Predictive Value of National Football League Scouting Combine on Future Performance of Running Backs and Wide Receivers

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Abstract

Teramoto, M, Cross, CL, and Willick, SE. Predictive value of National Football League scouting combine on future performance of running backs and wide receivers. *J Strength Cond Res* 30(5): 1379–1390, 2016–The National Football League (NFL) Scouting Combine is held each year before the NFL Draft to measure athletic abilities and football skills of college football players. Although the NFL Scouting Combine can provide the NFL teams with an opportunity to evaluate college players for the upcoming NFL Draft, its value for predicting future success of players has been questioned. This study examined whether the NFL Combine measures can predict future performance of running backs (RBs) and wide receivers (WRs) in the NFL. We analyzed the 2000–09 Combine data of RBs ($N = 276$) and WRs ($N = 447$) and their on-field performance for the first 3 years after the draft and over their entire careers in the NFL, using correlation and regression analyses, along with a principal component analysis (PCA). The results of the analyses showed that, after accounting for the number of games played, draft position, height (*HT*), and weight (*WT*), the time on 10-yard dash was the most important predictor of rushing yards per attempt of the first 3 years ($p = 0.002$) and of the careers ($p < 0.001$) in RBs. For WRs, vertical jump was found to be significantly associated with receiving yards per reception of the first 3 years ($p = 0.001$) and of the careers ($p = 0.004$) in the NFL, after adjusting for the covariates above. Furthermore, HT was most important in predicting future performance of WRs. The analyses also revealed that the 8 athletic drills in the Combine seemed to have construct validity. It seems that the NFL Scouting Combine has some value for predicting future performance of RBs and WRs in the NFL.

Key Words American football, rushing yards per attempt, receiving yards per reception, correlation, regression, principal component analysis

Introduction

The National Football League (NFL) invites hundreds of college football players each year before the NFL Draft, and conducts a series of physical and psychological measurements to evaluate the players, known as the NFL Scouting Combine (www.nflcombine.net). The Combine provides prospective players an opportunity to show team executives, coaches, and scouts their athletic abilities and football skills. The NFL teams can use the Combine data as one of their criteria to make a decision for selecting players in the upcoming NFL Draft.

The NFL Combine consists of the measurements of athletic abilities and position-specific skills, along with health screenings, interviews, and psychological testing (www.nflcombine.net; www.nfl.com/combine). Of these measurements, the data on athletic abilities are widely available to the public (e.g., CBSSPORTS.com: Draft Combine History, www.cbssports.com/nfl/draft/history). Table 1 summarizes the tests of athletic abilities conducted in the Combine (www.nfl.com/combine/workouts).

Although these tests have been extensively used to assess athletic abilities (6) and seem to address the components important for football performance (i.e., face validity), the value of the Combine for predicting future success of college football players in the NFL (i.e., predictive validity) has been questioned. Kuzmits and Adams (8) examined the relationships between the Combine measures (1999–2004) and performance of running backs (RBs), wide receivers (WRs), and quarterbacks (QBs) in the NFL. They found no significant correlations between the Combine measures and NFL performance except for the association of faster sprint time to better performance of RBs. In addition, it is uncertain if the NFL teams are fully using the Combine data to select players for the NFL Draft (9).

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Table 1. National Football League Scouting Combine workout drills.*†

Drill	Measured athletic ability	Testing protocol
40-Y	Speed and explosion	The player runs 40 yards as fast as possible
20-Y	Speed and explosion	This is the split time during first 20 yards for *40-Y*
10-Y	Speed and explosion	This is the split time during first 10 yards for *40-Y*
BP	Upper-body strength	The player performs 225-lb BP as many repetitions as possible
VJ	Lower-body explosion and power	The player jumps vertically as high as possible to touch the flag. A jump *HT* is measured between the player's reach and the flag
BJ	Lower-body explosion and strength	The player jumps horizontally as far as possible without moving at the landing
SHUTTLE	Lateral quickness and explosion	The player sprints 5 yards to the right, 10 yards to the left, and 5 more yards back to the starting position
CONE	Ability to change directions	As 3 cones are set up in an L-shape with 5 yards apart, the player sprints around the 3 cones following the predetermined route

*40-Y = 40-yard dash; 20-Y = 20-yard dash; 10-Y = 10-yard dash; BP = bench press; VJ = vertical jump; BJ = broad jump; SHUTTLE = shuttle run; CONE = 3 cone drill; HT = height.
†From NFL Scouting Combine Workouts (www.nfl.com/combine/workouts).

In this study, we speculated that another approach to the data analysis might unveil the relationships between the Combine data and NFL performance that may have been overlooked in the past. The aforementioned studies (8,9) used a (bivariate) correlation analysis to examine the Combine data and NFL performance. A major limitation of a correlation analysis is its inability to explore the relationship between a dependent variable and a set of "multiple" independent variables. It is possible that accounting for the effects of several Combine measures could predict future NFL performance of players better than a single measure of the Combine data. The primary aim of this study was to determine whether the NFL Combine measures could predict future success of RBs and WRs in the NFL, using correlation and regression analyses. We also examined construct validity of the 8 athletic drills in the Combine, using a principal component analysis (PCA). It was hypothesized that the NFL Scouting Combine has some value for predicting future performance of RBs and WRs in the NFL.

Methods

Experimental Approach to the Problem

This study analyzed the NFL Combine data of college football players who participated in the Combine between 2000 and 2009 and their on-field performance in the NFL. The Combine data analyzed in this study were 8 measures of athletic abilities listed in Table 1: 40-yard dash (*40-Y*), 20-yard dash (*20-Y*), 10-yard dash (*10-Y*), bench press (*BP*), vertical jump (*VJ*), broad jump (*BJ*), shuttle run (*SHUTTLE*), and 3 cone drill (*CONE*), along with height (*HT*) and weight (*WT*). Measures of NFL performance were: rushing yards per attempt (*Y/A*) of the first 3 years of the NFL careers and of the entire NFL careers for RBs, and receiving yards per reception (*Y/R*) of the first 3 years of the NFL careers and of the entire NFL careers for WRs. We also included in the data analysis the number of games played (*#G*) in the first 3 years of the NFL careers and in the entire NFL careers, and draft position (*Draft*; actual draft position or coded as "0" if undrafted). Career statistics were calculated based on the performance data up to the 2013 NFL season.

Subjects

Subjects for the data analysis in this study were college football players who participated in the NFL Scouting Combine as RBs or WRs between 2000 and 2009 ($N = 276$ for RBs and $N = 447$ for WRs). Running backs and WRs were chosen for our study because there are objective and measurable performance data available for these "skill positions" (8). Performance of QBs can also be quantified, for example, by the QB rating (10). However, QB performance is highly influenced by parameters that are either not measured in the Combine or are intangible and simply immeasurable. Therefore, we elected to confine our analysis to WRs and RBs. Institutional Review Board approval was not required for this study, as this study was a secondary analysis of data available through web-based public access domains which disclose no individual health information.

Procedures

The data of the NFL Combine and NFL performance were obtained from CBSSPORTS.com: Draft Combine History (www.cbssports.com/nfl/draft/history) and Pro-Football-Reference.com (www.pro-football-reference.com), respectively. First, college football players who participated in the NFL Scouting Combine between 2000 and 2009 as either RBs or WRs were identified from CBSSPORTS.com: Draft Combine History. Second, their Combine data were retrieved. Third, for each of RBs and WRs, on-field performance in the NFL (*Y/A* for RBs and *Y/R* for WRs of the

first 3 years of their NFL careers and of their entire NFL careers up to the 2013 season), along with their *#G* (in the first 3 years of their NFL careers and in their entire NFL careers up to the 2013 season) and *Draft*, were obtained from Pro-Football-Reference.com.

Statistical Analyses

We first examined the associations of the Combine measures to *#G*, *Draft*, and on-field NFL performance (i.e., *Y/A* for RBs and *Y/R* for WRs) using Pearson's correlation coefficients. Furthermore, correlations among the variables were examined to identify collinearity between any set of the variables. It is worth noting that although we commented above that a correlation analysis was not likely the best approach for drawing conclusions from these data, we used bivariate correlations here to screen and describe data, especially for the subsequent regression analysis, and not to draw inferential conclusions. Thus, *p*-values for correlation coefficients are not reported in this article. Missing values were excluded pairwise.

Next, a multiple linear regression (MLR) analysis was performed to examine whether the NFL Combine measures could predict future performance of RBs and WRs in the NFL. The predictor variables for the MLR analysis were selected based on the results of the aforementioned correlation analysis. Specifically, we chose the Combine measures having correlation coefficients with at least a small-size effect (i.e., $r \geq 0.10$ or $r \leq -0.10$ (4)) with *Y/A* or *Y/R*. Meanwhile, we included *HT* and *WT* as another sets of predictors in the MLR analysis regardless of their correlations with *Y/A* and *Y/R* because we believed that it would be essential to take into account players' anthropometric measures in the data analysis. Furthermore, *#G* and *Draft* were included in the regression models as covariates. *Y/A* for RBs and *Y/R* for WRs served as outcome variables in the MLR analysis. After the predictor variables were selected, another correlation matrix was constructed with missing values deleted listwise to ensure that the associations identified in the correlation analysis above were held consistent. We then performed a series of MLR analyses for RBs and WRs separately to examine the relative importance of the selected Combine measures in predicting their future performance in the NFL. All regression models were developed by the standard regression method (i.e., entering all predictors in a regression model simultaneously). Missing values were excluded listwise for all MLR analyses.

Last, we examined construct validity of the 8 athletic drills in the Combine. Specifically, a PCA was performed to identify underlying constructs within the 8 athletic Combine drills. The PCA was performed for the data of RBs and WRs, separately, with missing values deleted listwise. Although this was not a primary aim of the study, we believed that including the PCA would provide necessary validation of the intuitive constructs assumed to be represented in the Combine data.

Results

Correlations of Combine Measures to National Football League Performance in Running Backs

The results of the correlation analysis for RBs are presented in Tables 2 and 3. Forty-yard dash, *20-Y*, *10-Y*, and *CONE* had correlation coefficients with at least a small-size effect ($r \leq -0.1$) when paired with the first 3-year *Y/A*. The directions of these relationships were all negative, indicating that players with faster times on these measures tended to have greater *Y/A*. We observed the similar results between the Combine measures and the career *Y/A*, except that *BP* was another variable having a small-size correlation with *Y/A* ($r = -0.143$).

Correlations of Combine Measures to National Football League Performance in Wide Receivers

Tables 4 and 5 show the results of the correlation analysis for WRs. Bench press, *40-Y*, *20-Y*, *VJ*, and *BJ* had correlation coefficients with at least a small-size effect ($r \geq 0.10$ or $r \leq -0.10$) against the first 3-year *Y/R*. Wide receivers with faster times on *40-Y* and *20-Y* and greater distances on *VJ* and *BJ* tended to have better *Y/R*. Similar results were found for the career *Y/R*, except that the correlation coefficient between *20-Y* and the career *Y/R* was less than a small-size effect ($r = -0.090$).

Selections of Predictors for Regression Analysis

Based on the results of the correlation analysis above, *40-Y*, *20-Y*, *10-Y*, and *CONE* were first selected as the potential predictors for the MLR analysis of RBs, as these variables had at least a small-effect correlation with the first 3-year *Y/A* or career *Y/A*. However, *40-Y*, *20-Y*, and *10-Y* were highly correlated with each other (i.e., presence of collinearity). In fact, *20-Y* and *10-Y* are the split times for *40-Y* in the NFL Scouting Combine (www.nfl.com/combine/workouts). For the analysis of RBs, we selected *10-Y* as one of the predictors over *40-Y* and *20-Y* because RBs typically gain less than 10 yards per attempt, making *10-Y* more relevant to the performance of RBs. Bench press had a correlation coefficient of −0.143 with the career *Y/A* in the aforementioned correlation analysis. Meanwhile, when the correlation coefficients of the career *Y/A* to *10-Y*, *CONE*, and *BP*, along with *HT*, *WT*, *#G*, and *Draft*, were reanalyzed with missing cases deleted listwise, *BP* no longer had a small-effect correlation ($r = -0.079$). Therefore, *BP* was excluded from the list of predictors. The other potential predictors still had at least a small-size correlation with the first 3-year *Y/A* and career *Y/A*. Consequently, we chose *10-Y* and *CONE*, along with *HT* and *WT*, as the set of predictors for the MLR analysis of RBs, although, as mentioned previously, including *#G* and *Draft* as covariates. The resulting sample size was 84 for the analyses of the first 3-year *Y/A* and career *Y/A*.

Regarding the MLR analysis of WRs, *BP*, *40-Y*, *20-Y*, *VJ*, and *BJ* were first chosen as the potential predictors because of their small-effect correlations with the first 3-year and career *Y/R*. Of these variables, *BP* was first excluded from

Table 2. Correlation matrix of combine measures to on-field performance of the first 3-year NFL careers in RBs.*

	Y/A	*#G*	*Draft*	*HT*	*WT*	*BP*	*40-Y*	*20-Y*	*10-Y*	*VJ*	*BJ*	*SHUTTLE*	*CONE*
Y/A	1	0.175	0.021	−0.116	−0.089	−0.085	−0.119	−0.100	−0.105	−0.061	−0.015	0.065	−0.207
n		187	187	187	187	130	121	135	135	143	135	93	90
#G		1	−0.126	0.077	0.060	0.041	−0.188	−0.267	−0.157	0.119	−0.097	0.146	−0.300
n			187	187	187	130	121	135	135	143	135	93	90
Draft			1	−0.004	0.032	0.179	−0.125	−0.167	−0.138	0.017	−0.030	−0.002	−0.075
n				276	276	195	180	206	206	216	208	149	146
HT				1	0.552	0.098	0.009	0.092	0.045	0.140	0.006	0.051	0.111
n					276	195	180	206	206	216	208	149	146
WT					1	0.303	0.222	0.247	0.179	0.140	−0.026	0.071	0.356
n						195	180	206	206	216	208	149	146
BP						1	−0.336	−0.194	−0.244	0.126	0.211	−0.197	−0.049
n							130	166	166	173	166	121	117
40-Y							1	0.876	0.700	−0.404	−0.194	0.039	0.361
n								136	136	140	143	94	97
20-Y								1	0.794	−0.346	−0.004	−0.094	0.419
n									206	200	194	142	138
10-Y									1	−0.215	−0.182	0.103	0.349
n										200	194	142	138
VJ										1	−0.031	0.120	−0.060
n											204	149	146
BJ											1	−0.964	−0.165
n												149	146
SHUTTLE												1	0.421
n													135
CONE													1

*NFL = National Football League; RBs = running backs; *Y/A* = rushing yards per attempt; *#G* = number of games played; *Draft* = draft position; *HT* = height; *WT* = weight; *40-Y* = 40-yard dash; *20-Y* = 20-yard dash; *10-Y* = 10-yard dash; *BP* = bench press; *VJ* = vertical jump; *BJ* = broad jump; *SHUTTLE* = shuttle run; *CONE* = 3 cone drill.

Table 3. Correlation matrix of combine measures to on-field performance of the entire NFL careers in RBs.*

	Y/A	*#G*	*Draft*	*HT*	*WT*	*BP*	*40-Y*	*20-Y*	*10-Y*	*VJ*	*BJ*	*SHUTTLE*	*CONE*
Y/A	1	0.129	−0.018	−0.160	−0.127	−0.143	−0.131	−0.094	−0.109	−0.040	−0.003	0.033	−0.231
n		187	187	187	187	130	121	135	135	143	135	93	90
#G		1	−0.119	0.067	0.139	0.094	−0.193	−0.206	−0.068	0.121	−0.202	0.260	−0.067
n			187	187	187	130	121	135	135	143	135	93	90
Draft			1	−0.004	0.032	0.179	−0.125	−0.167	−0.138	0.017	−0.030	−0.002	−0.075
n				276	276	195	180	206	206	216	208	149	146
HT				1	0.552	0.098	0.009	0.092	0.045	0.140	0.006	0.051	0.111
n					276	195	180	206	206	216	208	149	146
WT					1	0.303	0.222	0.247	0.179	0.140	−0.026	0.071	0.356
n						195	180	206	206	216	208	149	146
BP						1	−0.336	−0.194	−0.244	0.126	0.211	−0.197	−0.049
n							130	166	166	173	166	121	117
40-Y							1	0.876	0.700	−0.404	−0.194	0.039	0.361
n								136	136	140	143	94	97
20-Y								1	0.794	−0.346	−0.004	−0.094	0.419
n									206	200	194	142	138
10-Y									1	−0.215	−0.182	0.103	0.349
n										200	194	142	138
VJ										1	−0.031	0.120	−0.060
n											204	149	146
BJ											1	−0.964	−0.165
N												149	146
SHUTTLE												1	0.421
n													135
CONE													1

*NFL = National Football League; RBs = running backs; *Y/A* = rushing yards per attempt; *#G* = number of games played; *Draft* = draft position; *HT* = height; *WT* = weight; *40-Y* = 40-yard dash; *20-Y* = 20-yard dash; *10-Y* = 10-yard dash; *BP* = bench press; *VJ* = vertical jump; *BJ* = broad jump; *SHUTTLE* = shuttle run; *CONE* = 3 cone drill.

Table 4. Correlation matrix of combine measures to on-field performance of the first 3-year NFL careers in WRs.*

	Y/R	*#G*	*Draft*	*HT*	*WT*	*BP*	*40-Y*	*20-Y*	*10-Y*	*VJ*	*BJ*	*SHUTTLE*	*CONE*
Y/R	1	0.187	−0.069	0.150	−0.042	0.181	−0.128	−0.103	0.027	0.246	0.114	−0.018	−0.016
n		257	257	257	257	33	170	188	188	193	174	148	145
#G		1	−0.295	−0.003	0.034	0.262	−0.091	−0.156	−0.143	0.160	0.093	−0.037	−0.106
n			257	257	257	33	170	188	188	193	174	148	145
Draft			1	0.011	0.038	−0.134	−0.168	−0.170	−0.165	0.068	0.138	−0.032	−0.136
n				447	447	60	281	351	351	349	322	275	272
HT				1	0.684	−0.081	0.266	0.224	0.194	0.028	0.130	0.166	0.086
n					447	60	281	351	351	349	322	275	272
WT					1	0.115	0.260	0.279	0.192	−0.004	0.058	0.207	0.128
n						60	281	351	351	349	322	275	272
BP						1	−0.046	−0.083	0.111	0.039	0.201	−0.086	−0.016
n							56	57	57	50	49	45	43
40-Y							1	0.845	0.585	−0.376	−0.418	0.213	0.324
n								232	232	215	202	182	180
20-Y								1	0.780	−0.228	−0.371	0.153	0.360
n									351	317	302	265	262
10-Y									1	−0.040	−0.249	−0.054	0.306
n										317	302	265	262
VJ										1	0.596	−0.317	−0.149
n											315	267	264
BJ											1	−0.145	−0.169
n												268	265
SHUTTLE												1	0.458
n													264
CONE													1

*NFL = National Football League; WRs = wide receivers; *Y/R* = receiving yards per reception; *#G* = number of games played; *Draft* = draft position; *HT* = height; *WT* = weight; *BP* = bench press; *40-Y* = 40-yard dash; *20-Y* = 20-yard dash; *10-Y* = 10-yard dash; *VJ* = vertical jump; *BJ* = broad jump; *SHUTTLE* = shuttle run; *CONE* = 3 cone drill.

Table 5. Correlation matrix of combine measures to on-field performance of the entire NFL careers in WRs.*

	Y/R	*#G*	*Draft*	*HT*	*WT*	*BP*	*40-Y*	*20-Y*	*10-Y*	*VJ*	*BJ*	*SHUTTLE*	*CONE*
Y/R	1	0.156	−0.064	0.194	−0.001	0.136	−0.113	−0.090	0.035	0.253	0.146	−0.020	−0.026
n		257	257	257	257	33	170	188	188	193	174	148	145
#G		1	−0.310	−0.008	0.085	0.339	−0.012	0.025	0.027	0.165	0.063	−0.083	0.021
n			257	257	257	33	170	188	188	193	174	148	145
Draft			1	0.011	0.038	−0.134	−0.168	−0.170	−0.165	0.068	0.138	−0.032	−0.136
n				447	447	60	281	351	351	349	322	275	272
HT				1	0.684	−0.081	0.266	0.224	0.194	0.028	0.130	0.166	0.086
n					447	60	281	351	351	349	322	275	272
WT					1	0.115	0.260	0.279	0.192	−0.004	0.058	0.207	0.128
n						60	281	351	351	349	322	275	272
BP						1	−0.046	−0.083	0.111	0.039	0.201	−0.086	−0.016
n							56	57	57	50	49	45	43
40-Y							1	0.845	0.585	−0.376	−0.418	0.213	0.324
n								232	232	215	202	182	180
20-Y								1	0.780	−0.228	−0.371	0.153	0.360
n									351	317	302	265	262
10-Y									1	−0.040	−0.249	−0.054	0.306
n										317	302	265	262
VJ										1	0.596	−0.317	−0.149
n											315	267	264
BJ											1	−0.145	−0.169
n												268	265
SHUTTLE												1	0.458
n													264
CONE													1

*NFL = National Football League; WRs = wide receivers; *Y/R* = receiving yards per reception; *#G* = number of games played; *Draft* = draft position; *HT* = height; *WT* = weight; *BP* = bench press; *40-Y* = 40-yard dash; *20-Y* = 20-yard dash; *10-Y* = 10-yard dash; *VJ* = vertical jump; *BJ* = broad jump; *SHUTTLE* = shuttle run; *CONE* = 3 cone drill.

Table 6. Summary of regression analysis of combine measures on predicting on-field performance of the first 3-year NFL careers in RBs.*†

Predictor	*B* (*SE*)	β	*t*	*p*	r^2	sr^2
#G	0.025 (0.007)	0.357	3.569	0.001	0.181	0.116
Draft	0.001 (0.001)	0.102	1.042	0.301	0.010	0.010
HT	−0.083 (0.065)	−0.162	−1.277	0.206	0.041	0.015
WT	0.006 (0.009)	0.082	0.611	0.543	0.020	0.003
10-Y	−4.930 (1.550)	−0.325	−3.182	0.002	0.154	0.092
CONE	−0.194 (0.425)	−0.052	−0.456	0.650	0.063	0.002

*NFL = National Football League; RBs = running backs; B = regression coefficient; β = standardized regression coefficient; r^2 = squared full correlation coefficient; sr^2 = squared semipartial correlation coefficient; *Y/A* = rushing yards per attempt; *#G* = number of games played; *Draft* = draft position; *HT* = height; *WT* = weight; *10-Y* = 10-yard dash; *CONE* = 3 cone drill.
†Outcome variable = *Y/A*; $N = 81$; $F_{(6,74)} = 5.907$; $p < 0.001$; $R^2 = 0.324$; Adjusted $R^2 = 0.269$.

the list of predictors, as the sample size was relatively small ($n = 33$). Next, as was the case with selecting the predictors for the MLR analysis of RBs, the presence of collinearity was a concern between *40-Y* and *20-Y*. We chose *40-Y* as one of the predictors for the MLR analysis of WRs because *40-Y* had a slightly higher correlation coefficient with *Y/R* than did *20-Y*, and because, as mentioned above, the correlation between *20-Y* and the career *Y/R* was less than a small-sized effect. We decided to retain both *VJ* and *BJ* in the set of predictors despite a somewhat high correlation between these 2 variables ($r = 0.596$). We believed that *VJ* and *BJ* assess different components of athletic abilities (vertical power vs. horizontal power), and that both measurements are important for WRs. In addition, an intercorrelation in this range generally does not induce serious multicollinearity problems in a MLR model (11). The reanalysis of correlation coefficients indicated that *40-Y* no longer had a small-size correlation with the first 3-year *Y/R* ($r = -0.060$) and career *Y/R* ($r = -0.080$), when all the potential predictors above were included with missing values deleted listwise; therefore, *40-Y* was excluded from the list of predictors. The other potential predictors still had at least a small-size correlation with the first 3-year *Y/R* and career *Y/R*. As a result, we chose *VJ* and *BJ*, along with *HT* and *WT*, as the set of predictors for the MLR analysis of WRs, however again, including *#G* and *Draft* as covariates. The resulting sample size was 170 for the analyses of the first 3-year *Y/R* and career *Y/R*.

Checking Assumptions for Regression Analysis

First, we inspected the residual plots between each of the selected predictors and the measures of on-field performance in the NFL (*Y/A* for RBs and *Y/R* for WRs). There was no apparent evidence of heteroscedasticity between each predictor and *Y/A* or *Y/R*. Next, we examined the normal probability and residual plots, and ensured that the assumptions of normality, linearity, and homoscedasticity were not violated for all regression models developed in our data analysis. There was no demonstrable multicollinearity among the predictors as evidenced by the tolerance values below 0.1 in all models (5). With respect to outlying cases, none of the Mahalanobis

Table 7. Summary of regression analysis of combine measures on predicting on-field performance of the entire NFL careers in RBs.*†

Predictor	*B* (*SE*)	β	*t*	*p*	r^2	sr^2
#G	0.009 (0.002)	0.441	5.276	<0.001	0.228	0.187
Draft	0.000 (0.001)	0.020	0.241	0.810	0.001	<0.001
HT	−0.070 (0.046)	−0.168	−1.532	0.130	0.084	0.016
WT	−0.002 (0.007)	−0.036	−0.308	0.759	0.057	0.001
10-Y	−4.979 (1.072)	−0.407	−4.645	<0.001	0.229	0.145
CONE	−0.333 (0.287)	−0.110	−1.158	0.250	0.088	0.009

*NFL = National Football League; RBs = running backs; B = regression coefficient; β = standardized regression coefficient; r^2 = squared full correlation coefficient; sr^2 = squared semipartial correlation coefficient; *Y/A* = rushing yards per attempt; *#G* = number of games played; *Draft* = draft position; *HT* = height; *WT* = weight; *10-Y* = 10-yard dash; *CONE* = 3 cone drill.
†Outcome variable = *Y/A*; $N = 82$; $F_{(6,75)} = 12.290$; $p < 0.001$; $R^2 = 0.496$; Adjusted $R^2 = 0.455$.

Table 8. Summary of regression analysis of combine measures on predicting on-field performance of the first 3-year NFL careers in WRs.*†

Predictor	*B* (*SE*)	β	*t*	*p*	r^2	sr^2
#G	0.076 (0.015)	0.340	4.939	<0.001	0.134	0.107
Draft	−0.002 (0.003)	−0.048	−0.702	0.484	0.011	0.002
HT	0.659 (0.124)	0.486	5.331	<0.001	0.069	0.125
WT	−0.055 (0.018)	−0.280	−3.075	0.002	0.001	0.042
VJ	0.264 (0.075)	0.300	3.514	0.001	0.077	0.054
BJ	−0.063 (0.044)	−0.123	−1.440	0.152	0.017	0.009

*NFL = National Football League; WRs = wide receivers; B = regression coefficient; β = standardized regression coefficient; r^2 = squared full correlation coefficient; sr^2 = squared semipartial correlation coefficient; *Y/R* = receiving yards per reception; *#G* = number of games played; *Draft* = draft position; *HT* = height; *WT* = weight; *VJ* = vertical jump; *BJ* = broad jump.
†Outcome variable = *Y/R*; $N = 163$; $F_{(6,156)} = 11.968$; $p < 0.001$; $R^2 = 0.315$; Adjusted $R^2 = 0.289$.

distances for any of the regression models exceeded the critical values of the χ^2 distribution at an alpha level of 0.001, indicating no apparent outliers (11). In addition, there were no cases that potentially had any undue influence on the regression coefficients, as no cases had Cook's distances greater than 1 in any of the models (11). However, some cases had standardized residual values above 3.0 or below −3.0, and thus were considered potential outliers (5). Although Cook's distances for these cases were still below 1, we excluded them from the final regression models to eliminate any undue influence of these cases on the regression coefficients. As a result, there were 3 and 2 cases excluded from the MLR analysis for the first 3-year *Y/A* and career *Y/A* for RBs, respectively, whereas, 7 cases were excluded from the MLR analysis for the first 3-year *Y/R* and career *Y/R* for WRs, respectively.

Regression Analysis on Combine Measures and Future Performance of Running Backs

The results of the MLR analysis on the Combine measures and performance of RBs in the first 3 years of the NFL career are presented in Table 6. The linear relationship of the selected predictors to the first 3-year *Y/A* was significant ($N = 81$, $F_{(6,74)} = 5.907$, $p < 0.001$, $R^2 = 0.324$, Adjusted $R^2 = 0.269$). The regression model explained 26.9% of the variance in the first 3-year *Y/A*. After adjusting for *#G* in the first 3 years and *Draft*, *10-Y* was the only significant predictor of the first 3-year *Y/A* ($p = 0.002$), which uniquely accounted for 9.2% of the variance in *Y/A* ($sr^2 = 0.092$). The negative regression coefficient for *10-Y* ($B = -4.930$) indicated that faster times on *10-Y* among RBs were associated with the greater *Y/A* in the first 3 years of the NFL. However, *CONE* was not significant to the regression model ($p = 0.650$), and neither was *HT* nor *WT*. The first 3-year *#G* was positively related to *Y/A*.

The analysis of predicting the career *Y/A* yielded the similar results with those for the first 3-year *Y/A* (Table 7). The regression model was significant ($N = 82$, $F_{(6,75)} = 12.290$, $p < 0.001$, $R^2 = 0.496$, Adjusted $R^2 = 0.455$), explaining 45.5% of the variance in the career *Y/A* by the predictors. After adjusting for the career *#G* and *Draft*, *10-Y* was

Table 9. Summary of regression analysis of combine measures on predicting on-field performance of the entire NFL careers in WRs.*†

Predictor	*B* (*SE*)	β	*t*	*p*	r^2	sr^2
#G	0.017 (0.004)	0.295	4.229	<0.001	0.096	0.078
Draft	−0.002 (0.002)	−0.070	−1.028	0.305	0.017	0.005
HT	0.627 (0.109)	0.532	5.755	<0.001	0.086	0.145
WT	−0.056 (0.015)	−0.333	−3.597	<0.001	0.003	0.057
VJ	0.189 (0.065)	0.251	2.894	0.004	0.086	0.037
BJ	0.004 (0.038)	0.010	0.117	0.907	0.047	<0.001

*NFL = National Football League; WRs = wide receivers; B = regression coefficient; β = standardized regression coefficient; r^2 = squared full correlation coefficient; sr^2 = squared semipartial correlation coefficient; *Y/R* = receiving yards per reception; *#G* = number of games played; *Draft* = draft position; *HT* = height; *WT* = weight; *VJ* = vertical jump; *BJ* = broad jump.
†Outcome variable = *Y/R*; $N = 163$; $F_{(6,156)} = 11.941$; $p < 0.001$; $R^2 = 0.315$; Adjusted $R^2 = 0.288$.

Table 10. Varimax rotated component matrix for 8 athletic combine drills obtained from PCA.*†

Position	Combine drill	Factor loadings 1	2	3	4
RB ($N = 68$)	*40-Y*	**0.915**	−0.131	0.066	−0.086
	20-Y	**0.874**	−0.242	0.297	−0.081
	10-Y	**0.816**	−0.324	0.153	−0.259
	VJ	−0.161	**0.888**	−0.079	0.105
	BJ	−0.306	**0.806**	−0.157	0.004
	SHUTTLE	0.051	−0.266	**0.872**	−0.131
	CONE	0.288	0.015	**0.867**	−0.065
	BP	−0.202	0.078	−0.144	**0.960**
WR ($N = 41$)	*40-Y*	**0.910**	−0.076	0.052	0.021
	20-Y	**0.882**	−0.321	0.156	−0.133
	10-Y	**0.861**	−0.308	0.200	0.027
	VJ	−0.207	**0.927**	−0.018	−0.115
	BJ	−0.308	**0.855**	−0.119	0.219
	SHUTTLE	0.103	0.055	**0.920**	−0.073
	CONE	0.164	−0.190	**0.874**	0.097
	BP	−0.030	0.040	0.017	**0.989**
Factor representation		Speed	Lower-body strength and power	Quickness and agility	Upper-body strength

*PCA = principal component analysis; RB = running back; *40-Y* = 40-yard dash; *20-Y* = 20-yard dash; *10-Y* = 10-yard dash; *VJ* = vertical jump; *BJ* = broad jump; *SHUTTLE* = shuttle run; *CONE* = 3 cone drill; *BP* = bench press.
†Factor loadings over 0.40 appear in bold.

significant to the model ($p < 0.001$), whereas *CONE* was not ($p = 0.250$). Ten-yard dash alone uniquely explained 14.5% of the variance in the career *Y/A* ($sr^2 = 0.145$). As was the case with the regression model for the first 3-year *Y/A*, faster times on *10-Y* among RBs were associated with greater career *Y/A*, shown by the negative regression coefficient of *10-Y* ($B = -4.979$). Furthermore, the career *#G* was positively related to the career *Y/A*. Height and *WT* were not the significant predictors of the career *Y/A*.

Regression Analysis on Combine Measures and Future Performance of Wide Receivers

Table 8 summarizes the results of the MLR analysis on the Combine measures and performance of WRs in the first 3 years of the NFL career. There was a significant linear relationship between the selected predictors and the first 3-year *Y/R* ($N = 163$, $F_{(6,156)} = 11.968$, $p < 0.001$, $R^2 = 0.315$, Adjusted $R^2 = 0.289$). The regression model explained 28.9% of the variance in the first 3-year *Y/R*. Height, *WT*, and *VJ* were the significant predictors of the first 3-year *Y/R* ($p \leq 0.05$) after adjusting for *#G* in the first 3 years and *Draft*. Based on the sr^2 values, each of these predictors uniquely explained 12.5, 4.2, and 5.4% of the variance in the first 3-year *Y/R*, respectively. The regression coefficient ($B = 0.264$) for *VJ* indicated that greater scores on *VJ* were associated with greater *Y/R* of the first 3 years. Height ($B = 0.659$) was positively associated with, and *WT* ($B = -0.055$) was negatively associated with the first 3-year *Y/R*, suggesting that taller and lighter WRs tended to have greater *Y/R* in the first 3 years of the NFL. However, *BJ* was not significant to the regression model ($p = 0.152$). The *#G* in the first 3 years was positively related to the first 3-year *Y/R*. According to the standardized regression coefficient, *HT* was the most important predictor of the first 3-year *Y/R*, as its standardized regression coefficient ($\beta = 0.486$) was the highest among the predictors.

Similar results were obtained for the regression model predicting the career *Y/R* (Table 9). The regression model was significant ($N = 163$, $F_{(6,156)} = 11.941$, $p < 0.001$, $R^2 = 0.315$, Adjusted $R^2 = 0.288$), explaining 28.8% of the variance in the career *Y/R*. After adjusting for the career *#G* and *Draft*, *VJ* was significant to the model ($p = 0.004$) whereas *BJ* was not ($p = 0.907$). Vertical jump alone could uniquely explain 3.7% of the variance in the career *Y/R* ($sr^2 = 0.037$). As was the case with the model for the first 3-year *Y/R*, greater *VJ* ability was associated with the greater career *Y/R* ($B = 0.189$). Once again, being taller and lighter among WRs were associated with the better career *Y/R* ($B = 0.627$ for *HT* and $B = -0.056$ for *WT*). The career *#G* was significantly associated with the better *Y/R* ($p < 0.001$). The standardized regression coefficients ($\beta = 0.532$) indicated that *HT* was the most important factor in predicting the career *Y/R* of WRs.

The PCA of the 8 athletic drills in the Combine using the data for RBs revealed that there were 4 underlying

components, which was determined by analyzing Kaiser-Meyer-Olkin value = 0.725; greater than the recommended cutoff value of 0.6; (7), Bartlett's test of sphericity ($p < 0.001$; (1)), the scree plot test (3), and the varimax rotated factor loadings. These 4 components explained 48.8, 14.9, 12.9, and 10.0% of the variance, respectively, with a total of 86.6% of the variance explained. Likewise, 4 components were identified in the data of WRs through the same analyses above, explaining 45.2, 18.2, 13.1, and 12.6% of the variance, respectively, with a total of 89.1% of the variance explained. Table 10 shows the rotated component matrix of the 8 athletic Combine drills for each of the RB and WR data. It was apparent that the 8 athletic drills in the Combine could be classified under the following categories: speed (*40-Y*, *20-Y*, and *10-Y*), lower-body strength and power (*VJ* and *BJ*), quickness and agility (*SHUTTLE* and *CONE*), and upper-body strength (*BP*). These classifications were in accordance with those proposed by the NFL Scouting Combine (www.nfl.com/combine/workouts).

Discussion

The results of the data analysis have indicated that of the 8 athletic measures in the NFL Combine, *10-Y* for RBs and *VJ* for WRs seem to be the most important in predicting their future performance in the NFL, when their performance is assessed by *Y/A* for RBs and *Y/R* for WRs, respectively. In addition, *HT* for WRs seems to be critical in producing better *Y/R* in the NFL. Meanwhile, our data analysis suggests that the Combine measures explain less than half of the variance in future performance of RBs and WRs in the NFL. The 8 athletic drills in the Combine were classified under 4 different categories: speed, lower-body strength and power, quickness and agility, and upper-body strength, indicating construct validity of these drills.

We found some significant associations of the Combine measures to future NFL performance of RBs and WRs which were not previously reported (8). This discrepancy in the results between the studies is likely due to the difference in data analysis strategies used (regression analysis vs. correlation analysis) between the studies. The MLR analysis used in our study enabled us to examine the relationships between Combine measures and NFL performance, although controlling for other Combine variables and potential covariates. Our study also included more Combine data than did Kuzmits and Adams (10 years vs. 6 years of data, (8)). These factors perhaps led to the different findings in this study.

It is important to underscore that a regression analysis can account for the effects of more than 1 independent/predictor variable when exploring the relationship to an outcome variable. This allows for a better understanding of the importance of predictors that can be overlooked by a correlation analysis. In our data analysis, for example, *CONE* had the highest correlation with the first 3-year *Y/A* and career *Y/A* in RBs. However, the MLR analysis revealed that *10-Y*, not *CONE*, was a significant predictor of *Y/A* when *#G*, *Draft*, *HT*, *WT*, and *10-Y/CONE* were held constant. An explanation for this finding is that *10-Y* and *CONE* share some variance in the first 3-year *Y/A* and career *Y/A*; therefore, the relationship between *CONE* and *Y/A* can also be explained partly by the relationship between *10-Y* and *Y/A*. This is not surprising in that players with faster times on *10-Y* should, in general, have faster times on *CONE*. Using a regression analysis enabled us to identify *10-Y* as a more important Combine measure in predicting future performance of RBs in the NFL, although, *CONE* had the highest bivariate correlation with *Y/A*. In the case of predicting future NFL performance of WRs, *VJ* had the highest bivariate correlation with *Y/R*. Meanwhile, the MLR analysis revealed that *HT*, not *VJ*, would be the most important in predicting their future performance when both were accounted for. If comparing 2 players with similar *HT*s, *VJ* would seem to be the next important predictor in *Y/R*. We believe therefore that our data analysis uncovered key parameters of the NFL Scouting Combine in relation to future success of RBs and WRs.

There are limitations associated with this study. Some Combine data contained a large number of missing values because not every player takes all of the Combine measurements. For example, of the 276 RBs examined in this study, only 149 and 146 of them took the *SHUTTLE* and *CONE* tests, respectively. Approximately, 71–78% of RBs took the *BP*, *VJ*, and *BJ* drills. Similar trends were also observed in WRs. In particular, only 60 of 447 WRs participating in the Combine during 2000–09 took the *BP* test. Because, missing cases should ideally be excluded listwise in a regression analysis (5), which was performed in our study, the presence of these missing values in the Combine data limited the sample sizes in our MLR analysis, potentially reducing statistical power. In addition, it is challenging to precisely quantify performance of football players, including RBs and WRs. We used *Y/A* for RBs and *Y/R* for WRs as the measures of performance in the NFL. However, these measures could also be influenced by factors other than the ability of an individual player. For example, some RBs and WRs are used mainly for a short-yard gain, and their performance may not be greatly reflected in their *Y/A* and *Y/R* statistics; yet, these players are still valuable to their teams. Some RBs are also used as a receiver quite often (e.g., LaDainian Tomlinson of the San Diego Chargers and New York Jets had at least 50 receptions 9 times in his career and recorded 100 receptions in the 2003 season, www.pro-football-reference.com/players/T/TomlLa00.htm). Furthermore, playing alongside a good offensive line for RBs and a good QB for WRs would certainly have a positive impact on their statistics, which is not accounted for in this study. If other appropriate measures of on-field NFL performance for RBs and WRs are identified and included in the set of dependent/outcome variables, another analytical approach, such as a canonical correlation analysis that allows for examining the relationship between 2 sets of multiple variables (i.e., more than 1 dependent/outcome variable and more than 1 independent/predictor

variable), may shed light on the predictive value of the Combine measures that were not manifested in this study. The NFL Scouting Combine also conducts drills for position-specific skills that should also be important for football players. In addition, the NFL teams review medical history and perform physical examination of players during the Combine (2). However, to the best of our knowledge, the results on position-specific drills of the NFL Combine, and those of medical history and physical examination, are not readily available in the public domain; therefore, we were unable to include these data in the analysis. Combining position-specific skills and/or injury risk with athletic measures in the data analysis might better be able to predict future success of football players in the NFL.

Practical Applications

This study indicates that the NFL Scouting Combine has some value for predicting future success of RBs and WRs in the NFL. The Combine data could be used to supplement the evaluation of college football players. Specifically, performance on *10-Y* and *VJ* may be used to predict future performance for RBs and WRs, respectively. Still, the Combine measures cannot explain a large part of variability in future performance of RBs and WRs. Hence, team executives, coaches, and scouts need to be cautious about using the Combine measures for selecting players for the NFL Draft. One approach to potentially improve the predictive value of the NFL Combine is to add tests that are not currently included in the Combine items, but that could be important for football players, such as visual response/reaction tests for RBs and hand coordination tests for WRs. Another approach could be to tailor the Combine test items specific to each position. For instance, *BP* performance does not seem to have a significant value for predicting future success of RBs or WRs. Eliminating the *BP* test for these positions could help the NFL teams save time and hence focus more on measuring other variables that are more relevant to the skill sets of these positions. We believe that it is also important to consider the overall physicality of players. For example, *HT* was found to be the most important predictor of *Y/R* in WRs. As WRs are getting taller and bigger, "how high WRs can reach" (i.e., taller players have an advantage) and "how much WRs can jump" is critical in catching the football. Therefore, it might be necessary to combine *HT* and *VJ* together in a future analysis of the Combine data. Future studies could be conducted to determine the usefulness of the NFL Scouting Combine for player evaluation when position-specific skills and/or injury risk are taken into account in the analysis. Moreover, the associations of the Combine measures to the future success of players in other positions would be of interest to investigate in the future.

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