radio Frequency Identification (RFID)

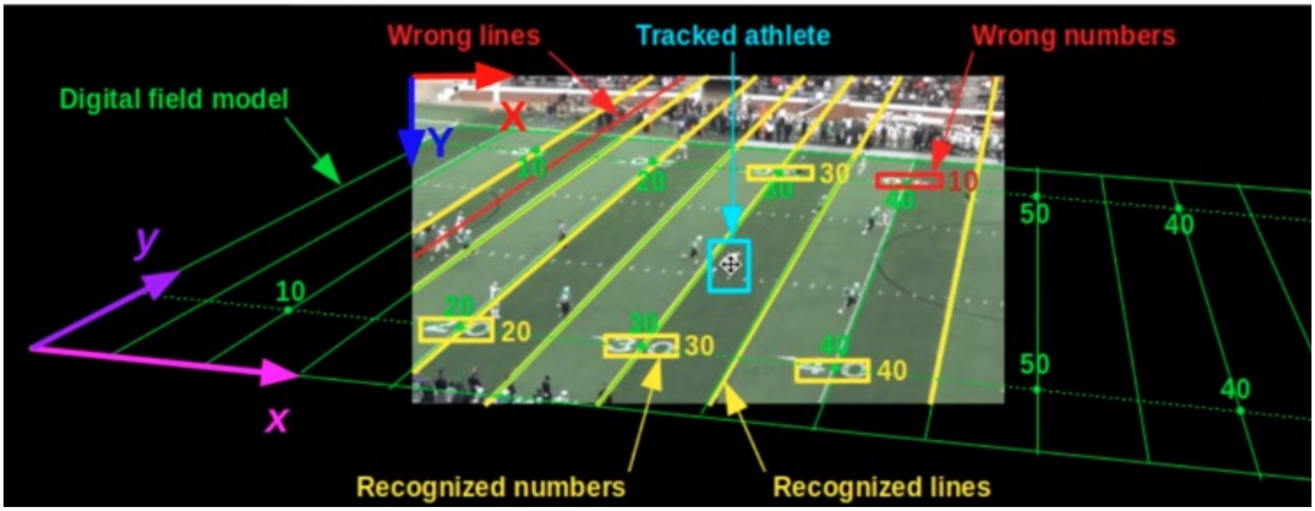
Zebra has been working with the NFL since 2014. Zebra developed a RFID system which allowed players to start wearing the RFID chips in games. What was missing was the context of knowing where the players were in relation to the football. Thus, the next big step came in 2017, when RFID chips were put in the balls. Through Zebra's partnership with the league, it worked with Wilson Sporting Goods to determine the best manner to install an RFID tag into the ball.

Two RFID chips, about the diameter of a nickel and thickness of two nickels, are located on each player's shoulder pads. On game days, data from those chips flows immediately into 22 lunchbox-sized receiver boxes located permanently in all 31 NFL stadiums as well as the stadiums in England and Mexico that host NFL games.



Examples of RFID player & football tracking

Computer Vision (CV)



Example of how computer vision operates

Computer vision is a subset of artificial intelligence that trains computers to process, analyze, and interpret visual data from images and/or videos using algorithms. One of the primary applications of computer vision in sports is player tracking. This involves the detection of the position of player(s) at a given moment in time on the field or court. Leveraging data generated from player tracking technology helps coaches improve team performance by analyzing the functional movement of players during practices and games. This includes advanced opponent scouting reports to identify favorable matchups, and objective player evaluations to identify hidden talent that would otherwise be missed. Today, the most advanced applications of computer vision in sport use automated segmentation techniques to identify regions that is likely to correspond to players.

The results obtained from a computer vision system can be augmented by applying machine learning and data mining techniques to the raw player tracking data. Once key elements in an image or video frame are detected, semantic information can be generated in order to create context on what actions the players are performing (i.e. ball possession, pass, run, defend and so on). These techniques can label semantic events, such as a run or pass play in football, and be used for advanced statistical analysis of player and team performance.[9]

Leaders in the market:

- Recruiting Analytics
- Hawk-Eye Innovations
- Boost Sport AI

Technology Comparison

Positional accuracy

According to a study in 2018[10], for the 10 Hz GPS, 18 Hz GPS, and 20 Hz LPS, the relative loss of data sets due to measurement errors was 10.0%, 20.0%, and 15.8%, respectively. This study shows that 18 Hz GPS has enhanced validity and reliability for determining movement patterns in team sports compared to 10 Hz GPS, whereas 20 Hz LPS had superior validity and reliability overall. However, compared to 10 Hz GPS, 18 Hz GPS and 20 Hz LPS technologies had more outliers due to measurement errors, which limits their practical applications at this time.

Accuracy of CV system depends on the film. However, Neil Johnson, Sports Analytics Developer, ESPN, in his research paper[11], concluded that his early tests showed the accuracy of CV in placing players within a foot of their true location at 94.5%. Making player tracking data more accessible lowers the barrier of entry and increases the timespan for which advanced methods of analysis can be practiced. He also added that the OpenPose estimation data itself provides an additional new frontier of data analysis that can increase the fidelity of analysis that relies on player tracking data.

Tracking data diversity

GPS and LPS monitors available in the market commonly have a triaxial accelerometer, a gyroscope and a magnetometer. All of these play a massive role in injury prevention designing return to play protocols. RFID chips from Zebra Technologies do not have the three components mentioned above, however, they can be used indoors where GPS monitors have a limited functionality. RFID receivers and antennas are calibrated to a main hub at every field or venue, which enables Zebra to deliver a reliable, real-time product that the NFL utilize. Computer vision systems can be used indoors or outdoors because the accuracy and tracking does not depend on putting a physical monitor on an athlete.

Retrospective analysis capability

Unlike the other systems mentioned above, Computer vision systems can track players without the need for an athlete to physically wear a monitoring device. CV's technological advantage in this space empowers coaches and evaluators to track successful players from the past to gain deeper insights into the trait(s) that made those players 'special'.

Real-time tracking capability

The wearable tech systems have real-time capability and CV systems can have it if developed.

Key Takeaways about CV

- *94.5% accurate within a foot to true location of the athlete*
- *Computer vision systems can be used indoors or outdoors because the accuracy and tracking does not depend on putting a physical monitor on an athlete.*
- *Enables coaches and evaluators to track successful players from the past to gain deeper insights into the unique trait(s) that made those players 'special'*

Scoring Methodology

This section of the paper uses the term 'successful player' throughout. A successful player will be defined as a player who at a minimum earned All-American honors at the collegiate level, and/or All-Pro honors at the NFL level.

Although not guaranteed, Recruiting Analytics' studies show that past performance can be a strong indicator of future success at the highest level of the sport. Leveraging the power of computer vision technology, RA found that the requisite traits found in NFL players can be identified as early as high school. Computer vision technology enables evaluators to analyze the high school tracking data of successful players from the past to detect the trait(s) that made him 'special'. This type of retrospective analysis allows college coaches to establish position-specific performance thresholds used to evaluate high school prospects, and to serve as early indicators of future success. For NFL coaches and personnel executives, high school tracking data, among many things, provides deeper insights into the progression of a draft prospect's raw and functional athleticism.

Recruiting Analytics' evaluation methodology consists of two main factors: an Athleticism Score (ATH Score) and a Production Score (PROD Score), which are both used to determine the RA Score that serves as the final overall player grade. Recruiting Analytics' ATH Score derives from objective evaluative metrics extracted by their AI-powered tracking technology, and Recruiting Analytics' PROD Score derives from objective advanced performance metrics. Each metric is collected and inputted into a data range, then allocated points based on the range in which they fall. The points from each metric are weighed into the final score for each category. Then, consistent with RA's belief that accurately projecting a player's success is a function of their athletic ability and their impact on the game, they integrate these two variables into the prospects' RA Score — the final evaluation grade for each player. Recruiting Analytics uses the players' overall RA Score to project their ability at the next level.

Athleticism is one of the most important traits when evaluating prospects. In the past, coaches and scouts were limited to measurables and camp times to determine a prospect's athleticism. Recruiting Analytics' ATH Score is a weighted scoring model made up of numerous position-specific variables extracted directly from prospects' film for a more practical and comprehensive evaluation of the players' athleticism in the context of a game. For example, some of the objective variables for an EDGE defender include the players' speed off the line, sack time, closing time to the ball carrier, as well as their average block shed time and peak impact force. Armed with this tracking data, coaches are able quantify the critical factors their eyes have been trained to spot when evaluating a player's tape.

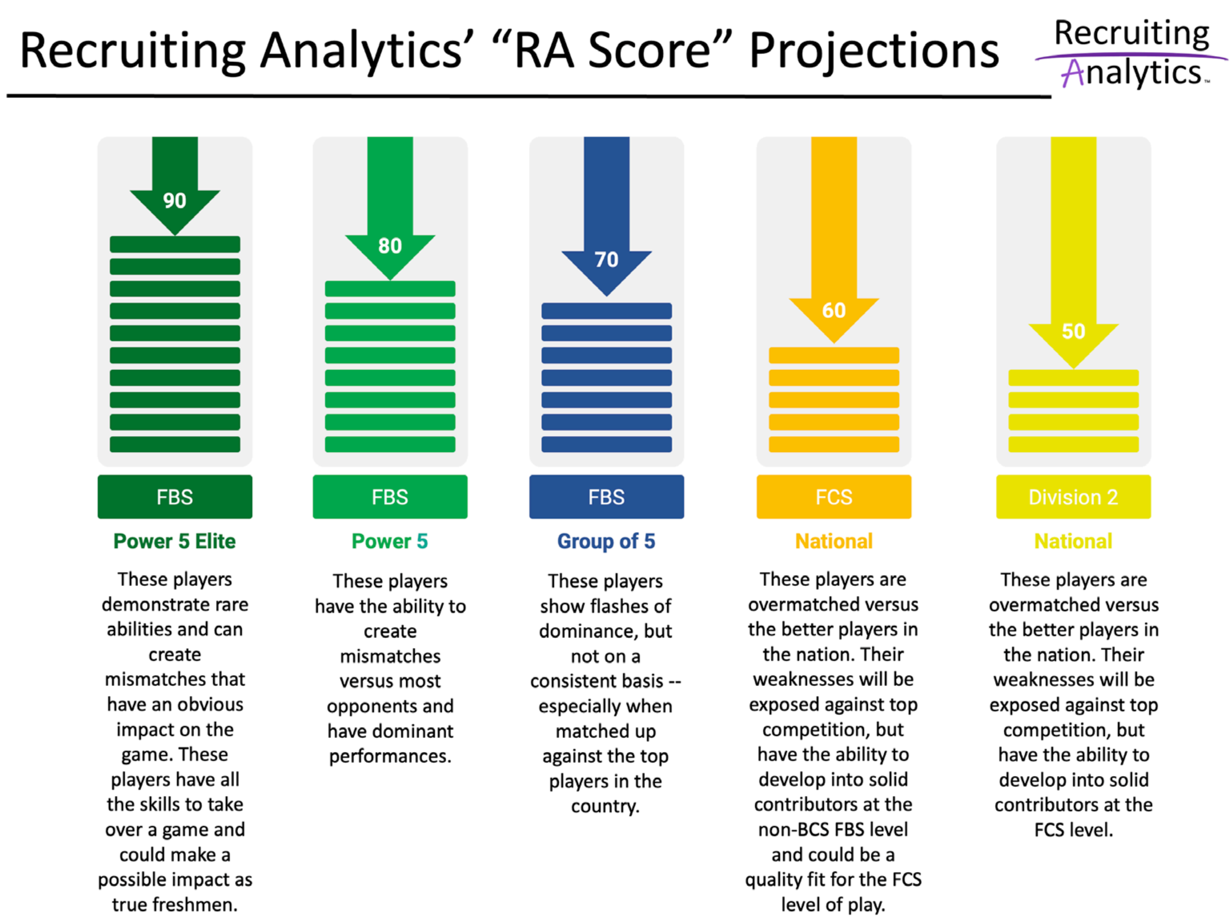
Leveraging the power of computer vision technology, Recruiting Analytics found that the requisite traits found in NFL players can be identified as early as high school.

Beyond the prospects' athletic ability, Recruiting Analytics determines their playmaking ability by weighting various position-specific on-field production metrics into its PROD Score. Examples of the production metrics in RA's PROD Score for EDGE defenders include Tackles for Loss, Forced Fumbles, Hurries, and Sacks. RA pairs the production metrics with the player's tracking data to comprise the overall PROD Score.

The RA Score is a combination of the prospects' ATH Score and PROD score — creating an objective 360-degree view of the players' ability. These grades are categorized based on the percentile in which they fall, then the percentiles are used to project the ceiling of the players' competition level. The chart below displays Recruiting Analytics' grade ranges for high school athletes.

The Recruiting Analytics' scoring model is adjusted for both size and level of competition. When RA's technology extracts a max speed from film, its implications vary greatly depending on the size and position of the prospect. That's why RA adds a Size Factor to each player's Athleticism Score — allocating more points to players who move better at greater sizes.

To adjust for the prospect's high school competition levels, Recruiting Analytics uses open source strength of schedule data to weigh the prospect's competition level into their RA Score. Greater competition will yield a greater additive effect on the RA Score, while weaker competition will yield a greater discount effect.



Results

Recruiting Analytics conducted a retrospective study of 446 NFL, Power 5 and non-Power 5 collegiate football players from 2011 to 2020, whose playing career experienced varying degrees of success ranging from All Pro to transfer portal. The sample consisted of sixty-seven wide receivers, forty-two running backs, 138 inside linebackers, forty-two edge defenders, and 157 defensive backs who were randomly selected including, but not limited to, All Americans, All Pros, and Small School NFL Players. RA hypothesized that high school tracking data measuring position-specific movements (e.g. speed, acceleration, change of direction, etc.) in the context of a game, is predictive of future success at the NCAA and NFL level. Therefore, Recruiting Analytics' objectives were to determine whether high school tracking data is a reliable source for projecting players to the collegiate level, and if high school tracking data is an early indicator of NFL talent.

The findings show that RA's scoring models' overall projection accuracy is 75.5%, a hit-rate that is three times higher than college football's average. The overall hit-rate for the edge defender scoring model was 91%, with a hit-rate of 96% for prospects projected to have elite Power 5 and Power 5 talent. The wide receiver scoring model's hit-rate was 81%, and 89% within the elite Power 5 and Power 5 talent band. The hit-rate for the running back scoring model was 79%. The defensive back scoring model produced a hit-rate of 75%. And the inside linebacker scoring model yielded a 70% hit-rate. Eighty-percent of the scoring model's misses can be attributed to the model grading players too harshly, producing lower than expected RA Scores. Table 2 summarizes the hit-rate results by position group and projection.
A subset of players (81), were randomly selected from the cohort to perform a deep dive into their collegiate and professional

Table 2: Scoring model position group hit-rate by projection

Position Group	Total	P5 Elite (90 or above)	P5 (80-89)	G5 (70-80)	FCS (< 70)	P5 Elite & P5	P5 & G5
EDGE	90.5%	75.0%	100.0%	86.7%	75.0%	95.7%	94.1%
WR	80.6%	100.0%	84.4%	70.0%	0.0%	88.9%	78.8%
RB	78.6%	50.0%	100.0%	45.5%	0.0%	93.3%	83.8%
DB	75.2%	88.9%	97.5%	42.6%	20.0%	97.0%	76.3%
ILB	66.9%	100.0%	95.7%	11.9%	100.0%	96.2%	63.1%
Total	**75.5%**	**89.6%**	**95.6%**	**43.0%**	**38.5%**	**94.9%**	**75.3%**

+(-) 2 point margin of error

career, where each player's snaps, games played, games started, awards, draft status, and Pro Football Focus grades were tracked. The trajectory of high school prospects above the median RA Score of 86.6 proved to be very promising at the collegiate and NFL level. Collegiately, said players went on to start 73% of games played, 98% earned All-Conference honors, 50% earned All-American honors, and 95% were drafted by the NFL. Professionally, these players went on to start 71% of games played, 42% were voted to the Pro Bowl, and 31% earned All-Pro honors. It's reasonable to expect an increase in Pro Bowls and All-Pros since the average number of seasons played by the players' studied is only two.

Table 3: Career path of high school prospects above median RA Score

CFB Career Summary		**NFL Career Summary**	
Avg. Snaps	1654	Avg. Snaps	1712
Avg. Games Played	37	Avg. Games Played	35
Avg. Games Started	27	Avg. Games Started	25
Game Started Rate	73%	Game Started Rate	71%
Avg. # of Seasons	3	Avg. # of Seasons	2
All Conference Rate	98%	Pro Bowl Rate	42%
All American Rate	50%	All Pro Rate	31%
Avg. PFF Floor	71.1	Avg. PFF Floor	64.5
Avg. PFF Ceiling	86.4	Avg. PFF Ceiling	75.0

Retrospective analysis results of select All-American, All-Conference, and 'small school' players in the NFL are fully presented in Appendix A.

The Physics Behind the Measurements

As discussed above, the various player tracking approaches are all designed to extract player positioning vs. time data, which then allows the calculation of traditional and emerging player metrics, such as those detailed in Table 1. However, it is useful to link such metrics to the more fundamental aspects of position, time, velocity and acceleration as defined in the context of physic and mathematics, while still grounding this discussion to sports phenomenology.

As elaborated on above, player athleticism is often defined in speed, explosiveness, burst, and acceleration, with various metrics and various units commonly used. These metrics date to the early 1900's with the introduction of the Sargent Jump Test, a vertical jump test put forth by Dr. Dudley Sargent. However, more than 100 years later, there remain critical gaps in the accuracy and even applicability of metrics used to measure athleticism in the context of football. Today, for example, it is common to measure "acceleration" using a 10-yard split, with a unit of seconds, to determine how fast a player "accelerates" to max speed. While useful, such a parameter is not actually a direct measurement of acceleration in the true sense.

Reverting to basic physics, a player may be represented by his position (i.e. exact location on the field) and the time corresponding to each position. Much of this article is devoted to capturing the position vs. time data, but for the moment, assume such data is known. We then define speed as change in position with time, or mathematically the rate of change of distance with respect to time. It is readily calculated as change in position (x2 – x1) divided by the time required to change that position (t2 – t1); hence the speed would be (x2 – x1)/(t2 – t1). Specifically, this would be the average speed of the player who traveled from position x1 at clock time t1 to position x2 at clock time t2. The true speed may not be constant over this distance, so the term average speed is used.

> *We then define speed as change in position with time, or mathematically the rate of change of distance with respect to time.*

For example, if a player crossed the 20 yard line (x1 = 20 yd) at a clock time of 1.50s into the play (t1 = 1.50 s), and the player then crossed the 30 yd. line (x2 = 30 yd) at a clock time of 2.39 s (t2 = 2.39 s), the average speed between the 20 and 30 yard line would be (30 - 20)/(2.39 – 1.50), which equals 11.2 yds/sec. This is 10.3 m/s or 23.0 mph, noting that Usain Bolt's top speed in the 100 m (as measured by radar at the World Championships, Berlin, 2009) is about 12.3 m/s (13.45 yds/sec or 27.5 mph), which is generally reached around the 70 m mark. For comparison, a lion can hit a top speed of 22 m/s (24 yds/s or 49.2 mph), while a cheetah can top out at 29 m/s (31.7 yds/s or 64.9 mph).

In physics, the terms speed and velocity are both used, with velocity specifically referring to the speed in a given direction. In football, the speed generally used is straight-line speed, and we will not consider velocity (speed and direction) further.

As noted above, the average speed is a representative speed over a representative distance, although in reality the player may be changing speed (i.e. speeding up or slowing down) over the measured interval, notably so for the commonly used 10-yard interval. In the perfect world of physics, we would have access to the instantaneous speed at every location. This is when the distance and time data is known perfectly, and the speed at every location is calculated from very small increments in distance and time. Mathematically, the true instantaneous speed is calculated from the rate of change of distance with respect to time at a single point from a continuous function of distance vs time, as determined by what is defined in calculus as a derivative.

In football, the extraction of time and distance depends on the methodology used, as related in this article, and therefore defines the accuracy of speed based on the accuracy of player time and location data, and the distance increment (i.e. 10 yards vs. 5 yards vs 1 yard) used to calculate the speed. Terms like “max speed” simply represent the calculation of speed at some finite number of locations and times, either using imaging data, GPS data, or radar, and is defined at the maximum value of speed recorded. We will not get into the physics of radar, but note that radar uses a technology that captures the rate of change of distance with time (i.e. speed) nearly continuously with a high degree of accuracy; hence it is very well suited to capture max speed provided the field of view is sufficient and aligned with the runner’s direction. Finally, we note that even position and time of a player is based on inherent assumptions of exactly what position we are referring to. Ideally, we would record the position of the player’s center of gravity, which in physics is used to represent the mass of a complex body (i.e. a person) as a single point in space. In reality, the player’s location is tracked using the methods related above, such as location of the jersey number, helmet, etc., leading to further limitations of player speed measurements with respect to the true definitions of physics.

In summary, a player’s speed or max speed as calculated from computer vision and imaging represents that player’s change in distance over a corresponding time, as rooted in the physics of motion. These numbers, however, always represent an average, as measured over some increment, and there is always a tradeoff of accuracy balancing the natural smoothing effect of using longer distances and greater times versus a loss of fidelity in seeing near-instantaneous speeds that might represents a player’s true abilities to display dynamic bursts of speed.

In the above narrative, the physics with regard to what defines a player’s speed and how it might be measured is relatively straightforward, although there are some nuances. The physics associated with acceleration is a different story, one with considerable confusion and lack of clearly defined metrics. In general, acceleration is understood as a measure of how long it takes to “go fast”, such as a dragster accelerating in the quarter mile, a jet fighter accelerating rapidly as it’s launched from the deck of an aircraft carrier, or a football player accelerating off the line of scrimmage.

In physics, we defined speed as a change in position divided by a corresponding change in time, with the units of speed coming directly from position divided by time; hence the units of speed always reflect length/time, such as yards per second, meters per second, or miles per hour. In physics, the true definition of acceleration follows the same logic, but acceleration is now defined as a change in speed divided by a corresponding change in time. Accordingly, the units of acceleration are always the units of speed (length/time) divided by the units of time, giving a final unit of length per time squared, such as meters per second squared (m/s^2) or feet per second squared (ft/s^2).

Simplest way to define acceleration in sport is 'how quick is an athlete?' whereas, speed can be looked at as the measure of 'how fast is he?'

For example, if a player started from rest on the 20 yard line as the ball is snapped, then v1 = 0 yds/s at the starting time of t1 = 0 s. The player then crosses the 30 yard line 2.2 seconds later (t2 = 2.2 s) at a speed of 9.4 yds/sec. The acceleration would be (v2 – v1)/(t2-t1), which equals 4.27 yds/s^2. Mathematically, this is the correct number, but a far more "common" unit of acceleration is ft/s^2 or m/s^2. Our player's acceleration translates to 12.8 ft/s^2 or 3.91 m/s^2. Let's go back to Usain Bolt's 100 m run at the 2009 World Championships. Bolt's maximum acceleration was measured by radar at 5.10 m/s^2. One often references the acceleration caused by the Earth's gravitational field, defined as 1 G, which defines how fast a dropped object will accelerate toward the Earth's surface (neglecting air resistance). One G is defined as 32.2 ft/s^2 or 9.81 m/s^2. If we ratio a person's acceleration to the Earth's pull, we talk about G's. Usain Bolt can accelerate at 0.52 G's (i.e. 5.1/9.81), or just about half the acceleration of the Earth's field, while our example player above can accelerate at 0.40 G's.

While there is precedent to referencing the acceleration of someone or something to the Earth's field as G's, it's not the most intuitive unit for sports and scouting. For convenience, we will define the Bolt (B) as an acceleration of 5.10 m/s^2 or 16.72 ft/s^2, based on Usain Bolt's world-class acceleration. Therefore, the acceleration of our example player is calculated as 0.77 B's. Now intuitively, this player is seen for this measurement to have an acceleration equal to 77% of Usain Bolt's maximum acceleration; hence a direct relative comparison to the one person generally considered and widely known as the world's fastest. We can now add other comparisons for context, the lion as mentioned above has a top acceleration of about 9.5 m/s^2, or an acceleration of 1.9 B's.

In summary, with regard to acceleration, we start with the comments offered above regarding speed. Namely, a player's acceleration as calculated from computer vision and imaging represents that player's change in speed over a corresponding time, as again rooted in the physics of motion. These numbers, however, always represent an average, as measured over some increment of speed and increment of time, and there is always a tradeoff of accuracy balancing the natural smoothing effect of using greater times and larger changes in velocity versus a loss of fidelity in calculating near-instantaneous accelerations that might represents a player's true ability to rapidly change speed, getting true explosiveness of the line.

We add a few final thoughts on acceleration in the context of scouting. True acceleration is not measured in seconds; hence a split time in measuring a running player is not reflective of acceleration. The measurement of a time for a player to run from a stand-still to max speed over a relatively short distance (e.g. 10 yards) does provide a relative measure of acceleration, in that one athlete's shorter time to 10 yards as compared to another would be reflective of a higher acceleration, but the unit of simple time (e.g. seconds) is not a true measure of acceleration in the context of actual physics. Note also that a player running at a consistent top speed over a 10-yard interval would have zero acceleration over that interval, because the speed, while fast, is not changing. It is therefore important to maintain the physics-based definition of acceleration, that is, the rate of change of speed with respect to time. We do propose the Bolt (B) as a convenient expression of acceleration by comparing the true acceleration of a given player to the acceleration (5.1 m/s^2) of a widely known elite athlete with extreme acceleration and speed over distances highly relevant to football, namely, 100m, a distance about 9 yards longer than a football field.

Key Takeaways Speed & Acceleration

- *Speed is generally referred as straight-line speed*
- *Max speed represents speed at a finite number of locations and times*
- *Speed is comparable to 'how fast'*
- *Acceleration is comparable to quickness*
- *Acceleration is measured with change in speed during a time period over a distance*

Conclusion

Evaluating and accurately projecting high school talent to college, and college talent to the pros has proven to be historically difficult due in large part to the subjective nature of film evaluations, the inability to quantify important intangibles, and the nonpredictive nature of traditional evaluation metrics such as height, weight and speed. Each year 67% of professional, collegiate and high school athletes are misevaluated by sports teams, costing an estimated $18 billion in salaries, scholarships, and financial aid. Recruiting Analytics' objectives were to determine whether high school tracking data is a reliable data source for projecting players to the collegiate level, and if high school tracking data is an early indicator of NFL talent, while providing additional physical context to the measure of speed and acceleration.

Acknowledging that the sample for this study did not include every collegiate and NFL wide receiver, running back, edge defender, defensive back and inside linebacker, the data may not precisely represent each position group as a whole. However, the findings reveal strong evidence that Recruiting Analytics' tracking technology and data can help coaches and evaluators improve their hit-rate by up to three times. RA's tracking data infused scoring models' have an overall projection accuracy of 75.5% driven by the inclusion of position-specific metrics found to be relevant by reverse engineering successful collegiate and NFL players.

Moreover, high school prospects above the median RA Score of 86.6 proved to be high-ceiling players with a favorable NFL trajectory. These players went on to start 73% of games played collegiately, 98% earned All-Conference honors, 50% earned All-American honors, and 95% were drafted by the NFL. Professionally, these players went on to start 71% of games played, 42% were voted to the Pro Bowl, and 31% earned All-Pro honors, all within an average of two seasons.

We can reasonably conclude that Recruiting Analytics' high school tracking data used to score and project players' collegiate ceiling is reliable. Additionally, the RA Score can serve as an early indicator of NFL talent.

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Cory Yates is the co-founder and CEO of Recruiting Analytics, a sports tech and data company that is reinventing how the sports industry identifies and evaluates talent in order to achieve a 99.9% hit-rate. Mr. Yates is a former college football player and coach with over 20 years of business analytics experience leading high financial impact businesses totaling nearly $3 billion in revenue.

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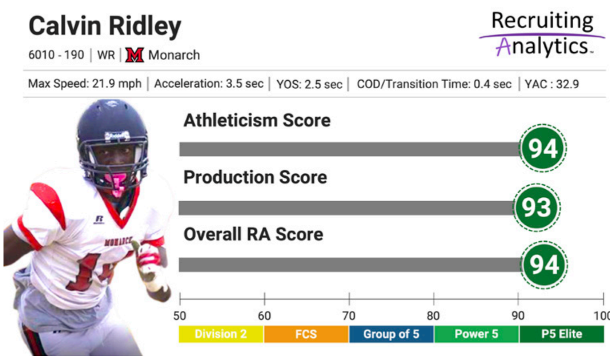
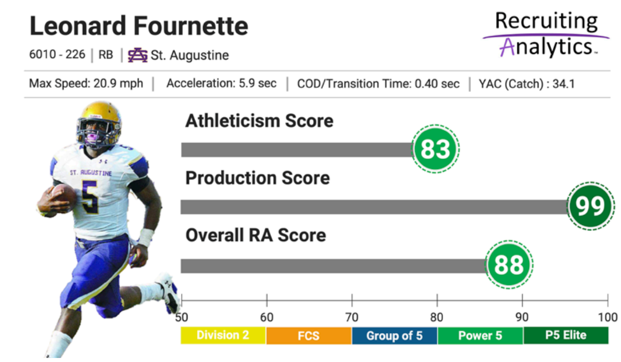
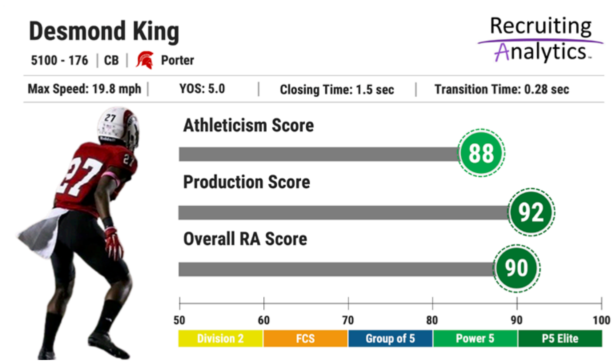
Kratik Malhotra is an internationally renowned sports scientist and data analyst currently serving as the director of sports science and analytics at Texas A&M University. He studied engineering, focused on artificial intelligence (AI), machine learning and neural networks at the University of Pune in India and earned a master’s degree in sports management with a focus on analytics from Florida State University.

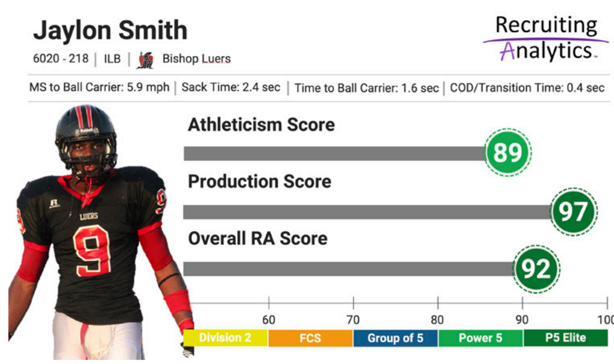
Appendix A

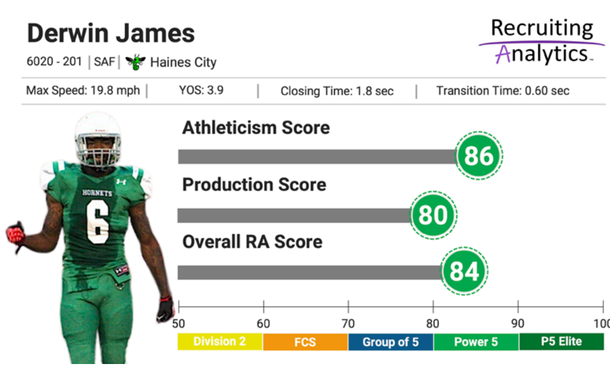
Retrospective Analysis Tesults of Select All-American Players

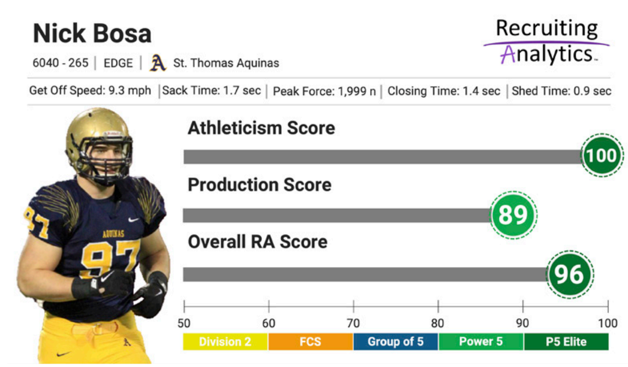




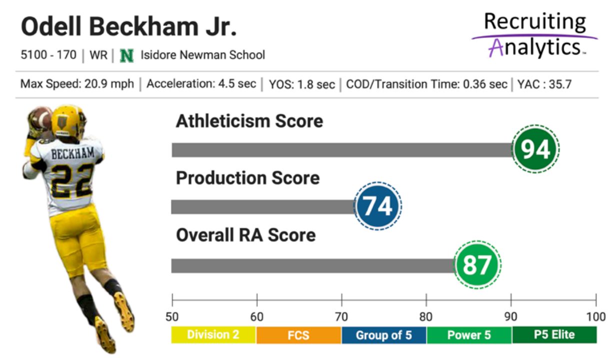


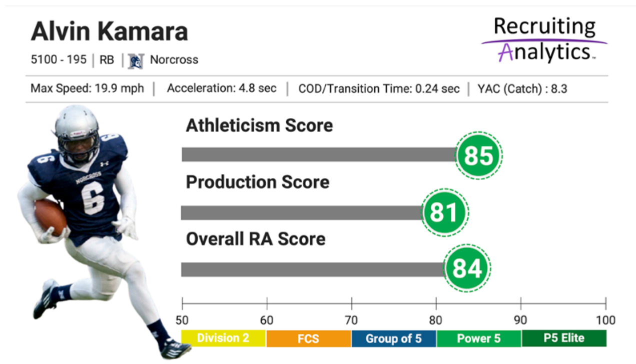


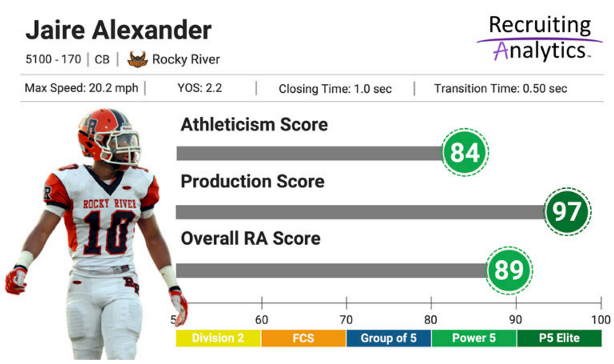


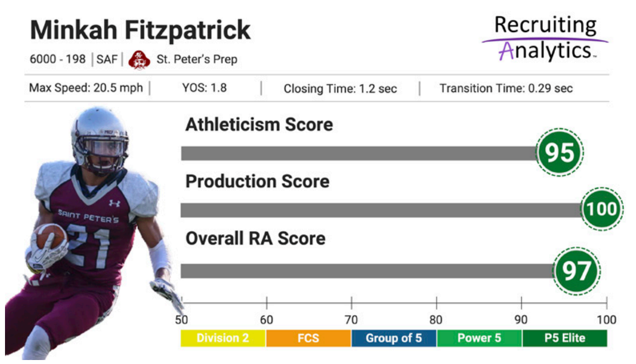


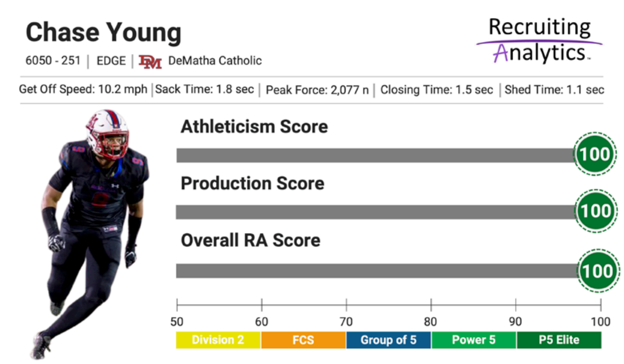
Retrospective Analysis Results of Select All-Pro Players

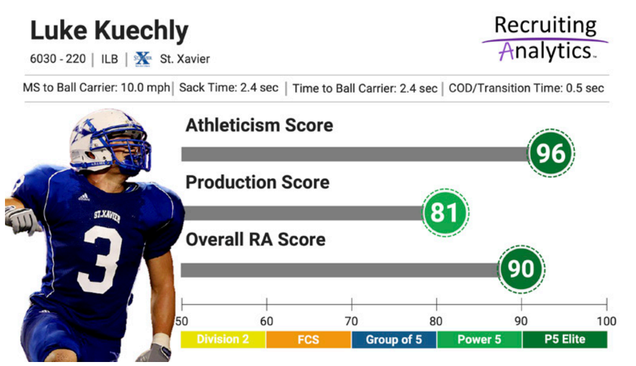




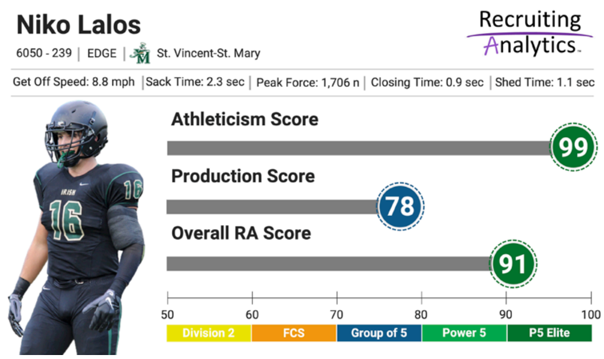


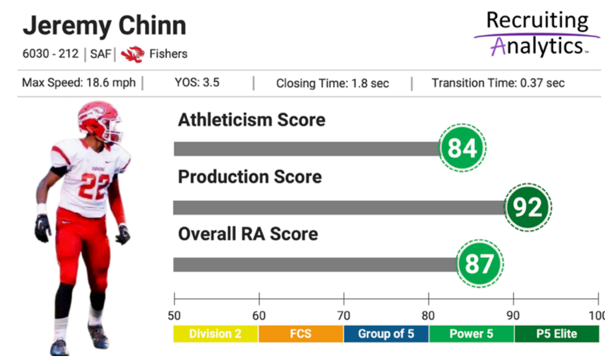


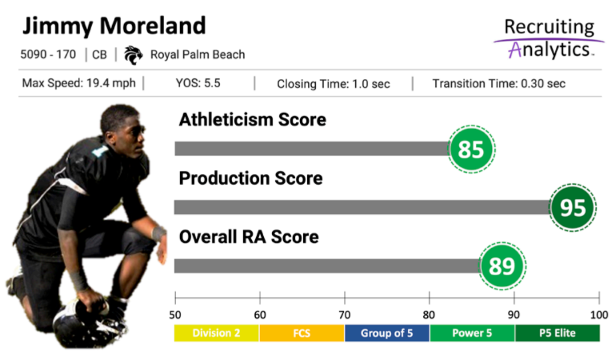


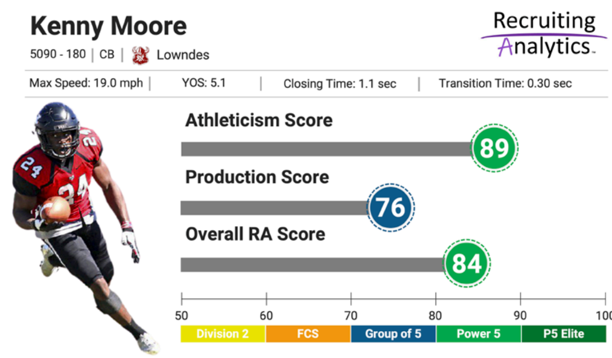


Retrospective Analysis Results of Select All-Pro Players









Endnotes

1 Nick Casserio, Houston Texans GM; 2021 Sloan Sports Analytics Conference ‘Say Goodbye to the 40-Yard Dash: The Future of NFL Roster Building’; Thomas Hall, ‘Analytics Reveal the Hit-Rate for Each of Broncos’ 4 Need Positions in Round 1’ Sports Illustrated, 2021, p. 1, https://www.si.com/nfl/broncos/news/denver-broncos-4-need-positions-in-round-1-hit-rate-revealed-by-analytics, (accessed 13 April 2021)

2 Interviews with over 150 college football coaches and director of player personnel, January 8 - August 6, 2019

3 Kevin Demoff, Los Angeles Rams COO; 2021 Sloan Sports Analytics Conference ‘Say Goodbye to the 40-Yard Dash: The Future of NFL Roster Building’

4 Howard, Rick. “Using LTAD to Program for a Middle School Athlete and a High School Athlete: Part 1-Generating an Athletic Profile in NSCA Coach.” NSCA Coach Vol. 5 – Issue 2 (2018):

5 Vic Fangio, Broncos Head Coach, “‘The tape is king’: HC Vic Fangio on evaluating prospects ahead of the NFL Draft,” interview by Matt Boyer. Denver Broncos YouTube channel, April 23, 2021.

6 https://imeasureu.com/2019/08/29/best-wearable-technology-athletes/

7 https://imeasureu.com/2019/08/29/best-wearable-technology-athletes/

8 https://latinamericanpost.com/35319-from-ballistic-missiles-to-balloons-this-is-sports-technology-for-statistics

9 https://www.sportperformanceanalysis.com/article/computer-vision-in-sport

10 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5805339/

11 https://global-uploads.webflow.com/5f1af76ed86d6771ad48324b/5f6a64711514cb41b91b37d5_Johnson_extracting_player_tracking_data-compressed.pdf