"You are Not Wrong about Getting Strong". An Insight into the Impact of Age Group and Level of Competition on Strength in Spanish Football Players.

ABSTRACT

Objective**:* This study aimed to compare the maximum and rapid force production of Spanish football players and explore the differences between age group and level of competition. ***Methods**:* A cross-sectional study was developed to evaluate the peak force (PF), relative PF, and rate of force development over 250ms (RFD_{0-250}) during the isometric mid-thigh pull (IMTP) between groups of football players based on age group (senior vs. junior) and level of competition (national vs. regional). 111 football players performed two IMTP trials on a force plate using a portable isometric rig. Two-way analysis of variance (ANOVA) with Bonferroni posthoc correction was applied, and statistical significance was set up at $p \leq 0.05$. The PF, relative PF, and RFD_{0-250} 0, 25, 50, 75 and 100 percentiles were also calculated and descriptively reported, separated by age group and level of competition. ***Results: The ANOVA revealed a significant main effect of the level of competition for the PF ($p<0.001$), relative PF ($p=0.003$), and RFD_{0-250} ($p<0.001$). There was a significant main effect of age group for the PF ($p<0.001$). There was a significant interaction effect of the age group*level of competition for relative PF ($p=0.014$). National players were stronger than regional players on the PF and RFD_{0-250} ($p<0.001$). Senior were stronger than junior players for the peak force ($p<0.001$). ***Conclusion:*** Maximum and rapid force production are crucial for Spanish football players as they progress in both level of competition and age groups. Practitioners should encourage young football players to prioritize strength development to improve their athletic performance.

Keywords

Soccer, force plates, percentiles, rate of force development, explosive strength.

INTRODUCTION

The evolution of football has led to a sport with many intermittent, high-intensity bouts of exercise, placing demands on both the aerobic and anaerobic systems [1,2]. During a match football players must consistently perform highly demanding motor skills including: sprinting, accelerations, decelerations, jumping and changing direction [1,3,4]. The performance of these motor skills is dictated by the neuromuscular system, which is underpinned by maximum strength levels [5], with recovery between high intensity tasks achieved via aerobic metabolism.

Maximum strength is a key factor in dynamic athletic performance [5]. Stronger players can sprint faster, jump higher, accelerate and decelerate more efficiently, have a better tolerance to workloads, and may present a lower risk of injury than their weaker counterparts [5–7]. The increased performance is likely due to the strong association between maximal and rapid force production [8], with increased relative force resulting in increased acceleration and increased impulse resulting in higher movement velocities. Researchers have also shown that stronger players recover quickly after matches, highlighting the importance of lower-body maximum strength in football players [9]. Therefore, lower-body maximum strength is considered an important physical characteristic of football players and should be of paramount importance to strength and conditioning coaches [3,4].

Muscular strength can be expressed across various conditions that are influenced by external load and the time available to express force, and as a result, several strength qualities exist [10]. Maximum strength is usually evaluated to obtain the potential of players' maximum force-generating capacity [4,10]. Lower-body maximum strength has commonly been evaluated in football players using the one-repetition maximum (1RM) test during the squat exercise [4], permitting strength coaches to effectively monitor changes in lower-body maximum dynamic strength across the season, categorise the players' training level and program training loads (i.e., intensities) using percentages of the 1RM [4,10]. However, although the 1RM test is highly reliable and requires no sophisticated or expensive equipment [11], assessing the 1RM squat in professional football can be perceived as a fatiguing, time-consuming protocol that may impose an increased potential for injury risks in players, since the exercise must be performed with proficient technique [12,13].

An alternative to evaluating the players' lower-body maximum strength is the implementation of the isometric mid-thigh pull (IMTP) test using a force plate. The IMTP test involves a maximum isometric lower-body effort while holding a bar that is set in the mid-thigh position, mimicking the start of the second pull phase of the clean, also known as the "power position" [12,14]. Although it was originally utilised by weightlifters, the test has gained substantial popularity for strength assessment in other sports and research purposes [12,14]. Briefly, Researchers have previously shown that the IMTP test is a safe, simple, and reliable option to evaluate the lower-body maximum force-generating capacity with an associated low measurement error in football players [11,12,15]. A further benefit of the IMTP is the ability to measure rapid force production, such as rate of force development (RFD) over specific epochs, which may be more informative than peak force alone.

The IMTP test has been included in several peer-reviewed studies involving football players [16–18]. For example, the IMTP relative peak force (peak force divided by body mass) has been shown to be highly correlated ($r = 0.76$) with the maximal sprint speed of professional youth football players (under 23 age group) from the English Championship [19]. A large cohort of English Premier League football players from the under 9 to under 21 age groups, were shown to produce higher allometrically scaled peak force in the IMTP test compared with a maturation-matched control group of non-football players [20]. In another study involving a large cohort of football players from English professional academies (league or category not stated), comprised of the under 12 to under 18 age groups, it was reported that absolute IMTP peak force discriminated between pre-, circa- and post-peak height velocity (PHV) groups, whereas relative IMTP peak force was only higher for the post-PHV group compared with the other two groups [18]. Collectively, the results of these studies indicate that lower-body maximum strength may be important for youth football players, develops with player maturation, and relates to their maximal sprint performance. However, researchers have primarily reported peak force and relative peak force, omitting RFD over specific epochs therefore limiting the available information regarding football player's rapid force production capability.

To the authors' knowledge, researchers have not confirmed whether maximum force (i.e., absolute, and relative peak force) and rapid force production (e.g., RFD), measured during the IMTP, may be important to categorise Spanish players of similar cohorts presented in previous studies [18–20]. Furthermore, researchers have not compared IMTP force production across age groups (senior vs. junior) and level of competition (national vs. regional) in Spanish football players. Therefore, the aim of this study was to compare the maximum and rapid force production of football players, measured during the IMTP test, and to explore the differences between age groups, level of competition and its hypothetical interference. It was hypothesised that national level senior players would be stronger than national level junior players and, irrespective of age, national level players would be stronger than regional level players, due to the increased demands of competition. The results of this study will provide greater insight into the force-generating capacity of Spanish football players, which will be useful for practitioners when identifying training priorities for their players.

METHODS

Subjects

An a priori sample size estimation was performed to calculate the sample size for the main effects and interaction of the analysis of variance (ANOVA) using G Power software (version 3.1, Heinrich Heine University, Düsseldorf, Germany); considering moderate effect sizes ($\eta_p^2 = 0.1$, F effect size = 0.33), an α level of 0.05, a statistical power level of 0.8, and 4 groups. The power analysis determined a minimum total sample size of 103 participants with an observed statistical power analysis of 0.8. Participants were 111 football players from four teams from a single Spanish La Liga football club (**Table 1**). Participants were stratified into groups according to their age group (senior vs. junior) and level of competition (national vs. regional). For this study, participants were considered senior players when they finished the academy period (i.e., over 19 years old), while junior players were within a team in the academy ranging from 16 to 19 years old. National and regional players were either senior or junior players competing in national or regional championships, respectively. The national level of competition has a presumably higher level of performance compared with the regional category. Furthermore, players from all teams trained five days per week on the football pitch and had previously been involved in strength training with two sessions per week over the past year. All tests were conducted in the pre-season, during the initial testing week that precedes the physical training preparation for the regular season. All participants and coaches were informed of the risks and benefits of the tests and provided informed consent before participation. Ethical approval was provided by the institutional review board (16_23_RNM_FP). Furthermore, for those under-age participants, informed consent was required from their parents or legal tutors apart from the club. The study conformed to the principles of the World Medical Associations Declaration of Helsinki.

[Table 1]

Design

A cross-sectional and descriptive study was developed to evaluate the force-generating capacity through the peak force, relative peak force, and RFD over 0-250 ms (RFD_{0-250}) during the IMTP, between groups of football players based on age group (senior vs. junior) and players' level of competition (national vs. regional). Participants were tested in their own gym facilities, favouring their ecological environment, during the pre-season, where no intense physical activity was performed for ≥24-hr before the testing session. All testing was conducted in the same hour range (09:00 – 13:00) for each participant, with data gathered over one week.

Testing procedures

The IMTP was performed with a portable isometric rig (Absolute Performance Ltd.). The vertical ground reaction force (vGRF) applied to the whole-body centre of mass during each test was recorded using a wireless dual force plate system with a sample rate of 1000 Hz (Hawkin Dynamics Inc.). The data were automatically low-pass filtered with a 50 Hz cut-off. The Hawkin Dynamics Inc. software (HD app) operates via an Android tablet that connects with the force plate system via Bluetooth and automatically analyses the vGRF (details provided in the next section) before immediately transferring the data via Wi-Fi to the Hawkin Dynamics Inc. cloud server. The force plates were placed on the portable isometric rig on flat, level ground and zeroed before each athlete. The accuracy of Hawkin Dynamics' hardware [21] and software [22] has been validated in previous studies.

The participants performed two to three trials of the IMTP during the pre-season training phase. As a general warm-up, participants performed 5 minutes of stationary cycling at a moderate intensity and after that, they performed exercises for dynamic mobility (bodyweight squats and lunges). Participants were individually adjusted to their best position (i.e., replicating the start of the second pull phase of the clean) to apply force during the IMTP test, ranging from a knee angle of 125-145º and a hip angle of 140-150º, although angles were not tested using a goniometer, following the guidelines and methodological considerations defined by [12]. Before performing the IMTP, participants completed a specific warm-up consisting of one five second isometric effort at 50 and 75% of maximum perceived effort during the IMTP. Participants were required to maintain a constant position throughout the test, keeping an upright trunk throughout the trial [12]. Participants performed two maximal efforts lasting approximately 5 seconds with 1.5 to 2 minutes between trials. During the IMTP, participants used lifting straps to prevent grip strength being a limiting factor [12]. For each test, participants were instructed to have a minimal pre-tension and push as hard and as fast as possible, aiming to push the ground away with the legs by driving the feet into the force plates while simultaneously pulling maximally on the bar and maintaining body posture to ensure a maximal isometric effort [12]. Maximal efforts commenced following the HD app signals of a visual flash and an auditive beep on the tablet which occurred after the players had been weighted for at least 1 s. In real-time, the researcher observed force traces to determine the attainment of a force plateau. Once a stable plateau was observable in the force trace for a period of around 1-2 seconds, the peak force was deemed to have been achieved. Participants completed an additional trial if they lost their posture, had a peak force ≥15% CV between trials (with between-trial force changes reported in real-time in the HD app), performed a countermovement before the start, or a submaximal effort was suspected [12].

Data analysis

The onset of maximal-force production for each trial was identified when the vGRF increased above the baseline force reading by more than 3 standard deviations. The peak force in the IMTP was calculated as the gross maximum force produced during the test (**Figure 1**). The IMTP peak force for each participant was also divided by their body mass to provide a relative score (relative peak force). The body mass was automatically recorded during a "weigh-in" application from the force plates, where participants stood still for one second to average their body weight, which was calculated as the lowest 1 s average of the vGRF during the weigh-in, identified by an optimization loop, and then body mass was calculated by dividing the body weight by the acceleration of gravity (9.81 $m \cdot s^2$). The $RFD_{0\text{-}250}$ (calculated as the average slope of the vertical ground reaction force applied during the isometric test between onset and 250 ms post-onset) was also recorded to better capture the rapid force production capabilities of the football players (**Figure 1**). The average of the two recorded trials was used for the statistical analyses. The inter-repetition coefficient variation (CV) and their associated 95% confidence interval were calculated for all metrics. The inter-repetition %CV was acceptable for the peak and relative peak force 5.6% (95% CI: 3.8 – 10.7), $RFD_{0\text{-}250}$ 6.60% (95% CI: 4.4 – 13.4). No test-retest reliability was applied since researchers have shown excellent test-retest reliability during the IMTP for football players [15].

Statistical analyses

Descriptive characteristics were calculated, and results are presented as means and standard deviations (mean ± SD). Normality was tested for all the variables using Shapiro-Wilk test. Levene's test was used to verify the homogeneity of the variables analysed. The anthropometric variables (height and body mass) and the force-generating capacity variables (peak force, relative peak force and $RFD_{0\text{-}250}$) were analysed according to age group (senior vs. junior) and level of competition (national vs. regional) factors. The interaction between age group and level of competition (age group*level of competition) was also analysed. For this purpose, a two-way ANOVA followed by Bonferroni post-hoc correction was implemented for each variable. Eta partial squared (η_p^2) was used to determine the magnitude of the effect independently of the sample size; η_p^2 has previously been recommended for ANOVA designs [23], and interpreted based on the recommendations of Cohen [24]: small <0.06, medium 0.06-0.14, and large >0.14. Then, if a significant effect was detected, Cohen's d effect size and their associated 95% confidence interval (CI) for pairwise comparison were applied and interpreted based on [25]: trivial <0.2, small $\geq$0.2 <0.6, moderate $\geq$0.6 <1.2, large $\geq$1.2 <2.0, very large $\geq$2.0. The peak force, relative peak force, and $RFD_{0\text{-}250}$ 0, 25, 50, 75 and 100 percentiles were also calculated and descriptively reported, separated by age group and level of competition. All statical tests were performed using JASP (JASP Team, version 0.17.3 [Computer Software], Amsterdam, The Netherlands). Statistical significance was set up at $p \leq 0.05$.

Results

The demographics and anthropometrics descriptive data are presented in **Table 1**. The results of the two-way ANOVA revealed that senior players were moderately heavier than junior players ($F=14.951$, $p<0.001$, $d= 0.739$ [0.347 – 1.131]). There were no other differences ($p > 0.05$) in anthropometrics between players.

The results of the two-way ANOVA with Bonferroni post-hoc correction revealed significant main effect of level of competition for the peak force ($F=13.07$, $p<0.001$), relative peak force ($F = 9.26$, $p=0.003$) and $RFD_{0\text{-}250}$ ($F=12.16$, $p<0.001$) with moderate effect sizes ($\eta_p^2 = 0.080 – 0.109$). There was a significant main effect of age group for the peak force ($F=12.89$, $p<0.001$) with moderate effect sizes ($\eta_p^2 = 0.069 – 0.107$). There was a significant interaction effect of age group*level of competition for relative peak force ($F=6.27$, $p=0.014$) with moderate effect sizes ($\eta_p^2 = 0.06$).

The results of Bonferroni post-hoc analysis revealed that national players were moderately stronger than regional players based on absolute peak force ($p<0.001$; $d = 0.691$ [0.301 – 1.082]), although this was only a small difference when expressed as relative peak force ($p=0.003$; $d = 0.264$ [0.117 – 0.644]). The $RFD_{0\text{-}250}$ was also moderately greater for the national players ($p<0.001$; $d = 0.667$ [0.277 – 1.057]) compared to the regional players. Senior players were moderately stronger than junior players based on absolute peak force ($p<0.001$; $d = 0.686$ [0.296 – 1.077]). Specifically, national and regional senior players were moderately ($d = 1.378$ [0.607 – 2.149]) and largely ($d = 0.914$ [0.159 – 1.669]) stronger than regional junior players, respectively. National junior players were moderately ($d = 0.919$ [0.215 – 1.622]) stronger than regional junior players (**Figure 2A**). National and regional senior players were relatively stronger than regional junior players with moderate effect sizes ($d = 0.845$ [0.101 – 1.594], d = 0.742 [0.007 – 1.491], respectively). National junior players were relatively stronger than regional junior players ($d = 1.061$ [0.350 – 1.771]) (**Figure 2B**). National senior and junior players exhibited higher rapid force production compared to regional junior players with moderate effect sizes ($d = 0.930$ [0.182 – 1.678]) (**Figure 3**). Descriptive percentiles (0, 25, 50, 75 and 100) separated by age group and level of competition are presented in **Table 2**.

[Figure 2]

[Figure 3]

[Table 2]

DISCUSSION

The aim of this study was to compare the maximum and rapid force production of football players, measured during the IMTP test, and to explore the differences between age group and level of competition. The main findings of this study were that: 1) as hypothesised, national level players were stronger than regional players in terms of maximum (i.e., peak force and relative peak force) and rapid force production (i.e., $RFD_{0\text{-}250}$), although this difference was only significantly and meaningfully greater compared to regional level junior players; 2) senior players were stronger than junior players, although this was only significant and meaningful for peak force. Contrary to our hypothesis, there was only an interaction effect for the relative peak force in favour of the national and regional senior players compared to regional junior players. There was no other interaction effect between factors, which may suggest that the development of maximum and rapid force production is important for athletic development if progressing in terms of both level of competition (i.e., national > regional) and age group (i.e., senior > junior) in Spanish football players. The results of this study will be useful for practitioners when identifying training priorities for their players, with the percentile data beneficial for coaches when benchmarking their athlete's performances.

The results of this study demonstrate that national level football players exhibit higher levels of absolute and relative maximal isometric force production, and $RFD_{0\text{-}250}$ than regional level football players, irrespective of whether they are senior or junior players. Such findings highlight the importance of both maximum and rapid force production in football players when playing at higher level of competition. This is unsurprising as Trecorci et al. [26], demonstrated greater sprint and jump performances in elite vs. sub-elite football players, with acceleration in these tasks underpinned by relative maximum force production. However, football players should not solely focus on maximizing their physical attributes. Instead, optimizing these physical attributes is an essential part of the complexity of team sports, characterized by various factors (e.g. technical skills, tactical behaviour, physical capacity) that are critical in determining success [27].

Senior players demonstrated greater absolute and relative peak force compared to junior regional players, although the magnitude of difference decreased once force was ratio scaled (i.e., relative peak force), which is in line with the findings of Morris et al. [18] who observed that increased in body mass, in youth football players, explained much of the higher absolute force production across age groups. Emmonds et al.[17] also reported similar observations in female football players, when divided into maturation offset groups, with more mature players demonstrating progressively higher absolute forces, but with minimal differences in relative peak force. Interestingly, Morris et al.[18] reported that both net impulse and relative net impulse were greater in the more mature football players, similar to the findings in the present study where senior national players demonstrated higher $RFD_{0\text{-}250}$ than junior regional players, although this may also be attributed to the level of competition.

It is important for practitioners to clearly understand that relative force production determines acceleration and that the duration of this acceleration determines movement velocity [5,8,28]. Football players should optimize their relative force production because the ability to rapidly accelerate, reach high speeds, decelerate, and change of direction may increase the chances of performing better with and without the ball during the game. This rationale highlights the importance of training to maximise both maximum and rapid force generation capacity in football players [2]. Note that training for maximum force production generally enhances rapid force production, especially in individuals who are not relatively strong [8,29]. However, Andersen et al. [30] previously reported that early RFD (i.e., RFD ≤100 ms) does not show substantial improvements with heavy strength training and therefore ballistic and plyometric training methods may also prove beneficial as part of a sequential training programme, to permit appropriate emphasis on specific force production characteristics. These results may be explained by the fact that the initial phase of rapid force development (RFD), occurring within the first 100 milliseconds after the onset of muscle contraction, is predominantly governed by neural activation and the muscle intrinsic contractile properties. In contrast, the later phase of RFD, which is commonly labelled beyond 100 milliseconds, appears to be more intimately associated with physiological adaptations that enhance maximal muscle strength such as morphological and structural components (e.g. muscle cross sectional area, muscle-tendon stiffness) [31,32]. As such, it is recommended that researchers determine the effects of different training methods on both early (i.e., ≤100 ms) and late phase (i.e., 150-250 ms) force production characteristics and how these relate to performance in different athletic tasks.

It is important to note that this study is not without limitations. The IMTP alone is not enough to fully understand a player's training needs. However, when used alongside other tests, it can provide valuable information on lower-limb strength and force-time qualities. Researchers should consider including the IMTP as part of a broader strength testing battery that looks at ballistic strength (e.g., CMJ), reactive strength (e.g., drop jump or rebound jump), and maximal dynamic strength (e.g., back squat), when designing a comprehensive training program for athletes [10]. Second, football players' rapid force production was evaluated using the late RFD (i.e., 0-250 ms). This temporal window was selected because assessing the RFD over shorter epochs is less reliable for multi-joint assessments, particularly in the absence of a series of familiarization testing sessions [12,28]. Such multiple familiarization sessions are not always feasible within real-world applied settings, which is the context within which this dataset was collected. Nonetheless, researchers have recommended the evaluation of the RFD over different time intervals ranging up to 300 milliseconds [10,28,31]. Third, football players were assessed in the pre-season, a phase which may represent suboptimal performance levels. It is also noteworthy that a single club was evaluated. Despite fulfilling the power analysis criteria, it is plausible to anticipate that different percentile data might be observed in other clubs with distinct training methodologies. Fourth, despite the football players' lack of previous experience with the IMTP test, they found the approximation series to help them become familiar with it, as players had low variation between trials (peak and relative peak force %CV = 5.6%; RFD_{0-250} 6.60%). This suggests that strength and conditioning coaches can consider using the IMTP not just for highly trained athletes but also as a safe and reliable assessment tool for individuals who are new to resistance training, like youth athletes, due to its simplicity in terms of technique requirements.

PRACTICAL APPLICATIONS

The development of maximum and rapid force production is important for athletic development if progressing in terms of level of competition (i.e., national > regional) and age group (i.e., senior > junior) in Spanish football players. The results of this study will be useful for practitioners when identifying training priorities for their players, with the percentile data beneficial for coaches when benchmarking their athlete's performances. Strength and conditioning coaches should encourage young football players to prioritize strength development to improve their athletic performance.

CONCLUSION

National and senior players were stronger than regional and junior players in terms of maximum (i.e., peak force and relative peak force) and rapid force production (i.e., RFD_{0-250}). There was only an interaction effect for the relative peak force in favour of the national and regional senior players compared to regional junior players. The development of maximum and rapid force production is crucial for the athletic advancement of Spanish football players as they progress in both level of competition (from regional to national) and age group (from junior to senior).

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FIGURE CAPTIONS

Figure 1. An example of the isometric mid-thigh pull test's force trace. **Peak force** represents the highest instantaneous vertical ground reaction force applied during the test. **RFD$_{0\text{-}250}$** is defined as the average slope of the vertical ground reaction force applied during the test between 0 and 250ms.

Figure 2. Raincloud plots of the maximum force production (panel A: peak force, panel B: relative peak force) of players according to age group (senior: panel's left side, junior: panel's right side) and level of competition (x axis). The scatterplots represent the distribution of the individual values. The whisker box represents the distribution and the middle line and bars represent the median, 95% confidence intervals, and SD of the given group. The raincloud plots represent the distributions overlapped of the two groups. PF peak force. *Significantly greater than regional junior players (p<0.001). #Significantly greater than regional junior players (p<0.05).

Figure 3. Raincloud plots of the rapid force production (RFD0-250) of players according to age group (senior: panel's left side, junior: panel's right side) and level of competition (x axis). The scatterplots represent the distribution of the individual values. The whisker box represents the distribution and the middle line and bars represent the median, 95% confidence intervals, and SD of the given group. The raincloud plots represent the distributions overlapped of the two groups. RFD rate of force development. #Significantly greater than regional junior players (p<0.05).

Table 1. Demographic and anthropometric characteristics of the football players

Sample size	25	24	32	30
Age group	Senior	Senior	Junior	Junior
Level of Competition	National	Regional	National	Regional
Age (years)	20.5 ± 1.4	20.3 ± 0.7	18.4 ± 0.6	17.3 ± 0.5
Height (cm)	183 ± 6.5	179 ± 6.6	179 ± 6.7	180 ± 7.3
Body mass (kg)	75.2 ± 6.3*	72.2 ± 7.3*	69.1 ± 5.7	68.2 ± 7.8
Body fat (%)	10,27 ± 0.8	10.40 ± 0.7	10.31 ± 0.9	10.52 ± 1.1

*Senior > junior (p<0.001).

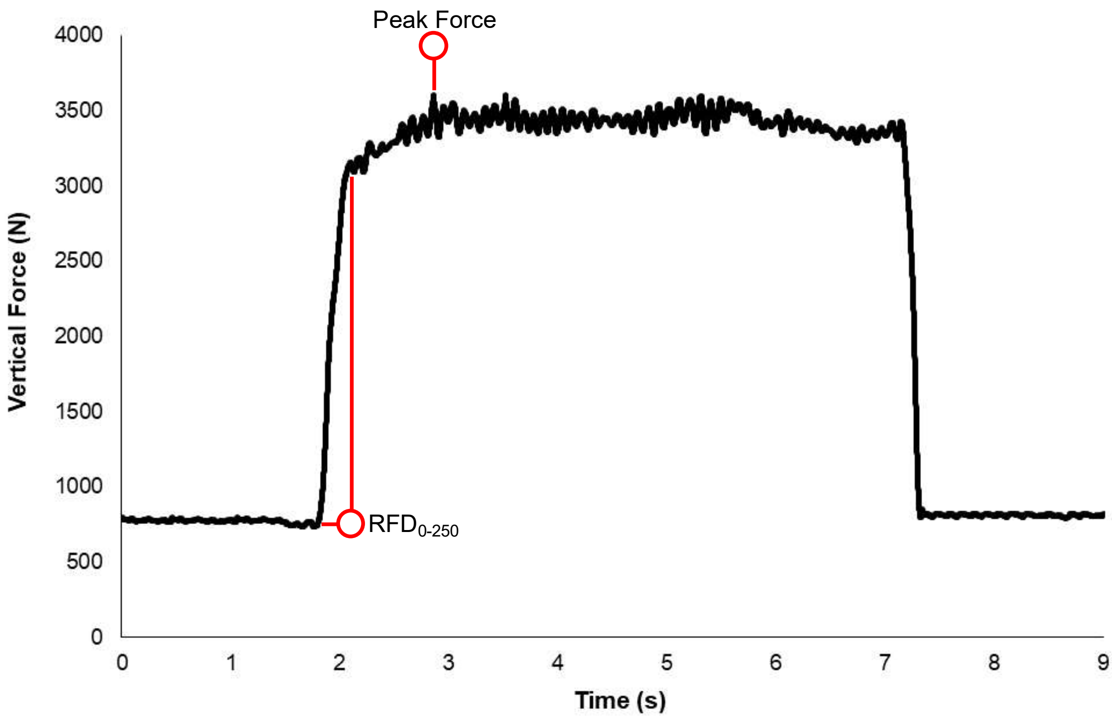

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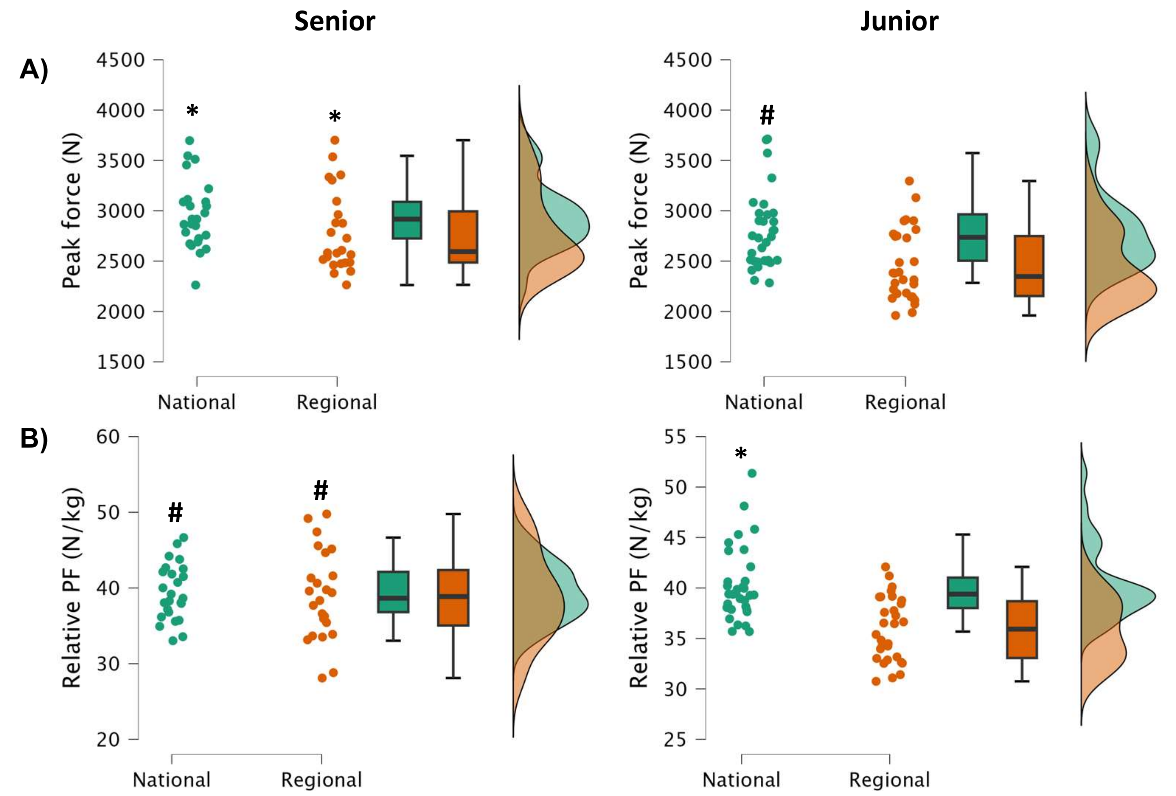
Table 2. Descriptive percentiles for the force-generating capacity of football players

Percentile	Age group	Level of competition	PF (N)	Relative PF (N/kg)	RFD_{0-250} (N/s)
0	Senior	National	2262	33.0	2221
		Regional	2264	28.1	2429
	Junior	National	2284	35.7	2721
		Regional	1960	30.8	1987
25	Senior	National	2725	36.8	4876
		Regional	2486	35.0	3573
	Junior	National	2504	38.0	4394
		Regional	2153	33.1	3534
50	Senior	National	2917	38.6	5171
		Regional	2595	38.9	4005
	Junior	National	2737	39.4	4676
		Regional	2347	35.9	3902
75	Senior	National	3089	42.1	5588
		Regional	2995	42.4	5113
	Junior	National	2965	41.0	5457
		Regional	2749	38.7	4466
100	Senior	National	3698	46.7	6814
		Regional	3702	49.8	7237
	Junior	National	3714	51.4	6387
		Regional	3296	42.1	6603

PF peak force, **RFD** rate of force development.



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*****Significantly greater than regional junior players ($p<0.001$).
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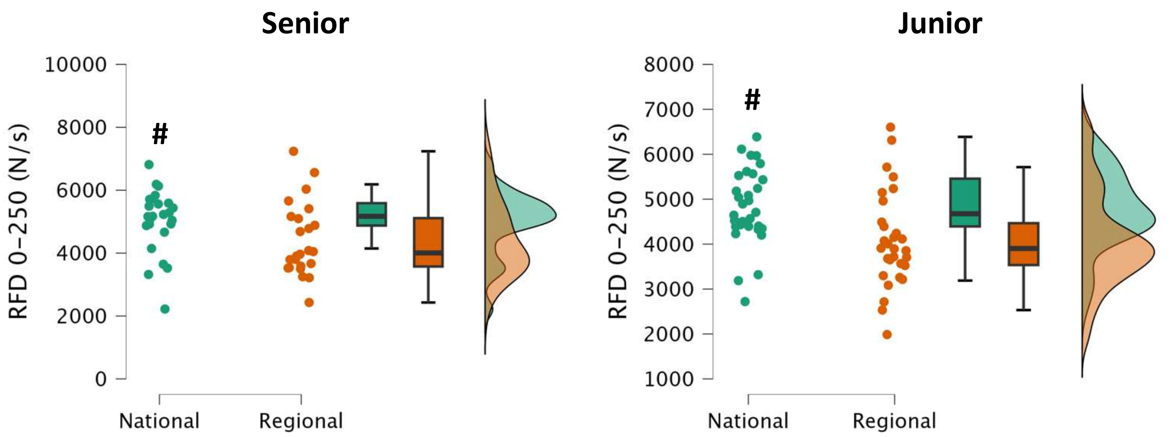

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