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Positional comparison of isometric mid-thigh pull characteristics in youth female netball players

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ABSTRACT

To examine isometric mid-thigh pull (IMTP) characteristics of female youth netball players by position (defenders, centers and shooters). Data were collected on 50 regional youth players and comprised of height and body mass, and IMTP relative force-time characteristics (peak force [PF] and force at 50 [F_{50}], 100 [F_{100}], 150 [F_{150}], 200 [F_{200}] and 250 [F_{250}] milliseconds). These were compared across netball positions via a series of one-way analyses of variance. Centers demonstrated greater F_{50} ($p = 0.025$, [Hedges g] $g = 1.04$), F_{100} ($p = 0.020$, $g = 1.14$), F_{150} ($p = 0.048$, $g = 0.76$) and F_{250} ($p = 0.035$, $g = 0.84$) compared to defenders. No statistical differences ($p > 0.05$) were observed in any IMTP characteristic between defenders and shooters, yet effect sizes revealed practical differences ($g = 0.07$ to 0.85). Similarly, no statistical differences ($p > 0.05$) were observed in any IMTP characteristic between centers and shooters, yet effect sizes revealed practical differences ($g = –0.63$ to 1.21). These findings demonstrate that IMTP force-time characteristics differ between defenders and centers in youth female netball players. Practitioners should consider developing their netball players' peak and rapid force production capabilities, while considering the specific demands on individual positions.

1. Introduction

Success in netball is highly dependent on physical fitness characteristics including strength, power, speed, and agility (Young et al., 2016). To perform consistently throughout the 60-minute game and recover effectively between bouts of high-intensity exercise, netball players must also display a high level of aerobic fitness (Chandler et al., 2014). This has been highlighted in previous work (Chandler et al., 2014), with heart rates reported between 75-85% of the maximum heart rate during match play. Furthermore, match-play analysis reveals center-court players (center, wing attack, wing defense) cover more distance (Davidson & Trewartha, 2008) and accumulate greater Player Load (Cormack et al., 2014; Graham et al., 2020; Young et al., 2016), compared to defenders (goal keeper, goal defense) and shooters (goal attack, goal shooter). These differences are likely due to the differing roles of the positions combined with positional restrictions during play relating to which areas of the court individual players can play in.

Netball players must successfully complete multiple high-intensity short-duration sprints, cutting and pivot maneuvers, and up to 60 jump landings per game (Fox et al., 2012; Fox et al., 2014), all requiring high levels of concentric and eccentric force production to generate high braking and propulsive impulses in as short a time as possible (Mothersole et al., 2013). The literature provides normative data for sprint time (Graham et al., 2019; Thomas et al., 2016; Thomas et al., 2016), change of direction (Barber et al., 2015; Graham et al., 2019; Thomas et al., 2016; Thomas et al., 2016), vertical jump (Graham et al., 2019; Thomas et al., 2016), maximum strength (Thomas et al., 2016), and a range of other characteristics including anthropometric and aerobic capacity measurements (Graham et al., 2019; Thomas et al., 2016). However, very little is known about the maximal isometric force production capabilities (peak and time-specific force) across netball playing positions. Knowledge of maximal isometric force production capabilities of netball players by position would assist coaches and practitioners to prescribe appropriate training programs in line with the position-specific demands shown to exist during training and competition.

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Previously, researchers have shown youth female netball players to demonstrate isometric mid-thigh pull (IMTP) relative peak force values of 26.6 to 30.70 $N \cdot kg^{-1}$ (Dos'Santos et al., 2015; Thomas et al., 2016, 2017). Additionally, the study reported absolute and time-specific IMTP force values to differ between under 15 and under 19 age categories. Specifically, under 19 players produced greater absolute time-specific force values compared to under 15 and under 17 players. Furthermore, small differences in relative peak force and relative time-specific force values were found between age categories, with the exception of relative force at 200 ms, whereby under 19 players demonstrated greater values than both under 15 and under 17 players. Measures of peak force during the IMTP are closely related to performance in dynamic tasks such as sprint speed (Brady et al., 2019), change of direction speed (Brady et al., 2018), and vertical jump performance (Thomas et al., 2016). Furthermore, force at specific time points assessed during the IMTP has been related to sprint (West et al., 2011), jump (West et al., 2011), and dynamic strength measures such as maximal back squat strength (Wang et al., 2016). These findings clearly highlight the importance of maximum strength in female netball athletes. The importance of strength may be explained by the fact that peak ground reaction forces and more importantly, impulse are direct determinants of sprint (Weyand et al., 2000; Weyand et al., 2010), change of direction (Dos'Santos et al., 2019), and vertical jump performance (Kirby et al., 2011). Furthermore, greater levels of maximum strength may improve an athlete's ability to hold static, and achieve dynamic positions such as jumping and landing (Mothersole et al., 2013), sprinting (McBride et al., 2009) and change of direction (Spiteri et al., 2014), providing a greater acceleration, production of higher eccentric forces, thus preparing athletes for the movement demands and injury risks associated with the sport of netball. Additionally, peak force and time-specific force measures derived using the IMTP are shown to be highly reliable (Brady et al., 2018; Comfort et al., 2019; Guppy et al., 2019; Stone et al., 2019). The IMTP also has an acceptably low smallest worthwhile change, making it useful for tracking acute and chronic fatigue, and long-term training adaptations (Brady et al., 2018; Stone et al., 2019).

Most of the existing literature focuses on the physical demands of netball match-play (Chandler et al., 2014; Cormack et al., 2014; Davidson & Trewartha, 2008) and physical characteristics such as sprinting, change of direction and jumping (Graham et al., 2019; Thomas et al., 2016; Thomas et al., 2019). There are currently no normative data available in the published literature regarding position-specific IMTP force-time characteristics in youth female netball players. Additionally, this data can be used for talent identification and creating position-specific benchmarks for maximal isometric strength measures. Therefore, the aim of this study was to determine differences in isometric force-time measures between positions (centers, defenders and shooters) of youth female netball players. Based on previous research on physical characteristics (Graham et al., 2019; Thomas et al., 2019), it was hypothesized that center players would demonstrate superior isometric mid-thigh pull force-time characteristics, as compared with defenders and shooters. It was further hypothesized that defenders and shooters would demonstrate similar maximal and rapid isometric force production characteristics, based on previous work in physical profiling of netball players (Graham et al., 2019; Thomas et al., 2019).

2. Methods

2.1. Participants

Female youth netball players (n = 50; age = 15.57 ± 1.19 years; height = 1.71 ± 0.07 m; mass = 64.35 ± 7.67 kg; maturity offset = 3.00 ± 0.77 years) participated in this study. A priori statistical power calculations, using G*Power (version 3.1.9.7) indicated that for a statistical power of ≥0.90, and effect size of 0.60 at an alpha level of $p \leq 0.05$, a sample size of ≥39 was required. Subjects were all experienced (>2-years, 2–3 x/week) with all elements of resistance training, and all sessions were supervised by qualified (Certified Strength and Conditioning Coach [CSCS] with the National Strength and Conditioning Association and Accredited Strength and Conditioning Coach [ASCC] with the United Kingdom Strength and Conditioning association) strength and conditioning coaches. All subjects were free of injury at the time of testing. All subjects were fully informed of the requirements of the investigation and provided appropriate consent to participate, with consent from the parent or guardian of all players under the age of 18. The investigation was also approved by the institutional review board, in line with the Declaration of Helsinki.

2.2. Procedure

A cross-sectional observational design of a regional female netball youth academy in the United Kingdom was conducted whereby subjects were assessed on height and body mass, and IMTP force-time measures (peak force [PF] and force at 50 [F50], 100 [F100], 150 [F150], 200 [F200] and 250 [F250] milliseconds) normalized to body mass ($N \cdot kg^{-1}$). Subjects were defined into positions by the team coaching staff, thus allowing comparisons between female youth netball players per their position. The positions were classified as: defenders (n = 14; goal keeper and goal defense), centers (n = 22; center, wing attack and wing defense) and shooters (n = 14; goal attack and goal shooter).

On arrival, all subjects had their height (Stadiometer; Seca, Birmingham, United Kingdom) and body mass assessed (Seca Digital Scales, Model 707) while in bare feet, measured to the nearest 0.1 kg and 0.01 m, respectively, and subsequently used to estimate maturity offset (Mirwald et al., 2002). Before testing, subjects performed a standardized warm-up, consisting of 10 body weight squats, 10 forward and 10 reverse lunges, and 5 submaximal countermovement jumps. All subjects rested the day before testing and were asked to attend testing in a fed and hydrated state, similar to their normal practices before training. All subjects were familiar with the tests performed in this study as part of their normal training and monitoring regime, yet further warm-up trials were performed before commencing maximal effort trials, as described below.

2.3. Isometric mid-thigh pull testing

For the IMTP, previously described procedures were used (Comfort et al., 2019). Briefly, using a portable IMTP rig (Fitness Technologies, Perth, Australia), an immovable cold rolled steel bar was positioned at a height that replicated the start of the second pull phase of the clean for each individual, with the bar fixed above the force platform to accommodate subjects of different sizes and proportions. This posture resulted in knee and hip angles of 125.3 ± 6.6° and 143.7 ± 8.4°, respectively (Comfort et al., 2019; Dos' Santos, Thomas, et al., 2017). Each subject performed 3 warm-up trials, one at 50%, one at 75%, and one at 90% of the subject's perceived maximum effort, each separated by 1 minute of rest. Once body position was stabilized (verified by watching the subject and force trace), the subjects were given a countdown of "3, 2, 1, Pull." Any obvious pretension was not permitted before initiation of the pull, with the instruction to pull against the bar "and push the feet into the ground as fast and hard as possible" which has previously been reported to produce optimal testing results (Halperin et al., 2016). Each IMTP trial was performed for approximately 5 seconds, and all subjects were given strong verbal encouragement during each trial. Subjects performed 3 maximal IMTP trials interspersed with 2 minutes of rest between trials.

Vertical ground reaction force data for the IMTP was collected using a portable force platform sampling at 1,000 Hz (9286AA, Kistler Instruments, Winterthur, Switzerland), interfaced with a laptop computer and specialist software (Bioware 3.1; Kistler Instruments) that allows for direct measurement of force-time characteristics. Raw unfiltered, force-time data was exported for subsequent analysis in a bespoke Microsoft Excel spreadsheet (version 2016, Microsoft Corp., Redmond, WA, USA). The maximum forces recorded from the force-time curve during the IMTP trials were reported as PF and subsequently ratio scaled (force / body mass [$N \cdot kg^{-1}$]). The onset of force production was defined as an increase in force greater than 5 SDs of force during the one-second period of quiet standing (Dos' Santos, Jones, et al., 2017), and subsequently force at 50- (F50), 100- (F100), 150- (F150), 200- (F200), and 250 ms (F250) were also determined and ratio scaled ($N \cdot kg^{-1}$). The best performance of the three trials was used for further analysis

2.4. Statistical Approach

Data are presented as either mean ± SD or mean with 95% confidence intervals (95% CI) where specified. Within-session reliability of dependent variables was examined using the intraclass correlation coefficient (ICC), typical error of measurement (TE) and coefficient of variation (CV). The magnitude of the ICC was interpreted as follows: low (<0.30), moderate (0.30–0.49), high (0.50–0.69), very high (0.70–0.89), nearly perfect (0.90–0.99), and perfect (1.0) (Koo & Li, 2016). Normality of data was confirmed by Shapiro–Wilk statistic and Q-Q plot analysis. A series of one-way analysis of variance were conducted to analyse differences in age, height, mass, maturity offset and IMTP force-time characteristics between positions. Where significant differences were found, Bonferroni post-hoc analyses were completed to detect differences between positions. The magnitude of differences between position groups was determined by calculating Hedges g effect size statistics (Hedges & Olkin, 2014), and interpreted as follows: trivial (≤0.19), small (0.20–0.59), moderate (0.60–1.19), large (1.20–1.99), and very large (2.0–4.0) (Hopkins, 2002). All statistical analyses were completed using SPSS (version 23, IBM, New York, NY, USA). An a priori alpha level of $p \leq 0.05$ was used as the criterion for statistical significance.

3. Results

Table 1 shows reliability of all IMTP variables was high to nearly perfect (ICC = 0.68–0.90), with acceptable variability (CV = 6.49–8.94%). Briefly, there were small, nonsignificant differences (g = –0.59 to 0.27, $p = 0.110$) in age between positions, while there was a large, significant difference (g = -1.21, $p = 0.024$) in height between centers and shooters (Table 2). There were small, nonsignificant differences (g = –0.52 to 0.55, $p = 0.147$) in mass between positions, whereas there were trivial to moderate, nonsignificant differences (g = -0.55 to 0.07, $p = 0.393$) in maturity offset between positions.

Table 1: Descriptive statistics and within–session reliability measures for performance measures

Variable	Mean	SD	ICC (95% CI)	TE (95% CI)	%CV (95% CI)
Force at 50 ms ($N \cdot kg^{-1}$)	12.73	1.46	0.68 (0.53–0.80)	0.84 (0.73–1.00)	6.73 (5.80–8.08)
Force at 100 ms ($N \cdot kg^{-1}$)	14.53	1.85	0.70 (0.56–0.81)	1.16 (1.00–1.38)	8.39 (7.22–10.08)
Force at 150 ms ($N \cdot kg^{-1}$)	16.07	1.91	0.75 (0.63–0.84)	1.38 (1.19–1.64)	8.94 (7.70–10.75)
Force at 200 ms ($N \cdot kg^{-1}$)	18.67	2.30	0.82 (0.72–0.89)	1.49 (1.29–1.78)	8.38 (7.22–10.07)
Force at 250 ms ($N \cdot kg^{-1}$)	20.65	2.86	0.84 (0.76–0.90)	1.44 (1.25–1.72)	7.61 (6.55–9.14)
Peak Force ($N \cdot kg^{-1}$)	28.27	7.16	0.90 (0.85–0.94)	1.70 (1.47–2.03)	6.49 (5.59–7.78)

ICC = intraclass correlation coefficient; TE = typical error of measurement; CV = coefficient of variation; CI = confidence interval

The results of post-hoc analysis revealed a moderate, significant difference in F50 (g = -1.04, p = 0.025) between defenders and centers, although moderate nonsignificant differences (g = -0.69, p = 0.123) were observed between defenders and shooters, while small, nonsignificant differences (g = 0.22, p = 0.876) were found between centers and shooters. Moderate, significant differences in F100 (g = -1.14, p = 0.020) were revealed defenders and centers, whereas moderate, yet nonsignificant differences (g = -0.85, p = 0.070) were found between defenders and shooters and trivial, nonsignificant differences (g = 0.14, p = 0.957) were exhibited when comparing centers and shooters. There was a moderate, significant difference in F150 (g = -0.76, p = 0.045) between defenders and centers, yet a moderate, nonsignificant difference (g = 0.63, p = 0.213) between centers and shooters. Small, nonsignificant differences in F150 (g = -0.23, p = 0.787) were found between defenders and shooters.

Post-hoc analysis revealed nonsignificant differences in F200 (p = 0.088) between positions, and these differences were of a moderate effect between defenders and centers (g = -0.78, p = 0.072), and a small effect between both defenders and shooters (g = -0.39, p = 0.494), and centers and shooters (g = 0.45, p = 0.581). A moderate, significant difference in F250 (g = -0.84, p = 0.035) was revealed between defenders and centers, whereas small, nonsignificant differences were found between defenders and shooters (g = -0.54, p = 0.272) and centers and shooters (g = 0.27, p = 0.676). No significant differences in PF (p = 0.204) were revealed between positions, and these differences were of a moderate effect between defenders and centers (g = -0.61, p = 0.329) and small effect between defenders and shooters (g = -0.48, p = 0.210) and a trivial effect between centers and shooters (g = -0.04, p = 0.891).

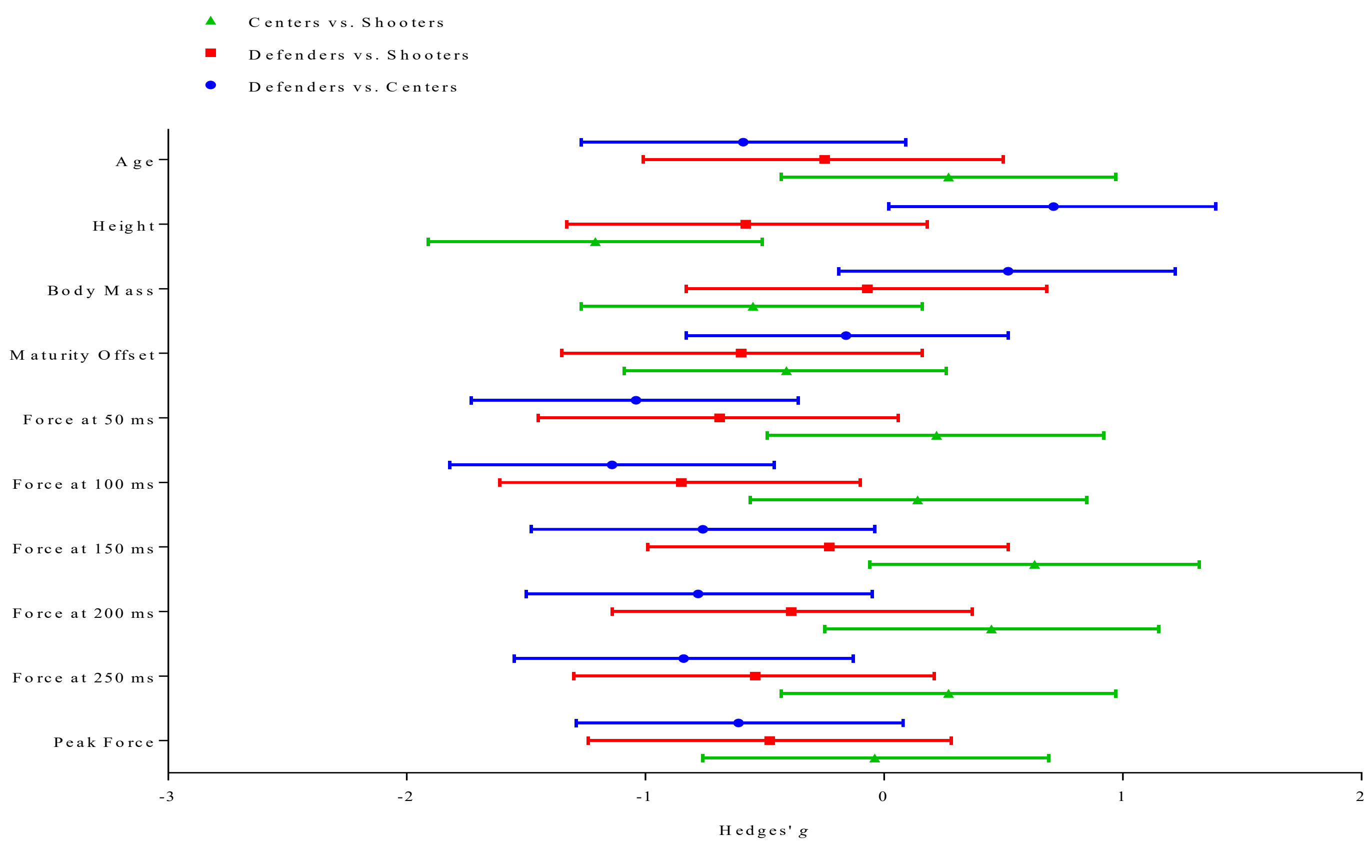

Figure 1: Hedges' g effect size differences in age, height, body mass, maturity offset and maximal isometric force-time characteristics of youth female netball players by playing position

Table 2: Age, height, body mass, maturity offset and maximal isometric force-time characteristics of youth female netball players by playing position

	Defenders (*n* = 14)	**Centers (*n* = 22)**	**Shooters (*n* = 14)**	**Defenders vs. Centers Hedges' *g***	**Defenders vs. Shooters Hedges' *g***	**Centers vs. Shooters Hedges' *g***
Age (years)	15.20 ± 1.05	15.85 ± 1.15	15.52 ± 1.34	-0.59 (-1.27 to 0.09)	-0.25 (-1.01 to 0.50)	0.27 (-0.43 to 0.97)
Height (m)	1.72 ± 0.05	1.68 ± 0.05	1.76 ± 0.07‡	0.71 (0.02 to 1.39)	-0.58 (-1.33 to 0.18)	-1.21 (-1.91 to -0.51)
Body Mass (kg)	65.83 ± 7.77	61.98 ± 5.84	66.61 ± 9.42	0.52 (-0.19 to 1.22)	-0.07 (-0.83 to 0.68)	-0.55 (-1.27 to 0.16)
Maturity Offset (years)	2.82 ± 0.70	2.95 ± 0.78	3.26 ± 0.81	-0.16 (-0.83 to 0.52)	-0.60 (-1.35 to 0.16)	-0.41 (-1.09 to 0.26)
Force at 50 ms ($N \cdot kg^{-1}$)	12.28 ± 1.23	13.66 ± 1.39†	13.35 ± 1.75	-1.04 (-1.73 to -0.36)	-0.69 (-1.45 to 0.06)	0.22 (-0.49 to 0.92)
Force at 100 ms ($N \cdot kg^{-1}$)	13.75 ± 1.70	15.84 ± 1.90†	15.58 ± 2.47	-1.14 (-1.82 to -0.46)	-0.85 (-1.61 to -0.10)	0.14 (-0.56 to 0.85)
Force at 150 ms ($N \cdot kg^{-1}$)	16.44 ± 3.01	18.53 ± 2.36†	16.99 ± 2.35	-0.76 (-1.48 to -0.04)	-0.23 (-0.99 to 0.52)	0.63 (-0.06 to 1.32)
Force at 200 ms ($N \cdot kg^{-1}$)	18.65 ± 3.97	21.31 ± 2.93	19.94 ± 3.15	-0.78 (-1.50 to -0.05)	-0.39 (-1.14 to 0.37)	0.45 (-0.25 to 1.15)
Force at 250 ms ($N \cdot kg^{-1}$)	19.99 ± 3.64	22.82 ± 3.21†	21.96 ± 3.44	-0.84 (-1.55 to -0.13)	-0.54 (-1.30 to 0.21)	0.27 (-0.43 to 0.97)
Peak Force ($N \cdot kg^{-1}$)	26.12 ± 4.05	28.79 ± 4.47	29.58 ± 7.56	-0.61 (-1.29 to 0.08)	-0.48 (-1.24 to 0.28)	-0.04 (-0.76 to 0.69)

†Significantly different ($p < 0.05$) from defenders
‡Significantly different ($p < 0.05$) from centers

4. Discussion

The aim of this study was to evaluate the IMTP force-time characteristics between position groups in youth female netball players. In agreement with our hypothesis, the results of this study indicate that moderate, significant differences in F50, F100, F150, and F250 existed between centers and defenders in youth female netball players. Yet, in contrast to our hypothesis, only trivial-to-moderate, nonsignificant differences in IMTP characteristics were observed between centers and shooters. Furthermore, trivial-to-moderate, nonsignificant differences in IMTP force-time characteristics existed between defenders and shooters. The trivial-to-moderate, nonsignificant differences in maturity offset (~0.5 years) help us to understand differences in maximal isometric force production capabilities between positions are not attributed to maturity. These findings are in agreement with previous research revealing position-specific physical profiles in academy- (Thomas et al., 2019) and state-level netballers (Graham et al., 2019). The current findings add to a growing body of literature on the physical characteristics of youth female netball players, and will serve as a basis for future studies, with the findings used to establish position-specific normative values for monitoring and assessment of youth level netball players.

In this study, center players demonstrated moderately and significantly greater F50 and F100 values compared to defenders, while shooters demonstrated moderate, nonsignificant higher values than defenders (Figure 1). Another important finding was that center players demonstrated moderately and significantly greater F150 values than defenders, and moderate, yet nonsignificant higher values compared to shooters. These findings may be explained by the fact that center players sprint, jump and change direction more often than defenders and shooters (Brooks et al., 2020; Chandler et al., 2014; Cormack et al., 2014; Graham et al., 2020); all of which are reliant upon producing high levels of force in a short period of time (Kirby et al., 2011; Spiteri et al., 2014; Weyand et al., 2010). Similarly, centers have shown to produce superior sprint, jump and change of direction performances compared to both defenders and shooters (Graham et al., 2019; Thomas et al., 2019). Considering a greater physical requirement for the center position, practitioners should allocate periods in their training programs for the development of maximal force to aid the long-term development of netball players and help prepare for the demands of training and competition.

The results of this study found small-to-moderate, nonsignificant differences in F200 amongst playing positions. In contrast, moderate, significant differences in F250 were found between centers and defenders, while small, nonsignificant differences were revealed between both defenders and shooters, and centers and shooters. It is somewhat surprising that no differences were noted in F200, yet differences were evident for F250. For all of the findings within this study it is advised practitioners interpret the data according to both statistical and practical significance. For example, findings which are statistically significant can have little practical meaning and similarly, outcomes that are not statistically significant can be practically or clinically meaningful. Moreover, magnitudes of difference with confidence limits are presented in Figure 1 to acknowledge the fact that not all changes are meaningful, and that some uncertainty always remains (Buchheit, 2017).

Trivial-to-moderate, nonsignificant differences in PF were found between positions. This finding suggests that according to our data, time-specific isometric force time characteristics may be able to better distinguish between netball playing positions, in contrast to peak values. These data must be interpreted with caution because previous studies have shown maximal isometric PF to strongly associate with sprint and change of direction time in youth female netball players (Thomas et al., 2016), while also distinguishing between superior vs. inferior sprint, jump, and change of direction performance in the same study. A recent study by Comfort et al. (2020) found greater changes in early isometric force production compared to PF in male youth soccer players, and this may partly be explained by differences between positions in inter- and intra-muscular coordination (Cormie et al., 2011), yet this was not explored in the current study. It may be that the positional demands of centers, such as increased multidirectional movement, increased player load, greater high-intensity actions and bouts (Brooks et al., 2020; Chandler et al., 2014; Graham et al., 2020), thus have to produce high levels of force in a short time, providing somewhat of a training stimulus in a variety of netball-specific tasks through training and competition. These findings may help us to understand position-specific maximal isometric force production capabilities of youth female netball players and potentially highlight the importance of developing this quality through training.

Another important finding is that, although not significantly different to other positions, shooters demonstrated the greatest PF values. Specifically, shooters revealed lower (small-to-moderate effects) F150, F200 and F250 compared to centers, but then demonstrated trivial ($g = 0.04$) differences to centers in PF values. It may be the case therefore, that there may be a window for further development of time-specific force production capabilities in shooters. This finding may have implications for monitoring maximal isometric force–time characteristics in relation to position-specific sporting movements, to evidence the planning of training drills and assist practitioners in devising periodized training programs.

A limitation of this study is that only one level of netball was examined. Previous research has found differences in physical demands between playing standards, (Cormack et al., 2014); thus, it is unknown whether the results of this study are transferrable to other populations (i.e. the professional or elite level). This study failed to record body composition measures for all subjects, thus it is unknown whether body fat levels may have contributed to differences in maximal and time-specific IMTP force production capabilities. In future investigations, it might be possible to examine the influence of body fat and body mass on IMTP force-time characteristics in youth female netball players. Notwithstanding these limitations, the study suggests that players within the current study were of similar chronological age, training age and status, and maturity status; and thus, can be considered a homogenous cohort.

In conclusion, this study achieved its major aim of identifying differences in the maximal isometric force production capabilities between position groups of youth female netball players.

Practitioners may utilise the results of this study for assisting in the creation of position-specific programs, whilst providing normative data when assessing maximal isometric force production capabilities in this population. In-line with previous studies (Graham et al., 2019; Thomas et al., 2019), the findings of this study indicate that centers exhibit greater maximal isometric force production capabilities compared to other positions. These differences could be attributed to both playing position and an individual's fitness. Such information regarding the maximal isometric force production capabilities of youth female netball players may be used by practitioners to individualize training programs to meet the physical requirements for playing positions. Indeed, center court players may need to complete more position-specific training to ensure they are meeting the demands of the playing position. Practitioners should consider developing their netball player's peak and rapid force production capabilities, while considering the specific demands on individual positions (Graham et al., 2019; Thomas et al., 2019). Further research should identify the importance of maximum strength in youth female netball players so that more specific training recommendations can be provided with regards to this capacity.

Conflict of Interest

The authors declare no conflict of interests.

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