Original Article

Association between vertical and horizontal force-velocity-power profiles in netball players

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ABSTRACT

Netball is a collective sport characterized by intermittent high-intensity actions. Therefore, the players must develop high levels of relative bilateral and unilateral strength and power for both improve performance and also reduce injury risk. The purpose of this study was (i) to provide a reference about the mechanical outputs obtained in the vertical (jumping) and horizontal force-velocity-power (FVP) profile and (ii) observe their relationship, besides the performance in jumping and sprinting in amateur female netball players (age = 24.3 ± 3.2 years, BM = 64.5 ± 5 Kg, height = 172.5 ± 6.2 cm). The variables for both FVP profiles (theoretical maximal force (F_0), theoretical maximal velocity (V_0) and theoretical maximal power output (P_{max})) were measured with two scientifically validated apps for iOS (My Jump 2 and My Sprint). Our results in regards to the vertical FVP suggest that netball players have low force deficit (36.2 ± 14.6%) and individualized training based on F-V profiling could be beneficial to address their deficit. The moderate correlations found for performance, V_0 and P_{max} suggest that the improvement in one of the skills (jumping or sprinting) may produce some positive adaptation to the other. However, no association was found in the force production (F_0) of the lower limbs for both FVP. Therefore, we recommend that netball players must train specifically ballistic actions in the vertical (jumping) and horizontal direction (sprinting) due to the specificity of both skills and the consequent impact of them on netball performance.
Keywords: Force; Velocity; Profile; App; Netball.

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INTRODUCTION

Netball is a collective sport characterized by intermittent high-intensity actions like sprinting, jumping, change of directions (COD), cutting and pivot movements (Fox, Spittle, Otago, & Saunders, 2013; Fox, Spittle, Otago, & Saunders, 2012; Thomas et al., 2019). A needs analysis and training recommendations study suggests that netball players must develop high levels of relative bilateral and unilateral strength and power. This is due to the high amount of ballistic actions that they perform but also to develop good control of the lower limbs and reduce the risk of common injuries (Thomas, Comfort, Jones, & Dos'Santos, 2017).

Several studies have reported a descriptive analysis of netball players or even the umpires of this sport (Spencer, McErlain-Naylor, Paget, & Kilding, 2019). Investigations have reported normative data for physical parameters and physiological characteristics of netball players according to their position (Thomas et al., 2019), level of performance and categories (Sinclair, Coetzee, & Schall, 2020; Thomas, Thomas Ismail, Comfort, Jones, & Dos'Santos, 2016) and even the umpires of this sport. The fitness testing batteries used provide the performance values based on the vertical (jumping) and horizontal (sprinting) application of strength. Interestingly, investigations have suggested that the maximal power output (P_{max}) resultant by the product between force (F_0) and velocity (V_0), is key for jumping and sprinting performance (Morin & Samozino, 2016; Samozino et al., 2016; Samozino, Rejc, Di Prampero, Belli, & Morin, 2012) and moreover, the production of horizontal force during sprinting has been identified as an injury-related factor (Mendiguchia et al., 2016, 2014). However, to the best of our knowledge, no investigations have observed the mechanical variables underlying during sprinting and jumping in netball players.

Validated field methods developed in recent years provide a macroscopic view about the mechanical outputs during jumping (Jiménez-Reyes, Samozino, Pareja-Blanco, et al., 2017; Samozino et al., 2012) and sprinting performance (P. Samozino et al., 2016). These approaches quantify the relationship between force-velocity-power (FVP) spectrum (Morin & Samozino, 2016). Moreover, the vertical FVP allow strength and conditioning coaches the identification of the deficit in either F_0 or V_0 for the optimal production of P_{max}, known as the force-velocity imbalance (F-V_{IMB}) (Jiménez-Reyes, Samozino, Brughelli, & Morin, 2017; Jiménez-Reyes, Samozino, Pareja-Blanco, et al., 2017; J. B. Morin & Samozino, 2016; Pierre Samozino et al., 2012).

The relationship between jumping and sprinting performance (Comfort, Stewart, Bloom, & Clarkson, 2014; Lockie et al., 2014; Randell, Cronin, Keogh, & Gill, 2010), and the vertical and horizontal FVP profiles have been observed in female and male practitioners in a large range of sports (football, basketball, rugby, etc.) and level of practice, however, Netball has not been explored yet in this area (Jiménez-Reyes et al., 2018). The findings showed that the P_{max} and the performance variables (jumping ability and 20m sprint) were the most correlated parameters. Low correlations were found for F_0 and V_0, especially in high level and elite athletes. Therefore, the vertical and horizontal FVP profile provide distinctive information about the maximal mechanical capacities of the lower limbs, and the use of both testing methods is recommended (Jiménez-Reyes et al., 2018). Monitoring the mechanical capabilities during jumping and sprinting ability in netball players may be relevant for strength and conditioning coaches to design training sessions based on F-V profiling, as it has been already addressed in other disciplines (Escobar Álvarez, Fuentes García, Da Conceição, & Jiménez-Reyes, 2019; Jiménez-Reyes, Samozino, Brughelli, et al., 2017; Jiménez-Reyes, Samozino, & Morin, 2019).

Due to the relevance of vertical and horizontal ballistic actions in netball performance (Sinclair et al., 2020; Thomas et al., 2017, 2019), a study observing the mechanical outputs for both FVP profiles and their level of association may be interesting for optimizing training sessions. The first aim of this study was to provide a reference about the variables of the FVP profile during jumping (F_0, V_0, P_{max} and $F\text{-}V_{IMB}$) and sprinting (F_0, V_0, P_{max}, S_{fv}, RF_{max} and D_{rf}) performance. A secondary aim was to investigate the relationship between both FVP mechanical outputs (F_0, V_0 and P_{max}) and performance variables (countermovement jump-CMJ and 20m sprint) in amateur netball players.

METHODS

Participants
Twenty-eight amateur female netball players (age = 24.3 ± 3.2 years, BM = 64.5 ± 5 Kg, height = 172.5 ± 6.2 cm) with more than five years of experience (6 ± 2) participated in this study. All participants completed 4–5 hours of training per week (Tuesday and Thursday) besides competition events during the weekend. All athletes received an explanation of the research, including the risks and benefits of participation. Prior to fitness testing, all players provided informed consent to participate in the study, by way of a structured consent form and PAR-Q. This study was approved by the ethics board at University Centre South Essex in agreement with the Declaration of Helsinki.

Instruments
Participants' body mass (BM) in Kg, and height were measured using a Tanita SC-330 (TANITA Corporation, *Itabashi-ku Tokyo*, Japan), and an aluminium stadiometer (Seca 713 model, Postfach, Germany) respectively.

My Jump 2: It is a scientifically validated smartphone app, based on video-analysis (Balsalobre-Fernández, Glaister, & Lockey, 2015). My Jump 2 provides the information regarding jump height, $F\text{-}V_{IMB}$ (%), F_0 (N/kg), V_0 (m/s) and P_{max} (W/kg), according to Samozino's method (Escobar Álvarez et al., 2019; Jiménez-Reyes et al., 2019; Jiménez-Reyes, Samozino, Pareja-Blanco, et al., 2017; Morin & Samozino, 2016; Samozino et al., 2014).

My Sprint: It is a scientifically validated app for iOS, based on video-analysis (Romero-Franco et al., 2017). My Sprint provides information regarding 40m sprint times and its different splits. Moreover, it also calculates the mechanical variables associated with the horizontal FVP profile such as F_0 (N/kg), V_0 (m/s), P_{max} (W/kg), S_{fv}, RF_{max} and D_{rf} (J. B. Morin & Samozino, 2016; P. Samozino et al., 2014).

Procedures
This study used a descriptive correlational design, which observes the association between the vertical and horizontal mechanical variables for the F-V profile (F_0, V_0 and P_{max}), and performance for CMJ and 20m sprint (5, 10, 15 and 20m).

Subjects met in two sessions for the measurement of the vertical (Thursday) and horizontal (Monday) F-V profile. Both testing-sessions were conducted indoors, on the same court where they usually trained, and all the participants wore their normal netball footwear.

First Session (CMJ performance and Vertical FVP profile)
Players performed a standardized warm-up: 20min jogging, dynamic stretching, range of movement exercises and preparatory CMJs. The F-V profile variables were measured with a field test based on 3 maximal vertical CMJs (highest score was selected for the analysis), using an Olympic barbell with the loads corresponding to 0%, 10%, 20%, 30%, 40%, 50% and 70% of their own body mass (2 minutes' recovery between jumps, and 4 minutes between loads) (Escobar Álvarez et al., 2019; Jiménez-Reyes et al., 2019;

Jiménez-Reyes, Samozino, Pareja-Blanco, et al., 2017; Morin & Samozino, 2016; Samozino et al., 2014; Samozino, Morin, Hintzy, & Belli, 2008; Samozino et al., 2012). CMJ height and the mechanical variables for the F-V profile (F_0, V_0 and P_{max}) were measured using *My Jump 2* on an iPhone device (iPhone 7; Apple, Cupertino, CA, USA) (Balsalobre-Fernández et al., 2015).

Second session (Sprint performance and Horizontal FVP profile)
A 30-minute warm-up was performed prior to completion of three repetitions of a 20m sprint test with 5min. of passive recovery between trials. The same iPhone 7 (iPhone 7; Apple, Cupertino, CA, USA) of the first day of testing was used for the measurement of sprinting performance and estimation of the variables associated with the horizontal P-F-V profile. The smartphone was placed on a tripod 20m from the track (frontal plane) using *My Sprint*, following previous recommendations (Romero-Franco et al., 2017). The best time of the three attempts was selected for the analysis of the split times (5, 10, 15 and 20m) and mechanical properties (F_0, V_0, P_{max}, S_{fv}, RF_{max} and D_{rf}) (Morin & Samozino, 2016; Samozino et al., 2016).

Statistical analysis
All data are presented as mean ± SD with IBM SPSS (IBM SPSS version 26.0; SPSS, Chicago, IL, USA) software. Normal distribution for the variables of the study were assessed with the Shapiro-Wilk test. The associations between the vertical and horizontal mechanical variables for the F-V profile, and performance variables were analysed using a Pearson correlation (level of significance set at $p \leq .05$) and the coefficient of determination (R^2). The chosen criteria to interpret the magnitude of the correlation (r) were: ≤ .1 = trivial,> .1 – .3 = small,> .3 – .5 = moderate,> .5 – .7 = large,> .7– .9 = very large,> .9 – 1.0 = almost perfect (Hopkins, Marshall, Batterham, & Hanin, 2009).

RESULTS

All the data regarding the variables of both FVP profiles are presented in Table 1. The main findings suggest that netball players have force deficit (36.2 ± 14.6%) (Jiménez-Reyes, Samozino, Brughelli, et al., 2017).

Table 1. Mean ± SD values for the CMJ and the mechanical outputs of the vertical FVP profile. Mean ± SD values for the 5m, 20m performance and the mechanical outputs of the horizontal FVP profile.

Vertical FVP profile	
CMJ (cm)	31.1 ± 3
F_0 (N/kg)	29.71 ± 3.4
V_0 (m/s)	3.17 ± 0.41
P_{max} (W/kg)	23.36 ± 2.19
F-V Deficit (%)	36.2 ± 14.6
Horizontal FVP profile	
5 m sprint (s)	1.51 ± 0.06
20 m sprint (s)	3.86 ± 0.16
F_0 (N/kg)	6.51 ± 0.6
V_0 (m/s)	7.29 ± 0.43
P_{max} (W/kg)	11.81 ± 1.44
Sfv	-57.82 ± 5.9
Rf_{max} (%)	41 ± 3
D_{RF} (%)	-0.08 ± 0.01

The associations between the performance variables (CMJ and 20m sprint) and the mechanical output for the vertical and horizontal FVP profiles (F_0, V_0 and P_{max}) can be seen in Table 2. Significant moderate correlations were found for performance (-.5), V_0 (-.4) and P_{max} (.4).

Table 2. Pearson correlation (r) and coefficient of determination (R^2) between the vertical and horizontal FVP profiles.

Variables	Vertical	Horizontal	r	R^2	p-value	Criteria
Performance	31.1 ± 3	3.86 ± 0.16	-.5	.26	.01*	Moderate
F_0 (N/kg)	29.71 ± 3.4	6.51 ± 0.6	.27	.08	.15	
V_0 (m/s)	3.17 ± 0.41	7.29 ± 0.43	-.4	.17	.03*	Moderate
P_{max} (W/kg)	23.36 ± 2.19	11.81 ± 1.44	.4	.16	.04*	Moderate

*The chosen criterion to interpret the magnitude of the correlation (r) was: ≤ .1 = trivial,> .1 – .3 = small,> .3– .5 = moderate,> .5 – .7 = large,> .7– .9 = very large,> .9 – 1.0 = almost perfect. Associations statistically significant (p ≤ .05) denoted in bold an *.The values provided for vertical and horizontal performance are based on CMJ and 20m sprint.*

DISCUSSION

The first aim of this study was to provide a reference for the mechanical variables of the vertical and horizontal FVP profile. Secondly, to observe the level of association between performance and the mechanical outputs of CMJ and 20m sprint.

The mean value for the $F\text{-}V_{IMB}$ during jumping in our participants suggest that amateur netball players have low force deficit (36.2 ± 14.6%), based on the $F\text{-}V_{IMB}$ thresholds proposed in a previous study: Well-Balanced<10%, Low Force-Velocity Deficit 10-40% and High Force-Velocity Deficit > 40% (Jiménez-Reyes, Samozino, Brughelli, et al., 2017; Jiménez-Reyes et al., 2019). It is important to mention that of 28 players 13 had high force deficit, 13 had low force deficit, and 2 had a well-balanced profile. Athletes with a well-balanced profile are something really uncommon (Jiménez-Reyes, Samozino, Brughelli, et al., 2017; Jiménez-Reyes et al., 2019). According to our results, Netball players must develop F_0 while reducing the $F\text{-}V_{IMB}$ to improve CMJ however, due to the differences on the magnitude of their *F-V* deficit different training plans must be designed for them (Escobar Álvarez et al., 2019; Jiménez-Reyes, Samozino, Brughelli, et al., 2017; Jiménez-Reyes et al., 2019).

The moderate correlation (see Table 2 and Figure 1) found for performance (-.5), suggests some association between the CMJ and sprinting, as it has been previously reported in the literature for different sports (Comfort et al., 2014; Cronin, Ogden, Lawton, & Brughelli, 2007; Jiménez-Reyes et al., 2018; Lockie et al., 2014; Randell et al., 2010). This may lead us to hypothesize that training programs aimed to improve CMJ could also result in the improvement of sprinting performance with this population. However, It is important to notice that our athletes are amateur and therefore, the magnitude of the correlation with a high level or elite population may be smaller, as it was reported by Jimenez-Reyes et al., (Jiménez-Reyes et al., 2018).

Moderate correlations were found for V_0 (-.4) and P_{max} (.4) as it has been previously reported in some other modalities (Jiménez-Reyes et al., 2018) however, no association was found for the force production (F_0) of the lower limbs in the vertical and horizontal profile. The absent of correlation for F_0 suggest that both actions (jumping and sprinting) must be trained and monitored specifically, as it has been previously recommended (Morin & Samozino, 2016). Previous studies have highlighted that the horizontal production of F_0 is an injury-related factor (Mendiguchia et al., 2016, 2014), therefore assume changes in one skill due to the changes on the other can be counter-productive for the athletes, not developing an appropriated control of the lower limbs and increase the risk of common injuries (Thomas et al., 2017).

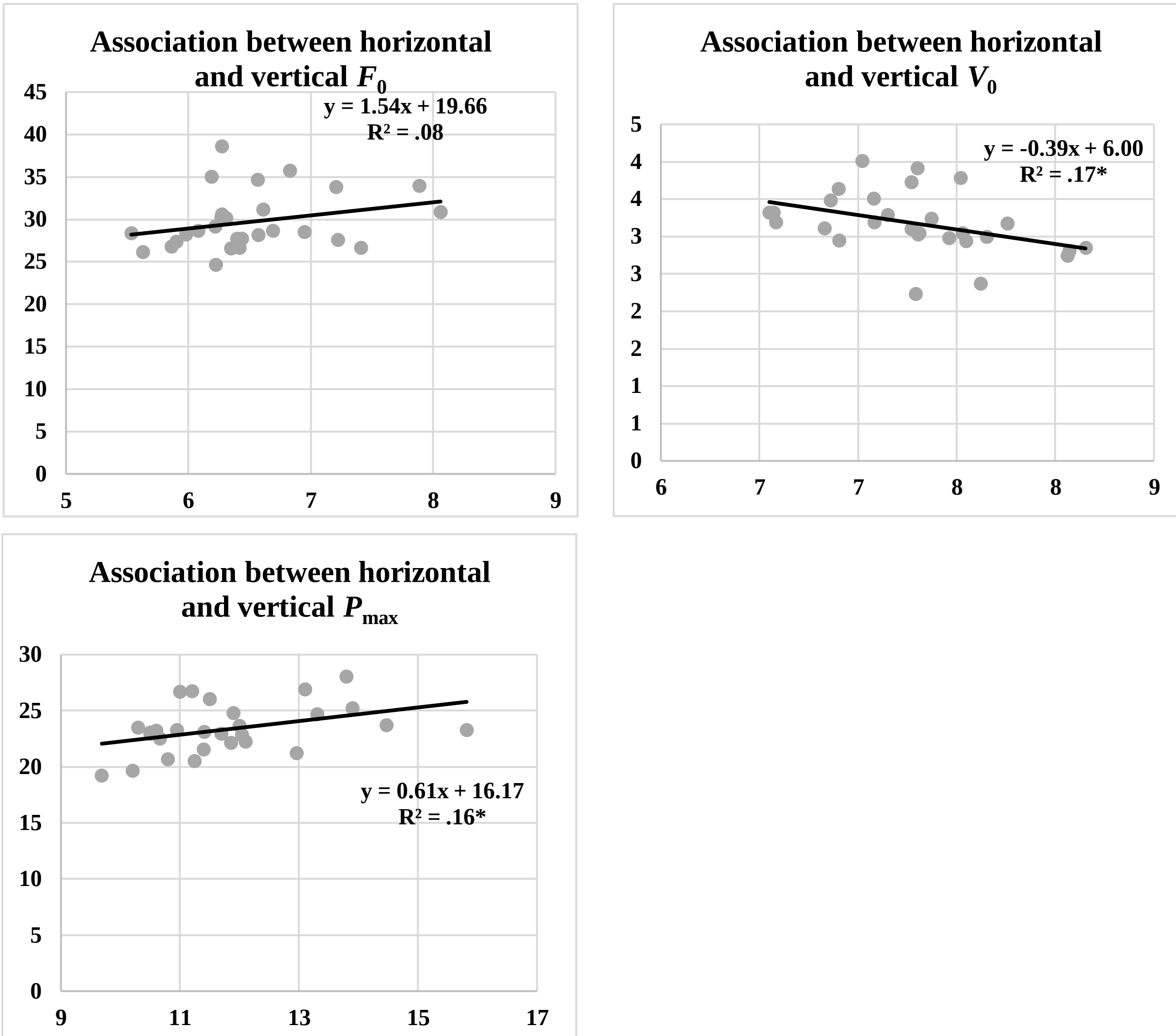

Figure 1. Coefficient of determination for the F_0, V_0 and P_{max} between the vertical and horizontal FVP profile. Associations statistically significant ($p \leq .05$) denoted with *.

Taking into consideration that jumping and sprinting skills are extremely relevant in netball performance (Fox et al., 2013; Fox et al., 2012; Thomas et al., 2019), the quantification of both FVP profiles may help to design and to monitor training programs according to the individual needs of each athlete. Therefore, we recommend specific and individualized training based on force-velocity profiling for the improvement of strength capabilities to enhance netball actions based on jumping and sprinting. Previous studies have designed training plans aimed to improve the F_0 and reduce the $F\text{-}V_{IMB}$ in jumping (Escobar Álvarez et al., 2019; Jiménez-Reyes, Samozino, Brughelli, et al., 2017; Jiménez-Reyes et al., 2019) and also improve the application of F_0 and P_{max} using horizontal resisted training (Cross et al., 2018; Morin, Capelo-Ramirez, Rodriguez-Pérez, Cross, & Jimenez-Reyes, 2020; Morin et al., 2016).

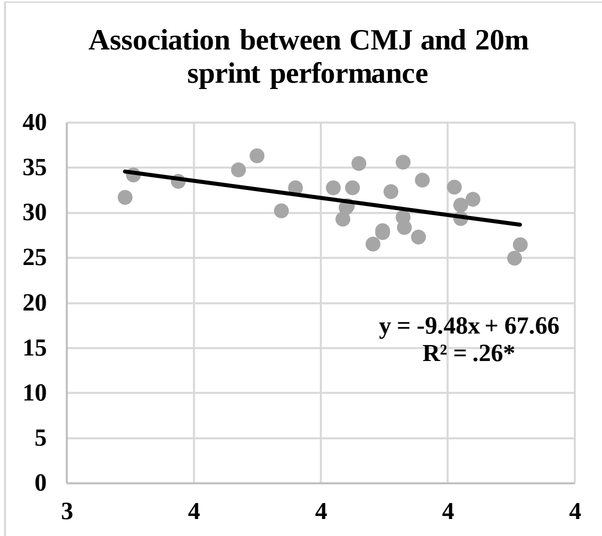

Figure 2. Coefficient of determination between the Jumping (CMJ) and sprinting performance (20m). Associations statistically significant ($p \leq .05$) denoted with *.

To the best of our knowledge, this is the first investigation observing the relationship between CMJ and sprint performance (20m) in netball players, in addition to the mechanical outputs of the vertical and horizontal FVP profile. This study might be useful for strength and conditioning coaches and practitioners, due to the use of approachable and low-cost methods (My jump 2 and My Sprint) for monitoring and assessing athletes. Moreover, the use of some other validated low-cost software can also be useful for the design of training plans (Jiménez-Olmedo, Penichet-Tomás, & Villalón-Gasch, 2021). Future studies may observe the association between sprinting and jumping performance on different levels of practice or even position within netball players, as it has been observed in other disciplines (Escobar Álvarez, Reyes, Pérez Sousa, Conceição, & Fuentes García, 2020). Also, it would be interesting to observe the effect of individualized training (based on the reduction of the actual $F\text{-}V_{IMB}$) on ballistic performance (jumping, sprinting and COD).

CONCLUSIONS

This study provides a reference about the FVP profile during CMJ, suggesting that amateurs netball players have force deficit and individualized training based on F-V profiling may be beneficial to enhance jumping ability. The moderate correlations found for performance, V_0 and P_{max} suggest that the improvement in one of the skills (jumping or sprinting) may produce some positive adaptation to the other. However, we recommend that netball players train specifically ballistic actions in the vertical (jumping) and horizontal direction (sprinting) due to the specificity of both skills and that no association was found in the force production (F_0).

AUTHOR CONTRIBUTIONS

Conceived and designed the experiments: JE, JPFG, FC, PJR. Performed experiments: JE. Analysed data: JE, JPFG, FC, PJR. Interpreted results of research: JE, JPFG, FC, PJR. Drafted manuscript and prepared tables/figures: JE, PJR. Edited, critically revised paper, and approved the final version of manuscript: JE, JPFG, FC, PJR.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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