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The Vertical Force-velocity Profile in Male Under-20 National Team Rugby XV Union Players

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ABSTRACT

Purpose: The main aim of the present study was to describe the Vertical Force-velocity (F-v) profile in male Under-20 (U-20) national team rugby XV union players. Also, as a secondary aim, we proposed to establish the relationships between anthropometric variables with F-v profile parameters. **Methods:** Ten elite rugby union players from Uruguayan National male U-20 team [age: 18.9 ± 0.3 years; body mass: 90.03 ± 9.09 kg; body mass index (BMI): 26.28 ± 1.33 kg·m^{-2}] were assessed in their F-v profile employing squat jump (SJ) with incremental loads. Moreover, we performed correlations between anthropometric variables [height, body mass, BMI, lower-limb length fully extended position (LL length), starting position of the jump (hs), and vertical push-off distance (hpo)] with the F-v profile variables [theoretical maximal force (F0), theoretical maximal velocity (V0), maximal mechanical power output (P_{max}), deviation from the optimal profile (Dev), force-velocity imbalance (FV_{imb}), SJ height (SJ0 h) and SJ power (SJ0 P)]. **Results:** Among the 10 rugby union players evaluated, 7 of them presented a force deficit, 2 were well balanced, and only one presented a velocity deficit. Thus, five athletes presented a high force deficit (37-52%), 2 a low force deficit (64 and 66%), 2 were well balanced (95 and 96%) and only one showed a low velocity deficit (136%). Furthermore, we found large to very large significant correlations among hs with F0, V0, FV_{imb} and Dev (r > 0.6; $p < 0.05$). Additionally, we found a very large significant correlation between SJ0 h with P_{max} (r = 0.757; $p = 0.011$). **Conclusion:** Male U-20 union rugby players presented force imbalance, which could suggest a greater emphasis of maximal strength performance for this sample.

Keywords: Team sports; elite athletes; field testing; muscular strength; vertical jump; neuromuscular function

INTRODUCTION

Strength is a key element in any training applied program in team sports (e.g., football, basketball, rugby, etc.) that promote the enhancement of performance in competitive situations (Jeffreys & Moody, 2021). On that way, several studies described that young athletes manifest a greater neuromuscular capacity at a higher competitive level (Correas-Gómez et al., 2023; Gissis et al., 2006; Jones et al., 2018). For example, Argus et al. (2012), demonstrated with rugby union players that competition at higher level was associated to absolute and relative strength and power in traditional exercises such as; squat, bench press, chest throw and vertical jump with load. Additionally, Jones et al. (2018) observed that the strength is a clear predictor of the highest competitive level in rugby union players during development stages.

Particulary, strength gains are based on a combination of several morphological and neuromuscular factors including; an increase in the cross-section area and changes in the architecture, a higher musculotendinous stiffness, an increase in the recruitment of motor units, a greater frequency of discharge of the motor units, and a neuromuscular inhibition of the antagonist musculature (Suchomel et al., 2018). There are a wide range of methods that can be used to improve muscular strength such as; weightlifting derivatives, plyometrics, ballistic training, eccentric training, etc. (Suchomel et al., 2018). Furthermore, there are different criteria to assessment acute/chronic changes in neuromuscular performance such as; vertical jump, 1RM, isometric or isotonic rate of force development, etc. (Haff et al., 2015; Suchomel et al., 2018), and more recently it has been suggested; the vertical or horizontal Force-velocity (F-v) profile (Baena-Raya et al., 2022; Morin & Samozino, 2016). Concretely, the F-v profile has become very popular tool to evaluate the daily neuromuscular performance, taking into account the athletes personal characteristics (Morin & Samozino, 2016; Samozino et al., 2008; Samozino et al., 2012). This tool allows strength coaches to create individualized strength programs with a valid, reliable, easy to implement and economical method (Morin & Samozino, 2016; Samozino et al., 2008).

Samozino et al. (2012) suggested there is an optimal individual profile in order to maximize neuromuscular function, while imbalances can negatively affect neuromuscular performance. In fact, it may happen that one individual presents a force deficit, while on the contrary another individual may present a velocity deficit (Samozino et al., 2012). This F-v imbalance (FV_{imb}) is calculated from the difference between the theoretically optimal and current F-v profiles of each participant (Samozino et al., 2013). Thus, the athletes can show a high force deficit (<60%), a low force deficit (60-90%), a low velocity deficit (>110-140%), a high velocity deficit (>140%) or be well balanced (>90-110%) (Jiménez-Reyes et al., 2017). For example, recently, Zabaloy et al. (2021) surprisingly noted that amateur rugby union players demonstrated F-v profiles oriented toward a force deficit. On the other hand, according to Jiménez-Reyes et al. (2017) ballistic performance is determined by the FV_{imb} and by the maximum power production (P_{max}). Therefore, it was proposed that to optimize training stimulus (Jiménez-Reyes et al., 2017; Samozino et al., 2013), strength and conditioning coaches and sports scientists should propose to increase P_{max} and/or reduce FV_{imb}. For this reason, it is important to evaluate and control changes in P_{max} and FV_{imb} to management training load throughout a competitive season (monthly/biannual/annual) (Morin & Samozino, 2016).

In disciplines such as team sports that involve explosive movements (jumps, sprints, changes of direction, etc.), and high-power production is required (Jeffreys & Moody, 2021); monitoring acute/chronic changes on the profile F-v allows us to know if an athlete has optimized his FV_{imb} after a training period (e.g., preseason) (Morin & Samozino, 2016). Therefore, scientists propose different strength training programs to optimize performance depending on the imbalance that athletes present. In case that the deficit is in force, greater emphasis will be proposed on high loads (i.e., >70% 1RM) to enhance the theoretical maximum force (F0), if the deficit is in velocity, greater emphasis will be on light loads (i.e., <70% 1RM) to enhance the theoretical maximum velocity (V0) (Jiménez-Reyes et al., 2017; Jiménez-Reyes et al., 2019; Simpson et al., 2021; Zabaloy et al., 2020). In this sense, a current study with highly trained rugby union players (Zabaloy et al., 2020) concluded that FV_{imb}-based strength programs induced improvements in sprint performance and F-v profile after a seven-week intervention. In addition, Simpson et al. (2021) recruiting professional rugby league players, and obtained greater longitudinal changes in maximal strength (3RM squat) and squat jump (SJ) in a group that the load was monitored according to the F-v profile regarding to unmonitored during 8 weeks. Moreover, Jiménez-Reyes et al. (2017) concluded that in two team sports (i.e., rugby and soccer) with semi-professional players, the improvements in vertical jump height were greater for F-v profile-based group compared to traditional strength training group across 9-week training. However, in contradiction to these aforementioned studies, some recent research that select different highly trained team sports athletes (Lindberg et al., 2021; Zabaloy et al., 2020) do not observe significant changes in the vertical jump height or linear sprint between groups (i.e., FV_{imb}-based vs. not FV_{imb}-based).

According to our knowledge, two articles have described the F-v profile in adults rugby union players (Zabaloy et al., 2020; Zabaloy et al., 2021), however, no studies have been found that include elite young rugby players (e.g., U-20), for the best of the author's knowledge. On the other hand, the relationships between the F-v profile variables and physical performance variables were previously described in rugby union players (Zabaloy et al., 2021). In addition, the relationships between the F-v profile variables and anthropometric variables were also described, but in youth basketball players (i.e., U-14, U-16, U18) (Jiménez-Daza et al., 2023). To the best of our knowledge, the relationships between anthropometric variables and the F-v profile variables were not analyzed in rugby union players yet.

Therefore, the main aim of the present study was to describe and analyze the F-v profile of elite rugby union players in U-20 male category of a National Team. On the other hand, as a secondary aim, we proposed to establish the relations between anthropometric variables and F-v profile parameters in rugby players. We hypothesized based on previous findings that the F-v profiles of elite male U-20 rugby players could have an F-v profile with force deficit.

METHODS

Participants

Ten elite rugby union players from Uruguayan National male U-20 team (age: 18.9 ± 0.3 years; body mass: 90.03 ± 9.09 kg), participated in this study. The participants had ~10 years of experience in sport training with a frequency of 3 times per week twice a day (2 hours duration). In addition, they had competitive experiences at a national and international level. Currently, some of these players were selected to participate in the major Rugby World Cup (France 2023) and the Olympic Games (Paris 2024). The inclusion criteria were: 1) integrate the male U-20 Uruguayan National Team; 2) not have any musculoskeletal injury or cardiometabolic disease; 3) do not consume stimulants or drugs not authorized (World Anti-Doping Agency, 2020); 4) participate in all experimental phases. Prior to complete the procedures, each participant was fully informed of the objectives, risks and benefits of the study through an informed consent. This study was approved by the Ethics Committee of Higher Institute of Physical Education, University of the Republic, Uruguay (Number 13/2022) and was conducted in accordance with the guidelines established in the Declaration of Helsinki (World Medical Association, 2013) following the update of Fortaleza 2013.

Procedures

Experimental design

To test the study hypothesis, we adopted a cross-sectional descriptive design with a single-blind approach. Participants were asked to: 1) attend with sports clothing and shoes; 2) not to perform vigorous activities 48 hours before the evaluations; 3) not to modify any aspect of their daily life (sleep, rest, nutrition, incidental physical activity, personal habits, etc.); 4) rest adequately during the measurement period and maintain an optimal state of hydration; 5) maintain homogeneous training.

In addition, it was requested to avoid the consumption of any type of stimulant that could enhance the physical response (e.g., mate, coffee, energy drinks, etc.). The evaluation was carried out on rubber floor in a closed space with control of environment conditions (temperature=21–23 °C, relative humidity=65–75%) during two different days. The data were taken in the afternoon between 5:00 p.m. and 10:00 p.m. The measurements were carried out in sub-groups of two to four players across 1 h. (Figure 1). Rugby players had extensive experience in physical assessments, so a familiarization period was not implemented. The procedures were executed during the COVID-19 pandemic and the players carried out a pre-season towards a World Rugby U-20 Trophy, although they did not have any competition.

Testing Procedures

As suggested by Morin & Samozino (2016), the initial measures were taken to determine the individual profile. Body mass (kg) was measured employing a valid digital electronic scale (HBF 514C, OMRON®, Kyoto, Japan) (Loenneke et al., 2013). Additionally, height (m) was measured using a stadiometer (2096 PP, Toledo do Brasil®, São Paulo, Brazil). Subsequently, the lower-limb length was measured fully extended position (m) (LL length), with the participants in supine position, using an anthropometric tape with precision of one millimeter (Sanny Medical®, São Paulo, Brazil). Then, with the participants in a standing position, the vertical distance between the floor and the greater trochanter (hs) was measured, maintaining an angle of 90° at the level of the knee utilized a goniometer (BaseLine, Patterson Medical®, Warrenville, Illinois, USA). This position was considered as the starting point for the jumps performed consecutively, being a reference to respect the initial angle of each repetition. The vertical push-off distance (hpo) was obtained from the subtraction between LL length and hs.

Prior to carrying out the test, a 15-min warm-up was performed, applying joint mobility exercises, squats with body mass (3 sets × 5 repetitions), and SJ (2 sets × 3 repetitions). Subsequently, the SJ assessment was performed with incremental loads using the valid and reliable application (My Jump 2, Apple Inc®, Cupertino, CA) (Balsalobre-Fernández et al., 2015; Bogataj et al., 2020), employing a cell phone (iPhone 6s, Apple Inc®, Cupertino, CA, USA) according to Simpson et al. (2021). To start, the rugby players assumed the starting position of 90° and was asked to maintain this position for two seconds, followed by an SJ. They were verbally instructed to apply the greatest possible force against the floor, seeking the greatest height in the jump, keeping the legs extended in the flight phase and landing in a plantarflexion position in the same starting place (Markovic et al., 2004). The SJ without additional load was performed with the arms crossed over the chest, and subsequently, this procedure was repeated with a barbell with 4 progressive loads (10, 20, 30 and 40 kg), adapted to what was proposed by Zabaloy et al. (2020). The hands, unlike the unloaded jump, were placed holding the bar on the shoulders at the height of the acromion with the feet approximately shoulder-width apart. Three jumps were performed with each load and then we utilized the highest height value to determine the F-v profile (Samozino et al., 2013; Zabaloy et al., 2021). If any of the instructions were not respected, the jump was not considered valid and had to be repeated with correct execution. The pauses were passive, being 2 minutes between jumps with equal load, while 4 minutes between the different load conditions (Zabaloy et al., 2020) (Figure 1).

Finally, according to Samozino et al. (2008) we were able to obtain the mean vertical force (F) and the mean vertical velocity (v) of each jump, subsequently from the product of the mean vertical force and the mean vertical velocity, we obtained the mean vertical power (P).

$$F = mg\left(\frac{h}{hpo} + 1\right)$$

$$v = \sqrt{\frac{gh}{2}}$$

$$P = mg\left(\frac{h}{hpo} + 1\right)\sqrt{\frac{gh}{2}}$$

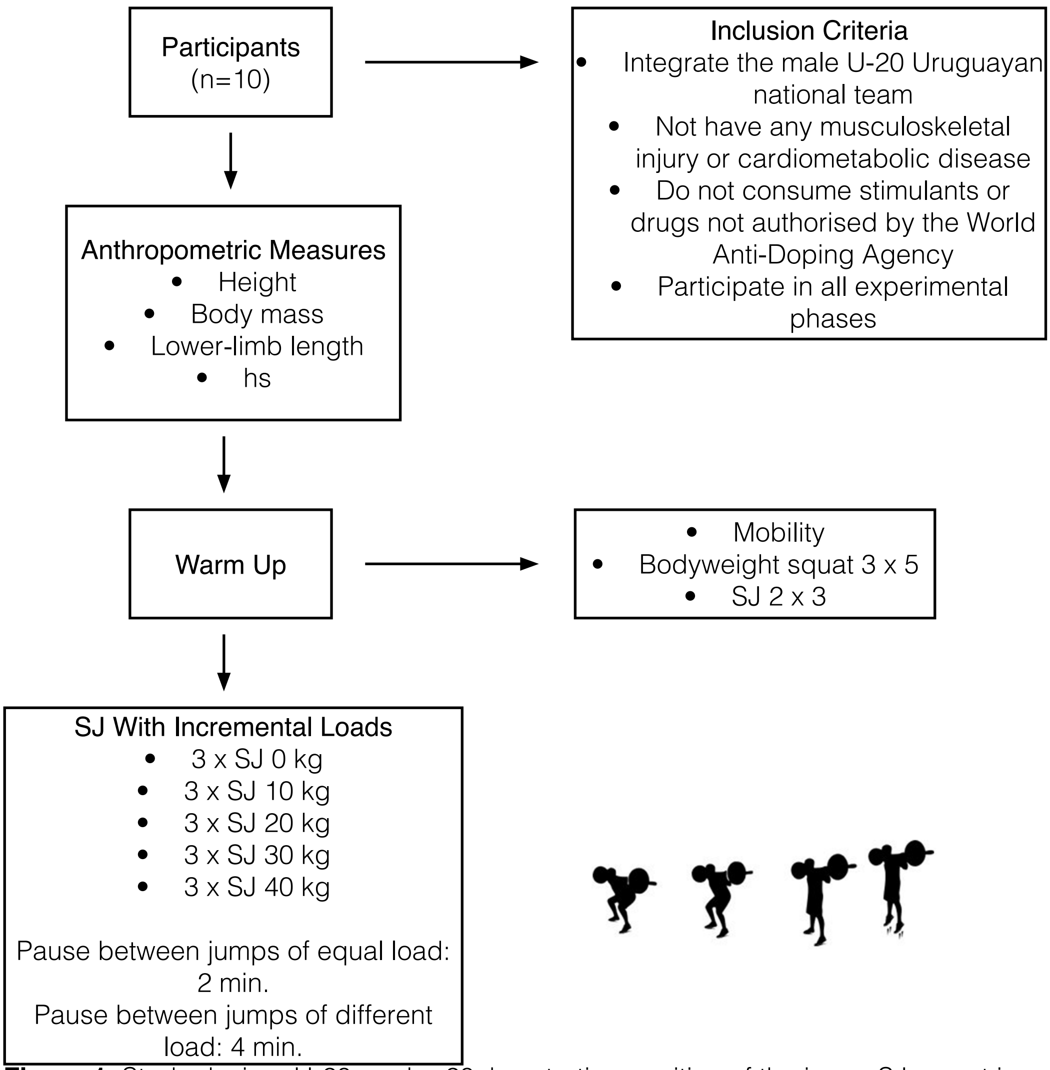

Figure 1. Study design. U-20: under-20; hs: starting position of the jump; SJ: squat jump.

On the other hand, the F-v and P_{max} profile of each player was obtained by criteria proposed by Samozino et al. (2012), while the FV_{imb} was determined from the difference between the current F-v profile and the theoretical optimum, as proposed by Samozino et al. (2012) as well, Samozino et al. (2013), and Morin & Samozino (2016) (Figure 2). After having the FV_{imb}, we calculated the 100% deviation (Dev), being this outcome, how far it was from its optimal profile in percentage.

Statistical Analysis

The data obtained in the evaluation were recorded manually, and subsequently inserted into a spreadsheet (v17 Excel, Microsoft®, Redmond, WA, United States) developed by Morin & Samozino (2016), with the purpose of determining the F-v profiles of each player. Regarding the verification of normality in the distribution of the data, the Shapiro-Wilk (<50) test was performed, and visual inspection of Q–Q plots and box plots. A descriptive analysis was carried out, where the values of the mean, standard deviation (SD) and limits of the 95% confidence intervals (95% CI) were considered. The intraclass correlation coefficient (ICC) and coefficient of variation (CV) was calculated to analyze the reliability of all measurements. Then, simple linear correlations were performed between the anthropometric variables (height, BM, BMI, LL length, hs and hpo) and the F-v profile variables (F0, V0, P_{max}, Dev, FV_{imb}, SJ0 h and SJ0 P), utilizing the Pearson Correlation Coefficient. The following criteria were adopted to interpret the magnitude of the correlation (r): 1) ≤0.1: trivial; 2) >0.1–0.3: small; 3) >0.3–0.5: moderate; 4) >0.5-0.7: large; 5) >0.7-0.9: very large and 6) >0.9-1.0: almost perfect (Hopkins et al., 2009). A statistical software (v15 SPSS®, Armonk, NY, United States) was implemented for all analysis and correlation graphs were made employing other software (v0.16.2 JASP®, Amsterdam, Netherlands). Post-hoc power analyses were calculated for all significant correlations using specific software (v3.1.9.7, G*Power®, Dusseldorf University, Düsseldorf, Germany): 1) alpha-value of 0.05; 2) correlation value found for each analysis; 3) number of participants of 10.

RESULTS

The result of the analysis of the reliability among measures was considered widely acceptable for ICC (i.e., ICC>0.70) and the CV (i.e., CV<10%) (Table 1) (Valenzuela et al., 2020).

From the data obtained, the individual profile of each player was created. Among the 10 rugby union players evaluated, 7 of them presented a force deficit, 2 were well balanced, and only one presented a velocity deficit. In fact, five of them presented a high force deficit (37-52%), 2 a low force deficit (64 and 66%), 2 were well balanced (95 and 96%) and only one showed a low velocity deficit (136%) (Figure 2). On the other hand, the player who presented the best-balanced profile (96%) was also the one who registered the best jump without load (53.15 cm). In addition, the player who had the worst performance in the unloaded jump (33.26 cm) presented a high force deficit (52%).

Table 1. Intraclass correlation coefficient and confidence interval.

	ICC (CI 95%)	CV (CI 95%)
SJ0 h (m)	0.968 (0.909 to 0.991)*	4.19 (2.39 to 5.99)
SJ10 h (m)	0.985 (0.956 to 0.996)*	3.19 (1.98 to 4.39)
SJ20 h (m)	0.987 (0.963 to 0.996)*	3.23 (1.83 to 4.62)
SJ30 h (m)	0.971 (0.917 to 0.992)*	4.78 (3.08 to 6.48)
SJ40 h (m)	0.985 (0.958 to 0.996)*	3.95 (2.46 to 5.45)

*ICC: intraclass correlation coefficient; CI: confidence interval; CV: coefficient of variation; SJ0-40 h: squat jump height with loads from 0 to 40 kg. Intraclass correlation coefficient is significant according the following level: * p < 0.001.*

Table 2. Anthropometric variables.

	Mean ± SD	CI 95%
Age (years)*	18.90 ± 0.32	(18.67 to 19.13)
Height (m)	1.84 ± 0.07	(1.78 to 1.89)
Body mass (kg)	90.03 ± 9.09	(83.53 to 96.53)
BMI ($kg \cdot m^{-2}$)	26.28 ± 1.33	(25.26 to 27.31)
LL length (m)	1.16 ± 0.07	(1.11 to 1.21)
hs (m)	0.65 ± 0.04	(0.62 to 0.68)
hpo (m)	0.51 ± 0.05	(0.47 to 0.54)

*Mean ± standard deviation (SD); CI: confidence interval; BMI: body mass index; LL length: lower-limb length fully extended position; hs: starting position of the jump; hpo: vertical push-off distance. *These variables did not have normal behaviour.*

Table 3. Height, velocity, force, and power against each load.

	SJ 0	SJ 10	SJ 20	SJ 30	SJ 40
h (m)	0.41 ± 0.06 (0.36 - 0.45)	0.33 ± 0.05 (0.30 - 0.37)	0.30 ± 0.05 (0.26 - 0.34)	0.26 ± 0.04 (0.23 - 0.29)	0.23 ± 0.04 (0.19 - 0.26)
v ($m \cdot s^{-1}$)	1.41 ± 0.10 (1.34 - 1.49)	1.28 ± 0.10 (1.21 - 1.35)	1.20 ± 0.10 (1.13 - 1.28)	1.13 ± 0.09 (1.07 - 1.20)	1.05 ± 0.10 (0.98 - 1.12)
F (N)	1595.37 ± 151.91 (1486.70 - 1704.04)	1629.81 ± 153.23 (1520.19 - 1739.43)	1710.90 ± 136.95 (1612.93 - 1808.87)	1789.28 ± 122.64 (1701.55 - 1877.01)	1845.89 ± 140.57 (1745.33 - 1946.45)
P (W)	2260.70 ± 316.83 (2034.05 - 2487.35)	2090.70 ± 311.82 (1867.63 - 2313.76)	2065.80 ± 295.65 (1854.30 - 2277.29)	2033.40 ± 249.11 (1855.19 - 2211.61)	1948.70 ± 297.30 (1736.02 - 2161.38)

Mean ± SD (CI 95%). h: height; v: mean vertical velocity; F: mean vertical force; P: mean vertical power; SJ 0-40: squat jump with loads from 0 to 40 kg.

Table 4. Vertical Force-velocity profile variables.

	Mean ± SD	CI 95%
F0 ($N \cdot kg^{-1}$)	29.54 ± 5.31	(25.74 to 33.34)
V0 ($m \cdot s^{-1}$)	3.81 ± 0.97	(3.12 to 4.51)
P_{max} ($W \cdot kg^{-1}$)	27.25 ± 4.37	(24.12 to 30.38)
Sfv (N·s/m/kg)	-8.57 ± 3.95	(-11.39 to -5.74)
Sfvopt (N·s/m/kg)*	-12.51 ± 0.77	(-13.06 to -11.96)
Dev (%)	38.90 ± 20.63	(24.14 to 53.65)
FV_{imb} (%)	68.30 ± 31.47	(45.79 to 90.81)
r^2	0.88 ± 0.06	(0.83 to 0.92)

*Mean ± SD (CI 95%). F0: theoretical maximal force; V0: theoretical maximal velocity; P_{max}: theoretical maximal mechanical power output; Sfv: slope of the linear F-v relationship; Sfvopt: the unique value of Sfv that maximizes jump height; Dev: deviation from the optimal profile; FV_{imb}: force-velocity imbalance. *These variables did not have normal behaviour.*

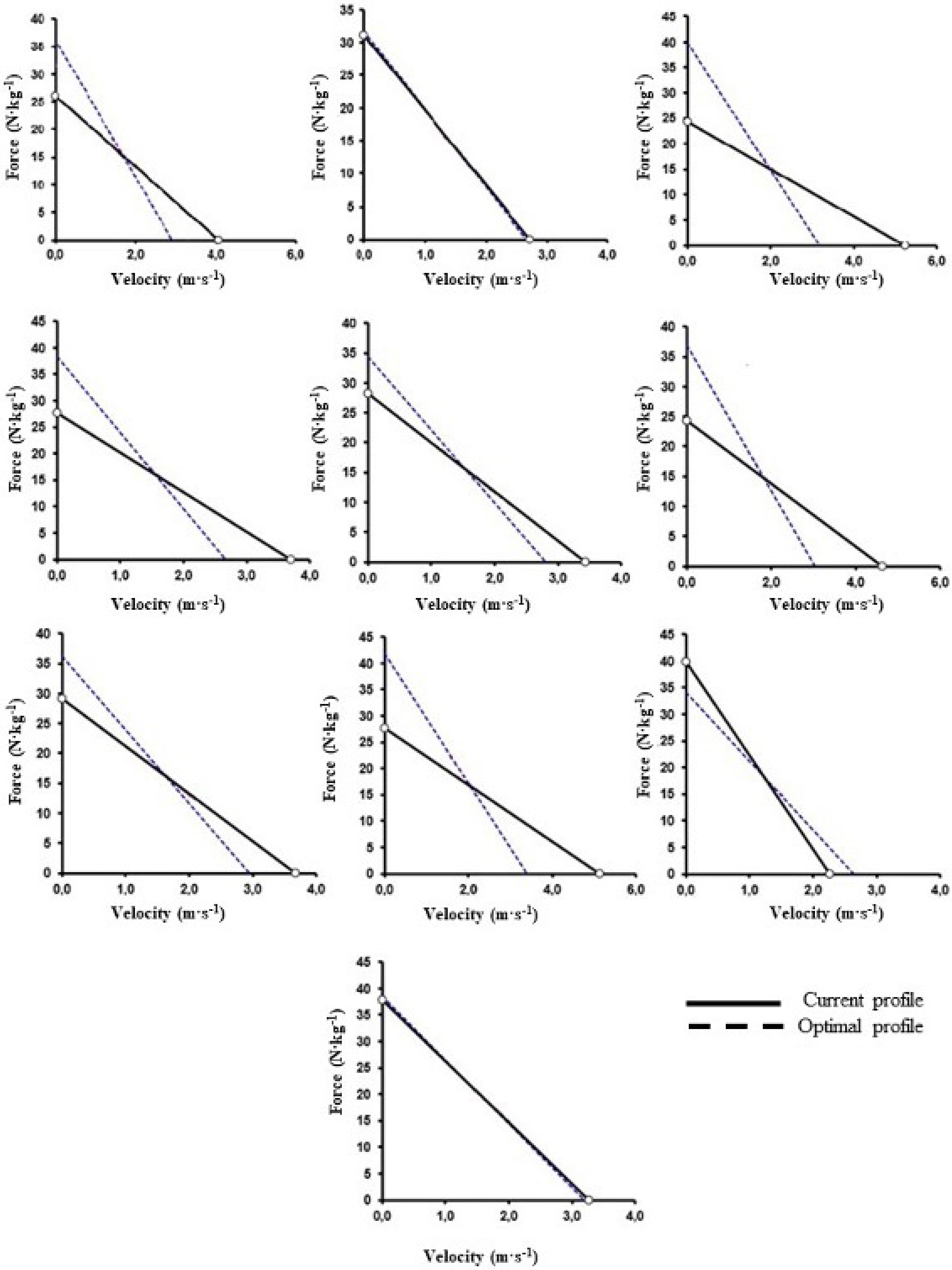

Figure 2. Current and optimal vertical Force-velocity profiles of the ten elite male U-20 rugby union players.

Table 5. Correlations between anthropometric variables and the Force-velocity profile variables.

	Height (m)	BM (kg)	BMI ($kg \cdot m^{-2}$)	LL length (m)	hs (m)	hpo (m)	F0 ($N \cdot kg^{-1}$)	V0 ($m \cdot s^{-1}$)	P_{max} ($W \cdot kg^{-1}$)	Dev (%)	FV_{imb} (%)	SJ0 h (m)	SJ0 P (W)
F0 ($N \cdot kg^{-1}$)	-0.591	-0.484	-0.118	-0.425	-0.754*	0.099	—						
V0 ($m \cdot s^{-1}$)	0.512	0.286	-0.124	0.443	0.768**	-0.088	-0.784**	—					
P_{max} ($W \cdot kg^{-1}$)	0.230	-0.013	-0.341	0.252	0.396	-0.016	-0.294	0.807**	—				
Dev (%)	0.119	0.055	-0.024	0.082	0.692*	-0.476	-0.681*	0.758*	0.440	—			
FV_{imb} (%)	-0.493	-0.347	0.032	-0.329	-0.709*	0.181	0.938***	-0.900***	-0.565	-0.691*	—		
SJ0 h (m)	0.201	-0.058	-0.485	0.280	-0.097	0.432	0.130	0.345	0.757*	-0.193	-0.141	—	
SJ0 P (W)	0.589	0.519	-0.011	0.503	0.263	0.411	-0.254	0.572	0.733*	0.019	-0.444	0.785**	—

*Correlation is significant according the following level: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$*
BMI: body mass index; LL length: lower-limb length fully extended position; hs: starting position of the jump; hpo: vertical push-off distance; F0: theoretical maximal force; V0: theoretical maximal velocity; P_{max}: maximal mechanical power output; Dev: deviation from the optimal profile; FV_{imb}: force-velocity imbalance; SJ0 h: squat jump height; SJ0 P: squat jump power.

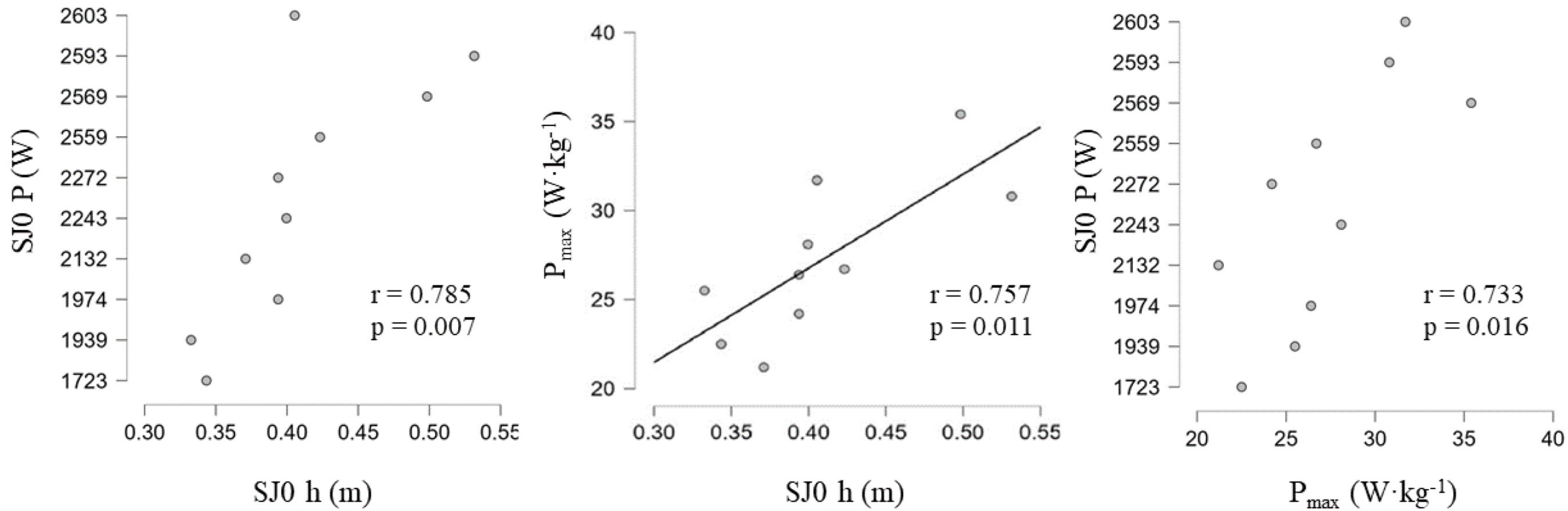

Figure 3. Correlation between SJ0 h with SJ0 P and P_{max}, and between P_{max} with SJ0 P. P_{max}: relative maximum power; SJ0 h: squat jump height; SJ0 P: squat jump power.

DISCUSSION

The main aim of the present study was to describe the F-v profile of elite rugby union players in a National U-20 male team. Additionally, as a secondary aim, we have analyzed the relationship between anthropometric variables and parameters obtained from this F-v profile. Firstly, the main findings of this study indicated that elite U-20 rugby union players showed a tendency towards force deficit (7 of the 10 evaluated players). Therefore, the main hypothesis proposed in the present study is accepted. Secondly, we found large to very large significant correlations between hs with F0, V0, FV_{imb} and Dev (r > 0.6; $p < 0.05$). Furthermore, we found a very large significant correlation between SJ0 h with P_{max} (r = 0.757; $p = 0.011$).

Our results showed that the elite rugby union players of U-20 Uruguayan National Team presented a tendency towards a force deficit when analyzing the FV_{imb} (FV_{imb} = 68.30 ± 38.90%) (Table 4, Figure 2). These findings are similar to those recorded in adults' amateur rugby union players where forwards presented an FV_{imb} of 76.08 ± 19.5% and backs 86.18 ± 26.51% (Zabaloy et al., 2021). Also, our data shows similar behavior to that previously presented in super league academy rugby league players, where 15 players showed a force deficit, two showed a velocity deficit and only one was well balanced (Nicholson et al., 2021). However, our data contrast with the previous information presented by Samozino et al. (2013), who demonstrated with a very small sample (four of six high-level rugby players) presented a velocity deficit. In this sense, Samozino et al. (2013) also suggested that this tendency of velocity deficit, could be due to the fact that rugby players use generally high loads (i.e., >70% 1RM) across strength training program. According to current scientific literature, it is clear that strength and power play a key role at the rugby competitive level (Argus et al., 2012). In general, rugby players present higher levels of strength in relation to other outdoor team sports (e.g., soccer) (Loturco et al., 2018).

In this context, for the sample of our study, the force deficit may be due to the fact that they are still young and need to accumulate a greater strength training volume near to 1RM, in order to develop their maximal strength and reduce the force deficit (Jiménez-Reyes et al., 2017; Jiménez-Reyes et al., 2019; Zabaloy et al., 2020). Furthermore, it is known that as rugby players elicit more experience in competitions level and maturation status, their levels of strength and power increase equally (Till et al., 2020). In this sense, Nishioka & Okada (2022) found a moderate correlation between F0 and relative 1RM in the half squat, for what they propose training with high loads to improve F0, given that, physical stimuli that involving high force productions, can induce changes in neuromuscular function such as; an increase in the recruitment of motor units, an augment in the firing frequency of motor units, a greater musculotendinous stiffness, and an improvement in neuromuscular inhibition of antagonist musculature (Suchomel et al., 2018). In this way, Suchomel et al. (2018) in a relevant review suggest that young people would benefit from maximal strength training and this aspect is basis for future progress in the rate of force development, and peak power. Thus, training aimed at increasing F0 during youth would initially help to enhance motor control and coordination, along with neural and morphological adaptations (Suchomel et al., 2018).

Regarding the F-v profile variables, the players in this study presented a SJ of 0.41 m, F0 of 29.54 $N \cdot kg^{-1}$, V0 of 3.81 $m \cdot s^{-1}$, P_{max} of 27.25 $W \cdot kg^{-1}$ and a FV_{imb} of 68.30% (Tables 3 and 4). In comparation with the study by Zabaloy et al. (2021) players showed lower values of SJ (-27%), V0 (-25%) and Pmax (-8.8%). According to Argus et al. (2012) and Baena-Raya et al. (2022), higher level players present higher levels of P_{max}. In this case, despite being U-20 players, they presented higher P_{max} values compared to the adult amateur players used in the sample by Zabaloy et al. (2021); this difference can be explained that they are national team players with a higher level of international competition (Argus et al., 2012; Baena-Raya et al., 2022). Additionally, our sample reached a greater height in the SJ (+14%) compared to the Brazilian U-20 players previously used by Kobal et al. (2016). Regarding to this point, Baena-Raya et al. (2022), suggested that the height elicited during an SJ can be a clear predictor of athletic level in athletic population.

In relation to the anthropometric variables, the players in our study were 18.9 years old, with a height of 184 cm and a body mass of 90.03 kg (Table 2). According to Jones et al. (2018) higher level players are taller and heavier compared to lower-level players, in one study that selected adolescent rugby union players. Currently, similar findings were found by Peeters et al. (2023) when they compared international vs non-international French U-20 rugby union players. In this sense, another prospective study carried out with 453 South African U-20 rugby union players, showed that the average height was

184 cm and the average body mass was 99 kg in 2010 (Lombard et al., 2015) after 13 years of follow up. This idea is in concordance with the previous hypothesis that players who have a higher competitive level are heavier given that South Africa competes in the World Rugby U-20 Championship, while the players in our sample from Uruguay participate in the second most important tournament, the World Rugby U-20 Trophy (https://www.world.rugby/tournaments/u20). In this way, Lombard et al. (2015) conclude that height, body mass, strength and speed improves with years of training, volume and level of accumulated sports competitions. These data have also been observed in other team sports (Pérez-Ifrán et al., 2023; Towlson et al., 2017).

Previous studies attempted to correlate profile variables with various performance variables in rugby players (Zabaloy et al., 2021), thus, our study investigated the existence of correlations between the F-v profile variables with anthropometric variables. Unlike Samozino et al. (2010) and Samozino et al. (2013) we did not find an association between hpo and SJ height; however, we find a significant relationship between hs with F0, V0, FV_{imb}, and Dev ($r > 0.6$, $p < 0.05$). Furthermore, a very large significant correlations were found between P_{max} with SJ0 h and SJ0 P ($r > 0.7$; $p < 0.05$), and between SJ0 h with SJ0 P ($r = 0.78$; $p < 0.01$) (Figure 3). Our study presents similar findings to those detected previously where it was shown that the height of the SJ depends on the P_{max} (Baena-Raya et al., 2022; Jiménez-Reyes et al., 2017; Samozino et al., 2012; Zabaloy et al., 2021). However, in accordance with Zabaloy et al. (2021) we do not found association between FV_{imb} and SJ height. These findings are contrasted with Samozino et al. (2012) and with Jiménez-Reyes et al. (2017), who affirm that ballistic performance, was determined by P_{max}, and influenced by FV_{imb}.

LIMITATIONS

Our sample was small according post-hoc power analyses, although, they were part of a U-20 national team rugby, so future studies should investigate similar topics recruiting larger samples. Our proposal it was carried out throughout the pre-season; therefore, the outcomes cannot be extrapolated to other periods of the year. On the other hand, the use of a mobile application to estimate jump height may not be as accurate as the use of force platforms (gold standard). Although, the use of applications provides practical interest for strength and conditioning coaches, due to their easy access and implementation and their low economic cost.

CONCLUSION

In conclusion, our sample presented force imbalance, which could suggest improving the strength levels (i.e., 1RM or peak strength) in this concrete population, in order to improve F0 and possible imbalance. On the other hand, P_{max} seems to be the most determining variable in the height of the SJ.

PRACTICAL APPLICATIONS

For strength and conditioning coaches, it could be of special relevance to develop maximal strength (i.e., >70% 1RM) to improve F0 in youth rugby union players and thus avoid possible force imbalances. Strength training should be aimed at improving 1RM in basic multi-joint exercises (i.e., squat, deadlift, bench press, etc.), and then in senior stages prioritize exercises more oriented toward improving V0 (i.e., jumps, assisted movements, etc.).

FUTURE RECOMMENDATIONS

Future designs should develop research analyzing the reasons for the discrepancies among studies and at the same time explore the differences among positions, competitive level or sex in order to generablilizate to rugby sport population. Besides, it is necessary to investigate how the F-v profile can be a predictor of competitive physical factors.

CONFLICTS OF INTEREST

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICAL APPROVAL

This study was performed in line with the principles of Declaration of Helsinki and was approved for local Ethics Committee (Approval Number 13/2022).

INFORMED CONSENT

Informed consent was obtained from all individuals participants.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from corresponding author upon reasonable request.

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