CONTACT TIME, FLIGHT TIME AND GROUND REACTION FORCES DURING A CONTROLLED RUNNING TRIAL OF ELITE AMERICAN FOOTBALL PLAYERS

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Running speed is influenced by vertical ground reaction force (vGRF) application, foot-ground contact time (T_c), flight time (T_F), and time taken to reposition the limbs in swing. The purpose of this study was to investigate running speed modulators in two groups of elite American football players [Skill (i.e. wide receivers, defensive backs, n=8) and Big Skill (i.e. linebackers, tight ends, n=8)]. Subjects ran at 6.5 m/s for 5 s on an instrumented treadmill. Peak vGRF, T_c and T_F were examined for overall associations and compared between groups. T_c was strongly associated with vGRF, $p<0.001$. Big Skill had larger absolute vGRF, $p=0.012$ than Skill. Skill players had larger T_F, smaller T_C, and smaller relative vGRF, although not significant. Elite American football players apply large forces over long foot-ground contact time during a controlled run.

KEY WORDS: speed mechanics, acceleration, kinetics

INTRODUCTION: Speed running is integral to the game of American football. Players across multiple positions are required to run at high velocities in situations that directly influence the outcome of the game. For example, during a pass play, a player from the opposing team will run to tackle the receiver or intercept the ball. These bouts are typically only 15-20 yds (13.7-18.3 m) with receivers running longer distances and lineman running shorter distances. While players will rarely achieve their top speed during a game, the ability to accelerate in the run is paramount. When summarizing almost two decades of physiological and biomechanical investigations, Weyand (2017) identified ground contact time (T_c) and flight time (T_F), vertical ground reaction force (vGRF), and limb acceleration during the swing phase as the modulators of top sprint performance in runners. Once out of the acceleration phase, faster runners will apply greater forces in shorter periods. Consequently, maximal speed in runners is largely explained by the maximum forces applied to the ground in relation to body mass (Weyand et al., 2010). Elite rugby players have been reported to achieve top speed (8.98$\pm$0.52 m/s) during a 50 m run by decreasing T_c (Barr, Sheppard, & Newton, 2013), but kinetics were not examined. Lockie and colleagues (2013) studied acceleration phase (0 to 10 m) kinematics in field sport athletes and found contact time predicted run velocity, but kinetics were also not examined. With limited data on kinetics of running in American football players, it is not as clear how players apply force and manage T_c and T_F for the shorter duration, sub-maximal running inherent to their sport. Top performers in the running events at the National Football League's (NFL) combine are usually the "Skill" players such as running backs, wide receivers and defensive backs (http://www.nfl.com/combine/tracker). But, "Big Skill" players such as linebackers, tight tends and fullbacks must also demonstrate speed. Therefore, the purpose of this study was to describe temporal and kinetic variables of sub-maximal controlled running of elite American football players. Further, we sought to examine differences in T_c, T_F, and peak vGRF between "Skill" vs. "Big Skill" players.

METHODS: Sixteen adult males (age, 22.7 ± 0.8 yrs; 1.87 ± 0.05 m; 99.4 ± 8.3 kg) undergoing specialized training at an off-campus performance center for the NFL combine volunteered for this study. All participants had just completed their collegiate football season and were active players training 5-6x per week. They were stratified into two groups based upon their playing position, Skill (i.e. wide receivers, defensive backs, n=8) and Big Skill (i.e. linebackers, tight ends, n=8). The University's Institutional Review Board approved the study, and subjects provided written informed consent. Data were collected over two days with each athlete reporting to one testing session. This study was part of a larger study monitoring pre-post changes in vertical and drop jumping, running mechanics, and bone density over the duration of the 7-week training camp. All participants underwent a standardized 25 min warm-up, consisting of dynamic stretching, muscle readiness and reactivity exercises designed for jumping and running activities. Participants immediately began testing post warm-up. A controlled sub-maximal running trial took place on an instrumented split belt treadmill (Bertec, Columbus, OH, USA). The treadmill belts were set at 6.5 m/s while the subject stood on the treadmill platform straddling the moving belts. Once the belts had reached the 6.5 m/s, subjects transferred their weight onto the moving belt holding the handrails adjacent to the treadmill and fixed at waist height. Subjects were instructed to take as many handrail-assisted steps as desired prior to release, and to look straight ahead (vs. down at the treadmill) during the test. Once the subjects released grip from the handrails, data were collected at 1000 Hz for five seconds. This time was selected to mimic most 40 yd (36.6 m) dash performances at the NFL combine. Subjects then transferred their weight back to a straddle position, and then the treadmill belt was decelerated to a stop (Figure 1). All trials were post-processed with a low pass Butterworth filter with a cut-off frequency of 40Hz. Data presented represent the average of two consecutive right leg steps. Steps where the subject's foot was not completely on the appropriate belt (i.e. right foot contacted left side belt) were omitted from the analysis. The variables of interest were defined as follows: (a) *ground reaction force (vGRF)* was the peak vertical ground reaction force [body weights (BW)] during the step, (b) *ground contact time* (T_C) was a measure of continuous foot-ground contact time (sec) with the treadmill when the vGRF exceeded 40N, and (c) *flight time* (T_F) was a measure of time (sec) that elapsed between the end of one foot-ground contact and the next.

Figure 1. Subject completing 5s run at 6.5 m/s on the instrumented treadmill.

Data were transferred to a customized Excel file to extract the dependent variables. Statistics Package for Social Sciences (ver. 25; IBM Corporation, New York, NY, USA) was used for statistical analyses. Pearson's correlation coefficients were calculated to determine associations between T_c, T_F, vGRF (N) and vGRF (BW) for all subjects. Independent Samples T-tests were used to determine differences in the dependent variables between the two position groups (Skill and Big Skill). Statistical significance for all tests was determined as $p<0.05$. Correlation strength was determined according to Hinkle, Wiersma, and Jurs (2003) and is as follows: 0.90 to 1.00 (-0.90 to -1.00) as very high, 0.70 to 0.90 (-0.70 to -0.90) as high, 0.50 to 0.70 (-0.50 to -0.70) as moderate, 0.30 to 0.50 (-0.30 to -0.50) as low, and 0.00 to 0.30 (0.00 to −0.30) as negligible.

RESULTS AND DISCUSSION: Table 1 presents the associations between T_c, T_F, and vGRF for all subjects. There were significant, positive, high correlations between T_c and absolute vGRF (r = 0.791, p < 0.001) and between T_C and relative vGRF (r = 0.839, p < 0.001). Subjects with longer Tc had higher peak vGRF during the treadmill run. Table 2 presents the means for T_c, T_F, and vGRF between the two position groups.

Table 1. Correlations between Contact Time, Flight Time, and Ground Reaction Forces for All Football Players (N=16).

Variable	T_C (s)	T_F (s)	vGRF (N)	vGRF (BW)
T_C (sec)	1	0.178	0.791*	0.839
T_F (sec)	0.178	1	0.082	0.116
vGRF (N)	0.791*	0.082	1	0.866*
vGRF (BW)	0.839*	0.116	0.866*	1

Note: * denotes statistically significant correlation, $p \leq 0.05$.

Table 2. Mean Contact Time, Flight Time and Ground Reaction Forces For Skill and Big Skill Players.

Variable	Skill (n=8)	Big Skill (n=8)	p value
T_C (sec)	0.448 $\pm$ 0.056	0.474 $\pm$ .046	0.336
T_F (sec)	0.115 $\pm$ 0.027	0.108 $\pm$ .037	0.658
vGRF (N)	1405.1 $\pm$ 227.7	1710.3 $\pm$ 193.1	0.012*
vGRF (BW)	1.55 + 0.23	1.64 + 0.14	0.371

Note: * denotes statistically significant difference, $p \leq 0.05$.

The purpose of this study was to describe temporal and kinetic variables of sub-maximal controlled running of an elite group of American football players. A secondary purpose was to examine differences in Tc, TF, and peak vGRF between "Skill" vs. "Big Skill" players. We sought to determine the relationship between T_c, T_F, and vGRF as well as identify differences in the dependent variables between Skill and Big Skill players. Results showed that there was a high, positive association between T_C and peak vGRF, whether expressed in absolute or relative terms, during the controlled running bout. Unexpectedly, we found that time spent during ground-contact increased as force applied to the ground increased. T_c is a relevant performance variable in running, as it is the only period when large amounts of muscle force are generated and transmitted to the support surface. In other studies of runners, shorter T_C has been associated with faster running time and greater force application (Paavolainen, Nummela, Rusko, & Häkkinen, 1999; Weyand, Sternlight, Bellizzi, & Wright, 2010). T_C in competitive sprinting is typically .100 to .250 sec, depending upon speed. Moir, Sanders, Button and Glaister (2007) reported contact times of 0.128 to 0.154 s during the first 3 strides of 20m sprints in male soccer, basketball and rugby players. T_C in the present study was notably longer at 0.461 s. The longer T_c in this study is concerning but may have been affected by the heavier mass of this group of subjects vs. previous research, the controlled speed at which the subjects ran (6.5 m/s), the method of determining T_C from kinetics (some previously cited studied used kinematics), or the familiarity with controlled running on an instrumented treadmill. Regarding the latter, American football players, many times run when already in motion or in lateral directions; they also can manipulate stride length on the field. Stride length has been positively associated with short distance running (0 to 20 m) in similar field sport athletes (Lockie, Murphy, Jeffries, & Callaghan, 2013). T_F of 0.112 s in the present study was in agreement with previously reported values ranging from 0.093-0.132 s in international rugby players (Barr, Sheppard & Newton, 2013) and elite junior sprinters (Manzer, Mattes & Hollander, 2016), and the recommended T_F of 0.12 s to achieve limb repositioning during the swing phase (Weyand, Sandell, Prime & Bundle, 2010). Big Skill (i.e. linebackers, tight ends) had higher relative vGRF than Skill (i.e. wide receivers, defensive backs). Absolute vGRF was the only statistically significant difference between the heavier mass Big Skill and lighter mass Skill groups, and was expected. While, not statistically different, Skill players who are known for their outstanding speed on the field, had shorter T_C than Big Skill players, as expected.

CONCLUSION: This study resulted in sport-specific findings during a sub-maximal controlled running trial by elite American football players. Foot-ground contact time and peak forces applied to the ground were positively associated in this group. This is counter to post-acceleration phase running in sprinters. Big Skill players, who were heavier, applied greater absolute and relative vertical forces during the run than Skill players. Further research will continue to analyze the modulators of running in elite American football players in a controlled laboratory setting in order to analyze athletes.

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