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Anthropometric and fitness profile of high-level basketball, handball and volleyball players☆

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ABSTRACT

Objective: The aim of this study was to compare several anthropometric and physiological variables between high-level basketball, handball and volleyball players.
Method: Forty-six Spanish first division professional players took part in our study. Height, standing reach, body weight, body fat percentages (by using Jackson & Pollock equation), vertical jumps (assessed by Bosco tests), 4 m × 5 m agility test and maximal power output in a bench press exercise were assessed.
Results: A one-way ANOVA, showed that basketball players had significant higher average height and standing reach values ($p < 0.01$) while volleyball players displayed the lowest body mass and handball players presented the highest body mass values. Body fat percentage was significantly lower ($p < 0.05$) in basketball and volleyball. Jump levels were significantly better in volleyball for the countermovement ($p < 0.05$) and the countermovement jump with arm swing ($p < 0.001$). Results of the agility test were significantly better in basketball ($p \leq 0.01$). In the concentric actions of maximal power tests basketball players obtained a higher mean power output for all loads ($p < 0.05$). In the eccentric phase volleyball players presented the lower outcome ($p < 0.001$).
Conclusions: There is evidence of anthropometric and physiological differences among the high-level team sports analyzed. Its assessment seems capital for the improvement of training strategies and accurate talent identification processes.
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Perfil antropométrico y de aptitud física de jugadores de alto nivel de baloncesto, balonmano y voleibol

Palabras clave:
Rendimiento deportivo
Perfil fisiológico
Deportes de equipo

RESUMEN

Objetivo: El objetivo del presente estudio fue comparar variables antropométricas y fisiológicas entre jugadores de baloncesto, balonmano y voleibol de alto nivel.
Método: Cuarenta y seis deportistas profesionales de primera división de España fueron evaluados. Valores de altura, alcance, masa corporal, porcentaje graso (mediante ecuación de Jackson y Pollock), salto vertical (mediante test de Bosco), test de agilidad de 4 × 5 m y potencia máxima de press banca fueron registrados.
Resultados: El análisis mediante ANOVA mostró que los jugadores de baloncesto presentaban mayores alturas y alcances ($p < 0.01$). Los jugadores de voleibol mostraban los valores más bajos de masa corporal

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y los de balonmano los más altos de la muestra. El porcentaje de grasa en baloncesto y voleibol fue el más bajo ($p < 0.05$). Los valores de salto fueron mejores en voleibol para el salto con contra movimiento ($p < 0.05$) y salto con contra movimiento y uso de brazos ($p < 0.001$). Los resultados del test de agilidad fueron mejores en baloncesto ($p \leq 0.01$). En las acciones concéntricas del *press banca*, los baloncestistas obtuvieron mayor potencia media en todas las cargas ($p < 0.05$). En la fase excéntrica los jugadores de voleibol presentaron los valores menores ($p < 0.001$).
Conclusiones: Se muestran diferencias antropométricas y fisiológicas entre deportes de equipo. Su evaluación parece clave para la mejora del entrenamiento y para conducir mejores procesos de selección de talentos.
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Perfil antropométrico e de aptidão física de jogadores de alto rendimento de basquetebol, andebol e voleibol

Palavras-chave:
Performance atlética
Perfil antropométrico
Equipas desportivas

R E S U M O

Objetivo: O objetivo do presente estudo foi comparar variáveis antropométricas e fisiológicas entre jogadores de basquetebol, andebol e voleibol de alto rendimento.
Método: Quarenta e seis jogadores profissionais da primeira divisão profissional da Espanha fizeram parte desse estudo. Valores de altura, alcance, massa corporal, percentual de gordura (utilizando equação de Jackson & Pollock), salto vertical (medido com o teste de Bosco), teste de agilidade 4×5 e potência máxima no exercício supino reto foram registrados.
Resultados: Uma ANOVA one-way mostrou que os jogadores de basquetebol apresentavam uma média significativamente maior na altura e alcance ($p < 0.01$), enquanto que os jogadores de voleibol apresentaram os valores mais baixos de massa corporal e os jogadores de andebol os valores mais altos da amostra. O percentual de gordura foi significativamente menor ($p < 0.05$) nos jogadores de basquetebol e voleibol. Os valores de salto foram significativamente melhores no jogadores de voleibol para o salto com contramovimento ($p < 0.05$) e no salto com contramovimento com utilização do balanço dos braços ($p < 0.001$). Os resultados do teste de agilidade foram significativamente melhores no basquete ($p \leq 0.01$). Nas ações concêntricas dos testes de potência máxima os jogadores de basquetebol obtiveram uma média maior de potência para todas as cargas ($p < 0.05$). Na fase excêntrica os jogadores de voleibol apresentaram o resultado mais baixo ($p < 0.001$).
Conclusões: Há diferenças antropométricas e fisiológicas entre as equipas de desportosde alto nível analisadas. A sua avaliação parece primordial para a melhoria das estratégias de treino e processos de identificação de talentos precisos.
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Introduction

One of the most recent and relevant research topics in the field of team sports training has been the establishment of a reference fitness profile for every single sport. Although it is commonly accepted that team sports training needs a multifaceted approach to understand all of the performance factors affecting competition, it is also well known that the enhancement of fitness levels is relevant to obtain a better result. Each one of these team disciplines seems to present a particular anthropometric and physiological profile due to specific functions and requirements for each position of the game. However, some common characteristics can be defined when comparing different sports. The correct definition of reference profiles in sport is not only important for proper coaching of elite populations; it is also essential to conduct proficient talent selection processes.

Sprinting performance, strength, and muscular power are thought to be important for successful participation in basketball.[1] Anthropometrically, basketball players have shown a notable average height in several studies[2,3] even when conducted with players from different nationalities.[4] Most notably, several authors have found that anaerobic performance is crucial in basketball, with critical elements in the game such as quick change of direction, acceleration, deceleration and jumping ability.[1,3,5] However, physical characteristics are not homogeneous for all the positions of the game. Centers and forwards are taller, heavier, and show a higher percentage of body fat than guards.[3] Previous studies suggest that the characteristics of junior basketball players differ slightly, in the above-mentioned parameters, from those playing in high-performance situations.[1]

Differing definitions of the sport of handball have been discussed within the literature. Gorostiaga et al.[6] define team handball as an intermittent, high-intensity sport that stresses running, jumping, and throwing abilities with high demands of physical capacity. The authors support the idea that handball requires great strength levels to hit, block, push, turn, change speeds and grab opponents during games. Hermassi et al.[7] stated that handball is a strenuous contact sport that places emphasis on running, jumping, sprinting, throwing, hitting, blocking, and pushing. From the authors' point of view, muscular strength and power, technical and tactical skills are the factors that give a clear advantage in high-level competitions. Marques[8] defined handball as an explosive sport with continuous sprints, jumps, changes of direction and explosive ball throwing, including body contact. Several studies describe the anthropometric characteristics of handball players,[9,10] and similar to basketball, particular characteristics for the different positions of the game exist. Pivots and backs tend to be the tallest players, while goalkeepers present the higher percentage of body fat.[9] Also, significant differences can be found in the body mass and hand-length of the backs.[11]

Volleyball physiological profiles seem to be similar to those of basketball and handball. Sheppard et al.[12] defined volleyball as a sport characterized by short and frequent explosive activities such as jumping, diving, and ball play. Jumping activities can include movements with horizontal approaches or without any approach, but generally involving a countermovement (jump setting, jousts, and blocking). Several studies have related an optimized fitness in volleyball to a remarkable and durable jumping ability.[8,13] Fontani et al.[14] identified an average of 96.5 jumps performed by a high-level volleyball player in the course of a match, supporting previous findings.[15] Stretch-shortening cycle performance and the ability to tolerate high stretch loads, appear to be critical for a proficient volleyball performance.[16] Regarding anthropometric profiles, great height, lean body and low fat percentage seem good markers of high-level volleyball players.[17] Middle blockers are typically heavier and taller than setters and outside hitters. Setters are the players with lowest average height, weight and standing reach.[13] However, studies considering right side hitters as a specific position of the game, point to these players as the second group in height and weight behind the middle blockers.[12] Several studies have explored the differences between high-level and development players in volleyball. Sheppard et al.[13] conducted a study with players from the U-21 teams of Australia and Brazil and the U-19 team of Brazil. The authors found similar general and positional characteristics to those described earlier in this article. In all of these studies there is a consistent assessment of jump ability, being this expression of power highly correlated with the strength output in squat exercise.[18]

Thus, the final purpose of this investigation was to perform a comparative anthropometric and physiologic study between high-level basketball, handball and volleyball players, helping future talent selection processes and athletic orientation, while carrying out a new proposal of tests for team sports.

Method

A transversal descriptive study with first division basketball, handball and volleyball players from three different Spanish professional clubs was conducted. To study the different anthropometrical and physiological variables a battery of anthropometric measurements (height, standing reach, body weight and body fat percentage) and functional tests (vertical jumps, 4 m × 5 m agility test and maximal power output in a bench press exercise) was performed during a competitive period. This approach allowed comparisons between sports to define a fitness profile in each of them.

Subjects

Forty-six male first division professional Spanish players (age 26.1 ± 4.8 years; height 194.0 ± 7.3 cm; standing reach 234.1 ± 30.3 cm; body mass 91.9 ± 9.0 kg; body fat 9.2 ± 2.7%) from three different sports took part in our study (basketball, $n = 18$; handball, $n = 15$; volleyball, $n = 13$). The participants came from 14 different countries and 22 of them had been selected in the past, at least once, to participate in activities of their senior national teams. Three ethnic groups were represented within the sample. All the subjects received a clear explanation of the study, including the risks and benefits of participation, and provided written informed consent in accordance with the Declaration of Helsinki, and the requirements of the Ethics Committee of the University of Vic (Barcelona, Spain) for human testing and data analysis.

Procedures

Testing was conducted over three separate sessions. In the first session the subjects were tested for anthropometric measures and jump performances. Weight was assessed on a calibrated platform scale (Carry, Korona, UK) with an accuracy of ±0.1 kg. Height was measured on a height scale (Height Rod, Soenhle, Germany) with an accuracy of ±0.01 m. Standing reach was assessed using a vertical jump-measuring device (Vertec, Gill Athletics, USA). Body fat percentages were calculated using the equation of Jackson & Pollock[19] and measuring the skinfold thickness at seven sites (chest, axilla, triceps, abdominal, subscapular, suprailiac and thigh) by using a caliper (Holtain Skinfold Caliper, Holtain, UK). One experienced anthropometrist carried out all the anthropometric tests following the anthropometric measurement protocols established by the International Society for the Advancement of Kinanthropometry (ISAK). Vertical jumps were measured using a contact mat (Ergojump-Plus, Ergotest Innovation, Norway) consisting on a switch mat connected to a digital timer (with an accuracy of ±0.001 s). This system has been demonstrated to be reliable for the measurement of flight time.[20] The assessed jumps were the squat jump (SJ), countermovement jump (CMJ) and countermovement jump with arm swing (CMJas). All subjects were familiar with the jump techniques, and performed two jumps of each type, with a resting period of 10 s between them. During the second session, the players were tested in the 4 m × 5 m agility test. The 4 m × 5 m agility test consisted of a four times back and forth run, covering a five meters distance. The runs were performed on a basketball court with a wooden floor and the time was recorded using photocell beams (MuscleLab, Ergotest Innovation, Norway) placed at the start and finish lines. Every subject completed two bouts, with a three-minute resting period between them. In the third session, maximal power output was tested in a bench press exercise using a flat bench and an Olympic barbell (Olympic Flat Bench, Technogym, Italy). Mean power was measured with a linear encoder (Muscle Lab linear encoder, Ergotest Innovation, Norway) attached to the bar. One end of the linear encoder cord was attached to the barbell, and the other end was coiled around a spool on the floor positioned perpendicular to the movement of the barbell. The linear encoder measured velocity and displacement of the barbell from the spinning movement of the spool, while mass was entered via a keypad into the software tool. The sensitivity of load displacement was approximately ±0.075 mm, with data sampled and velocity calculated at a frequency of 100 Hz. Power was calculated as the product of force and velocity. The entire displacement and time for the concentric phase were used to calculate the mean values for velocity ($m\,s^{-1}$), force (N), and power (W). Subjects performed two separated attempts executing two maximal lifts with loads of 20, 40, 60 and 80 kg, and a three-minute resting period between bouts. The mean power output was recorded for each lift, and the highest mean power during eccentric and concentric phases recorded was used for the analysis.

Statistical analysis

Descriptive data is presented as mean and standard deviation, with range values expressed as minimum and maximum. Differences between disciplines were analyzed using a one-way ANOVA for most variables. For those cases that failed in the normality or equal variance tests, we performed a Kruskal–Wallis one-way ANOVA on ranks. The significance level for the tests was established at $p \le 0.05$. When significant differences were found, we proceeded to compare between groups with a Holm–Sidak post hoc analysis in the case of the ANOVA, and Dunn's post hoc analysis for Kruskal–Wallis ANOVA. These methods are widely accepted

Table 1
Characteristics and anthropometric values of the subjects participating in the study (values are mean ± standard deviation).

	Basketball (n = 18)		Handball (n = 15)		Volleyball (n = 13)	
	Mean (±SD)	Range	Mean (±SD)	Range	Mean (±SD)	Range
Age (yr)	25.40 (5.20)	20.0–34.0	25.50 (4.10)	19.0–33.0	27.90 (4.90)	20.0–40.0
Height (cm)[*,a]	197.10 (8.81)	179.0–211.0	191.03 (5.66)	182.0–202.0	193.23 (5.90)	185.0–201.0
Standing reach (cm)[**,a,b]	256.40 (13.08)	234.0–279.0	249.40 (9.24)	231.0–262.0	249.69 (8.64)	239.0–263.0
Weight (kg)	92.64 (9.76)	79.0–108.6	94.01 (8.89)	82.6–106.8	88.49 (7.37)	73.3–97.0
Body fat (%)[**,a,c]	7.42 (0.99)	6.2–10.4	12.54 (1.73)	9.7–15.8	7.85 (1.05)	6.5–10.2

Body fat was calculated using Jackson & Pollock equation, 2004.
[a] Basketball vs. handball.
[b] Basketball vs. volleyball.
[c] Handball vs. volleyball.
[*] $p < 0.05$.
[**] $p < 0.01$.

as the first procedure to find statistical differences between groups.

Results

Anthropometrically, players from the three disciplines showed different characteristics (Table 1). Basketball players were significantly the tallest ($p < 0.01$) and presented the highest average standing reach value ($p < 0.05$) among the three sports. Basketball and volleyball players showed significant lower percentage of body fat ($p < 0.05$) than handball players. Volleyball players showed non-significant better average values than handball players in height and standing reach, and displayed lower average weight. Despite not having the heaviest player in their group, handball had the highest average body weight values in our study.

Jump tests indicated significant differences between disciplines in the CMJ ($p < 0.05$) and CMJas jumps ($p < 0.001$). No significant differences were found when the SJ was tested (ranges for volleyball 31.80–56.50 cm; basketball 31.20–56.75 cm; handball 33.90–43.80 cm). Volleyball players (range 40.70–56.40 cm) showed better performances in the CMJ when compared to basketball (range 30.88–57.38 cm) and handball players (range 35.20–47.00 cm). Same results were observed in the CMJas jump (ranges for volleyball 52.07–67.56 cm; basketball 35.92–65.79 cm; handball 44.60–53.20 cm). We found no significant differences between basketball and handball players in any type of jump (Fig. 1).

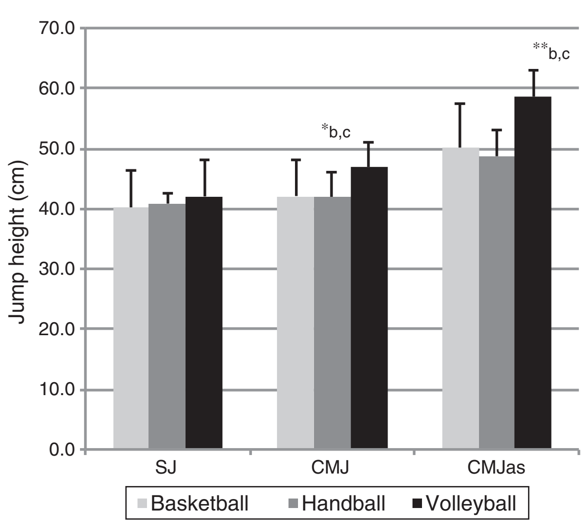

Fig. 1. Comparison of jump tests among the three sports. *$p \leq 0.05$; **$p \leq 0.01$; a: basketball vs. handball; b: basketball vs. volleyball; c: handball vs. volleyball.

Volleyball players were the ones presenting larger increases between jump modalities, with an average improvement of 4.72 cm between SJ and CMJ and 16.56 cm between CMJ and CMJas jumps (which represented a gain of 10.09% and 26.16%). The increase between SJ and CMJ jumps in handball players was 1.35 cm (5.95%) and in basketball players 2.98 (6.19%). These improvements were 6.19 cm (12.04%) and 8.05 cm (15.42%) respectively in each of these sports, between CMJ and CMJas jumps.

Agility tests indicated significant differences between the three groups (Fig. 2). Basketball players (range 4.65–5.45 s) performed significantly better ($p < 0.001$) than handball (range 5.11–5.81 s) and volleyball players (range 5.36–6.13 s). On the other hand handball players showed better values than volleyball players ($p < 0.005$).

Maximal power tests showed differences between groups, loads and movement phases (Table 2). For the 20 kg load, during the concentric phase we found significant differences ($p < 0.005$) between the three groups. Basketball players reached a higher mean power output followed by handball players and both groups obtained higher values than volleyball players ($p < 0.001$ vs. basketball; $p < 0.05$ vs. handball). When the load was increased (40, 60 and 80 kg) we observed the same pattern: basketball players obtained significant higher values than those from handball and volleyball ($p < 0.001$). Handball and volleyball players showed no significant differences for any of the three higher load values. During the eccentric phase, volleyball players presented the lower outcome of the sample compared to basketball players and handball players, except in the 80 kg load, at which no differences with handball average outcomes were detected. No significant differences between

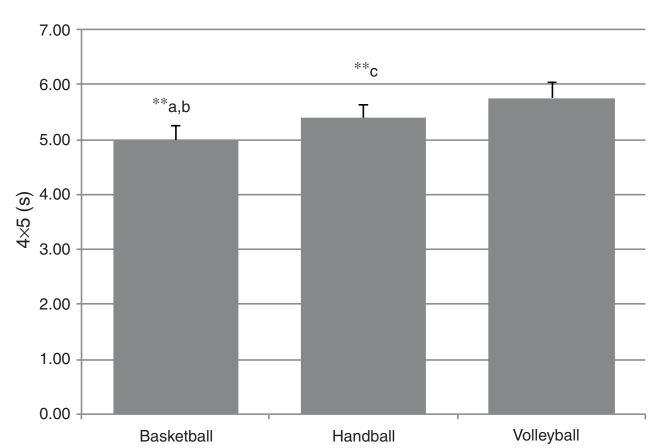

Fig. 2. Comparison of 4 m × 5 m agility tests among the three sports. *$p \leq 0.05$; **$p \leq 0.01$; a: basketball vs. handball; b: basketball vs. volleyball; c: handball vs. volleyball.

Table 2
Values obtained from bench press power test (expressed in watts) in concentric (C) and eccentric (E) actions (normal values are mean ± standard deviation and range, not normal values are median and range).

	Basketball ($n = 18$)		Handball ($n = 15$)		Volleyball ($n = 13$)	
	Mean (±SD)	Range	Mean (±SD)	Range	Mean (±SD)	Range
20C (W)[**,a,b,c]	607 (52)	537–696	539 (69)	401–643	487 (68)	357–601
20E (W)[**,b,c]	540 (112)	385–707	575 (121)	392–861	267 (93)	76–428
40C (W)[**,a,b]	793 (68)	667–897	629 (93)	525–839	569 (87)	439–702
40E (W)[**,b,c]	782 (112)	549–962	756 (138)	549–1003	463 (131)	183–633
60C (W)[†,**,a,b]	781 (–)	589–880	570 (–)	272–915	589 (–)	340–697
60E (W)[**,b,c]	820 (136)	524–1011	854 (192)	575–1332	502 (163)	227–787
80C (W)[†,**,a,b]	708 (–)	489–780	512 (–)	391–709	501 (–)	149–669
80E (W)[†,**,b]	776 (–)	544–949	727 (–)	221–1092	466 (–)	226–1001

[**] $p < 0.01$.
[a] Basketball vs. handball.
[b] Basketball vs. volleyball.
[c] Handball vs. volleyball.
[†] Kruskal–Wallis ANOVA on ranks.

basketball and handball were observed in this phase of the movement.

Discussion

The main results of the present study indicate that the anthropometric and physiological profiles of basketball, handball and volleyball players are significantly different. Basketball players are taller than handball players. Volleyball and basketball players show higher standing reach values than handball players, whereas the latter have the higher body fat percentages among the three sports. Although significant differences were not found, handball is the discipline where players have the highest body weight and body fat percentages, presenting a height and standing reach values closer to volleyball than to basketball players. Thus, our findings regarding basketball anthropometric profile match those from the literature[2,4,21] even presenting the highest standard deviation values in height, standing reach and weight among the three sports. These findings reinforce the idea that in basketball, there are important anthropometric differences between backcourt and frontcourt players.[3] Our findings are similar to those from Toriola et al.[22] who compared Nigerian basketball and volleyball players, finding similar weight values in the two sports, although basketball players were taller and had higher fat percentage. Regarding team handball, our study also found similar anthropometric profiling values to others within the literature.[8] The fact that team handball is a sport with continuous body contact, explains a profile with the highest average values of body weight.[7] Similar demands seem to be common in basketball frontcourt players (centers and power forwards).[3] Handball players showed interesting differences between players, when analyzing the different ranges, indicating specific adjustments to the different requirements of each position.[9,11] Volleyball players, in our study, had lower body weight but similar body fat percentages to those found in basketball. These findings concur with the lean body mass and a low percentage of body fat found in volleyball players by some other studies.[16] The average height and standing reach of volleyball players, indicated the relevance of these anthropometric characteristics in a sport where most players are involved in attack and blocking actions.[14,17,18] The lack of body contact during volleyball games supports the idea that those players do not need to develop high body mass to improve their performances.[16] To reinforce this idea, studies like the one from Berg et al.[21] identified that high body contact, and the much shorter duration of high-intensity actions, could explain a higher weight, higher fat mass and higher fat free mass in sports like American football when compared to basketball players.

Differences in jump performances among the athletes of the three sports have been found. Volleyball players displayed significant higher levels than basketball and handball players in CMJ and CMJas jumps. Likewise, volleyball players showed higher but non-significant performances in SJ. These outcomes appear to be a consequence of the great similarities of the tested jumps with the movements of volleyball blocking actions and the high demand that volleyball has for this action in the games,[12,16,17] with the largest number of jumps per player and match[14] when comparing with basketball[23] and handball.[24] Squat jump performances were similar in all three sports, due to common requirements of muscular strength and power in all of the disciplines, showing similar levels for the three sports when performing nonspecific technical actions.[18] Additional literature data match with our results in the case of basketball.[25]

As previously discussed, agility and the ability to change the direction are important in all team sports. This aspect seems even more relevant in small-sided sports as those in our study.[1,4,8] It is interesting to notice that sports with larger courts (basketball and handball) performed significantly better than volleyball. This is more than likely due to the smallest distances covered in volleyball rallies that, in most cases, are even shorter than those in the test. The differences in performance between basketball and handball players can be attributed to the low requirements of movement in positions such as goalkeepers or defensive specialists in handball. Basketball does not have similar profiles, and all the players on the court should perform a greater percentage of the total movements, fast breaks and transitions between courts. Interestingly, in previous years Berg et al.[21] found exact average values on sprinting performance between basketball and football players, indicating that not only the covered distance is important in the development of the different abilities of the athletes, but also the distance per player ratio and the number of contact actions during the game can be important factors.

Volleyball players had lower mean power outputs in the maximal power tests performed in our study during both, concentric and eccentric phases. There are several explanations for this result. Firstly, volleyball players do not have contact with the opponent during their game. Therefore, their needs of carrying and moving heavy loads are low in absolute terms. On the other hand, the ball used in this sport is the lightest among disciplines, and setting and hitting techniques involve chest muscles less than in the other two sports. The values obtained in basketball and handball are similar in eccentric and concentric phases in almost all loads. The only exception is the lower load (20 kg) wherein basketball players showed significant differences ($p < 0.05$). These results must be interpreted with caution because to our knowledge, this may be due simply to a higher affinity of certain specific movement patterns of the sport with those performed in the test. The use of both arms while passing, shooting, rebounding or fighting for the ball is common in basketball, while in handball this is almost an exception. This aspect should be taken into account by adjusting the load parameters to the specific strength needs of each discipline. No important differences were observed in the results of the concentric and eccentric phases of the bench press tests. That led us to conclude that the use of the concentric phase is enough to assess the power qualities of different team sport players.

In conclusion, this research has found significant differences in the anthropometric and physiologic characteristics of high-level male basketball, handball and volleyball players. Basketball and volleyball players presented more height and higher standing reach and lower weight and fat mass when compared to handball players. CMJ jump tests favored volleyball players whereas handball and basketball players showed higher maximal upper body power output. Basketball players also stood out in the agility tests compared with the other sports.

Although there is no consensus in the scientific literature on the use of a single battery of tests to assess fitness in team sports, our proposal seems valid finding significant differences between three different disciplines. Coaches and practitioners may take in consideration our findings for a proper orientation of physical training. Thus, even though some similarities among the three analyzed sports were found, a different orientation of strength and conditioning sessions in every sport is recommended. Our main findings can also be useful to improve player selection processes based on fitness characteristics, as well as for establishing reference anthropometric and physiological baselines. However, further work needs to be done to generalize these findings and to establish a baseline age at which the physiological differences between high-level profile individuals appear.

Conflicts of interest

The authors have no conflicts of interest to declare.

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