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Momentum, Rather Than Velocity, Is a More Effective Measure of Improvements in Division IA Football Player Performance

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Momentum, Rather Than Velocity, Is a More Effective Measure of Improvements in Division IA Football Player Performance

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ABSTRACT:

Speed, or the time to complete straight runs or agility drills, is commonly used to assess performance in collegiate American football players. However, it is common for players' speeds to plateau by the second year of eligibility, whereas their body masses continue to increase. The purpose of this study was to track change in speed, body mass, and momentum (body mass · velocity), across Division 1 football players' 4-year careers (n = 512). Complete data were derived for the 40-yd sprint (n = 82), the proagility shuttle (n = 73), and the L drill (n = 73) from the same NCAA Division 1 team over a 15-year period. Significant changes were seen for velocity between year 1 and the next 3 playing years ($p < 0.05$), with no differences between years 2 and 4, whereas body mass increased significantly across all playing years ($p < 0.05$). Further momentum increased across all years for all tests ($p < 0.0001$). These results indicate the importance of including changes in body mass when evaluating performances during sprints and change of direction drills. Our results also suggest that using sprint or agility drill times to evaluate playing potential across football players' collegiate careers may be ineffective and can provide players with a false and disheartening picture of their improvements across their careers. Momentum, which incorporates training-induced increases in both speed and body mass, would be a more relevant and supportive measure of players' improvements. In addition, the simple computation of this variable, using existing speed and body mass data, may be an important addition to the National Football League combine as a measure of playing potential in the professional game.

Introduction

During the National Football League (NFL) combine, collegiate players perform a select test battery in hopes of being drafted to play professional American football (4,8,9,15,21). The standard battery consists of the 40-yd sprint, 5-10-5 (proagility) shuttle, L drill, NFL 225 bench press repetition test, vertical jump, and standing long jump (4,8,9,15,21). While this is the core testing battery, other tests, such as the long shuttle, are also included for certain skilled positions based on requests from specific teams. A player's performances on these tests are then used by scouts, coaches, player personnel, and management as drafting criteria. Although many studies have examined the ability of the NFL combine to predict a player's opportunity for success at the professional level, the findings of these studies are inconsistent. For example, Sierer et al. (21) reported that maximal velocity in the 40-yd sprint was a good predictor of selection in the NFL draft. Kuzmits and Adams (15) reported that no consistent relationships were found between NFL performance and combine scores, with the exception of sprint scores for running backs, whereas Clark et al. (4) confirmed the importance of velocity and velocity-specific training to combine performance. The findings by Asprey et al. (1) also supported the importance of sprint times as indicators of inclusion of running backs and wide receivers on the 5-year NFL roster; however, measures of power, such as the vertical jump and long jump, seemed to be better predictors for tight ends and the lineman's inclusion was predicted by both types of combine measurement. Furthermore, Hedlund (8) found that it was unlikely for a skill player who ran a 4.59 or slower 40-yd sprint to be invited to the NFL probowl, which is considered a premier showcase of the best current NFL players by position. These results indicate that speed is an important determinant of success in American football. By contrast, Vincent et al. (22) reported correlations with 40-yd sprint times ranging from highs of $r = -0.346$ for quarterback yards rushing and $r = -0.042$ for running backs' longest runs to lows of $r = 0.062$ for defensive ends' solo tackles and $r = -0.029$ for defensive tackles' assisted tackles. Based on the importance of speed in American football, this attribute is a primary focus of most strength and conditioning programs for this sport (7). However, several studies have shown that although strength increases for NCAA Division 1 football players over the course of their collegiate career, performance in the 40-yard sprint, proagility, and L-drill times tend to plateau (13,18). Furthermore, it is not uncommon for many collegiates to record slower sprint and change of direction (COD) times than they achieved in high school (23). Although these differences may be accounted for by differences in manual versus electronic timing (17), they may also be attributable to changes in body mass that occur with physical maturation and additional physical training (12,18). Because American football is predominately a collision sport, the momentum of a player (body mass × velocity), on impact with another player, may be more important than absolute speed alone. Nonetheless, the importance of momentum as it relates to player performance is not typically measured in this sport (2). The impact of momentum on player performance has been investigated in several other sports. For example, Baker and Newton (2) quantified sprint momentum using the average velocity of Division I and Division II professional rugby players across their best 10-m sprint and discovered that overall larger players, who were able to achieve speeds comparable with smaller ones, were most likely to be successful in the sport. In fact, these researchers reported no significant differences in speed performance between the groups (10-m sprint: Division I = 1.61 seconds and Division II: 1.60 seconds), but when momentum was calculated, Division I players produced significantly higher values than Division II players. Previous research has also reported that momentum was the best determinant of playing time among elite rugby union players and high-school American football players when compared with the other variables measured (2,3,14). Barr et al. (3) tested junior and senior rugby union players during the 40-m dash. They used 0–10 m velocity to compute an initial momentum and 30–40 m average velocity to compute a maximum sprint momentum, providing average, albeit short distance average, velocities across each split. Similarly, Jalivand et al. (14) reported momentums for the 0–4.57, 0–9.14, and 0–36.58-m splits during a 36.58-m sprint by high-school football players. However, none of these studies examined differences in momentum during a COD task. Similar to the studies cited above, we calculated momentum during the COD tests using average velocity scores. This computation can be considered appropriate for American football because the game is characterized by frequent multidirectional sprints that require a player to rapidly accelerate and decelerate over short distances (6,7). Therefore, the purpose of this investigation was to examine the momentum during the speed and COD tests commonly performed in the NFL combine testing battery. We hypothesize that momentum will provide a better overall assessment of changes in performance over a football player's competitive career than linear or COD speed. To test this hypothesis, speed and momentum values produced by collegiate football players over 4 years were analyzed. The results of this study should allow strength and conditioning professionals to more effectively evaluate the results of comprehensive strength and conditioning programs on players' performance and provide a more comprehensive perspective on the physical attributes (i.e., body size, linear speed, and COD) that should be prioritized to optimize performance for American football players.

Methods

Experimental Approach to Problem

The data used for this analysis were collected by the university's athletic performance training staff as part of their winter, off-season testing procedures of players in a Division 1 collegiate football program. Sprint and COD momentums were computed as the product of the players' recorded body mass multiplied by their average velocity over the course of the test. Velocity was calculated as the distance specified by the test divided by the individual's time to completion. Velocity and momentum values for each test were compared across 4 years with examine differences between the test by year and differences in changes across years to determine which variable would be a better indicator of improvement across the players' collegiate careers.

Subjects

As is commonplace in Division 1 football, very few players completed 4 full years of training because of attrition or injury; therefore, of the 512 players, 18-23 years of age, who participated in the training program, data from 78 were used in these analyses because players were lost to attrition, transfer, turning professional, and injuries. These data were collected over a 15-year period. The players were evaluated at the conclusion of a 6-week winter conditioning program designed to increase strength, power, speed, and agility. The testing program was part of the regular training procedures for the team, and all players provided a waiver of consent to participate. No players younger than 18 years were included in the study. The study protocol was approved by the University of Missouri institutional review board in accordance with the Declaration of Helsinki. The inclusion criteria were that players had performed the testing battery in 4 consecutive off-season periods for a specific test. Written informed consent was obtained from all subjects.

Procedures

All tests were administered by the university's athletic performance staffs who were Certified Strength and Conditioning Specialists. The procedures for each of these tests were consistent for each year and were conducted in the following manner.

Body Mass

Each subject's body mass was recorded each year using a standard doctor's beam scale (Mettler Toledo, Columbus, OH). The subjects would stand on the scale and remain motionless until the beam indicator was aligned with the center mark and remained stable. Body mass was recorded to the nearest 1lb in accordance with program policy and then converted to kilograms by dividing body mass in pounds by 2.2.

Performance Testing

All sprint and COD tests were performed on an indoor artificial turf surface (Indoor Field Turf; Field Turf, Montreal, CA) with the distance measured using a steel tape measure. Players wore cleats and standard issue T-shirts and shorts.

40-yd Sprint

For all 40-yd sprint tests, the player ran 2 trials separated by a minimum of 5-min recovery. Starting position was a 3-point stance (1 hand on the ground). The electronic timing device (SpeedTrap, Model II; Brower Timing Systems, Draper, UT) was triggered using a touch pad at the ground hand and ended when the player broke an infrared beam placed 75 cm above the ground at 40 yds.

Proagility Shuttle

During the ProAgility (ProA) test, the player ran a minimum of 2 trials separated by at least a 5-min recovery. Starting position was straddling a yard marker line with 1 hand on the ground. The players then self-selected the direction of their initial movement. They ran 5 yds in the initial direction, turned 180° because their outside hand touched the line, and then ran 10 yds in the opposite direction where they touched the line with their outside hand. Then, they ran back through the original starting line. Two test administrators with handheld stopwatches (Model SC-5-5; Robic, Inc., Orange, CA) recorded time to completion. Each administrator was positioned approximately 3 meters from the player, and players were required to face the administrators for each turn. Time was started based on the initial movement of the player and finished when any part of the player's body crossed the finish line. The best time for 2 trials was recorded to the nearest 0.10 seconds, with the average times recorded by both test administrators used as the player's final time.

L drill

Each player ran a minimum of 2 L-drill trials separated by a minimum recovery of 5 minutes between trials. They were timed by 2 testers with handheld stopwatches (Model SC-5-5; Robic, Inc.). Again, the average of the times recorded on the 2 stopwatches was used as the final time. During the starting position, the player had a 3-point stance with his hand on a line. The trial began at the first visible movement by the player. The player sprinted 5 yds straight ahead, touched a line with their right hand, performed a 180° turn, sprinted 5 yds back to the original start line, and again touched the line with their right hand. The player then immediately performed another 180° turn and sprinted 5 yds, made a 90° COD to the right and sprinted 5 yds, performed a 180° spin around a cone, sprinted straight ahead 5 yds, to where they turned

90° to the left, and sprinted a final 5 yds through the original start line. The best time of these 2 trials was recorded to the nearest 0.10 seconds.

40-yd Sprint Momentum

This variable was calculated using the best time recorded for the 2 40-yd sprint repetitions converted to a velocity by dividing the distance (36.6 m) by the time. This was then multiplied by the subjects' body mass in kg, which provided the momentum ($kg \cdot m^{-1} \cdot s^{-1}$).

Proagility Momentum

Proagility momentum was calculated using the best time of the Pro-A shuttle and converted to a velocity by dividing the distance of the drill (18.3 m) by the time. This was then multiplied by players' body mass in kg to compute the momentum ($kg \cdot m^{-1} \cdot s^{-1}$).

L-drill Momentum

To calculate L-drill momentum, the best time for the L drill was recorded and converted to a velocity by dividing the distance of the drill (27.45 m) by the time. This was then multiplied by players' body mass in kg, providing the momentum ($kg \cdot m^{-1} \cdot s^{-1}$).

Statistical Analyses

Initially, a visual inspection of the data (boxplot) was conducted, and z-score distribution was analyzed to detect the presence of outliers. Data normality was assessed using the Kolmogorov-Smirnov test. Separate repeated measures analyses of variances were used to compare changes in body mass, velocities, and momentums during the 40-yd sprint, ProA, and L drill across 4 years. Sphericity of the data was assessed using Mauchly's test of sphericity. Greenhouse-Geisser adjusted values were reported if the assumption of sphericity was violated. Follow-up analysis included LSD ***post hoc*** comparisons for variables that differed across years. Confidence intervals for mean differences were calculated for all pairwise comparisons at a 95% confidence level. Between-year effect sizes were calculated using Cohen's ***d*** (d) and were interpreted using the Hopkins scale (11), where effect sizes were considered trivial, small, moderate, large, very large, and nearly perfect when Cohen's ***d*** values were 0.0, 0.2, 0.6, 1.2, 2.0, and 4.0, respectively. Partial-eta squared (η_p^2) and observed power were reported for main effect comparisons by year. Data were reported as mean ± ***SD*** , and the statistical significance level was set a priori at $p \leq 0.05$. All statistics were performed using IBM SPSS 26 (IBM, New York, NY).

Results

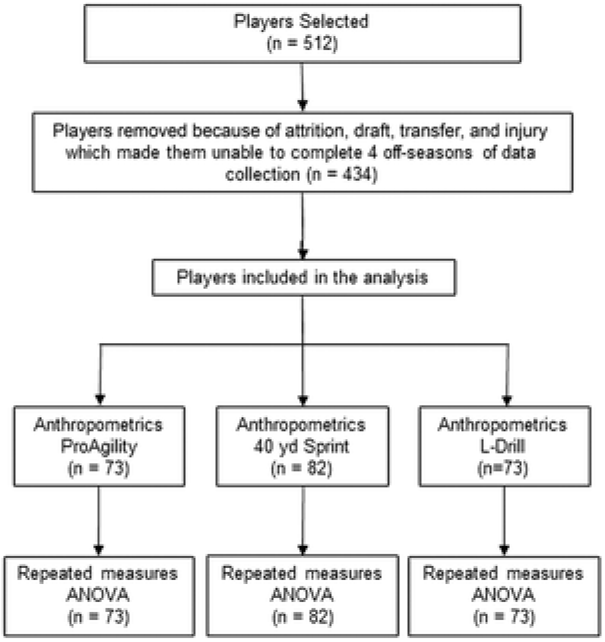
Subjects' characteristics for each test are provided in Table1. Figure 1 provides a CONSORT diagram showing subjects' flow through the study.

Table 1. Descriptive measures of subjects by sample.*

	n	**Height (m)**	**Body Mass (kg)**
40-yard sprint	82	1.86 ± 0.05	103.4 ± 18.4
ProAgility test	73	1.86 ± 0.05	103.6 ± 19.1
L-drill test	73	1.86 ± 0.06	103.1 ± 19.2

*Results are means ± ***SD.*** Body mass is the average across the 4 playing years.

Figure 1. CONSORT diagram showing the flow of subject data through the analysis.



40-yd Sprint

The data for 40-yd velocity violated the assumption of sphericity (Mauchly's W = 0.846, p = 0.022). Using the Greenhouse-Geisser adjusted values, the repeated measures analysis revealed a significant main effect for 40-yd sprint velocities between years (F(2.7,216) = 6.784, $p < 0.0001$, $\eta_p^2 = 0.078$, observed power = 0.964). ***Post hoc*** analysis showed that 40-yd velocity in years 2 (mean difference (M_{diff}) ± SE = −0.080 ± 0.019 $m \cdot s^{-1}$, $p < 0.0001$, $d = -0.17$), 3 (M_{diff} ± SE = −0.064 ± 0.022 $m \cdot s^{-1}$, $p = 0.004$, $d = -0.14$), and 4 (M_{diff} ± SE = −0.059 ± 0.021 $m \cdot s^{-1}$, $p = 0.007$, $d = -0.13$) were significantly faster than year 1; however, no significant differences were seen between years 2, 3, and 4. For body mass of subjects contributing data to the analysis of the 40-yd sprint, a Greenhouse-Geisser correction was once again used due to a violation in the assumption of sphericity (Mauchly's W = 0.757, $p < 0.0001$). A significant main effect was detected for the year (F(2.5,203.8) = 52.106, $p < 0.0001$, $\eta_p^2 = 0.391$, observed power = 1.000). ***Post hoc*** analysis revealed significant increases in mass across all years (Table 2).

Table 2. Differences in body mass (kg) across years of play for 40-yd sprint subjects (n = 82).*

Year	Year	M Diff	SE	Sig.	95% CI diff	d
1	2	−2.09 †	0.35	<0.0001	−2.79 to −1.39	−0.12
	3	−3.60 †	0.43	<0.0001	−4.47 to −2.74	−0.19
	4	−4.55 †	0.47	<0.0001	−5.49 to −3.61	−0.23
2	3	−1.51 †	0.32	<0.0001	−2.16 to −0.87	−0.08
	4	−2.46 †	0.39	<0.0001	−3.23 to −1.69	−0.12
3	4	0.95 †	0.34	0.007	0.27 to 1.63	−0.03

*. M_{Diff} represents the year in column 1 minus the year in column 2.
†. Significantly different than the year in column 1.

Repeated measure analysis of the 40-yd sprint momentums also showed a significant difference between years (F(2.5,201.8) = 60.12, $p < 0.0001$, $\eta_p^2 = 0.429$, observed power = 1.000) using the Greenhouse-Geisser adjustment due to a violation in sphericity (Mauchly's W = 0.748, $p < 0.0001$). As was the case with body mass, the pairwise comparisons revealed significant differences between all years of play (see Table 3).

Table 3. Differences in 40-yard sprint momentum across years of play for 40-yd sprint subjects (n = 82).*

Year	Year	M Diff	SE	Sig.	95% CI diff	d
1	2	−24.40 †	2.94	<0.0001	−30.259 to −18.55	−0.25
	3	−34.45 †	3.60	<0.0001	−41.612 to −27.29	−0.34
	4	−40.74 †	3.89	<0.0001	−48.477 to −33.00	−0.42
2	3	−10.05 †	2.72	<0.0001	−15.462 to −4.63	−0.10
	4	−16.33 †	3.43	<0.0001	−23.158 to −9.50	−0.16
3	4	−6.29 †	2.85	0.030	−11.947 to −0.62	−0.06

* M_{Diff} represents the year in column 1 minus the year in column 2.
† Significantly different than the year in column 1.

Figure 2 presents values for 40-yd sprint velocities, body masses, and momentums for playing years 1–4.

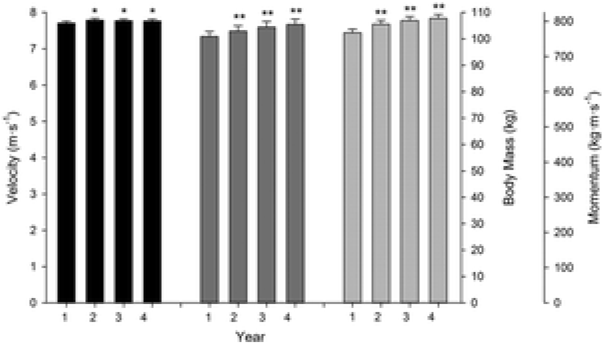


Figure 2. Velocities, body masses, and momentums for the 40-yd sprint across 4 years of competition ($n = 82$). *Significantly different from year 1 ($p < 0.0001$). **Significantly different from all previous years ($p < 0.0001$).

ProAgility

For ProA velocity, there was also a violation of the assumption of sphericity (Mauchly's W = 0.779, $p < 0.003$). Analysis using the Greenhouse-Geiser correction showed a significant main effect for playing year ($F(2.6,185.1) = 6.49$, $p < 0.0001$, $\eta_p^2 = 0.083$, observed power = 0.949). Pairwise comparisons revealed significant differences between year 1 and year 2 ($M_{\text{diff}} \pm SE = -0.062 \pm 0.015$, $p < 0.0001$, $d = 0.26$) and year 3 ($M_{\text{diff}} \pm SE = -0.049 \pm 0.018$, $p = 0.009$, $d = 0.26$) and year 4 ($M_{\text{diff}} \pm SE = -0.062 \pm 0.018$, $p = 0.001$, $d = 0.26$), but for no other comparisons. The analysis of body mass for subjects included in the analysis of ProA performance, there was again a violation in the sphericity of the data (Mauchly's W = 0.749, $p < 0.0001$). Using the Greenhouse-Geisser correction, a significant main effect was found for year of play ($F(2.5,179.4) = 43.53$, $p < 0.0001$, $\eta_p^2 = 0.377$, observed power = 1.000). Post hoc analysis revealed significant differences among all playing years (Table 4).

Table 4. Differences in body mass (kg) across years of play for ProA subjects ($n = 73$).*

Year	Year	M Diff	SE	Sig.	95% CI diff	D
1	2	−2.24†	0.38	<0.0001	−3.00 to −1.47	−0.12
	3	−3.50†	0.46	<0.0001	−4.42 to −2.58	−0.19
	4	−4.53†	0.51	<0.0001	−5.56 to −5.56	−0.24
2	3	−1.26†	0.35	<0.0001	−1.95 to −0.58	−0.07
	4	−2.30†	0.42	<0.0001	−3.13 to −1.47	−0.12
3	4	−1.03†	0.37	0.006	−1.76 to −0.30	−0.05

* M_{Diff} represents the year in column 1 minus the year in column 2. ProA = ProAgility test.
† Significantly different than the year in column 1.

The repeated measures analysis of the ProA momentums also showed a violation in sphericity (Mauchly's W = 0.814, $p = 0.012$). Analyses using the Greenhouse-Geisser adjustment revealed a significant difference between years (F(2.6,188.0) = 75.03, ***p*** < 0.0001, η_p^2 = 0.510, observed power = 1.000). Once again, similar to body mass, pairwise comparisons revealed significant differences between all years of play (Table 5).

Table 5. Differences in momentum ($\text{kg·m}^{-1}\text{·s}^{-1}$) across years of play for ProA subjects (***n*** = 73).*

Year	**Year**	**M Diff**	**SE**	**Sig.**	**95% CI diff**	**d**
1	2	−22.78 †	2.02	<0.0001	−26.81 to −18.74	−0.45
	3	−28.87 †	2.22	<0.0001	−31.31 to −22.44	−0.52
	4	−32.28 †	2.80	<0.0001	−37.86 to −26.70	−0.54
2	3	−4.10 †	1.96	0.040	−8.00 to −0.19	−0.08
	4	−9.51 †	2.52	<0.0001	−14.53 to −4.48	−0.15
3	4	−5.41 †	2.28	0.020	−9.95 to −0.87	−0.09

*M_{Diff} represents the year in column 1 minus the year in column 2. ProA = ProAgility test.
† Significantly different than the year in column 1.

Figure 3 presents values for ProA velocities, body masses, and momentums for playing years 1–4.

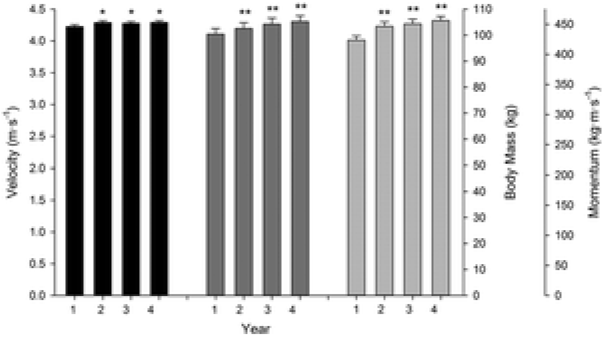


Figure 3. Velocities, body masses , and momentums for the ProAgility test across 4 years of competition (***n*** = 73). *Significantly different from year 1 (***p*** < 0.0001). **Significantly different from all previous years (***p*** < 0.0001).

L-drill

The L-drill velocity data violated the assumption of sphericity (Mauchly's W = 0.123, ***p*** < 0.0001). Using the Greenhouse-Geisser correction, the repeated measures analysis showed a significant main effect for the year of play (F(1.4,102.6) = 4.61, ***p*** = 0.022, η_p^2 = 0.060, observed power = 0.666). ***Post hoc*** analysis showed that L-drill velocity during year 1 was significantly slower than year 2 (M_{diff} ± ***SE*** = −0.058 ± 0.011 m·s^{-1}, ***p*** < 0.0001, ***d*** = −0.27), 3 (M_{diff} ± ***SE*** = −0.056 ± 0.017 m·s^{-1}, ***p*** = 0.001, ***d*** = −0.27), and 4 (M_{diff} ± ***SE*** = −0.096 ± 0.036 m·s^{-1}, ***p*** = 0.010, ***d*** = −0.33). By contrast, no significant differences were seen between years 2, 3, and 4. For L-drill subjects' body mass, there was again a violation in the assumption of sphericity (Mauchly's W = 0.672, ***p*** < 0.0001). Using a Greenhouse-Geisser correction, a significant main effect was detected for the year (F(2.4,169.7) = 47.10, ***p*** < 0.0001, η_p^2 = 0.395, observed power = 1.000). ***Post hoc*** analysis revealed significant increases in mass across all years (Table 6).

Table 6. Differences in body mass (kg) across years of play for the L-drill subjects (***n*** = 73).*

Year	Year	M Diff	SE	Sig.	95% CI diff	D
1	2	−2.37 †	0.43	<0.0001	−3.24 to −1.52	−0.12
	3	−4.21 †	0.56	<0.0001	−5.33 to −3.08	−0.20
	4	−5.84 †	0.91	<0.0001	−6.47 to −4.12	−0.25
2	3	−1.83 †	0.39	<0.0001	−2.60 to −1.05	−0.09
	4	−2.92 †	0.46	<0.0001	−3.82 to −2.01	−0.14
3	4	1.09 †	0.41	0.009	1.90 to 0.28	−0.05

* M_{Diff} represents the year in column 1 minus the year in column 2.
† Significantly different than the year in column 1.

Repeated measure analysis of the L-drill momentums also showed a significant difference because of the year (F(1.6,114.5) = 34.72, ***p*** < 0.0001, η_p^2 = 0.328, observed power = 1.000) using the Greenhouse-Geisser adjustment due to a violation in sphericity (Mauchly's W = 0.179, ***p*** < 0.0001). Pairwise comparisons revealed significant differences between all years of play (Table 7). Figure 4 presents values for L-drill velocities, body masses, and momentums for playing years 1–4.

Table 7. Differences in L-drill momentum ($kg \cdot m^{-1} \cdot s^{-1}$) across years of play (***n*** = 73).*

Year	Year	M Diff	SE	Sig.	95% CI diff	D
1	2	−5.65	1.17	<0.0001	−8.00 to −3.32	−0.11
	3	−20.50	2.20	<0.0001	−24.87 to −16.12	−0.36
	4	−28.21	4.16	<0.0001	−36.51 to −19.92	−0.48
2	3	−14.85 †	2.23	<0.0001	−19.28 to −10.41	−0.26
	4	−22.56 †	4.01	<0.0001	−30.56 to −14.57	−0.38
3	4	−7.72 †	3.76	0.044	−15.22 to −0.22	−0.12

* M_{Diff} represents the year in column 1 minus the year in column 2.
† Significantly different than the year in column 1.

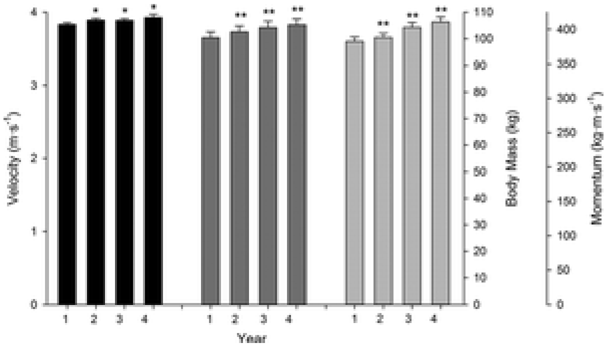


Figure 4.
Velocities, body masses, and momentums for the L drill across 4 years of competition (***n*** = 73). *Significantly different from year 1 (***p*** < 0.0001). **Significantly different from all previous years (***p*** < 0.0001).

Discussion

The major finding of this study was that momentum, rather than velocity, was the factor in which Division 1 American football players made their greatest gains across their playing years. In addition, our results show that the improvements in momentum were attributable to increases in body mass because velocity values plateaued after the gains made after their first year of play. To the best of our knowledge, these are the first results that demonstrate the importance of considering both increases in body mass and movement speed for maximizing improvements as players advance through their playing careers. Furthermore, our results argue for the use of momentum, rather than simply speed, when assessing players' performance potential for the NFL. Previous research suggests that in collegiate and elite level players, there seems to be a ceiling effect in relation to speed development, whereas body mass continues to increase throughout a player's collegiate career. For example, in a sample of 92 offensive and defensive linemen and 64 skill (wide receivers and defensive backs) players from an American NCAA Division 1 football team assessed over 4 years of eligibility, Jacobson et al. (12) reported that the only significant improvement in 40-yd sprint speed was made between years 1 and 2. By contrast, they noted that the players consistently gained body mass, although gains were not statistically significant after year 2. Our results are similar to those reported by these researchers; however, we found that 40-yd sprint velocity plateaued by year 2, whereas body mass increased significantly across all years of play. The difference between the 2 studies may be attributable to our inclusion of quarterbacks, linebackers, defensive ends, and specialty players in our sample and the analysis of the entire team without subdividing the sample by position, which may be considered a limitation. In another study that examined the effects of training history, player position, and body composition on performance in 261 Division 1A American football players, Miller et al. (18) reported no significant improvements in 40-yd sprint times or 20-yd shuttle times across players' 4-year careers; however, changes in body mass were evidenced across this period. Once again, these results mirror those reported in this study. The importance of the combined effects of 40-yd sprint time and body mass is evidenced by the significant increases in momentum seen between all playing years and the significant improvement and substantial effect size seen between years 1 and 4 (***p*** < 0.0001; ***d*** = 0.45). In a study that included data from 289 players of a NCAA Division III football team, Hoffman et al.

(10) reported findings similar to ours, with no significant improvements for their sample in the 40-yd sprint, ProA, or line drill times. In addition, although their players increased body mass across all years, the only significant change was between years 1 and 4.Although none of these studies assessed momentum during sprints or agility drills, it should be noted that they all reported significant increases in power across the 4 years of testing, strengthening our contention that measuring momentum during sprints, and agility drills may be an important added component when assessing playing capacity. These results showing little change in 40-yd sprint times, coupled with significant increases in body mass and momentum, across the 4-year testing periods, bring into question the tradition of reporting only time when evaluating players' potential or fitness status. Clearly, speed alone does not fully explain the changes that are made as a result of training and maturation of the player and may not be appropriate to examine changes over time. As the momentum changes because of sprint times and changes in body mass, the utilization of momentum seems to be a better variable to monitor changes in 40-yd sprint performance in collegiate American football players. When comparing the times for the ProA test and the L drill, the same trend was seen. There were no significant differences in the times recorded on the test after year 2; however, as noted above, there was a significant increase in body mass every year. Once again, the significant improvements in ProA and L-drill momentum across all playing years ($p < 0.0001$) and large effect sizes for ProA ($d = 0.54$) and L drill ($d = 0.48$) from year 1 to year 4 support the argument that momentum, rather than speed, is the more effective measure of players' progress, potential, and game-specific fitness. The concept of including body mass as a variable when assessing physical performance in American football players is not unique, although it has not been applied as a critical variable when evaluating sprint and agility drill performances. For many years, practitioners have computed jump height power using body mass through various equations, such as the Sayers equation (19). Notably, Jacobson et al. (13) used this equation to account for the changes in power due to body mass over the career with the football players. Indeed, these equations have been well received by coaches and have been the subject of internet articles and conference lectures aimed at this population (16), indicating their benefits over jump height when examining changes that have occurred as a result of training because changes in body mass commonly occur with training. Until now, the evaluation of sprint momentum has been mainly limited to the assessment of rugby players (3,5,12,20) with only 1 publication related to American football (14). In addition, the mention of momentum, whether in the evaluation of sprinting or COD, is almost nonexistent in the lay literature. Nonetheless, this metric may prove to be as important to the evaluation of American football players because it has been in rugby.

Practical Applications

Our results suggest that assessing playing potential across an American football collegiate career using sprint or agility drill times may provide players with an incomplete picture of the improvement made over their careers. Momentum, which takes into account training-induced increases in both speed and body mass, would be a relevant and supportive measure of players' improvements in football-specific physical performance. In addition, the simple computation of this variable, using existing speed and body mass data, should be included in the NFL combine as a measure of playing potential in the professional game.

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