Artículo original / Original Article

Correlation among repeated sprint ability, vertical force-velocity profile, and 30-15 IFT performance in elite youth basketball players

Relación entre la capacidad de repetir sprints con el perfil de fuerza velocidad vertical y el rendimiento en el 30-15 IFT en jugadores de baloncesto jóvenes de alto nivel

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Abstract

Basketball is a high intensity intermittent sport. The aim is to analyze the relationship between the vertical force-velocity profile (FV-v profile) and performance in the 30-15 intermittent fitness test (30-15 IFT), with the repeated sprint ability (RSA), both linear and with changes of direction (COD). 42 basketball players, 32 males (n1=32) and 10 females (n2=10) were evaluated. Measurements of the FV-v profile, the 30-15IFT test, the modified Running-Bassed Anaerobic Sprint Test (RASTm) and the modified Illinois Test with 4 intermittent repetitions were performed, also analyzing the countermovement jump loss (CMJloss) in the latter two. Significant relationships were found between imbalance in the FV-v profile and CMJloss in the modified Illinois test both in the whole sample ($r = 0.49$, $p < 0.001$), and in the men´s subgroup ($r = 0.67$, $p < 0.001$), although not in women ($r = 0.13$, $p = 0.71$). In addition, there was a significant relationship between the velocity achieved in the 30-15 IFT (VIFT) and the fatigue index (FI) in the RASTm ($r = -0.33$, $p < 0.05$). Optimization of the FV-v profile has a positive influence on CMJloss in RSA with COD. Specific endurance exerts a small influence on RSA without COD.

Keywords: repeated sprint ability; vertical force-velocity profile; specific endurance; CMJ loss; fatigue

Resumen

El baloncesto es un deporte de alta intensidad intermitente. El objetivo es analizar la relación entre el perfil fuerza-velocidad vertical (perfil FV-v) y el rendimiento en el 30-15 intermittent fitness test (30-15 IFT), con la capacidad para repetir sprints (RSA) lineales como con cambios de dirección (COD). 42 jugadores de baloncesto, 32 hombres (n1=32) y 10 mujeres (n2=10) fueron evaluados. Se midieron el perfil FV-v, el test 30-15IFT, el Running-Bassed Anaerobic Sprint Test modificado (RASTm) y el Test de Illinois modificado con 4 repeticiones intermitentes, analizando la pérdida de salto (CMJloss) en estos dos últimos. Se hallaron relaciones significativas entre el desequilibrio en el perfil FV-v y la CMJloss en el test de Illinois modificado ($r = 0{,}49$, $p < 0{,}001$), en el subgrupo de hombres ($r = 0{,}67$, $p < 0{,}001$), aunque no en las mujeres ($r = 0{,}13$, $p = 0{,}71$). Hubo relación significativa entre la velocidad alcanzada en el 30-15 IFT (VIFT) y el índice de fatiga (IF) en el RASTm ($r = -0{,}33$, $p < 0{,}05$). La optimización del perfil FV-v tiene relación con la CMJloss en la RSA con COD en hombres. La resistencia específica ejerce una pequeña influencia sobre la RSA sin COD.

Palabras clave: capacidad para repetir sprints; perfil fuerza velocidad vertical; resistencia específica; pérdida de CMJ; fatiga

Introduction

Basketball is a sport characterized by a combination of high and low-intensity actions (Bayón et al., 2015; Ben Abdelkrim et al., 2010; Figueira et al., 2021; Rojas-Valverde et al., 2022; Scanlan et al., 2012) in which the effective contribution of aerobic and anaerobic systems is fundamental for performance (Balsalobre-Fernández. et al., 2014). A study with time-motion analysis evaluated such actions, which were mainly walking, running, and, to a lesser extent, jumping and resting actions (Narazaki et al., 2009). Slightly more recent data indicates that during the game, various actions occur including walking, jogging, running at moderate intensity, high intensity running, and sprinting. On average, between 4.9 accelerations of moderate intensity are performed every 30 seconds, along with 4.6 decelerations (Vázquez-Guerrero et al., 2020). High-intensity and low-intensity actions occur constantly, with actions such as sprints, lateral movements, and jumps happening every minute. Some studies show that this intermittency is becoming more pronounced, with a higher frequency of high-intensity actions (Stojonavic et al., 2018).

Short duration sprints combined with partial recovery periods are common in team sports (Ben Abdelkrim et al., 2010; Gharbi et al., 2015) and it's known as repeated sprint ability (RSA) (Girard et al., 2011). This is considered as one of the determinants of performance in such sport modalities (Girard et al., 2011; Thurlow et al., 2023). These are high-intensity actions with recovery times of less than 60 seconds. The concept of short duration sprints involves sprint actions lasting less than 10 seconds with incomplete recovery, less than 30 seconds (Bishop et al., 2006). Based on this, the need arises to incorporate stimuli in training programs with the aim of improving RSA (Maggioni et al., 2019).

RSA is conditioned by factors such as motor neuron excitability, phosphocreatine (PCr) availability, metabolite accumulation, neural activity, as well as other factors such as decreased muscle stifness or environmental alterations (Girard et al., 2011). On a practical level, the question arises as to what training stimuli are capable of influencing these factors to improve this capacity.

Traditionally, the influence of maximal oxygen consumption (VO2max.) has been studied. Theoretically, a better efficiency of aerobic metabolism would lead to a better restoration of PCr (Machado et al., 2021), which hypothetically would result in lower losses of speed between sets, decreasing the fatigue index (IF). It has been suggested that athletes with a better aerobic status or fitness have a more efficient oxidative metabolism and a better restoration of cellular deposits (Bishop et al., 2011). Many studies that have analyzed it have concluded that there is no relationship that would justify that the improvement of VO2max leads to an improvement in RSA (Castagna et al., 2007; Ferrari Bravo et al., 2008; Stojanovic et al., 2012a).

However, other studies present conflicting data. High levels of VO2max improve performance in RSA (Padilla & Lozada, 2013) or have correlations with IF, with lower indices found as VO2max levels increase (Gharbi et al., 2015). On the other hand, it seems that maximal aerobic speed training has a significant positive impact on IF (Buchheit & Ufland, 2011).

The evidence is not entirely clear regarding the influence of VO2max on RSA, which may indicate that they are distinct but somewhat related capabilities.

Basketball is an intermittent sport, therefore, establishing relationships between RSA with performance in more specific endurance stimuli could be of interest. High correlations have been found between RSA and the velocity achieved in the 30-15 IFT (VIFT), both for the total time in RSA test ($r = 0.88$, $p < 0.001$) and with the IF ($r = 0.73$, $p < 0.001$) (Buchheit, 2008).

Other authors have attempted to analyze the influence of strength on the RSA. It is suggested that the relationship between strength and RSA can be explained by the ability to maintain muscle recruitment and fiber synchronization capacity, mainly under fatigue conditions (Bishop et al., 2011). Different studies have tried to analyze this relationship, although most of the research found is with soccer players. One of these studies analyzes the effects of an explosive strength program, based on plyometrics and multi-jumping. The authors conclude that this type of stimulus has no clear effect on RSA (Buchheit et al., 2010). In this regard, Padilla and Lozada found correlations between 0.68 and 0.75 between different RSA variables and squat jump (SJ), countermovement jump (CMJ) and countermovement jump with arms (CMJa) performance (Padilla & Lozada, 2013). Other authors have wanted to analyze the relationship between maximal strength and RSA. Knee extensor strength has been found to have a strong relationship with RSA (Newman et al., 2004). Stojanovic et al. (2012) propose enhancing explosive strength training programs for basketball players to improve repeated sprint ability (RSA), citing a strong correlation between strength, vertical jump height, and RSA, attributed to the efficient functioning of the alactic anaerobic system and better utilization of phosphocreatine (PCr). The study by Gonzalez-Frutos et al. also found significant relationships between loaded vertical jump (50% of body weight) and IF in RSA ($r > 0.7$; $p < 0.01$) (Gonzalez-Frutos et al., 2021). In short, the results found in the different studies are not clear and the methodologies are different.

The vertical force-velocity profile of the lower limbs (FV-v profile) is a relevant factor in explosive force-dependent actions (Jiménez-Reyes et al., 2014) and its use for training optimization has been used in recent years, so it is worth asking whether this indicator could be relevant in RSA. This profile establishes a relationship between the application of force and speed, identifying optimal values that would lead to improved power production, tailored to each athlete. This assessment allows determining the extent (percentage of imbalance) to which there may be an imbalance between force or speed production in the measured profile, compared to a theoretical optimal profile where power production would be maximal (Samozino, et al., 2014).

In relation to the primary demands of basketball, it is noted that short-duration and high-intensity efforts do not consistently follow a linear pattern. Various authors, through time-motion analysis, have confirmed the frequent occurrence of changes of direction (COD), characteristic of multidirectional sports (Ben Abdelkrim et al., 2010; Brini et al., 2022; Brughelli et al., 2008; Narazaki et al., 2009). Hence, achieving high levels of COD is regarded as a crucial physical demand for basketball players (Sugiyama et al., 2021). Consequently, the evaluation of Repeated Sprint Ability (RSA), which encompasses changes in direction, holds significance within the context of basketball (Padulo et al., 2015).

Finally, regarding the mentioned variables, differences between men and women exist. Men have a greater ability to apply force, as evidenced by higher values obtained in the FV-v profile, although they do not show a different trend in terms of the balance of this profile (Nuzzo, 2022; Hicks et al., 2023). The cardiovascular performance is also lower, with typically reduced levels of maximal oxygen uptake (VO2max) (Besson et al. 2022). Similarly, performance in change of direction (COD) tasks is higher in men compared to women (Baena-Raya et al., 2024). Regarding high-intensity intermittent activities, women appear to recover better and experience less speed decrement compared to men when recovery times are short (Schmitz et al., 2020).

In line with the above, the main objectives of the study are as follows:

- To determine the relationship between the final velocity achieved in the 30-15 intermittent fitness test (VIFT) and the ability to repeat sprints with and without changes of direction.
- To examine the relationship between indirectly estimated maximal oxygen consumption through the 30-15 intermittent fitness test and the ability to repeat sprints with and without changes of direction.
- To analyze the relationship between the imbalance in the vertical force-velocity profile and the ability to repeat sprints with and without changes of direction.
- To analyze all variables in relation to the sex of the athlete.

Methods

Sample

The sample selected for the study was of 42 athletes (N=42; age: 17.5 ± 1.52 years; height: 1.92 ± 0.10 m; body mass: 83.30 ± 12.36 kg) 32 men (n1=32; age: 17.47 ± 1.50 years; height: 1.95 ± 0.09 m; body mass: 85.87 ± 11.08 kg) and 10 women (n2=10; age: 17.60 ± 1.65 years; height: 1.81 ± 0.06 m; body mass: 70.89 ± 9.18 kg), all belonging to a basketball club in the Community of Madrid, at the highest competitive level in their respective categories. Those athletes who were injured or had just recovered from an injury were excluded. All study participants were informed of the objectives, potential risks, and methods and signed an informed consent form, as did the legal guardians of minors among the players. The study was designed in compliance with the recommendations for clinical research of the Declaration of Helsinki of the World. The local institutional human research ethics committee approved the study protocol (CIPI/18/195). Tables 1, 2, and 3 display the descriptives.

Table 1. Descriptive Statistics of the Whole Sample

	Age	*Height*	*BM*	*%ImbFV*	*VO2max.*	*VIFT*	*IF RASTm*	*CMJloss RASTm*	*IF Ill*	*CMJloss Ill*
Mean	17,50	1.91	82.30	50.36	49.90	19.06	8.18	6.33	8.88	10.16
Std. Deviation	1,52	0.10	12.36	26.12	3.56	1.49	4.25	4.25	4.82	6.19
Minimum	15	1.74	62.00	2.00	41.55	16.00	0.55	0.45	1.21	0.05
Maximum	23	2.20	110.80	91.00	55.11	22.00	20.67	21.295	23.92	28.04

Std. Deviation = standard deviation; BM = body mass; % ImbFV. = imbalance with respect to the optimum vertical force-velocity profile; CMJloss. RASTm. = CMJ loss in RASTm; IF. RASTm. = IF in RASTm; CMJloss. Ill. = CMJloss in modified Illinois test; IF Ill. = IF in modified Illinois test; VIFT = velocity achieved in the 30-15 IFT; VO2max. = maximal oxygen consumption

Table 2. Descriptive Statistics of the men Sample

	Age	*Height*	*BM*	*%ImbFV*	*VO2max.*	*VIFT*	*IF RASTm*	*CMJloss RASTm*	*IF Ill*	*CMJloss Ill*
Mean	17,46	1.95	85.87	45.62	50.06	19.44	7.98	5.69	8.88	10.78
Std. Deviation	1,50	0.09	11.08	26.21	2.86	1.29	3.68	5.39	5.17	6.52
MInimum	15	1.77	64.20	2.00	44.80	17.00	1.86	0.45	1.21	0.05
Maximum	23	2.20	110.80	84.00	55.11	22.000	16.87	21.295	23.92	28.04

Std. Deviation = standard deviation; BM = body mass; % ImbFV. = imbalance with respect to the optimum vertical force-velocity profile; CMJloss. RASTm. = CMJ loss in RASTm; IF. RASTm. = IF in RASTm; CMJloss. Ill. = CMJloss in modified Illinois test; IF Ill. = IF in modified Illinois test; VIFT = velocity achieved in the 30-15 IFT; VO2max. = maximal oxygen consumption

Table 3. Descriptive Statistics of the women sample

	Age	*Height*	*BM*	*%ImbFV*	*VO2max.*	*VIFT*	*IF RASTm*	*CMJloss RASTm*	*IF Ill*	*CMJloss Ill*
Mean	17,60	1.81	70.89	66.56	45.19	17.85	8.81	8.38	8.92	8.17
Std. Deviation	1,65	0.06	9.18	20.13	3.10	1.51	5.92	6.70	3.71	4.70
Minimum	16	1.74	62.00	30.00	41.55	16.00	0.55	1.64	4.72	0.05
Maximum	20	1.92	91.00	91.00	52.23	21.50	20.67	21.295	16.64	28.04

Std. Deviation = standard deviation; BM = body mass; % ImbFV. = imbalance with respect to the optimum vertical force-velocity profile; CMJloss. RASTm. = CMJ loss in RASTm; IF. RASTm. = IF in RASTm; CMJloss. Ill. = CMJloss in modified Illinois test; IF Ill. = IF in modified Illinois test; VIFT = velocity achieved in the 30-15 IFT; VO2max. = maximal oxygen consumption

Instruments

The 30-15 intermittent fitness test (30-15 IFT) was used to evaluate VIFT and estimate VO2max. This test was devised by Martin Buchheit to assess specific endurance capacity in intermittent team sports. While not tailored specifically for basketball, it has been utilized to evaluate these athletes, proving to be both valid and reliable (Jelicic et al., 2020). Additionally, it features a protocol adapted to the dimensions of a basketball court. The test consists of running a distance of 28 meters round trip following the pace set by an acoustic signal. It intersperses running phases, with a duration of 30 seconds, with recovery phases of 15 seconds. The 30-15 IFT App, developed by Martin Buchheit, is available for both Android and Apple operating systems. It incorporates audio prompts to guide the pace of the test and is available in three languages, catering to various sports. VO2max estimation was calculated using the following formulaVO2max (ml/kg/min) = 28.3 - 2.15 G - 0.741 E -0.0357 MC + 0.0586 E x VIFT + 1.03 VIFT; G being the sex (2 women, 1 men), E the age, VIFT the maximum speed reached in the test and MC the body mass.

For the estimation of the FV-v profile, the My Jump 2 App, developed by Carlos Balsalobre, was used, known for its reliability and validity in measuring vertical jump height (ICC=0.97-0.99, $p<0.05$) (Gallardo-Fuentes et al., 2016). It allows the calculation of the FV-v profile and the estimation of the imbalance (with strength or speed deficit) with respect to the theoretical optimal profile, with an incremental vertical jump test with 4 loads.

For the assessment of RSA without change of direction, the modified Running-Based Anaerobic Sprint Test (RASTm) was used, since some authors propose that the original distance of 35 meters may be too long in this sport modality (Padulo et al., 2015). The protocol was 6 sprints of 20 meters with a passive recovery of 10 seconds. The following formula was used to calculate the IF: ((Worst time * 100) / best time) - 100. To assess the effect of fatigue, an evaluation of CMJ height loss (CMJloss), a widely contrasted method (Sánchez-Medina & González-Badillo, 2011), was also performed between the beginning and the end of the test, with the following formula: 100-((Final jump*100) /initial jump). It consists of performing a CMJ before and after the test or trial to be carried out. This way, the accumulated fatigue in the test can be assessed by the percentage decrease in height observed. The CMJ is a significant indicator of the neuromuscular status of the athlete, hence its decrease can be regarded as an indicator of performance decline or accumulated fatigue (Balsalobre et al., 2014). To measure the partial times of each sprint, Witty Wireless Training Timer Micro Gate photoelectric cells (Witty Wireless Training Timer, Microgate, Bolzano, Italy) were used, and for the vertical jump the My Jump 2 App was used.

For the assessment of the RSA with change of direction, the Illinois test was used (Hachana et al., 2013), in this case with 4 repetitions with a recovery of 10 seconds of passive recovery. The test consists of completing the course shown in Figure 1. Modifications were applied to the original protocol, so that the athletes didn't start lying down and didn't need to touch the cones during direction changes. This test was chosen for its reliability and validity (Hachana et al., 2013), and for being suitable for evaluation in basketball players (Asadi, 2013). The measurement and calculation of CMJloss and IF was performed in the same way as with RASTm.

Intervention protocol

Measurements were conducted over 4 sessions, with each team completing measurements over 2 weeks in weeks where no more than one match was played. Two tests were administered weekly, with a minimum separation of 48 hours between them and avoiding testing on the day after a match. Measurements were taken prior to the team's training session to prevent fatigue from interfering with the results. On day 1, the FV-v profile was performed. On day 2, the 30-15 IFT was performed. On day 3, the RASTm was performed. Finally, on day 4 the evaluation was concluded with the modified Illinois test.

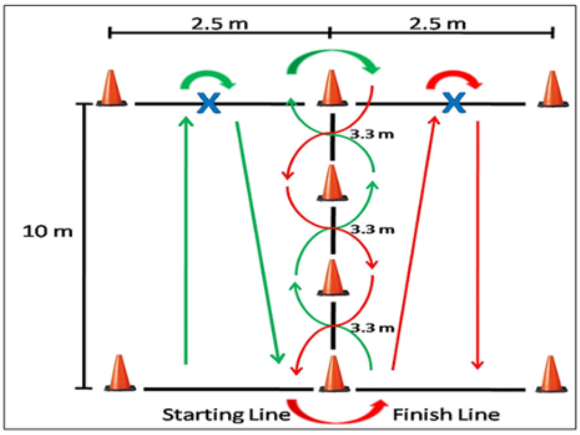

Figure 1. Illinois Agility Test (Raya et al., 2013. p. 954)

Day 1 (FV-v profile)

A warm-up involving continuous running, joint mobility exercises, and CMJ jumps without load was conducted. The test consisted of a protocol of 4 CMJ of progressive load, starting with no load for the first jump and gradually increasing to a load where 15-20 centimeters were reached on the final jump, with a 2-minute rest between each jump. In all sets, athletes were strongly encouraged to apply maximum force. Two attempts were made with each load. The percentage of imbalance with respect to the theoretical optimal profile was obtained.

Day 2 (30-15 IFT)

A warm-up consisting of continuous running and joint mobility was performed. After the warm-up, the test was performed. Following the warm-up, the test commenced using Level 2, beginning at 10 km/h. The test concluded when the athlete failed to reach the designated line indicated by each sound signal on two consecutive occasions, experienced fatigue, or voluntarily stopped. Athletes were encouraged to maintain their pace. Estimated VO2max and VIFT were obtained.

Day 3 (RASTm)

A warm-up including continuous running, joint mobility exercises, skipping exercises, and progressive sprint series was conducted. Prior to commencing the test, the athlete's CMJ was measured. 6 repetitions of 20 meters sprint were executed with a 10-second recovery period between each repetition. Following the completion of the last repetition, another CMJ was performed immediately. The IF and CMJloss were then obtained.

Day 4 (Modified Illinois test)

The warm-up included continuous running, joint mobility exercises, skipping drills, progressive sprint series, and two repetitions of the test itself at low intensity to familiarize with the course. Before starting the test, the athlete's CMJ was measured. The 4 repetitions were performed with 10-second recovery. After finishing the last repetition, another CMJ was performed immediately. The IF and CMJloss were then obtained.

Data analysis

The statistical software JASP - 0.18.0 was utilized for data analysis. Mean and standard deviation were computed for each of the variables analyzed. Pearson's correlation coefficient was employed to establish relationships between the variables under investigation. Furthermore, correlation analysis was conducted for the entire sample, as well as for the male and female groups separately. In this study, correlations were considered statistically significant if the p-value was less than 0.05. Additionally, stricter significance levels were applied, with p-values less than 0.01 and 0.005, to assess the robustness of the observed associations. All correlation coefficients (R) were presented with 95% confidence intervals, both upper and lower.

Results

The results are presented below in the form of tables showing the data for the entire sample, in addition to the subgroups of men and women separately (**Table 2**, **Table 3**, and **Table 4**). **Figures 2**, **3** and **4** show the regression lines of the statistically significant correlations.

Table 2. Whole sample correlations

	Pearson´s R	*p*	*Lower 95% CI*	*Upper 95% CI*
% ImbFV. – CMJloss.RASTm.	0,035	0,824	-0,271	0,336
% ImbFV. – IF. RASTm.	0,227	0,148	-0,083	0,497
% ImbFV. – CMJloss. Ill.	0,492***	< ,001	0,221	0,692
% ImbFV. – IF. Ill.	0,235	0,133	-0,074	0,503
VIFT – CMJloss. RASTm.	-0,126	0,427	-0,414	0,185
VIFT – IF. RASTm.	-0,334*	0,031	-0,579	-0,033
VIFT – CMJloss. Ill.	-0,040	0,803	-0,339	0,268
VIFT – IF. Ill.	-0,071	0,655	-0,367	0,238
VO2max. – CMJloss. RASTm.	-0,114	0,474	-0,404	0,197
VO2max. – IF. RASTm.	-0,300	0,053	-0,554	0,004
VO2max. – CMJloss. Ill.	0,034	0,831	-0,273	0,334
VO2max. – IF. Ill.	-0,075	0,638	-0,370	0,234

% ImbFV. = imbalance with respect to the optimum vertical force-velocity profile; CMJloss. RASTm. = CMJ loss in RASTm; IF. RASTm. = IF in RASTm; CMJloss. Ill. = CMJloss in modified Illinois test; IF Ill. = IF in modified Illinois test; VIFT = velocity achieved in the 30-15 IFT; VO2max. = maximal oxygen consumption

* p < ,05; ** p < ,01; *** p < ,005

Table 3. Men´s subgroup correlations.

	Pearson´s R	*p*	*Lower 95% CI*	*Upper 95% CI*
% ImbFV. – CMJloss.RASTm.	-0,164	0,368	-0,485	0,195
% ImbFV. – IF. RASTm.	0,134	0,465	-0,225	0,461
% ImbFV. – CMJloss. Ill.	0,668***	< ,001	0,417	0,825
% ImbFV. – IF. Ill.	0,259	0,152	-0,099	0,557
VIFT – CMJloss. RASTm.	0,098	0,593	-0,259	0,432
VIFT – IF. RASTm.	-0,304	0,091	-0,590	0,050
VIFT – CMJloss. Ill.	-0,073	0,693	-0,411	0,283
VIFT – IF. Ill.	-0,003	0,985	-0,352	0,346
VO2max. – CMJloss. RASTm.	0,162	0,375	-0,198	0,583
VO2max. – IF. RASTm.	-0,291	0,106	-0,581	0,064
VO2max. – CMJloss. Ill.	0,026	0,888	-0,371	0,326
VO2max. – IF. Ill.	-0,003	0,987	-0,351	0,346

% ImbFV. = imbalance with respect to the optimum vertical force-velocity profile; CMJloss. RASTm. = CMJ loss in RASTm; IF. RASTm. = IF in RASTm; CMJloss. Ill. = CMJloss in modified Illinois test; IF Ill. = IF in modified Illinois test; VIFT = velocity achieved in the 30-15 IFT; VO2max. = maximal oxygen consumption

* p < ,05; ** p < ,01; *** p < ,005

Table 4. Women´s subgroup correlations.

	Pearson´s R	*p*	*Lower 95% CI*	*Upper 95% CI*
% ImbFV. – CMJloss.RASTm.	0,438	0,205	-0,264	0,837
% ImbFV. – IF. RASTm.	0,473	0,168	-0,223	0,850
% ImbFV. – CMJloss. Ill.	0,133	0,714	-0,542	0,704
% ImbFV. – IF. Ill.	0,179	0,621	-0,508	0,727
VIFT – CMJloss. RASTm.	-0,365	0,299	-0,809	0,343
VIFT – IF. RASTm.	-0,400	0,253	-0,822	0,307
VIFT – CMJloss. Ill.	-0,430	0,214	-0,834	0,273
VIFT – IF. Ill.	-0,392	0,263	-0,819	0,316
VO2max. – CMJloss. RASTm.	-0,395	0,259	-0,820	0,313
VO2max. – IF. RASTm.	-0,369	0,294	-0,810	0,340
VO2max. – CMJloss. Ill.	-0,388	0,268	-0,818	0,319
VO2max. – IF. Ill.	-0,480	0,161	-0,852	0,215

% ImbFV. = imbalance with respect to the optimum vertical force-velocity profile; CMJloss. RASTm. = CMJ loss in RASTm; IF. RASTm. = IF in RASTm; CMJloss. Ill. = CMJloss in modified Illinois test; IF Ill. = IF in modified Illinois test; VIFT = velocity achieved in the 30-15 IFT; VO2max. = maximal oxygen consumption

* p < ,05; ** p < ,01; *** p < ,005

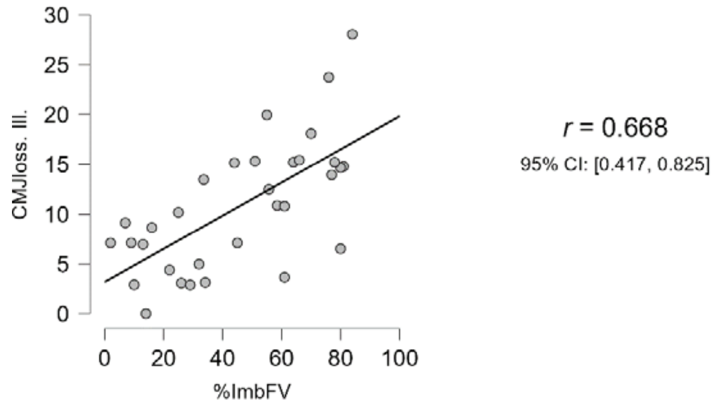

Figure 2. Correlation between FV-v profile and CMJloss in the modified Illinois test in the men´s subgroup.

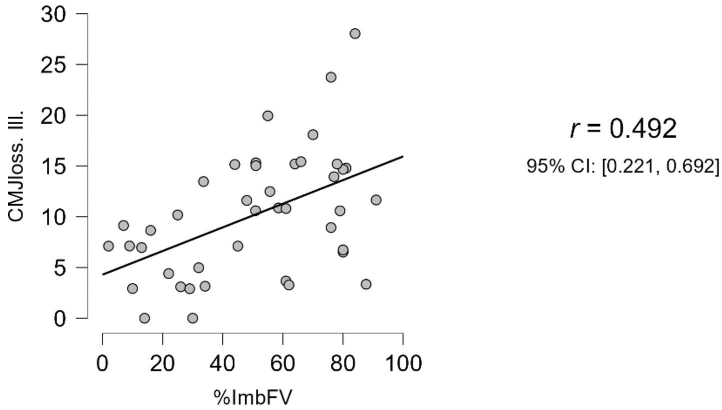

Figure 3. Correlation between FV-v profile and CMJloss in the modified Illinois test in the whole sample.

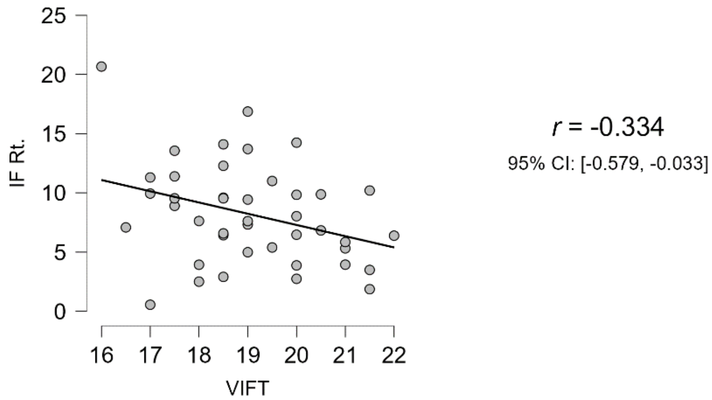

Figure 4. Correlation between VIFT and IF in the whole sample.

Discussion

The study aimed to determine the relationship between the final velocity achieved in the 30-15 intermittent fitness test (VIFT) and the estimated VO2max. in the aforementioned test with the RSA with and without changes of direction, analyze the relationship between the imbalance in the vertical force-velocity profile and RSA and without changes of direction, and analyze all variables in relation to the sex of the athlete. It showed some significant correlations in the variables analyzed. The main interest of the study lies not only in the relationship between the variables but also in the differences that may be shown between gender. However, analyzing the general results of the whole sample may also be of interest.

The current study analyzed correlations between FV-v profile and muscle strength in relation to RSA. Previous studies differed in both methodology and variables analyzed, not only in comparison to the present work but also among themselves. These variations included assessments of maximum or explosive strength, intervention programs, and differing variables analyzed such as IF, mean time, or best time (Buchheit et al., 2010; González-Frutos et al., 2021; Newman et al., 2004; Padilla & Lozada, 2013; Stojanovic et al., 2012). In none of them was the FV-v profile analyzed in relation to the RSA. Therefore, it is complicated to establish comparisons with existing research. In the review conducted by Babiloni-López et al. (2022), no studies were found that examine the relationship between the FV-v profile and RSA.

In the present study, significant correlations were found between CMJloss in modified Illinois and imbalance in the FV-v profile ($r = 0,49$, $p < 0,001$). When trying to establish sex differences, the results showed that it was much higher in men than in women. In this case, the findings are very promising ($r = 0,67$, $p < 0,001$). The relationship seems to be high. In the case of women, the results showed no relationship ($r = 0,13$, $p = 0,71$). It would be valuable to investigate whether these results are attributed to the small sample size, the influence of the menstrual cycle, or if the FV-v profile doesn't significantly affect jump performance during RSA tasks involving directional changes in women. In other studies where this profile was measured in female athletes, the menstrual cycle was not considered (Jiménez-Reyes et al., 2018; Sánchez-López & Rodríguez-Pérez, 2018), suggesting that it does not appear to be a determining factor. Despite abundant information on strength training and the menstrual cycle, there's limited research on the relationship between the FV-v profile and menstrual cycle (Babiloni-López et al., 2022), specifically regarding whether the imbalance percentage varies across different phases. García-Pinillos et al. (2021) study found no significant differences in CMJ performance or sprint force-velocity profiles across menstrual cycle phases. Nevertheless, it remains unclear whether the timing of the menstrual cycle affects the FV-v profile based on current evidence, although indications suggest otherwise. which would be of great interest to better understand these results.

On the other hand, no significant correlations were found between the IF of both tests nor the CMJloss in the RASTm. Therefore, it seems that a more optimized FV-v profile has an influence on the jumping ability under fatigue conditions of a basketball player. This relationship is observed only in the test with changes of direction, which aligns with the characteristics of this sport modality (Narazaki et al., 2009; Ponce-Bordón et al., 2021; Stojonavic et al., 2018; Vázquez-Guerrero et al., 2020).

This holds potential significance for sports performance, particularly in basketball, where vertical jumps can significantly impact athletes' overall performance (Ben Abdelkrim et al., 2010). The ability to maintain jump height or minimize losses during a competition can be of great interest to coaches, as performance in actions such as rebounds, block attempts, and other game actions may be less affected by fatigue. Typically, optimizing the FV-v profile leads to performance improvements in ballistic or very high-intensity actions (Morin & Samozino, 2016).

Additionally, these results may also suggest a contribution to reducing fatigue in such vertical actions. It appears that the FV-v profile has had no influence on IF, so that optimizing the FV-v profile would not lead to less influence of fatigue on sprinting, which is a force application of the horizontal vector. There could be other relevant factors such as maximum horizontal force application (F0) or maintenance of horizontal force production (DRF) that may have greater relevance, given that there is no known optimal horizontal profile to date (Jiménez-Reyes et al., 2018). Commented factors such as F0, DRF and even others such as effective horizontal force ratio (RFpeak) and peak power (Pmax) measured in the horizontal velocity force profile may have greater relevance on speed in sprinting or changes of direction, so perhaps this relationship could also occur in RSA and under the influence of COD (Baena-Raya et al., 2022; Baena-Raya, Rodríguez-Pérez, et al., 2021; Baena-Raya, Soriano-Maldonado, et al., 2021; Robles-Ruiz et al., 2023).

Regarding the VIFT, a significant correlation was found with the IF in the RASTm ($r = -0.33$, $p < 0.05$), which was slightly higher than that with respect to VO2max. The findings of Buchheit (2008), who reported a correlation between

VIFT and IF in the RSA test of r = 0.73 ($p < 0.001$), could not be replicated, given that the observed relationship is not as strong. While the relationship in this case is not very strong, it appears to account for some of the variance. When analyzing these same variables in terms of male and female samples, the relationships exhibited similar values but are not statistically significant (-0.30 for the male sample and -0.40 for the female sample). Thus, a small portion of the variance in the IF in the RASTm can be explained by the VIFT, the specific endurance capacity. As discussed in the introduction, athletes with better specific endurance capacity may experience less performance decrement in short-duration sprints (Buchheit & Ufland, 2011; Gharbi et al., 2015; Padilla & Lozada, 2013). However, the relationship is not substantial, suggesting that the influence may not be high.

In the modified Illinois test, the data did not show significant relationships with IF in the total and male samples, concerning the VIFT. This test entails greater variability in directional changes compared to the 30-15 IFT protocol. Therefore, this variable, such as COD, may suggest that the influence of specific endurance capacity on RSA is reduced. As highlighted in the introduction (Ben Abdelkrim et al., 2010; Brini et al., 2022; Brughelli et al., 2008; Narazaki et al., 2009), the conditions and demands of a basketball game require frequent COD. Thus, the value of specific endurance capacity in sports performance may diminish if it does not help mitigate or influence the loss of speed in these crucial actions (Sugiyama et al., 2021). Lastly, considering the CMJ loss in both tests, the relationships, though not significant, were larger in females. In the total and male samples, they were never above 0.1 or -0.1, being -0.36 (RASTm) and -0.43 (modified Illinois) in the female sample. It appears that specific endurance capacity cannot affect the jump loss of a basketball player, as these variables seem unrelated. As mentioned earlier, the force application vector is not the same.

Concerning the relationship with estimated VO2max, there were no clear relationships. Regarding IF and CMJloss in the modified Illinois test, there seemed to be no significant relationship, as was the case with RASTm. When analyzing both sexes separately, the relationships between VO2max and the different parameters in both RSA tests showed higher correlations in females, for both IF and CMJ loss, even in the modified Illinois test, reaching values close to -0.5 (r = -0.48). However, none of the correlations were significant. With respect to the results in men, the relationships were very low for both IF and CMJloss with values between 0,16 and -0,29. Therefore, although it seems that there may be a minimal relationship, much greater in women, it is very unclear and not significant. VO2max may have a very low influence on RSA test with and without directional changes in men. This contrasts with other data in the literature, which showed that both men and women respond similarly to RSA stimuli in relation to their VO2max, demonstrating similar aerobic capacities (Mageean et al., 2011). These results are related to those of other authors commented previously (Castagna et al., 2007; Ferrari Bravo et al., 2008; Stojanovic et al., 2012), as the association is unclear. As discussed, higher VO2max. may lead to better PCr regeneration (Girard et al., 2011), but it seems not to be a determinant factor for performance, at least in this case estimated indirectly. Other studies have also shown a disparity of results. The work conducted by Jones et al. (2013) demonstrated significant correlations between the mean time in an RSA test and VO2max values, in contrast to the study by the Gharbi et al. (2015) group, where the results did not show any significant relationship between VO2max and any of the RSA variables analyzed (mean time, IF, total time).

It would be of interest to analyze these variables in a larger sample of women to obtain more reliable results. Additionally, employing a stress test with spirometry to determine VO2max. would be recommended, as the ratio could differ and potentially be higher than in men. Although the 30-15 IFT has proven to be a valid and reliable way to measure aerobic performance in athletes, specifically in basketball players, this estimation by means of a field test does not have the same reliability as a direct estimation test, so the results should be taken with caution (Covic et al., 2016; Grgic et al., 2021).

Conclusions

Our study reveals an important connection. There's a significant link between the FV-v profile imbalance and CMJ loss in RSA tests with COD. Interestingly, this association is strong among men but not among women. Notably, this relationship doesn't appear in RSA tests without COD or in terms of the IF, which reflects speed loss in RSA.

Additionally, specific endurance capacity has a small yet meaningful impact on RSA without COD. However, this influence doesn't extend to RSA with COD or CMJ loss.

Practical applications

The optimization of the FV-v profile, aiming to minimize imbalance, may result in reduced vertical jump losses following RSA stimuli in male basketball players. Given the significance of both vertical jump and RSA in this sport, training strategies targeting profile balance could be integrated into training programs. Consequently, measuring the FV-v profile and tailoring strength training accordingly could be essential, not only for maximizing strength but also for minimizing vertical jump performance decrement during a game.

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