ORIGINAL ARTICLE

Are there differences in maximal isometric force and rapid force characteristics in Division II American collegiate football players?

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ABSTRACT

The aim of this study was to see if maximal isometric force characteristics could discriminate positional groupings in division II American college football players. Methods: Thirty-eight male collegiate athletes (mean ± SD: age 20.37 ± 1.62 years, height 185.37 ± 5.04 cm, and weight 101.89 ± 20.13 kg) performed maximal isometric mid-thigh pulls. Peak force, time-specific force, and rate of force development was calculated from a force-time curve. A one-way ANOVA with Bonferroni post-hoc adjustments was used to examine position differences between Line (n = 16), Large Skill (n = 9), and Small Skill (n = 13) position groups with α priori set at $p < .05$. Results: There was a significant difference for peak force, where OD/L and LS had greater PF compared to SS ($p \leq .001$ – .026), additionally, OD/L had greater PF than LS ($p = .022$). Time-specific force-time curve forces (PF50ms–PF250ms) reported greater forces for OD/L and LS compared to SS ($p \leq .001$ – .036), and PF150 was greater for OD/L compared to LS ($p = .047$). For RFD, LS had greater RFD compared to SS and OD/L for RFD 0-50ms ($p = .005$ – .020). Conclusion: These findings suggest the importance of assessing time-specific forces, and RFD phases from isometric force-time curves with American football players. Coaches and strength staff may refer to these findings when designing conditioning programs for collegiate football players.
Keywords: Performance analysis, Rapid strength, Rapid force, Force-Time curve.

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INTRODUCTION

Athletic performance can vary depending on sport, however, for American football athletes, a multitude of abilities are required for success (Black & Roundy, 1994; Burke et al., 1980; Fry & Kraemer, 1991; Fry et al., 1991; Secora et al., 2004). For example, it is suggested that American football players should strength train and condition their bodies to be able to achieve optimal aerobic fitness, muscular endurance, upper and lower body muscular strength and power, maximal sprinting and agility performance (Black & Roundy, 1994; Fry & Kraemer, 1991; Garstecki et al., 2004; Mann et al., 2016). While possessing said characteristics for athletic performance are important, when using force plates, Merrigan et al., (2022) reported specific countermovement jump outcomes between different positions on the team. Specifically, skill and hybrid players reported greater jump height, braking and propulsive forces/power, and modified reactive strength index compared to other positions. Further, lineman created the greatest absolute forces but were slower (time wise) during jumping attempts. Although dynamic training can be beneficial for athletes (bench press, squat, power clean, sprint and agility training), the ability to assess isometric strength (dynamometer, load cell, force plates) can provide both reliable and in-depth analyses (Christ et al., 1994; Comfort et al., 2019; Thompson, Ryan, Sobolewski, Smith, Conchola, et al., 2013). Specifically, analysis of an isometric force-time curve (time-specific and rate of force development across a phase of time) enables researchers the ability to assess a multitude of variables that are important, i.e., maximum force, rate of force development, early and late RFD (Aagaard et al., 2002; Andersen & Aagaard, 2006; Andersen et al., 2010). For example, it typically takes (>300 milliseconds) to achieve maximal strength when performing an isometric contraction (Aagaard et al., 2002; Andersen et al., 2010), however, early rapid force/strength (<100 ms) and late force/strength (>200 ms) can directly tie back to muscle fibre type, and neural properties (Andersen & Aagaard, 2006).

While a handful of studies have assessed American football players on isometric strength (Johnson et al., 2025; McGuigan & Winchester, 2008; Thompson, Ryan, Sobolewski, Smith, Conchola, et al., 2013), previous literature either assessed starters (Johnson et al., 2025), starters vs. non-starters (Thompson, Ryan, Sobolewski, Smith, Conchola, et al., 2013), or attempted to see if weight room strength and the IMTP correlated (McGuigan & Winchester, 2008). Additionally, while able to differentiate athletic status (starter vs. non-starter), Thompson et al. (2013) assessed quadriceps and hamstrings (individually), using an isokinetic dynamometer. While their findings are unique (hamstring early RFD was greater for starters compared to non-starters), assessing athletes from a multi-joint position (isometric mid-thigh pull), can depict greater specificity to sport, rather than maximum voluntary isometric contractions from an isokinetic dynamometer. Further, using force plates enables researchers the ability to perform field-based tests rather than lab-based testing, potentially allowing for greater participation rates within the team, and faster data collection sessions. Based on limited research investigating maximal and rapid isometric force characteristics as a tool to predict positional football playing ability, further research is needed. We hypothesized that peak force, time-specific areas of the force-time curve, and RFD phases would be different between the positions due to positional movements and requirements within the sport. Therefore, the purpose of the present study, was to assess positional groupings (skill, big skill, and line) for PF, PF at time-specific areas, and rate of force development during different phases of the force-time curve.

METHODS

Participants

Thirty-eight male collegiate athletes (mean ± *SD:* age 20.37 ± 1.62 years, height 185.37 ± 5.04 cm, and weight 101.89 ± 20.13 kg) volunteered to participate in the study. All participants were on roster with a division

II American collegiate football team, free of musculoskeletal injuries and had been participating in a structured off-season strength and conditioning program. All participants signed consent forms, which were approved from the Universities Institutional Review Board (2024-114).

Research design

Participants were assessed during their morning training sessions (0900 – 1400 hours) during phase 1 of off-season training in which athletes were not participating in on-field football practices. For each participant, testing was completed within one day in the following order: height and weight, and muscular strength. All assessments occurred after the participants completed an organized workout from the strength coach; no lower-extremity exercises were performed on the day of assessments.

IMTP testing protocol

All IMTP assessments were conducted on a Hawkin Dynamics force plate system (5th Generation; Westbrook, Maine, USA) with a sampling frequency of 1,000 Hz. The IMTP attempts were assessed using the testing protocols recommended by Comfort et al. (Comfort et al., 2019). Specifically, participants positioned themselves on the force plates where knee angle (125° - 145°) was confirmed using a goniometer. The lifting rack and placement of the bar was assessed and properly placed for each participant at a height that replicated the start of the second phase of a clean (Comfort et al., 2019). A standard 45lb. barbell (Legend Fitness Olympic Barbell, Knoxville, TN, USA) was positioned underneath safety racks secured to a weight rack (Legend Fitness, Knoxville, TN, USA).

For each IMTP attempt, the participant began by taking all the slack out of the barbell stoppers and leaving the body positioned in a locked manner. The test administrator began a three second countdown for the athlete. Once the participant began the pull, the administrator used verbal encouragement throughout the effort "*pull, pull, pull….*" During the IMPT attempts, participants were encouraged to pull as hard and fast as possible, the pull lasted approximately three seconds, and the participant was informed of when the test was completed. Three minutes of rest was allowed between each trial of the IMTP, with three total trials completed. If errors occurred within the testing protocol, an additional trial was completed for correct data results. All participants were able to complete their IMPT testing within 5 attempts.

Statistical analysis

Descriptive statistics, means and standard deviations were calculated for each variable. A one-way ANOVA with Bonferroni post-hoc adjustments was used to examine the group-specific positions OD/L (Line) (n = 16), LS (Large skill), (n = 9), and SS (Small Skill) (n = 13) for all dependent variables (PF, PF50 ms-PF250 ms, and RFD50 ms-RFD250 ms). The highest IMPT attempt per participant was used for statistical analysis. Statistical analyses were performed using PASW software version 28.0 (SPSS Inc, Chicago, IL, USA), and an alpha level of $p \leq .05$ was used to determine statistical significance.

RESULTS

Descriptive demographic information is expressed in Table 1.

Force

There was a significant difference for PF ($p \leq .001$; $\eta_p^2 = 0.540$), PF50 ($p \leq .001$; $\eta_p^2 = 0.503$), PF100 ($p \leq .001$; $\eta_p^2 = 0.398$), PF150 ($p \leq .001$; $\eta_p^2 = 0.500$), PF200 ($p \leq .001$; $\eta_p^2 = 0.500$), and PF250, ($p \leq .001$; $\eta_p^2 = 0.469$). Post-hoc analysis revealed OD/L and LS had greater PF compared to SS ($p \leq .001$ – .026), additionally, OD/L had greater PF compared to LS ($p = .022$). Significant differences for PF50-PF250 were seen where greater force was seen for OD/L and LS compared to SS ($p \leq .001$ – .036), and PF150 was greater for OD/L compared to LS ($p = .047$).

Rate of force development

There was a significant difference for RFD 0-50ms (p = .004, η_p^2 = 0.267), while no differences were seen for any other RFD metrics (p = .061 – .252). For RFD 0-50 ms, post-hoc analysis revealed LS had greater RFD compared to SS and OD/L (p = .005 – .020).

Table 1. Mean and standard deviations (SD) demographic data of positions.

	Line (n = 16)		**Big skill (n = 9)**		**Skill (n = 13)**		***p*-value**
	Mean	SD	Mean	SD	Mean	SD	
Age (yrs)	20.25	1.24	21.11	2.03	20.00	1.68	.271
Height (cm)	188.43	3.15	185.71	4.22	181.38	4.93	<.001*‡
Weight (kg)	121.00	11.15	99.07	9.20	80.33	6.38	<.001*‡†
Academic Class	1.88	0.89	2.78	1.20	1.85	1.28	.079

*Note. *Significantly greater (line vs. skill), ‡ Significantly greater (line vs. big skill), ‡ † Significantly greater (big skill vs. skill).*

DISCUSSION

Findings from the present study showed dissimilar force and rate of force development outcomes within a cohort of DII NCAA collegiate football players (grouped by position type). Significant differences were seen for all isometric force variables throughout a force time curve (Peak Force, PF50 ms, PF100 ms, PF150 ms, PF200 ms and PF250 ms) for OD/L and large skill compared to small skill players (Table 2), peak force and peak force at 150ms was greater for line compared to large skill athletes. When assessing rate of force development, large skill players possessed greater RFD 0-50 ms vs. line and small skill players (Table 3).

Table 2. Absolute Force mean (SD) maximum force (N) values for all time-specific time points for IMTP for all grouped positions.

	Peak force	**PF50**	**PF100**
Line	3546.13 ± 416.65	2278.44 ± 294.48	2674.88 ± 458.46
Big skill	3111.89 ± 327.84†	2322.33 ± 331.91	2664.56 ± 344.15
Skill	2668.31 ± 322.93*‡	1730.00 ± 208.20*‡	2049.77 ± 273.24*‡
	PF150	**PF200**	**PF250**
Line	2870.69 ± 377.96	2914.19 ± 287.46	2959.38 ± 367.67
Big skill	2550.22 ± 213.00†	2749.44 ± 366.09	2764.00 ± 328.62
Skill	2202.85 ± 241.11*‡	2269.38 ± 254.93*‡	2294.31 ± 254.69*‡

*Note. *Significantly greater (line vs. skill), † Significantly greater (line vs. big skill), ‡ † Significantly greater (big skill vs. skill).*

Table 3. Mean (SD) rate of force development (N.s-1) values for all time phases for IMTP for all grouped positions.

	RFD 0-50 ms	**RFD 0-100 ms**	**RFD 0-150 ms**
Line	9775.00 ± 4358.77∞	8851.88 ± 3984.13	7206.75 ± 2514.91
Big skill	15140.00 ± 6093.54	10992.22 ± 3281.36	6565.81 ± 1239.62
Skill	8466.15 ± 3162.79‡	7430.77 ± 2310.89	5974.31 ± 1478.96
	RFD 0-200 ms	**RFD 0-250 ms**	
Line	5622.50 ± 1481.01	4678.75 ± 1340.84	
Big skill	5920.56 ± 1638.96	4814.67 ± 1192.77	
Skill	4813.46 ± 1134.97	3950.46 ± 893.72	

Note. ∞ Significantly greater (big skill vs. line), ‡ Significantly greater (big skill vs. skill).

Peak force

Although PF is a common metric for discriminatory purposes (starter vs. non-starter) and sporting type (football, cyclists, rugby) (Johnson et al., 2025; McGuigan & Winchester, 2008; Thompson, Ryan, Sobolewski, Smith, Conchola, et al., 2013; Wang et al., 2016; West et al., 2011; Wilson & Murphy, 1995), findings from the present study observed significant differences for PF relating to positional grouping, where OD/L and LS players had greater PF compared to SS players. Additionally, PF was greater for OD/L compared to LS players. The present findings allows for one direct comparison (football groupings) where Johnson et al., (2025) reported no significant differences for PF between any of the positional groupings. These differences could be related to the overall sample size (16 vs. 38) dissimilar sample within each grouping (3 OD/L, 6 LS, 9 SS) vs. (16 OD/L, 9 LS, 13 SS), and status (starters vs. all athletes). Additionally, maximal IMTP testing protocols could also relate to the differences in findings (15-20 seconds of rest between attempts vs. 3 minutes rest). Be that as it may, there is a paucity of literature to compare the present IMTP findings to American football players (Johnson et al., 2025; McGuigan & Winchester, 2008), future research may want to assess IMTP with American football athletes across different collegiate levels (I, II, III, NAIA, JUCO), specifically, maximal force and rapid force characteristics, and if there are any differences within or between positions, playing status, etc.

Maximal force at specific time points

The present study observed significant differences for isometric force at specific time points of the force-time curve (PF50 ms, PF100 ms, PF150 ms, PF200 ms and PF250 ms), where OD/L and large skill had greater force compared to small skill players. Interestingly, pertaining to American football, and the IMTP, there is no previous literature that assessed early components of the force time curve (0-100 ms). When comparing the present study to a single joint maximum voluntary contraction Thompson et al., (2013) reported greater hamstring peak torque at 30ms for DI football starters compared to non-starters. While the present study did not assess status (starter vs. non-starter), the ability to produce force, quickly, is important for a multitude of athletic movements (Comfort et al., 2019). Pertaining to later force time curve epochs (i.e. >100 ms), Johnson et al. (2025) reported LS athletes had greater PF250 ms compared to SS players. These findings are somewhat similar, as the present study observed that both OD/L and LS players had greater PF250 ms compared to SS players. As previously mentioned, status (starter vs. entire sample), sample size (16 vs. 38) and IMTP protocol (15-20 seconds of rest between attempts vs. 3 minutes rest) could contribute to the dissimilar findings. Nevertheless, the present findings highlight the importance of being able to explosively apply forces, and to be able to attain the rapid and maximal force over the duration of the isometric contraction. For example, research suggests time specific force output relates to dynamic performance (Dos' Santos et al., 2017). Specifically, Dos' Santos, Jones, et al., (2017) found maximum power clean strength positively correlates with PF100 ms, PF150 ms, PF200 ms and PF250 ms when assessing rowing, soccer, bicycle motocross, and hockey athletes. While the aforementioned study included a variety of sporting types, their findings, coupled with the present study, highlight the importance of athletic performance occurring in a short amount of time (0-250 ms).

Rate of force development

Although a majority of coaching metrics want to assess strength, speed, and other observatory outcomes (Barker et al., 1993; Black & Roundy, 1994; Fry & Kraemer, 1991; Fry et al., 1991; Garstecki et al., 2004), RFD can allow coaches and researchers the ability to see the rate of force over specific durations (RFD 0-300 ms), and what factors may be contributing to the outcomes (skeletal or neural properties) (Aagaard et al., 2002; Andersen & Aagaard, 2006; Andersen et al., 2010). Although RFD, specifically early RFD (0-100 ms) has been shown to discriminate starters vs. non-starters in DI collegiate football players (Thompson, Ryan, Sobolewski, Smith, Conchola, et al., 2013), limited research has assessed RFD within collegiate football players (Johnson et al., 2025; McGuigan & Winchester, 2008; Thompson, Ryan, Sobolewski, Smith, Akehi, et al., 2013; Thompson, Ryan, Sobolewski, Smith, Conchola, et al., 2013). Authors that have assessed RFD with collegiate football players have shown a multitude of outcomes (weight room strength and athletic performance, starter vs. non-starter with early RFD, player groupings and RFD outcomes), however, only one study has looked at force time curve metrics, assessing both early and late RFD (Thompson, Ryan, Sobolewski, Smith, Conchola, et al., 2013), thus, the present study has limited studies to compare to. Nevertheless, when comparing positional groupings (SS, LS, OD/L) Johnson et al. (2025) reported significant differences for RFD 0-250ms, which LS had greater RFD compared to SS and OD/L. These findings are dissimilar to the present study, where RFD differences were only seen for early RFD (RFD 0-50ms), in which LS had greater RFD 0-50ms compared to other positional groupings. Potential differences could be related to sample size (16 vs.38) status (starters vs. non-classified), recovery between attempts (15-20 seconds of rest between attempts vs. 3 minutes rest). While athletic status for collegiate football players comprises a wide range of metrics (strength, speed, power, agility, body composition) it is highly suggested that future research assesses force time metrics (both early and late), with starters vs. non-starters, as well as positional groupings.

Regardless of position, or status (starter vs. non-starter), maximum force throughout a force-time curve can be advantageous for positions on the field and can aid with program design for strength coaches. Future studies may want to assess maximum force, and force time curve characteristics with force plates, and may want to measure said metrics throughout different portions of a season (In, Off, Post, Pre), how force time curve for strength/force is impacted within a competitive season, or pre- and post- testing of a training mesocycle. The present study, and Johnson et al., (Johnson et al., 2025) (both using portable force plates) reported early and overall RFD being higher for LS athletes compared to their cohorts. However, future research is needed over said variables, with other American football players.

CONCLUSION

When assessing said strength and rate of force development by positional grouping (OD/L, LS, SS), differences were seen, specifically where PF was significantly greater for OD/L and LS vs. SS players. Further, OD/L had greater PF than LS players and PF at 150ms was greater for line compared to large skill athletes. When looking at PF across specific time points (PF50-PF250 ms), OD/L and LS players had greater force than SS players. Assessing RFD showed RFD 50 ms was greater for LS compared to OD/L. Findings from the study indicate the importance of assessing strength, and rate of force development from an maximal IMTP contractions while using force plates. This assessment allows for further comprehension of force-time curve metrics, per individuals, or groupings within an athletic team. It also provides insights into the physiological aspects of differing roles and the needs that each possess within their position. Although assessing athletes with force plates would be ideal in all practical settings, this is not a practical purchase for all levels of strength and conditioning professionals. The findings from the current field of research and this study can help to further explain the connection that needs to be made with increasing force and rate of force production in the development, progression, and specificity of training competent athletes for their position needs.

AUTHOR CONTRIBUTIONS

Data curation by E.C., T.R.; formal analysis, E.C., and T.R. Conceptualisation, E.C., T.R. Methodology, E.C., T.R., R.W., A.W., M.N. Investigation - E.C., T.R., R.W., A.W., M.N. Writing—original draft preparation, E.C.

and T.R. Writing—review and editing, T.R., R.W., A.W., and M.N. All authors commented on previous versions of the manuscript. All authors have read and agreed to the published version of the manuscript.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

INSTITUTIONAL REVIEW BOARD STATEMENT

The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board from the University of Central Oklahoma (2024-114, dated 12.05.2024).

INFORMED CONSENT STATEMENT

Informed consent was obtained from all participants involved in the study and their parents/guardians.

DATA AVAILABILITY STATEMENT

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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