



Original/Deporte y ejercicio

# Physical fitness, adiposity and testosterone concentrations are associated to playing position in professional basketballers

Jesús Gustavo Ponce-González<sup>1</sup>, Hugo Olmedillas<sup>1</sup>, Julio Calleja-González<sup>2</sup>, Borja Guerra<sup>1</sup> and Joaquín Sanchis-Moysi<sup>1</sup>

<sup>1</sup>Laboratory of Human Performance, Physical Exercise and Health, Faculty of Physical Education and Sport Sciences, Department of Physical Education, University of Las Palmas de Gran Canaria.<sup>2</sup>Department of Physical Education and Sports, Faculty of Sport Sciences, University of the Basque Country, Spain.

## Abstract

The effects of basketball on basal concentrations of testosterone and cortisol and its associations to body composition and physical performance remain to be determined.

**Aim:** the main aim of this study was to determine the effects of playing position on physical fitness, percentage of body fat and hormonal profile in professional basketball players (BP).

**Method:** jump performance (SJ, CMJ and ABK), 30 m running speed and treadmill VO<sub>2</sub>max tests were conducted in 12 male BP (24.1 years) from the first division league of Spain (ACB). The percentage of body fat was determined from anthropometry, and hemoglobin, glucose, testosterone and cortisol concentrations were measured from fasting blood samples. BP were divided into 3 groups depending on playing positions: guards (GU), forwards (FW) and centers (CE) (n = 4 in each group).

**Results:** GU had greater percentage of body fat (%BF) than CE (p < 0.05). CE developed greater positive mechanical impulse than GU in all jump types (p < 0.05) and achieved higher maximal instantaneous power than GU and FW in the SJ and ABK (p < 0.05). Centers had more plasma testosterone than guards (p < 0.05). All groups a similar relative VO<sub>2</sub>max.

**Conclusion:** center position was associated to lower adiposity and higher jumping performance than playing as guards. All playing positions induced a similar effect on aerobic power.

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Key words: Basketball. Fat. VO<sub>2</sub>max. Testosterone. Cortisol.

## CONDICIÓN FÍSICA, ADIPOSIDAD Y CONCENTRACIONES DE TESTOSTERONA ESTÁN ASOCIADAS A LA POSICIÓN DE JUEGO EN BALONCESTISTAS PROFESIONALES

### Resumen

Los efectos de jugar al baloncesto sobre las concentraciones basales de testosterona y cortisol, así como su asociación a la composición corporal y el rendimiento físico aún están por determinarse.

**Objetivo:** el principal objetivo de este estudio fue determinar los efectos de la posición de juego sobre la condición física, el porcentaje de grasa corporal y el perfil hormonal en jugadores de baloncesto profesionales (BP).

**Metodología:** la capacidad de salto (SJ, CMJ y ABK), la velocidad en 30 m y el VO<sub>2</sub>max en tapiz rodante se midió en 12 varones BP (24,1 años) pertenecientes a la primera división de la liga de España (ACB). El porcentaje de grasa corporal se determinó a partir de la antropometría, y las concentraciones de hemoglobina, glucosa, testosterona y cortisol se midieron a partir de muestras de sangre en ayunas. Los baloncestistas se dividieron en tres grupos en función de las posiciones de juego: bases (GU), aleros (FW) y pivots (CE). Resultados: GU tuvo mayor porcentaje de grasa corporal (% GC) que CE (p < 0,05). CE desarrolló mayor impulso positivo mecánico que GU en todos los tipos de saltos (p < 0,05) y logró mayor potencia instantánea máxima que GU y FW en el SJ y ABK (p < 0,05). Los pivots tenían más testosterona plasmática que los bases (p < 0,05). Todos los grupos mostraron similar VO<sub>2</sub> máx.

**Conclusión:** la posición de pivots fue asociada a una menor adiposidad y a una mayor capacidad de salto en comparación con los bases. Todas las posiciones de juego indujeron un efecto similar sobre la potencia aeróbica.

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Palabras clave: Baloncesto. Grasa. VO<sub>2</sub>máx. Testosterona. Cortisol.

**Correspondence:** Jesús Gustavo Ponce González.  
Departamento de Educación Física.  
Campus Universitario de Tafira.  
35017 Las Palmas de Gran Canaria, España.  
E-mail: jesus.ponce.gonzalez@gmail.com

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## Abbreviations

ABK: Abalakov.  
ACB: First division league of Spain.  
BP: Basketball players.  
CE: Centers.  
CMJ: Counter movement jump.  
FW: Forwards.  
GU: Guards.  
IUA: Use of arm-swing.  
M: Normalized for body size.  
MIP: The maximal instantaneous power.  
MIV: The maximal instantaneous vertical velocity.  
MP: The mean power.  
NBA: National basketball association league of United States.  
PI: The positive mechanical impulse.  
RFD: The mean rate of force development.  
S: Power.  
SJ: Squat jump.  
VCO<sub>2</sub>: Co<sub>2</sub> production.  
VE L/min, VO<sub>2</sub> L/min: Ventilation.  
VHJ: The vertical height jump.  
VO<sub>2</sub>: Measure oxygen uptake.  
VO<sub>2</sub>max: Maximal oxygen uptake.  
VT: Vertical velocity at takeoff.  
VT<sub>2</sub>: Ventilatory threshold.  
Hemoglobin (Hb) and hematocrit (Hct) were measured by microcentrifugation (Allegra™ 25R Centrifuge, Beckman Coulter, California, USA) and cyanometHb (Boehringer Mannheim GmbH test combination, Mannheim, Germany), respectively.  
SD: Mean value ± standard deviation.  
LSD: Fisher's least significant difference.  
BMI: Bodymassindex.  
RSA: Repeated Sprint Ability.

## Introduction

Basketball is one of the most popular sports throughout the world. The first division of the Spanish basketball league [Basketball Clubs Association (ACB)] is considered the best league in the world by most coaches and players, after the NBA (National Basketball Association league of United States)<sup>1</sup>. Physical characteristics of professional basketball players have been reported in players enrolled in different basketball leagues<sup>1,2</sup>, but limited data is available with ACB or NBA players<sup>3,4</sup>. However it remains to be determined the influence of playing position on physical fitness and fat mass in professional basketball players.

Basketball requires the combination of low and high-intensity actions<sup>5</sup>. Also the RSA relevance as determinant of ability to reproduce high intensity efforts thought the entire basketball game should not be omitted<sup>6</sup>. A major part of these actions are high-intensity and recruits the anaerobic metabolism<sup>5,7</sup>, among them the jumps and sprints are the most frequent<sup>2,5,8</sup>. Together

with jumping and sprinting, aerobic power has been recently associated to performance in Tunisian basketball players<sup>2</sup>. These impairments in performance highlight that coaches should plan conditioning programs based on repeated sprint and repeated jump ability, strength, sprint and jump capacities following specific sessions<sup>9</sup>. In this population maximum oxygen consumption (VO<sub>2</sub>max) positively correlated to the time spent in high-intensity actions during a basketball match<sup>8</sup>. Low-intensity running or walking during the short periods of time between high-intensity actions stimulates aerobic metabolism and accelerates the recovery<sup>2,10,11</sup>, which allows maintaining anaerobic power and capacity during the basketball game<sup>12</sup>. It remains to be determined whether jumping, sprinting performance and VO<sub>2</sub>max is associated to playing position in ACB players.

Testosterone is an anabolic hormone which regulates body composition. High blood concentrations of testosterone are associated to increased muscle mass and strength in humans<sup>13</sup> and decreased fat mass<sup>14</sup>. In contrast, cortisol is a catabolic hormone with opposite effects. A decrease in the testosterone/cortisol ratio can lead to overtraining syndrome, characterized by a decreased sport-specific physical performance<sup>15</sup>. Little information exists about the physiological profiles of professional basketball players<sup>4,5</sup>. The effects of basketball on basal concentrations of testosterone and cortisol and its associations to body composition and physical performance remain to be determined. This information could be very useful to develop more specific training programs for basketball players.

The main aim of this study was to determine physical fitness, fat mass accumulation and hormonal profile of professional basketball players from the ACB league. A secondary aim was to test the hypothesis that playing position is associated to differences these variables.

## Methods and Participants

### Participants

Twelve male basketball players (24.1 ± 4.9 years) from a first division team of the ACB in a selective n agreed to enroll in the study. All players had been participating in the last 6 final stages (Play-offs) of the ACB and in the Eurocup Basketball (Union of European Basketball Leagues, ULEB Eurocup). Their current dedication to competitions, sport specific and physical conditioning training sessions was 24 hours per week. All participants performed a similar physical conditioning training program and used the same relative loads during the resistance training sessions. Players were assigned to 3 groups depending on their playing positions, guards (n=4), forwards (n=4), and centers (n=4). Each participant, as well as the basketball club were informed about the aims and procedures of the study and gave their informed written consent. Our selection of highly trained

and motivated basketballers. This study was based on our experience that competitive athletes are generally willing and able to withstand considerable discomfort. The coaches were informed carefully about the experimental procedures and the possible risk and benefits of the project with the approval of the local committee of ethics of the University of Las Palmas de Gran Canaria and gave written consent to participate in this study, which conformed to the Declaration of Helsinki.

The tests were conducted in two different days during the preparation phase of the season. The first day, subjects were asked to attend to the laboratory in fasting conditions for blood collection, anthropometrics determinations, and to perform an incremental exercise test on treadmill to measure  $\text{VO}_2\text{max}$ . At least 72 h later, the participants performed the jump tests and the 30 m running speed test.

### Dynamic force

The forces generated during vertical jumps were measured with a force plate (Kistler, Winterthur, Switzerland) and were used to determine the jumping height as previously reported<sup>16</sup>. Each participant performed three kinds of maximal jumps following the protocol proposed by Bosco et al<sup>17</sup>. The squat jump (SJ): starting with knees bent at 90° and without previous counter movement, the counter movement jump (CMJ): starting from a standing position that allows counter movement to be able to reach knee bending angles of around 90° just before impulsion, and the “Abalakov jump” (ABK), same protocol than the CMJ but with arms free to help the subject to jump up.

The vertical height jump (VHJ), vertical velocity at takeoff (VT), the mean rate of force development (RFD), the positive mechanical impulse (PI), the mean power (MP), the maximal instantaneous power (MIP) and the maximal instantaneous vertical velocity (MIV) were determined by the best of three trials in all kinds of jumps, SJ, CMJ and ABK.

The RFD was obtained by linear regression of the force time relationship during the impulse phase of the SJ, CMJ and ABK between 25% and 75% of the peak force<sup>16</sup>. The “index of elasticity” was determined by calculating the difference between the CMJ and SJ vertical jump height, multiplied by one hundred and divided by SJ vertical jump height<sup>18</sup>.

$$IE = \frac{(CMJ - SJ) * 100}{SJ}$$

In addition, the index “Use of Arm-swing” (IUA) was calculated for the SJ and CMJ with the following formula<sup>18</sup>.

$$IUA_{sj} = \frac{(ABK - SJ) * 100}{SJ}$$

$$IUA_{cmj} = \frac{(ABK - CMJ) * 100}{CMJ}$$

Parameters related to the strength and power ( $S$ ) were normalized for body size ( $M$ ) through an allometric scaling model ( $S = a \cdot M^b$ ) based on the simple theory of geometric similarity proposed by Markovic and Jaric<sup>19</sup>.

$$S_n = \frac{S}{M^{0.67}}$$

### Running speed test

A 30-m sprint, starting in a stationary position, was performed on the basketball court. Time was recorded by 7 photocells prepared every 5 meters (Multicellular Equipment General ASDE, Valencia). The timer was automatically activated upon crossing the first cell and corresponding records were collected at distances of 5 and 30 meters. To perform this test subjects were encouraged to run as fast as possible the 30 meters. Each subject performed 3 trials and the fastest was taken as the representative value of the test.

### Percentage of body fat

The protocol “O-Scale System” was used to determine the anthropometric measurements<sup>20</sup>, which includes a body mass, height, skinfolds and circumferences measurements. The values the percentage of body fat were determined according to athlete-specific equation of Jackson and Pollock<sup>21</sup>. All skinfolds were measured using a skinfold caliper (Holtain, Ltd., Crymych, United Kingdom) which exerts a constant pressure of 10 g/mm<sup>2</sup> and has an accuracy of 0.1 mm, as described by Ara et al<sup>22</sup>.

### Treadmill $\text{VO}_2\text{max}$ Test

To perform the incremental test, the EKG electrodes were placed to monitor the heart rate response (Schiller AT12). Then a face mask was connected to the gas analyzer (Vmax N29; SensorMedics, California, USA) to measure oxygen uptake ( $\text{VO}_2$ ) and  $\text{CO}_2$  production ( $\text{VCO}_2$ ). When subjects were ready, they started the exercise test on a treadmill (PowerJog M30) with a constant slope of 1%, starting with a warming up of 3 minutes at a constant speed of 6 km/h, over a distance of 300 meters. Then a ramp incremental speed exercise was started at 8 km/h, and the speed was increased by 0.5 km/h every 30 seconds to exhaustion. Ventilation (VE) (L/min),  $\text{VO}_2$  (L/min), heart rate (bpm) and the second ventilatory threshold have been determined as has been described by Lucia et al<sup>23</sup>. The second ventilatory threshold ( $\text{VT}_2$ ) have been defined as the point before a second exponential increase in VE and the  $\text{O}_2$  equivalent accompanied by a non-linear increase in the  $\text{CO}_2$  equivalent as described by Reinhard et al<sup>24</sup>.

During the test, the values of the gas analyzer were captured breath by breath and averaged every 20 s.

### Blood samples

The subjects reported to the laboratory at 8.00 after an overnight fast and an antecubital vein was catheterized. After 10 min rest in the supine position a 20 ml blood sample was withdrawn. Serum glucose was measured by the hexokinase method using Gluco-quant reagents (Roche/Hitachi, 11876899216, Indianapolis, USA). Circulating concentrations of total testosterone and cortisol were determined using commercially available enzyme-linked immunosorbent assay (ELISA) kits (DRG Diagnostics, DRG Instruments GmbH, Marburg, Germany). Hemoglobin (Hb) and hematocrit (Hct) were measured by microcentrifugation (Allegra™ 25R Centrifuge, Beckman Coulter, California, USA) and cyanomet Hb (Boehringer Mannheim GmbH test combination, Mannheim, Germany), respectively.

### Statistical Analyses

The data are presented as mean value  $\pm$  standard deviation (SD). Differences between groups were tested using ANOVA with the Fisher's least significant difference (LSD) post hoc test. In addition, to determine if differences in physical fitness between playing positions could be accounted for height or weight, analy-

ses of covariance were performed with the body mass index (BMI) as covariate. Pearson correlation coefficients were calculated to determine the relationships between variables. Analysis were considered statistically significant when  $P < 0.05$ . The data were analysed using the statistical package SPSS, PC program, version 19. (SPSS Inc., USA).

## Results

### Physical characteristics

Physical characteristics of all basketball players are summarized in table I. Centers were taller than guards and forwards ( $P < 0.05$ ), and heavier than guards ( $P < 0.05$ ). The percentage of body fat was greater in guards than in centers ( $P < 0.05$ ).

### Physical fitness

Guards were faster than forwards, and centers, in the 5 first meters of the 30m running speed test ( $P < 0.05$ ). This result in the 5 first meters was maintained after accounting by BMI. Moreover, guards were faster than centers at the end of 30 meters ( $P < 0.05$ ). Guards were faster than forwards and center at the end of 30 meters after accounting by BMI ( $P < 0.05$ ). In turn, forwards were faster than centers at the end of 30 meters ( $P < 0.05$ ), and this result was maintained after accounting by BMI. Positive correlations were found

**Table I**  
Characteristics of professional basketball players belonging to the ACB league\*

Variables	All players (n = 12)	Guards (n = 4)	Forwards (n = 4)	Center (n = 4)	Perimeter players (n = 7)	Inside players (n = 5)
Age (year)	24.1 $\pm$ 4.9	24.1 $\pm$ 7.3	24.4 $\pm$ 5.6	23.7 $\pm$ 1.7	25.2 $\pm$ 5.9	22.5 $\pm$ 3.0
Height (cm)	196.4 $\pm$ 10.1	186.8 $\pm$ 4.4†	195.5 $\pm$ 7.4‡	206.9 $\pm$ 5.6	189.3 $\pm$ 5.6&	206.3 $\pm$ 5.0
Weight (kg)	91.8 $\pm$ 10.6	83.2 $\pm$ 4.9†	90.4 $\pm$ 8.2	101.7 $\pm$ 9.6	86.9 $\pm$ 7.9	98.6 $\pm$ 10.9
Body fat (%)	10.3 $\pm$ 1.0	10.9 $\pm$ 0.7†	10.3 $\pm$ 1.2	9.5 $\pm$ 0.6	10.7 $\pm$ 0.9&	9.5 $\pm$ 0.5
Hemoglobin (mmol·L <sup>-1</sup> )	14.5 $\pm$ 0.9	14.8 $\pm$ 1.2	14.7 $\pm$ 0.5	14.0 $\pm$ 0.9	14.7 $\pm$ 0.9	14.3 $\pm$ 0.9
Hematocrit (%)	43.4 $\pm$ 2.3	44.2 $\pm$ 2.2	43.9 $\pm$ 2.5	41.8 $\pm$ 2.0	43.7 $\pm$ 2.1	42.9 $\pm$ 2.7
Testosterone (ng/mL)	6.8 $\pm$ 1.7	6.0 $\pm$ 0.5†	7.0 $\pm$ 2.5	7.8 $\pm$ 1.2	6.0 $\pm$ 1.3&	8.3 $\pm$ 1.3
Cortisol ( $\mu$ g/dL)	18.0 $\pm$ 7.8	20.8 $\pm$ 4.8	18.4 $\pm$ 8.6	13.7 $\pm$ 10.9	19.0 $\pm$ 6.9	16.1 $\pm$ 10.2
VO <sub>2</sub> max (mL/kg/min)	57.7 $\pm$ 5.5	58.0 $\pm$ 5.0	57.5 $\pm$ 4.6	57.5 $\pm$ 8.7	57.0 $\pm$ 4.3	58.7 $\pm$ 7.5
HRmax (b·min <sup>-1</sup> )	188.9 $\pm$ 6.8	191.8 $\pm$ 10.3	188.7 $\pm$ 1.5	185.3 $\pm$ 3.2	190.7 $\pm$ 8.2	186.3 $\pm$ 3.2
VT <sub>2</sub> (% VO <sub>2</sub> max)	90.4 $\pm$ 4.8	90.9 $\pm$ 5.3	89.4 $\pm$ 7.1	90.8 $\pm$ 2.9	89.6 $\pm$ 5.9	91.6 $\pm$ 2.9
HR <sub>VT2</sub> (b·min <sup>-1</sup> )	178.2 $\pm$ 8.6	177.8 $\pm$ 11.4	177.0 $\pm$ 5.2	180.0 $\pm$ 10.1	177.0 $\pm$ 9.4	180.0 $\pm$ 8.3

\* Values are expressed as mean  $\pm$  SD; HR max = maximal heart rate obtained in the treadmill VO<sub>2</sub>max test; VT<sub>2</sub> = 2<sup>nd</sup> ventilatory threshold

† Statistically significant at  $p < 0.05$  for guards vs. center

‡ Statistically significant at  $p < 0.05$  for forwards vs. center

& Statistically significant at  $p < 0.05$  for perimeters vs. inside players

between height and the first 5 meters and 30 meters running time ( $r = 0.77$ ,  $P < 0.01$  and  $r = 0.78$ ,  $P < 0.01$ ; respectively). These correlations were maintained after accounting by BMI ( $r = 0.79$ ,  $P < 0.01$  and  $r = 0.76$ ,  $P < 0.01$ ; respectively).

The jumping height during SJ, CMJ and ABK was similar in guards, forwards and centers; even when it was adjusted by BMI. In all type of jumps, the positive mechanical impulse and the maximal instantaneous power were higher in centers than in guards (all  $P < 0.05$ ), and mean power was also higher during CMJ and ABK ( $P < 0.05$ ). The positive mechanical impulse remained increased in centers than in guards in all type of jumps when the results were adjusted by BMI ( $P < 0.05$ ). In turn, when the maximal instantaneous power was adjusted by BMI showed significant higher values in centers than in guards in SJ ( $P < 0.05$ ), and it showed a trend in CMJ and ABK ( $P = 0.06$  and  $P = 0.06$ ; respectively). However, the mean power was similar after accounting by BMI.

Maximal instantaneous power was greater in centers than in forwards during SJ ( $P < 0.05$ ). However, when the differences between centers and forwards were performed after accounting by BMI, the results showed that center had higher positive mechanical impulse in CMJ ( $P < 0.05$ ), and it showed a trend in SJ and ABK ( $P = 0.08$  and  $P = 0.07$ ; respectively). Moreover, the maximal instantaneous power showed a trend in SJ after accounting by BMI ( $P = 0.06$ ).

When all players were considered together, the IE was positively correlated with the  $IUA_{sj}$  ( $r = 0.94$ ,  $p < 0.05$ ) and inversely correlated with height ( $r = -0.67$ ,  $p < 0.05$ ); even when the results were accounted by BMI.

No significant differences by playing positions were found in  $VO_{2max}$ , second ventilatory threshold and HRmax.

### Hormones and blood measurements

Table I summarizes the hormonal profile of the basketball players. Plasma testosterone was higher in centers than in guards ( $P < 0.05$ ). No differences between groups were observed Hb, Hct, glucose and cortisol (Table I).

When all subjects were considered together an inverse correlation was observed between plasma testosterone and the percentage of body fat ( $r = -0.79$ ;  $P < 0.05$ ) (Fig. 1).

### Discussion

To our knowledge, this is the first study that has examined the differences between playing positions in anthropometry measurements, maximum speed, explosive power of lower limbs, maximal oxygen consumption and the second ventilatory threshold in

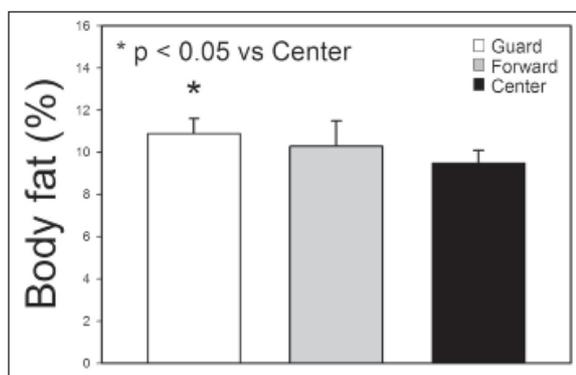


Fig. 1.—Percentage of body fat divided by playing position. Guards had more percentage of body fat when were compared with centers ( $p < 0.05$ ).

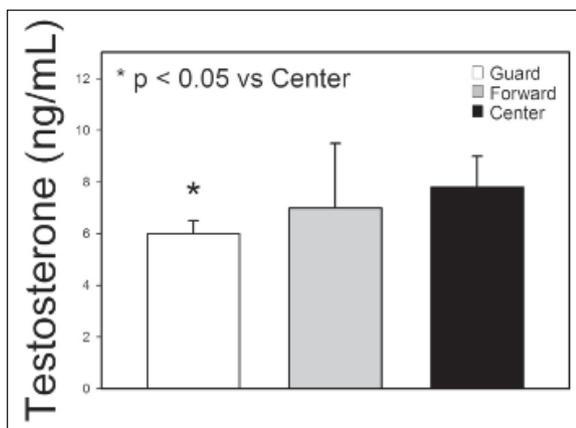


Figure 2. Plasma testosterone level divided by playing position. Plasma testosterone was higher in centers than guards ( $p < 0.05$ ).

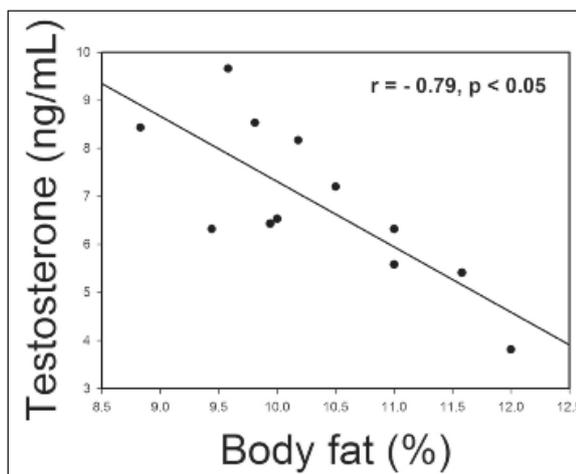


Figure 3. Correlation between Plasma testosterone and percentage of body fat. Our results showed that plasma testosterone had a negative correlation with percentage of body fat ( $r = -0.79$ ;  $p < 0.05$ ).

elite basketball players from ACB league. In agreement with previous studies our results show that, players who used to play close to the ring (inside players) where taller and heavier than the others<sup>1,25</sup>. The height

**Table II**  
Lower limbs explosive power and biomechanical performance of professional players belonging to the ACB league\*

Variable	All players (n = 12)	Guards (n = 4)	Forwards (n = 4)	Center (n = 4)	Perimeter players (n = 7)	Inside players (n = 5)
VHJ (cm)	30.6 ± 5.5	30.1 ± 5.7	28.5 ± 3.2	33.2 ± 7.3	29.6 ± 4.6	31.9 ± 6.8
VT (m/s)	2.5 ± 0.3	2.5 ± 0.4	2.4 ± 0.1	2.5 ± 0.3	2.5 ± 0.3	2.5 ± 0.3
RFD (kgf·s <sup>-1</sup> )	690.7 ± 415.4	610.0 ± 370.0	703.7 ± 435.2	758.4 ± 539.8	669.2 ± 405.7	720.8 ± 475.0
PI (kgf·s <sup>-1</sup> )	23.1 ± 3.7	20.6 ± 2.1†	22.1 ± 3.0	26.7 ± 3.2	21.4 ± 2.7	25.5 ± 3.9
MIV (m/s)	2.5 ± 0.2	2.5 ± 0.2	2.5 ± 0.1	2.6 ± 0.3	2.5 ± 0.2	2.6 ± 0.3
MP (W)	1742.2 ± 310.6	1623.4 ± 362.8	1667.2 ± 217.0	1935.9 ± 314.2	1683.9 ± 275.7	1823.7 ± 370.2
MIP (W)	4242.4 ± 745.8	3639.4 ± 413.0††	4033.8 ± 389.9‡	5053.9 ± 543.9	3872.0 ± 448.8&	4760.9 ± 807.0
MPn (W/kg)	84.3 ± 12.6	83.9 ± 17.9	81.5 ± 8.1	87.6 ± 13.0	84.6 ± 12.7	84.0 ± 13.9
MIPn (W/kg)	204.7 ± 24.5	188.4 ± 21.3†	197.2 ± 10.8‡	228.6 ± 20.9	194.4 ± 16.9	219.2 ± 27.8
VHJ (cm)	36.8 ± 4.1	37.7 ± 3.8	35.6 ± 4.6	37.2 ± 4.9	37.4 ± 3.8	36.1 ± 4.9
VT (m/s)	2.7 ± 0.1	2.7 ± 0.1	2.6 ± 0.2	2.7 ± 0.2	2.7 ± 0.1	2.7 ± 0.2
RFD (kgf·s <sup>-1</sup> )	1159.8 ± 812.7	1345.4 ± 925.8	847.4 ± 249.3	1286.7 ± 1142.3	1106.1 ± 735.8	1235.1 ± 996.0
PI (kgf·s <sup>-1</sup> )	25.2 ± 3.3	22.9 ± 1.0††	24.6 ± 3.4	28.2 ± 2.8	23.9 ± 2.6	27.0 ± 3.5
MIV (m/s)	2.8 ± 0.1	2.8 ± 0.2	2.8 ± 0.1	2.8 ± 0.2	2.8 ± 0.1	2.8 ± 0.1
MP (W)	2689.9 ± 337.4	2472.9 ± 265.2†	2625.7 ± 330.9	2971.2 ± 252.7	2545.7 ± 312.4	2891.9 ± 281.7
MIP (W)	4706.6 ± 675.7	4159.2 ± 218.3††	4607.3 ± 605.9	5353.2 ± 537.6	4399.4 ± 521.4	5136.6 ± 671.8
MPn (W/kg)	130.1 ± 9.5	127.7 ± 8.8	128.5 ± 13.7	134.3 ± 5.6	127.7 ± 11.5	133.5 ± 5.2
MIPn (W/kg)	227.5 ± 19.8	215.1 ± 4.6†	225.1 ± 21.9	242.2 ± 20.8	220.7 ± 16.7	237.0 ± 21.5
IE (%)	22.6 ± 17.5	27.0 ± 13.0	26.1 ± 23.5	14.6 ± 16.7	28.0 ± 18.5	15.0 ± 14.5
VHJ (cm)	44.2 ± 4.4	43.7 ± 1.8	43.9 ± 4.3	45.0 ± 7.0	44.4 ± 2.8	43.9 ± 6.5
VT (m/s)	2.9 ± 0.1	2.9 ± 0.1	2.9 ± 0.1	3.0 ± 0.2	2.9 ± 0.1	2.9 ± 0.2
RFD (kgf·s <sup>-1</sup> )	639.7 ± 481.3	541.7 ± 235.5	680.1 ± 444.5	697.2 ± 759.6	556.9 ± 325.0	755.6 ± 670.7
PI (kgf·s <sup>-1</sup> )	27.7 ± 3.8	25.1 ± 1.7†	27.2 ± 3.4	30.9 ± 3.9	26.3 ± 2.9	29.7 ± 4.2
MIV (m/s)	3.0 ± 0.1	3.0 ± 0.1	3.0 ± 0.1	3.0 ± 0.2	3.0 ± 0.1	3.0 ± 0.2
MP (W)	2873.4 ± 448.1	2491.8 ± 276.9††	2847.3 ± 371.5	3281.2 ± 323.6	2666.6 ± 386.5&	3162.9 ± 385.3
MIP (W)	5753.2 ± 932.1	4991.7 ± 546.4††	5566.8 ± 605.8‡	6701.0 ± 709.2	5299.5 ± 662.7&	6388.3 ± 930.8
MPn (W/kg)	139.1 ± 17.4	128.7 ± 10.6	139.7 ± 19.5	148.9 ± 18.7	133.9 ± 16.9	146.4 ± 17.2
MIPn (W/kg)	277.6 ± 28.2	257.7 ± 19.1†	272.0 ± 17.7	303.2 ± 28.3	265.6 ± 20.0	294.6 ± 31.2
IUA <sub>(SJ)</sub> (%)	47.4 ± 22.7	48.5 ± 23.8	55.4 ± 25.5	38.3 ± 21.5	52.7 ± 24.9	40.0 ± 19.0
IUA <sub>(CMJ)</sub> (%)	20.2 ± 6.6	16.4 ± 7.7	23.6 ± 3.9	20.7 ± 7.2	19.2 ± 6.9	21.7 ± 6.7

\* Values are expressed as mean ± SD; VHJ = vertical height jump; RFD = mean rate of force development; PI = positive mechanical impulse; MPn = mean power normalized by weight; MIPn = maximal instantaneous power normalized by weight; IE = index of elasticity; IUA = index of use of arm-swing.  
† Statistically significant at p<0.05 and †† at p < 0.01 for guards vs. center.  
‡ Statistically significant at p<0.05 for forwards vs. center.  
& Statistically significant at p<0.05 for perimeter players vs inside players.

and heavy build of centers is useful in their physical low-post battles, in their responsibility at rebounds and to shoot near to basket<sup>26</sup>.

In agreement with Parr *et al.*<sup>27</sup>, the percentage of body fat was lower in centers than guards. In contrast to our findings, several studies have reported higher percentage of body fat in centers than in guards<sup>1,25</sup>. It is known that there is an inverse correlation between fat mass and plasma testosterone. In support, in our study plasma testosterone was inversely correlated with percentage of body fat. In addition, a high plasma testosterone level in centers could facilitate the hypertrophic response to strength training<sup>13</sup>.

Basketball rules were changed by the “Fédération Internationale de Basketball” (FIBA) in the year 2000. Both the aerobic and anaerobic capacity has been measured in elite basketball players during the period before (1994-2000) and after (2001-2004). Cormery *et al.* have suggested that this change in rules is responsible for an increase in  $VO_2$ max, aerobic and anaerobic threshold of 7.8%, 12.8% and 7.3%, respectively. Furthermore, this increase was gradual between 2001 and 2004, while no difference was found between 1994 and 2000. Therefore, it may have been an increasing trend in  $VO_2$ max and anaerobic threshold along these last years, but no data exist in the literature to prove this hypothesis. However, our study showed normal values of  $VO_2$ max ( $57.7 \pm 5.5$  mL·kg<sup>-1</sup>·min<sup>-1</sup>) similar to previous studies negating the possibility of such an increase in  $VO_2$ max with the change in rules, at least in the ACB players.

The second ventilatory threshold may reach values between 80-95% of  $VO_2$ max in well-trained athletes<sup>28,29</sup>. In our players the second ventilatory threshold was reached at  $90.5 \pm 5.4\%$   $VO_2$ max with  $178.2 \pm 8.6$  of  $HR_{VT}$  (b·min<sup>-1</sup>). This slight increase can be caused by rule changes that occurred in the year 2000 and also by changes in training routines mimicking much of the play style of the NBA, with higher physical demands. For example, centers are required to be faster because they need to play on the perimeter, the game speed is becoming higher and defenses are turning more aggressive.

On the other hand, it is important to analyze the lower limbs explosive power and maximal speed in 30 meter as McInnes *et al.*<sup>5</sup> showed that basketball player performs (mean  $\pm$  SD)  $997 \pm 183$  movements during a match, of which  $46 \pm 12$  were vertical jump shares and  $105 \pm 52$  were short sprints<sup>5,30</sup>. Similar values were found by Ben Abdelkrim *et al.*<sup>13</sup> (mean  $\pm$  SD)  $1050 \pm 51$  movements during a match, where  $44 \pm 7$  were vertical jump actions,  $55 \pm 11$  sprints and  $97 \pm 14$  medium-high intensity run. In the latest study, they note that the actions of high intensity (sprints, jumps and high-specific movements), 22.8% belong to pure actions of jumps, to which we would have to add a percentage belong to the 48.7% of high-specific movements, because it includes shot actions and lay-ups that require jumping. The remaining 28.5% belongs to the movements during a match are performed in sprint actions<sup>31</sup>.

Performance of 27-m sprint test was significantly correlated with playing time in NCAA Division I male basketball players<sup>32</sup> nevertheless performance of 20-m sprint test was not significantly correlated to playing position in women basketball players from the English National League Division II<sup>33</sup>. However, in our study we found that guards and forwards were faster than centers in 30 meters. In addition, player's height and 30-m speed (m/s) were inversely correlated ( $r = -0.77$ ;  $p \leq 0.05$ ). The differences found among playing positions in the 30-m sprint test showed that height may be a limiting factor on the maximum speed in basketball players.

No significant differences between playing position were found in other studies in 20-m sprint performance<sup>33</sup>. In addition, we found that guards were faster than centers in the first 5 meters of the 30-m sprint test. Thus, the velocity of the first meters with the ball domain may be a limiting factor to make a successful penetration.

The vertical height jump CMJ was assessed by Ostojic *et al.*<sup>1</sup> on using a force platform (Newtest Power-timer Testing System, Oulu, Finland), resulting in average  $54.4 \pm 7.7$  cm,  $59.7 \pm 9.6$  cm (Guards),  $57.8 \pm 6.5$  cm (Forwards) and  $54.6 \pm 6.9$  cm (Centers). Average vertical jump height was not statistically different between different positional roles, although vertical jump power was significantly higher in centers ( $p < 0.01$ ) than in guards. Estimated percentage of fast muscle fibers (fast twitch) was similar in all positional roles.

Several authors have reported that the mean of vertical height jump (VHJ) in male basketball players was more than 60 cm in contrast with our results  $30.6 \pm 5.5$  cm for SJ,  $36.8 \pm 4.1$  cm for CMJ and  $44.2 \pm 4.4$  cm for ABK<sup>1,5</sup>, however the jumps were not performed on a force platform or was measured through the center of gravity. Our results agree with a recent research in elite Italian male players<sup>33</sup>. For vertical height jumps (VHJ), we found similar results among different positional roles as previously reported<sup>1</sup>. Furthermore, we obtained higher values in centers than the other players, similar to male basketball players of NCAA division I<sup>25</sup>.

The measurement of index of elasticity (IE) is critical in sports where jumping ability plays an important role<sup>34</sup> and therefore it is advisable to carry out tests to assess this capability. However, no differences between playing position were found in our study. The correlation between IE and  $IUA_{(sj)}$  showed the importance of muscle elasticity in the countermovement jump and arms swing. On the other hand, the strong inverse correlations between  $VHJ_{(sj)}$  with IE and  $IUA_{(sj)}$  showed that players who jump less than others, they get to optimize their jump performance with the countermovement and the arms swing.

Some studies have compared performance during jump and sprint tests between playing positions players of different competitive levels and age<sup>1,2,25,33,36</sup>. A pioneer study conducted in players of the National Collegiate Athletic Association (NCAA, United Sta-

tes) showed that vertical jump power was significantly higher in forwards and centers than in guards<sup>25</sup>. Ostojic et. al.<sup>1</sup> obtained similar results in Serbian first national league players and found no differences in jumping height between playing positions. Futures studies should be analyze these differences between men and women.

## Conclusion

In summary, this study shows that centers are heavier, taller and are able to develop greater power during vertical jumps compared to guards and forwards. Inside players have a higher basal plasma testosterone concentration and lower percentage of body fat than perimeter players. However, perimeter player are faster than inside players. Finally, our study shows that VO<sub>2</sub>max in ACB players is similar to other European leagues players. The values obtained in this study might be useful for coaches and physical trainers, as it provides the necessary information to focus on the importance of physical fitness according to the playing position of professional basketball players.

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## Conflict of Interest

The authors have no conflicts of interest with regard to this research or its funding.

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