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RESEARCH

Longitudinal comparison of the relationship of energy intake with body composition and physical performance in elite female basketball and volleyball players

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Abstract

Purpose To maximise sporting success, disciplines such as basketball and volleyball need to improve their methods of analysing the sporting performance and fitness of their athletes. Although energy intake quantities have been established at a theoretical level for women to perform at a sporting level, it has been found that these energy intake levels are not met or followed and that, despite this, the performance of female players is not diminished. Thus, the purpose of this research study was to describe and compare the anthropometric characteristics of these two disciplines and to identify the differences in actual and theoretical energy intake, as well as to observe physical performance in both disciplines.

Methods Anthropometric data, continuous quantitative data, training time and characteristics, and energy intake data were collected. Performance tests included upper and lower body strength, speed, agility, and endurance tests. Dietary monitoring showed lower intakes of total energy, carbohydrate and protein than theoretically recommended. However, the athletes experienced overall improvements in performance and body composition.

Results The mean total energy intake was 20.2 ± 4.3 kcal·kg^{-1}·day^{-1}. The minimum individual mean intake was 9.8 kcal·kg^{-1}·day^{-1} and the maximum was 25.95 kcal·kg^{-1}·day^{-1}. Carbohydrates accounted for $54.3\% \pm 8.8\%$ of the energy intake; $20.3\% \pm 6.5\%$ from fats; $25.4\% \pm 5.7\%$ from proteins.

Conclusions Current data suggest that, although a cause-effect relationship between dietary intake and BC performance cannot be determined, elite athletes in these sports disciplines may experience beneficial outcomes despite having lower total energy, CHO, protein, and fat intakes than previously recommended in the literature.

Keywords Energy · Basketball · Volleyball · Performance · Women

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Abbreviations

IMTG	Intramuscular glycogen and triglycerides
BC	Body composition
CHO	Carbohydrates
EFVPs	Elite female volleyball players
EFBPs	Elite female basketball
FFQ	Food frequency questionnaire
CHSND	Centre for higher studies in nutrition and dietetics
BM	Body mass
BMI	Body mass index
ISAK	International society for the advancement of kineanthropometry
TEM	Technical error of measurement
AM	Adipose mass
FFM	Fat-free lean mass
BM	Bone mass
WHR	Waist-to-hip ratio

SJ	Squat jump
CMJ	Countermovement jump
ABK	Abalakov jump
DJ	Drop jump
RSA	Sprint repeat ability
ICC	Intraclass correlation coefficient
COD	Change of direction
IAGT	Illinois agility test
IET	Intermittent endurance test
LEA	Low energy availability
RED-s	Relative energy deficiency in sport

Introduction

The performance of two indoor disciplines such as basketball and volleyball, which are intermittent sports, require the utilization of both anaerobic and aerobic energy systems during training and competitive matches [1, 2]. Therefore, the diverse and demanding requirements of a competitive season in both disciplines can lead to fatigue [3, 4] due to inadequate recovery since there is insufficient time between training sessions and matches for full recovery to occur [5, 6]. Consequently, athletes will experience a decrease in technical–tactical performance and technical efficiency [7]. It is for these reasons that strategies aimed at accelerating recovery [8], mitigating fatigue and maintaining performance throughout the season [9] should be considered.

In this regard, proper nutrition has been shown to be an important aid in attenuating fatigue by providing energy and nutrients that lead to the restoration of glycogen and intramuscular glycogen and triglycerides (IMTG) helping to maximize muscle protein synthesis [10]. Proper in-season nutrition has also been shown to improve body composition (BC) [3] a crucially important element for performance and health maintenance in both disciplines [11] due to the frequent and intense nature of the defensive and offensive jumping, blocking, punching, striking, finishing, charging and sprinting required in these disciplines; all of which require a significant amount of strength, agility and speed. Therefore, given that performance is the main concern in the season, monitoring dietary intake to assess whether the total energy intake is adequate is considered paramount, as well as the consumption of each macronutrient. Consequently, nutritional recommendations for carbohydrates (CHO) are clearly established for athletes with moderate-intense training levels (i.e., 2–3 h/day for 5–6 times/week), such as elite basketball and volleyball players for adequate performance [12].

However, these recommendations are not differentiated by gender, an aspect to consider due to physiological factors among others [13]. More specifically, it is known that female athletes should place less emphasis on very high CHO intake and more emphasis on quality protein and fat intake in the context of energy balance to enhance training adaptations and improve overall health [14]. In relation to these indications, recent studies have analysed metabolism during moderate exercise in women and men. While this process is similar in both genders, there are small quantitative differences. Women tend to use a higher proportion of fat and less carbohydrate than men during exercise [15–18]. This is due, in part, to disparities in sex hormone levels between genders [17, 18]. In addition, women have been found to have higher intramuscular triglyceride stores compared to men [19, 20]. In this regard, previous research into elite female volleyball players (EFVPs) has shown that a diet with higher protein and fat, but a lower CHO and total energy intake than international recommendations has provided improvements in strength training performance [21]. Thus, without gender-specific recommendations, female players in these sport disciplines may have an inadequate intake of the specific macronutrients they need to achieve optimal substrate utilisation during the competitive season, leading to negative consequences on performance, BC, and health [22].

Linked to this aspect of nutrition, general fitness is a factor in performance as it relates to the special skills required in both disciplines, understood as skills derived from basic physical abilities. Since it is well established that a periodised programme of strength conditioning and general endurance [23, 24] will benefit an important aspect of these disciplines such as BC. Therefore, it seems necessary to monitor nutrition along with training throughout the season, as athletes are in a frequent state of fatigue and may be pushing their limits. It has been shown that inadequate nutrition will hinder the athlete's ability to provide skeletal muscle with the necessary substrate [25] to handle the repeated stressors of a season, thus decreasing performance and weakening their health. In fact, it has previously been reported that when elite female athletes do not receive specific nutritional guidelines, many have a negative energy balance throughout the competitive season [26]; therefore, by monitoring dietary intake in conjunction with training, an assessment of dietary intake can be made to determine if current nutritional guidelines [22, 24] are being met to maintain performance, proper BC and health. In addition, research on the energy intake of elite female basketball (EFBPs) or volleyball players during a season compared to the actual intake with the established recommendations shows that participants often do not meet the theoretical requirements, and despite these circumstances, players can improve their performance [27]. Consequently, the reality of in-season energy intake among elite female players in these disciplines in relation to current guidelines is unknown to the authors. Similarly, it remains to be elucidated whether current energy intake guidelines are necessary for these athletes to improve BC, performance, and health during the competitive season or whether an alternative strategy may produce beneficial results in these respects.

Therefore, the main objective of this study was to investigate the specific dietary intake of elite female basketball and volleyball players and to assess the impact of specific energy intake through macronutrient consumption and its relationship with sporting performance in their respective disciplines, as well as to assess their nutritional intake and what relationship this has with their BC during the first 16 weeks of the competition season. A secondary objective was to compare total energy intake and macronutrient distribution with established, but not sex-specific, recommendations [3, 22, 24]. It was hypothesized that female athletes would improve their performance and BC during the season and that female players would consume less total energy and less CHO compared to establish recommendations, due to different substrate utilization requirements than that of males.

Materials and methods

The data collected included height and weight measurements, which provided insight into the physical characteristics of the participants. In addition, information was collected on the amount of time each participant spent training. Energy intake was also recorded, which shed light on the participants' nutritional habits and general dietary patterns.

In addition, participants underwent a series of tests to assess various aspects of their fitness. These included strength tests to measure power and muscle capacity, speed tests to measure speed and agility, agility tests to assess coordination and balance, and endurance tests to determine cardiovascular and muscular endurance.

Participants

Twenty-three female players (11 volleyball and 12 basketball players) were assessed at 2 points in time during the 2018–19 season. A first data collection time (T1) in September 2018, pre-season; and a second time (T2) in January 2019, during the first competitive break. All the players competed at elite level in their respective disciplines, Iberdrola First Division Women's Volleyball League, and DIA Women's Basketball League 1.

Within the volleyball players, four of these players had previously represented a national team (one Spanish player; two Argentinean players; one American player). The typical work week had an average weekly training of 19.5 h (not including matches) consisting of 3 double training sessions of 120 min of technical–tactical aspects (morning) and 150 min of physical conditioning (afternoon) (Monday, Wednesday and Thursday), 2 days with a 180 min session on Tuesday (180 min of physical conditioning) and Friday (180 min of technical-tactical aspects), a competition day (Saturday) and a rest day (Sunday).

As for basketball, six of these players have represented a national team (three Spanish players; two Croatian player; one Senegalese player; one Swedish player). In this discipline, a typical working week had an average of 22.5 h of training (excluding competition). It included 3 double training sessions: 150 min of technical-tactical work (in the morning) and 180 min of physical work—Monday, Wednesday, and Thursday, and two sessions (Tuesday/Friday) of 180 min, in which physical and technical–tactical (Tuesday) or only tactical (Friday) aspects were developed; the day of the match (Saturday/Sunday) and a rest day after the match (Table 1).

The work performed during the training sessions was agreed on by the coaching staff and was therefore representative of the workload experienced during that period of the season [28, 29] (Fig. 1). The sample size (SS = 21.75) was determined using the G* Power package (version 3.1.9.2) with a finite population of 23 subjects. We assigned a confidence level of 95% (with a margin of error of 0.05), giving the event the same probability of occurrence as non-occurrence, resulting in a large effect size between the two groups (ES = 0.9), yielding a power of 80% [30].

The participants in both disciplines followed a similar diet established by the respective coaching staffs of each of the participating clubs. Before the start of the study, it

Table 1 General characteristics

Age (years)		t	*p*	Body mass (kg)	t	*p*	Height (cm)	t	*p*	Experience in the discipline (yrs)	Elite level (yrs)
T1										V	
V	24.1 ± 2.7	−0.959	0.332	69.9 ± 9.2	−1.723	0.085	177.0 ± 0.1	−0.624	0.520	15.0 ± 2.8	4.2 ± 2.2
B	26.0 ± 5.9			77.9 ± 12.4			178.9 ± 6.9				
T2										B	
V	24.5 ± 2.7	−0.944	0.338	70.1 ± 8.9	−1.315	0.184	177.0 ± 0.1	−0.624	0.520	14.7 ± 2.9	5.0 ± 1.1
B	26.3 ± 5.9			75.8 ± 11.4			178.9 ± 6.9				

T1 time 1, *T2* time 2, *V* volleyball players, *B* basketball players, *t* t de student; *p* *p*-value

Fig. 1 Time and type of training performed by female basketball and volleyball players in each week of the study. *B* basketball, *V* volleyball, *TTT* technical and tactician training

was determined that the participants were ready to play and train with guarantees (i.e., that none had any injuries). None of the players had any injuries, allergies, or hormonal disturbances during data collection. In addition, none of the participants were to be under the influence of any type of illegal drugs or taking medication that affected body weight.

Experimental procedures, associated risks and benefits were explained to each athlete, and each player signed a written consent form prior to participation, always following the ethical guidelines dictated in the Helsinki Declaration of the World Medical Association (2013) [31] for medical research on human subjects and with the approval of the project of the Ethics Committee for Research Involving Human Subjects of the University of the Basque Country, Number: M10_2017_216. It should be noted that the data obtained have been treated with the utmost confidentiality and scientific rigour, their use being restricted by the guidelines of the research projects following the scientific method required in each case, complying with Organic Law 15/1999, of 13 December, on the Protection of Personal Data (OLPPD); the procedures used have respected the ethical criteria of the Responsible Committee for Human Experimentation (established by Law 14/2007, published in the Official State Gazette no. 159).

Experimental design of the procedure

The present study was conducted under non-experimental conditions (ecological validity), so the technical staff and participants did not receive any input from the research team. The training data, competition schedule and match results were provided by the coaching staff of the team [32].

Evaluation plan

Measurements were taken at two points in the season (T1: September 2018, week 1 of mesocycle 1 of macrocycle 1, pre-season; T2: January 2019, week 13, mesocycle 1 of macrocycle 2, first competitive break) immediately before a training session. These periods were chosen as it was expected that there would be substantial variation in the parameters to be monitored [21] (Fig. 2).

Measurements were performed in the sports hall where players train and compete in the same session, to avoid variations in environmental or biological conditions affecting the results [33]. In volleyball: "El Ferial" sports hall—Haro (La Rioja) (T1: humidity 42%; temperature 28.1 °C. T2: humidity 39%; temperature 14.9 °C. Humidity difference of 3% and temperature difference of 13.2 °C between times. In basketball: "José Antonio Gasca" municipal sports centre—San Sebastián (Guipúzcoa) (T1: humidity 71%; 28.7 °C. T2: humidity 47%; 16.4 °C. Humidity difference of 24% and temperature difference of 12.3 °C between both times.

For the evaluation, pre-test actions were controlled by determining that no physical exercise was performed within 24 h prior to analysis. Within 4 h prior to the test, no solid or liquid food was to be ingested, only maintaining a correct hydration status, and having last urinated and/or defecated 30 min prior to data collection were considered [34].

Dietary and nutritional intervention and assessment

Participants were instructed by dieticians in proper food tracking and intake assessment techniques. Specifically, the dieticians taught the players how to use a food frequency questionnaire (FFQ) and how to complete a 7 day dietary recall. For the FFQ, which had been previously validated

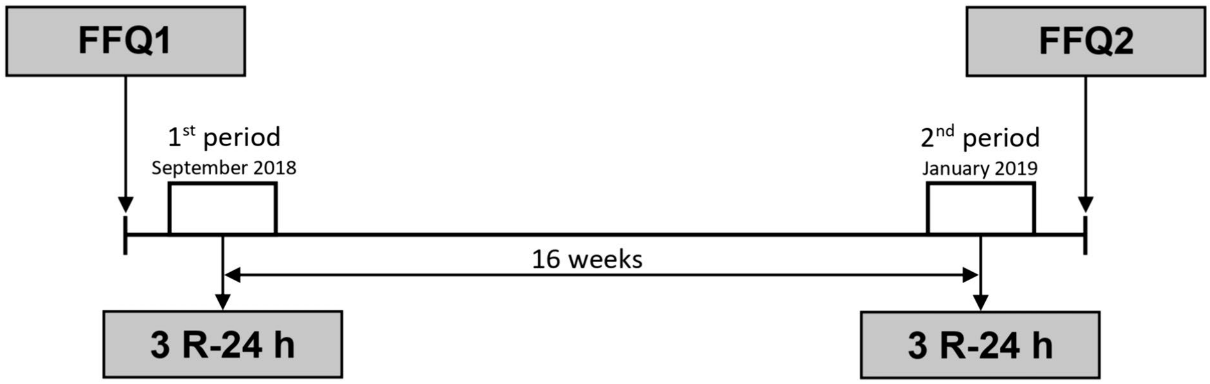

Fig. 2 Study design. *FFQ* Food consumption frequency questionnaire, *3 R-24 h* estimated daily nutrient intake in 24 h for the last three days

for the female population [35] and used in other research [36], subjects at T2 were asked to recall their average energy intake over the previous 16 weeks. The FFQ included 139 different foods and beverages, sorted by food type and meal pattern. To help recall average intake, the FFQ had "frequency" categories of consumption based on the number of times a food was consumed per day, week, or month. Daily intakes of total energy (kcal) and of each macronutrient were calculated by dividing the reported intake by the frequency in terms of days [35].

Second, 7 day dietary recalls were completed at T1 and T2 and examined to determine whether the results were like those of the FFQ. If participants weighed the food, these data were used in the dietary recall. However, when food was not weighed, portion size was calculated from available information, including product names, location of food consumption, standard food weight, or by the participant's indication of portion size via a picture booklet containing a total of 500 food pictures. Once portion size was calculated, food values were converted into total energy intake and macronutrient distribution using the online version of the validated dietary software package, Easy Diet (online version, Spain), which is based on the food composition tables produced by the Centre for Higher Studies in Nutrition and Dietetics (CHSND). We then compared total energy intake and the distribution of specific macronutrient intake with established, non-sex-specific guidelines for total kilocalories: 50–80 $kcal \cdot kg^{-1} \cdot day^{-1}$ [37]; protein: 1.6–1.8 $g \cdot kg^{-1} \cdot day^{-1}$ [38]; fat: 20–35% of total caloric intake [39]; and CHO: 5–8 $g \cdot kg^{-1} \cdot day^{-1}$ [37].

Anthropometric and BC measures

Anthropometric and BC assessments included: height, body mass (BM), body mass index (BMI), body fat percentage, limb circumferences for muscle and fat mass, and somatotype. Anthropometric data were extracted according to the recommended of the International Society for the Advancement of Kineanthropometry (ISAK) techniques [40]. The technical error of measurement (TEM) for height (cm) and BM (kg) was less than 0.02%.

The order of anthropometric data collection was:

a) Body Mass: was measured with a SECA® scale (Seca Corp., Hanover, Md., USA) (accuracy: 0.1 kg; range: 2–130 kg). BMI was calculated using the formula BM/height2 (kg/m^2).
b) Height was obtained using the Holtain® measuring rod (Holtain® Ltd., Dyfed, UK) with millimetre accuracy. Measuring ranges from 60 to 209 cm.
c) Skinfolds: were measured in triplicate with a Harpenden plicometer and analysed by two observers. The sum of 8 skinfolds (mm) was calculated (biceps, triceps, subscapular, iliac crest, supraspinal, abdominal, front thigh and calf). TEMs for all skinfold measurements were less than 2.6%.
d) Bone diameters and muscle perimeters: diameters (cm) (humerus biepicondileus, femur biepicondileus and biostyloid) and perimeters (cm) (relaxed arm, contracted arm, forearm, wrist, thorax, waist, hip, thigh, calf, ankle, and mid-thigh) were measured with a Lufkin® W606PM 6 mm × 2 m executive diameter metal tape measure (Lufkin®, Ohio, USA) with an accuracy of 1.0% (Lufkin®, Ohio, USA). USA) with an accuracy of 1 mm. All TEMs for the circumferences evaluated were less than 0.45%.

All were performed under the same conditions and times under the marking and measurement procedures of the ISAK (2001). In addition, the same internationally certified anthropometrist (ISAK Level III Certificate #636,739,292,503,670,742) took measurements for all participants, at both time points T1 and T2.

Independent study variables: body mass, height, skinfolds, muscle diameters, bone diameters. Dependent study variables: Percentage of adipose mass (%AM), percentage of fat-free lean mass (%FFM), percentage of bone mass (%BM), body mass index (BMI), waist-to-hip ratio (WHR), endomorphy, mesomorphy and ectomorphy. The anthropometric somatotype method of, which divides morphostructure into fat-free lean mass (FFM), bone mass (BM) and adipose mass (AM), was used in this study. Analysing %AM, %FMM and %BM as well as BMI and WHR.

Limb circumference–muscle mass and fat mass

We conduct a comprehensive study to predict the BC of the participants, focusing especially on AM and FFM.

Somatotype

For somatotype components (i.e., mesomorphy, ectomorphy and endomorphy), the equation of Carter & Heath [41] was applied for females, % adipose mass = 3.5803 + (summations of 8 skinfolds × 0.1548). The skinfolds included in the equation are biceps, triceps, subscapular, iliac crest, supraspinal, abdominal, front thigh and calf.

Physical performance tests

Several physical fitness tests representing different aspects related to basketball and volleyball performance were used to assess physical performance in basketball and volleyball. The tests took place in the afternoon (± 17.00) on the respective days. They were conducted in the sports hall under the humidity and temperature conditions described above. First, a standardised warm-up of 20 min was carried out to adequately prepare the athletes for the different tests (jumping, strength, movement speed, agility, and intermittent endurance). A rest period of 5 min was observed between attempts and between the different exercises. These exercises were selected for the test as they have all been previously used to improve performance in each of the two disciplines [42], followed by a specific description-justification of each exercise to be performed.

The order of the tests was as follows: squat jump (SJ), countermovement jump (CMJ), Abalakov jump (ABK), drop jump (DJ), medicine ball throw (3 kg), speed test without change of direction (20 m), sprint repeat ability with change of direction (RSA), Illinois agility test with change of direction (COD) and Yo-yo intermittent endurance test (IET) (II) (Fig. 3).

Warm-up

Firstly, at the time of the sport performance tests a standardised and supervised 20 min warm-up was performed to adequately prepare the players for the tests. The warm-up included 5 min of jogging forwards and backwards, and work in waves of jumping on one leg (right and left, forwards and backwards), hip opening and closing, arm circumduction and heel running forwards and backwards. Acceleration and injury prevention exercises such as hand planks from a standing position, jumps with trot from midfield, sprints from prone, lunges with trunk twist, squats with jump, explosive push-ups, hamstring stretches on trot, forward strides, zigzag running, and pyramid stretches from quadruped [43].

Performance tests

Jumping (SJ, CMJ, ABK, DJ) A Chronojump® Bosco System DIN-A1 contact platform [44] was used to collect these data. Controlled by a chronometric device that is responsible for timing the state changes of the detection device, the error of the microcontroller is 0.1%, giving a validity of 0.95 (ICC).

This device (Chronopic 3) was validated by the American College of Sports Medicine (ACSM) in Seattle'09 [45]. Across the whole spectrum studied; with a low signal (corresponding to the contact time in a jump) the mean error is 0.04 ± 0.18%, while with a high signal (flight time) the mean error is 0.05 ± 0.19% [46].

Squat jump (SJ): This exercise assesses the maximum concentric dynamic strength of the lower limbs. Its relation to basketball refers to jumping capacity and acceleration capacity [47]. It is an indicator of the percentage of fast fibres. To this manifestation is added a second factor of "contractile capacity", related to the capacity to synchronise the contraction of the fibres to have a more homogeneous value of instantaneous recruitment.

Its index represents the maximum slow force developed in a slow concentric exercise derived from Hill's Law (squats or press at 45°). To reduce the margin of error, great care must be taken in the technique of execution i.e., that there is no repulsion before the jump and that it starts from a static position of half squat.

In this test, the subject must perform a vertical jump starting from a semi-flexed position with knees at 90º, with the trunk straight and hands at the waist. No countermovement must be performed prior to the jump, nor must the subject assist in the impulsion with the arms or trunk.

Countermovement jump (CMJ) [48]: Participants started in a standing position with both feet together and were asked to jump as high as possible with a quick countermovement, keeping their hands on their hips. The flight time was used to calculate the change in the height of the body's centre of gravity. The calculation of jump height assumed that the take-off and landing positions of the body's centre of gravity. Two trials per participant were allowed, separated by 1 min of recovery, and the best one was recorded. The CMJ is characterised by very low inter-trial variability (coefficient of variation of 3.0%) [49]. The CMJ test has shown the highest

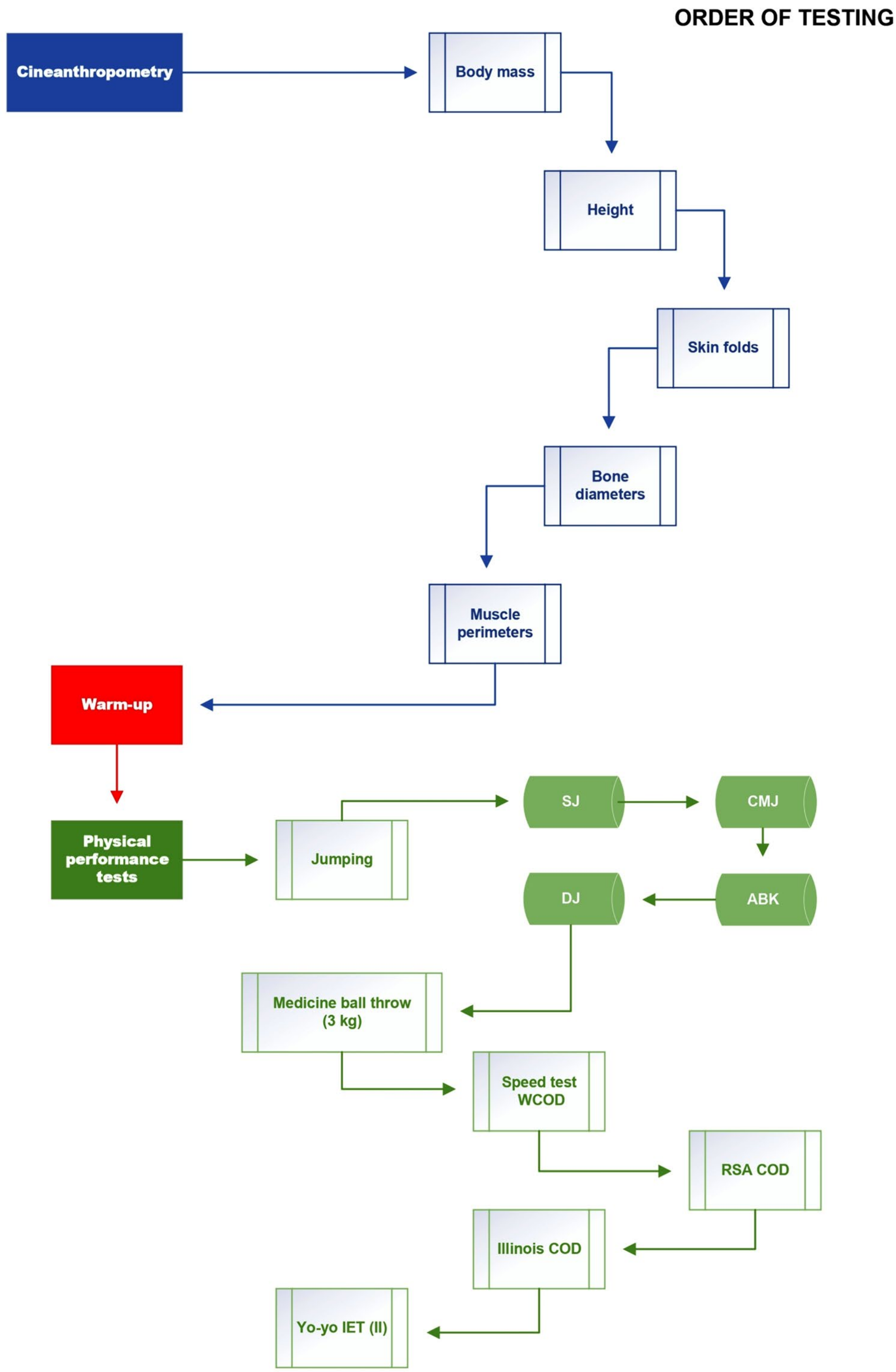

Fig. 3 Order of tests. *SJ* squat jump, *CMJ* countermovement jump, *ABK* Abalakov jump, *DJ* drop jump, *WCD* without change of direction, *RSA COD* sprint repeat ability with change of direction, *Illinois* Illinois with change of direction agility test, *Yo-yo* Yo-yo intermittent endurance test

relationship with the explosive power factor ($r = 0.87$), i.e., the highest factorial validity. And based on these results, it can be concluded that the CMJ is one of the most reliable and valid field tests for the estimation of lower limb explosive power.

Abalakov: This test is similar to the SJ test, but with a variation of the starting position, as participants start from an upright position, without prior knee flexion, to perform a subsequent knee flexion–extension at maximum execution speed.

This test assesses the explosive strength as well as the maximum power of the lower limb with the idea of estimating the "reflex-elastic-explosive" manifestation. Considering the execution time of this exercise and the fact that approximately 50% of this time is damping (mainly eccentric), it appears that the stretch reflex is released in this phase and not in the acceleration phase. By the percentage difference between the heights reached in the Abalakov and in the CMJ, we can quantify these two heights produced by the arms and we define this as the arm utilisation index [50]. This jump test shows a high correlation coefficient (0.969–0.995) and a low coefficient of variation (1.54–4.82%), with a factor analysis resulting in 82.90–95.79% of the variance of all jump tests [44].

In this jumping test, the arms move forward, and the athlete jumps as high as possible, landing back on the carpet with both feet at the same time. The take-off should be from both feet, without initial steps or shuffling, and the participants should also not pause at the base of the squat.

Drop jump [51]: This is a jump after a fall from a given height, starting from a position with the legs extended and with a downward movement. The continuous movement must be performed with the hands on the hips and the trunk straight, determinants of the "reflex-elastic-explosive" manifestation to verify and evaluate this manifestation of strength. Reliability results with an intraclass ratio coefficient of 0.70–0.92, a standard error of measurement of 8.5–18.4 microseconds (ms) and a coefficient of variation of 3.6–6.4% [47].

In this type of jump, the subject must stand on a step or plinth at a certain height (20–100 cm), must drop onto the contact platform, and once he/she has contacted the platform, must generate a sudden and maximum effort that propels him/her vertically upwards.

Medicine ball throwing test (3 kg) The conditional capacity of strength is fundamental in basketball considering the characteristics of the effort in this sport modality composed of short and intense efforts that lead to sporting success. The most used tests in this sport to control and assess the effect of training on the upper body are usually two: the medicine ball throw for the assessment of power or the 1RM strength test of the bench press.

For the measurement of upper body strength, the medicine ball throwing test was used with a test–retest reliability of $r = 0.98$, whereas previously a correlation coefficient of $r = 0.96$ was obtained. Test validity has been reported [52] according to the intraclass correlation coefficient (ICC) of 0.98, between the means of each throwing modality (standing, kneeling, sitting, one-handed); and a correlation coefficient of $r = 0.49$, $p < 0.01$.

Medicine ball throwing consists of throwing the ball with the feet together bending the knees and trying to make it go as far as possible.

Speed test without change of direction (20 m), sprint repeat ability with change of direction (RSA) and Illinois COD agility test For this/these tests MicroGate® Witty Wireless Training Timer photoelectric cells were used, which has a minimum resolution of 0.125 ms (ms), an event delay of 1 ms and uses a redundant code with information accuracy check and self-correction, with a pulse transmission accuracy of 0.4 ms.

Speed test (20 m) without change of direction: Participants could perform 2 trials for the 20 m sprint, starting from a stationary standing position, and the fastest attempt was recorded. The sprint was performed on the side of the basketball court and the time was recorded by photocells (Witty-Gate®; MicroGate Timing Systems S.R.L., Bolzano, Italy) placed at the start and finish lines. The 20 m sprint test demonstrated high levels of reliability (test–retest correlation coefficient of 0.91) and required no prior practice session [53], with intraclass correlation indices of 0.11–0.49 and coefficients of variation of 16.8–51.0% [54].

This test consists of covering 20 m at the maximum possible speed. The athletes stand behind the starting line and on demand run the 20 m in the shortest possible time.

Repeated sprint ability test with change of direction (RSA): Repeated sprint ability (RSA) has been considered for some years as a type of activity representative of the high-intensity movements performed by players in team sports. While performance in most intermittent sports is dominated by technical and tactical efficiency, the importance of RSA as a crucial physical component of performance in intermittent sports is proposed [55], although it has been questioned. Furthermore, the development of fatigue in these sports has been related to the ability to repeat sprints with an overall coefficient of variation between subjects for total repeated sprint time of 2.3%. Participants performed seven repetitions of running at maximum intensity (34.2 m), with active recovery pauses of 25 s between each repetition.

Illinois COD (change of direction) agility test (IAGT): The Illinois agility test considered a standard agility test [56] due to its high validation and reproducibility [57] and is used to measure speed and agility abilities to react, accelerate, decelerate, and change direction of movement, and to quantify directional ability change in basketball players. The intraclass correlation coefficient and standard error of measurement values for the test are 0.96 (95% CI, 0.85–0.98) and 0.19 s, respectively. The validity of the COD IAGT with *t*-test shows $r = 0.31$ [95% CI, 0.24–0.39]; $p < 0.05$ [58], concluding that the COD IAGT appears to be a reliable and valid test.

In this test, the length of the course is 10 m, and the width (distance between the start and finish points) is 5 m. Four cones are used to mark the start, finish and the two turning points. Four other cones are placed in the centre at the same distance. Each cone in the centre is 3.3 m apart. Subjects must lie face down (head towards the starting line) and hands at shoulder height. On the command 'Go' the stopwatch is started, and the athlete gets up as quickly as possible and runs around the course in the direction indicated, without knocking over the cones, to the finish line, where the timing stops.

Yo-yo IET (II) For the intermittent endurance test the Yo-yo Pro-4.49 application was used, an application aimed at group testing and advanced individual testing to perform the Yo-Yo intermittent test (Recovery Level 1, 2 and Endurance Level 1, 2).

The intermittent Yo-Yo IET consists of a twenty-metre round-trip run with a five-metre round-trip recovery walk for 10 s, responding to the pace/speed indicated by the program and reaching your maximum endurance. The total distance covered thus determines the result of the test.

There is currently a strong trend in team sports to assess aerobic performance from an incremental and intermittent test with pause, inspired by the 20 m-SRT [59]. A clear example of this is the use of the YOYO IETt at either of its two levels. Thus, the literature recommends the use of this test [60] to measure the ability to repeat high-intensity intermittent efforts and/or the capacity to recover from this type of exercise. Therefore, its validity and applicability has been studied in several team sports, including basketball [59]. The validity of this test is based on the association obtained between the meters accumulated in the test and the total performance in competition (total meters run) and/or the meters run at high intensity (runs above 15 km/h). The relationships obtained in basketball are $r = 0.77$.

Statistical analysis

All data are expressed as mean ± SD. To determine the normality of the variables considered, the Shapiro Wilk normality test ($n < 30$; sample size of less than thirty participants) was performed. The parametric Student's *t*-test was applied assuming a normal distribution. The percentage change (Δ%) from T1 to T2 in the outcome variables was calculated with the following formula: [(T2-T1) /T1] × 100. With a sample of 23 participants, G*Power 3.1.9.7 software was used to determine the sample size (22.54), power analysis and effect size. Among participants effect sizes were calculated using partial eta squared (η^2_p). Since this measure is likely to overestimate the effect size, values were interpreted according to Ferguson (2009) as no effect if $0 \leq \eta^2_p < 0.05$; a minimal effect if $0.05 \leq \eta^2_p < 0.26$; a moderate effect if $0.26 \leq \eta^2_p < 0.64$; and a strong effect if $\eta^2_p \geq 0.64$. Pearson's correlation analysis and the correlation magnitude were applied. The magnitude of correlation coefficients was determined as trivial ($r < 0.1$), small ($0.1 < r < 0.3$), moderate ($0.3 < r < 0.5$), high ($0.5 < r < 0.7$), very high ($0.7 < r < 0.9$), almost perfect ($r > 0.9$) and perfect ($r = 1$) [61]. In turn, the effect size variation is indicated providing a convenient (though not exhaustive) representation of the required sample size change and a more intuitive and practical approach to probabilistic inference [62] based directly on the uncertainty of the true value of the statistic.

The incidence of overweight in the study sample was calculated using BMI, and according to a World Health Organisation report [63], obesity is defined as a BMI ≥ 30 kg/m^2 and overweight as a BMI of 25–29.9 kg/m^2 for the general population, and to the authors' knowledge there is no specific index for top-level athletes. Although it should be noted that a player with high muscle mass and low levels of fat could be classified as overweight based on BMI when this participant is not overweight. The values of the measurements obtained are recorded in an Excel spreadsheet for subsequent statistical analysis using Windows SPSS 25.0® software (Inc., Chicago, IL, USA). The level of significance is $p < 0.05$.

Results

At the level of results, it has been considered at a general level that the significance of the difference obtained is somehow significant when it deviates from what is expected in a way that cannot be assumed to occur by chance alone, since in this way as we say it is unlikely that the result occurs due to chance or random fluctuation.

Food frequency questionnaire

With the data collected in this questionnaire we have proceeded to see if the intake of the sportswomen remains within the parameters established in the literature, not to extrapolate the results to the general population, due firstly to the small number of people we are working with and secondly to the fact that this population is not random but very specific. Thus, we have tried to maintain the ecological validity of the process, a limitation being the fact that we only have one valid data collection in this aspect.

Total daily energy intake and macronutrient distribution

Table 2 shows the mean daily total energy intake and macronutrient distribution among the 23 female athletes. The specific intake of macronutrients was, proportionally 54.3% ± 8.8% on average of the total energy intake came from CHO. Fat constituted 20.3% ± 6.5% of the total energy intake per day. Protein intake was equivalent to 25.4% ± 5.7% of the total energy intake.

At the energy level and in comparison, with the guidelines established for female basketball players, 100% of the participants consumed less energy than the recommended

Table 2 Energy and macronutrients consumed by elite female basketball and volleyball players (EFBPs; $n = 12$/EFVPs; $n = 11$) during the 16 weeks of the study

	$n = 23$			Recommended intake ranges
	Mean ± SD	Maximum	Minimum	
Energy ($kcal \cdot d^{-1}$)	1477.0 ± 342.7	2436.7	875.0	50–80 $kcal \cdot kg^{-1} \cdot day^{-1}$
Energy ($kcal \cdot kg^{-1} \cdot d^{-1}$)[a]	20.2 ± 4.3	25.9	9.8	
Proteins ($g \cdot d^{-1}$)	73.4 ± 16.2	100.1	30.4	1.2–2 $g \cdot kg^{-1} \cdot day^{-1}$
Proteins (%)	25.4 ± 5.8	39.3	15.7	
Proteins ($g \cdot kg^{-1} \cdot d^{-1}$)[b]	1.0 ± 0.2	1.6	0.3	
Fats ($g \cdot d^{-1}$)	58.9 ± 19.8	91.7	24.8	20–35%
Fats (%)	20.3 ± 6.5	32.7	8.7	
Fats ($g \cdot kg^{-1} \cdot d^{-1}$)	0.8 ± 0.3	1.3	0.3	
Carbohydrates ($g \cdot d^{-1}$)	163.2 ± 64.3	402.7	86.5	5–8 $g \cdot kg^{-1} \cdot day^{-1}$
Carbohydrates (%)	54.2 ± 8.9	73.2	37.7	
Carbohydrates ($g \cdot kg^{-1} \cdot d^{-1}$)[d]	2.2 ± 0.6	3.8	1.1	
	EFBPs ($n = 12$)			Recommended intake ranges
	Mean ± SD	Maximum	Minimum	
Energy ($kcal \cdot d^{-1}$)	1534.5 ± 372.3	2436.7	1045.3	50–80 $kcal \cdot kg^{-1} \cdot day^{-1}$
Energy ($kcal \cdot kg^{-1} \cdot d^{-1}$)[a]	19.7 ± 3.3	25.1	13.0	
Proteins ($g \cdot d^{-1}$)	81.3 ± 11.6	100.1	63.1	1.2–2 $g \cdot kg^{-1} \cdot day^{-1}$
Proteins (%)	26.6 ± 6.4	39.3	18.2	
Proteins ($g \cdot kg^{-1} \cdot d^{-1}$)[b]	1.1 ± 0.2	1.6	0.9	
Fats ($g \cdot d^{-1}$)	50.0 ± 11.1	69.5	34.7	20–35%
Fats (%)	16.4 ± 3.2	21.2	8.7	
Fats ($g \cdot kg^{-1} \cdot d^{-1}$)	0.7 ± 0.1	1.0	0.4	
Carbohydrates ($g \cdot d^{-1}$)	187.8 ± 78.2	402.7	86.5	5–8 $g \cdot kg^{-1} \cdot day^{-1}$
Carbohydrates (%)	57.0 ± 7.7	73.2	41.1	
Carbohydrates ($g \cdot kg^{-1} \cdot d^{-1}$)[d]	2.4 ± 0.7	3.8	1.1	
	EFVPs ($n = 11$)			Recommended intake ranges
	Mean ± SD	Maximum	Minimum	
Energy ($kcal \cdot d^{-1}$)	1114.4 ± 311.8	1865.2	875.0	50–80 $kcal \cdot kg^{-1} \cdot day^{-1}$
Energy ($kcal \cdot kg^{-1} \cdot d^{-1}$)[a]	20.7 ± 5.3	26.0	9.8	
Proteins ($g \cdot d^{-1}$)	64.8 ± 16.4	83.0	30.4	1.2–2 $g \cdot kg^{-1} \cdot day^{-1}$
Proteins (%)	24.1 ± 4.5	29.8	15.6	
Proteins ($g \cdot kg^{-1} \cdot d^{-1}$)[b]	1.0 ± 0.3	1.4	0.3	
Fats ($g \cdot d^{-1}$)	67.7 ± 23.8	91.7	24.8	20–35%
Fats (%)	24.6 ± 6.5	32.7	12.6	
Fats ($g \cdot kg^{-1} \cdot d^{-1}$)	1.0 ± 0.4	1.4	0.3	
Carbohydrates ($g \cdot d^{-1}$)	136.4 ± 29.3	186.1	97.8	5–8 $g \cdot kg^{-1} \cdot day^{-1}$
Carbohydrates (%)	51.3 ± 9.3	70.7	37.7	
Carbohydrates ($g \cdot kg^{-1} \cdot d^{-1}$)[d]	2.0 ± 0.5	2.7	1.3	

Data are expressed as mean ± SD

[a]Intake was lower than the recommendations set out in most of the EFVPs/EFBPs

[b]Intake was lower than the recommendations set out in most of the EFVPs/ EFBPs

[c]Intake was lower than the recommendations set out in most EFVPs/ EFBPs

[d]Intake was below the recommendations set out in most of the EFVPs/ EFBPs

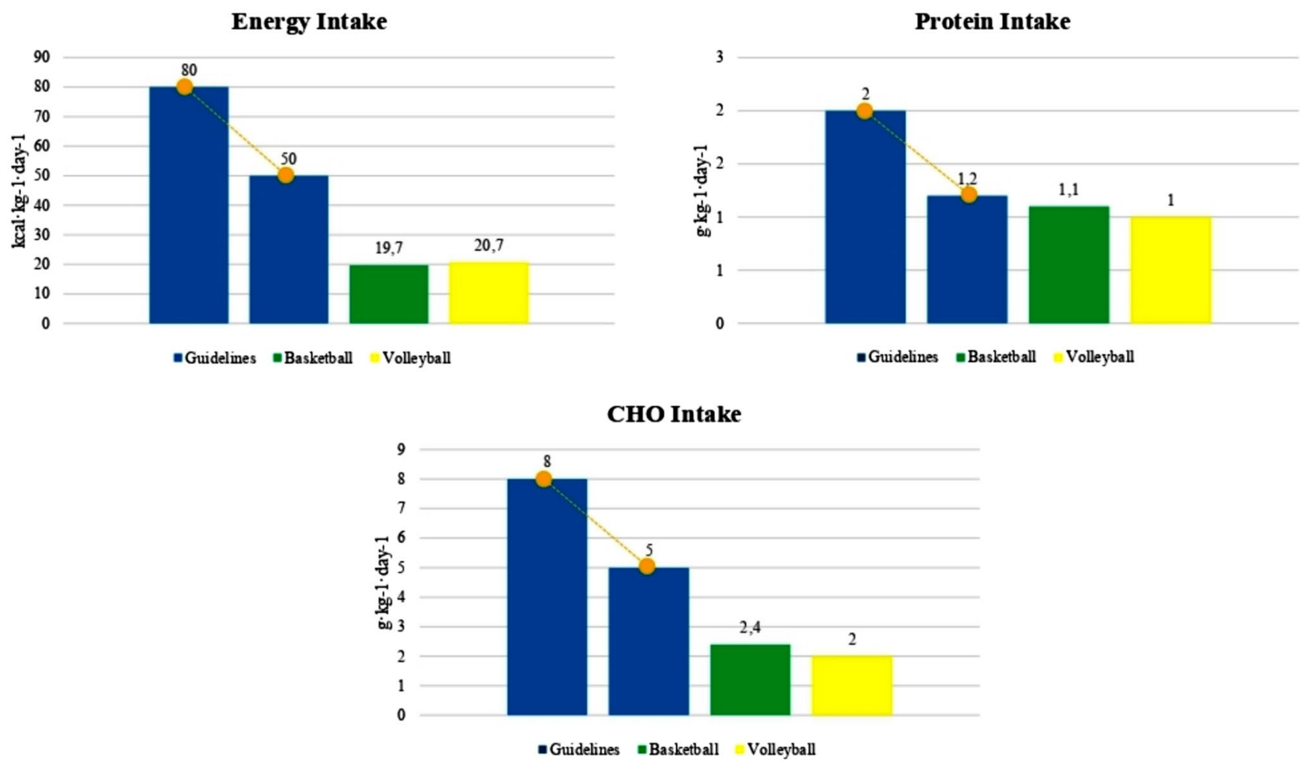

Fig. 4 Ratio of recommended intake to intake produced in each discipline by EFBPs and EFVPs over the 16 weeks of the study

values (50–80 kcal·kg^{-1}·day^{-1}), a situation that is also repeated for CHO intake (5–8 g·kg^{-1}·day^{-1}). As for fat intake, 91.6% did not comply with the established recommendations for fat intake percentages (20–35%), and as for protein intake, 83.3% did not comply with the established consumption recommendations (1.2–2 g·kg^{-1}·day^{-1}). As for the volleyball players, 100% of the participants consumed less energy than recommended, a situation that was repeated for CHO intake, with all participants below the recommended amount (Fig. 4). In terms of fat intake, 25% of the players are below the recommended percentage of fat intake and 75% of them have a lower than recommended protein intake. Overall, none of the participants consumed more macronutrients than recommended (Table 2).

Body composition (BC) assessments

Absolute and percentage changes for all body composition measures can be seen in Table 3.

BM and BMI

It can be seen (Table 3) that there have been changes ($p > 0.05$) for body mass in basketball participants contrary to volleyball participants. This situation has been repeated also for BMI.

Body adipose percentage and adipose mass (kg)

We appreciated that for EFBPs there was a very small decrease from T1 to T2 in body adipose percentage, and in absolute adipose mass. However, for EFVPs an increase in body adipose percentage and absolute adipose mass was observed. In the absolute sum of 8 skinfolds the EFBPs showed a decrease between time points, and the EFVPs an increase. In terms of effect size, there was a strong effect for both change in body adipose percentage, absolute f adipose mass and a decrease in absolute sum of 8 skinfolds in both disciplines (Table 3).

Percentage and absolute muscle mass

There was little substantial change in the percentage muscle mass (Table 3) of EFBPs and absolute muscle mass. There was a significant increase in both percentage muscle mass and absolute muscle mass in the EFVPs. Furthermore, there was a strong effect for both parameters on EFBPs and a moderate one for EFVPs.

Somatotype

Changes in somatotype (Table 3) were calculated using the equation developed by Carter and Heath (1990). Moderate

Table 3 Body composition characteristics of elite female basketball and volleyball players (EFBPs/EFVPs) at baseline (T1), post-test (T2) and percentage change

EFBPs								
	T1 (n = 12)	T2 (n = 12)	t	%Δ	p	η^2_p	Change magnitude	Probabilistic inference
Body mass (kg)	77.8 ± 12.4	75.7 ± 11.4	2.201	−2.5 ± 3.2	0.028	0.975	Large	Probably beneficial
BMI (kg/m^2)	24.2 ± 3.0	23.6 ± 2.6		−2.5 ± 3.2	0.028	0.960	Large	Probably beneficial
Body fat (%)	20.5 ± 3.5	20.0 ± 3.0		−1.5 ± 9.2	0.491	0.806	Large	Possibly beneficial
Body fat (kg)	16.2 ± 5.3	15.4 ± 4.2		−3.9 ± 10.9	0.256	0.902	Large	Probably beneficial
∑8SF (mm)	132.4 ± 35.7	126.7 ± 27.3		−2.9 ± 13.5	0.353	0.813	Large	Possibly beneficial
Muscle mass (%)	34.0 ± 3.2	34.8 ± 2.7		2.3 ± 3.9	0.063	0.926	Large	Possibly beneficial
Muscle mass (kg)	26.1 ± 2.7	26.1 ± 3.0		−0.3 ± 3.4	0.813	0.957	Large	Possibly trivial
Endomorphia	5.3 ± 1.0	5.2 ± 0.9		4.4 ± 17.6	0.445	0.795	Medium	Probably beneficial
Mesomorphia	3.6 ± 1.5	3.6 ± 1.4		23.0 ± 57.9	0.991	0.979	Large	Almost certain beneficial
Ectomorphia	2.0 ± 0.6	2.0 ± 0.6	0	0.0 ± 0.0	1.000	1.000	Large	Unclear
EFVPs								
	T1 (n = 11)	T2 (n = 11)	t	%Δ	p	η^2_p	Change magnitude	Probabilistic inference
Body mass (kg)	69.9 ± 9.3	70.1 ± 9.0	2.228	0.3 ± 2.5	0.723	0.983	Large	Possibly trivial
BMI (kg/m^2)	22.3 ± 3.1	22.4 ± 2.8		0.3 ± 2.5	0.815	0.987	Large	Possibly trivial
Body fat (%)	19.0 ± 3.2	19.6 ± 4.0		3.0 ± 16.4	0.442	0.681	Medium	Probably harmful
Body fat (kg)	13.3 ± 2.9	13.9 ± 4.0		3.3 ± 16.0	0.336	0.859	Large	Probably harmful
∑8SF (mm)	110.7 ± 28.6	114.0 ± 32.6		3.9 ± 23.5	0.586	0.657	Medium	Probably harmful
Muscle mass (%)	34.2 ± 3.8	35.7 ± 3.9		5.1 ± 13.4	0.352	0.361	Small	Probably beneficial
Muscle mass (kg)	23.7 ± 2.5	25.0 ± 3.8		5.3 ± 11.87	0.26	0.610	Medium	Probably beneficial
Endomorphia	4.9 ± 1.0	5.1 ± 1.3		−1.8 ± 10.3	0.299	0.737	Medium	Possibly beneficial
Mesomorphia	2.3 ± 1.2	2.7 ± 1.4		2.2 ± 11.2	0.262	0.751	Medium	Possibly beneficial
Ectomorphia	1.9 ± 0.5	1.9 ± 0.5	0	0.0 ± 0.0	1.000	1.000	Large	Unclear

BMI body mass index, *∑8SF* summation of 8 body skinfolds, *t* t de student, *% Δ* percentage change, *p* *p*-value, *η2p* effect size

($p > 0.05$) changes can be seen in endomorphy and strong in mesomorphy in the EFBPs. Whereas there are aspects that do not present significant changes in the EFVPs neither for endomorphy nor for mesomorphy. However, there was a moderate effect in favour of increased endomorphy in basketball and volleyball as well as in EFVPs mesomorphy and a strong effect in EFBPs mesomorphy.

Performance tests

Absolute and percentage changes between pre-test (T1) and post-test (T2) for all performance measures are shown in Table 4. From T1 to T2, there were significant increases in SJ, CMJ, DJ and in the intermittent endurance test in the EFBPs, but only in the intermittent endurance test for the EFVPs. In addition, in basketball there was a strong effect for changes in the ABK, shot put, RSA and intermittent endurance test, and moderate for SJ, DJ, 20 m and the agility test. Whereas in volleyball there was a strong effect for the CMJ, ABK, DJ, shot put, RSA, Illinois test and intermittent endurance test (Table 4).

Relationship between dietary intake and performance changes

Figure 5 shows a bivariate (strong and very strong) correlation analysis between dietary intake and performance. In female basketball players, significant negative correlations were observed between CHO intake and percentage decrease in CMJ ($r = -0.529$; $p = 0.077$ [ns]) and between protein intake and percentage decrease in medicine ball throwing ($r = -0.561$; $p = 0.058$ [ns]). Among female volleyball players, significant negative correlations were observed between total energy intake and percentage decrease in the intermittent endurance test ($r = -0.586$; $p = 0.058$), between CHO intake and percentage decrease in the CMJ ($r = -0.672$; $p = 0.024$), between protein intake and percentage decrease in medicine ball throwing ($r = -0.507$; $p = 0.112$ [ns]) and with the intermittent endurance test ($r = -0.809$; $p = 0.002$), and in fat intake and the intermittent endurance test also ($r = -0.539$; $p = 0.087$ [ns]). In turn for volleyball players, we see an inverse negative relationship between CHO intake and the percentage decrease in the agility test ($r = -0.640$; $p = 0.034$). Furthermore, as seen in the r value, all significant

Table 4 Performance results of elite female basketball (EFBPs and volleyball (EFVPs) players at baseline (T1) and post-test (T2) and percentage change of the different tests

EFBPs								
	T1 (n = 12)	T2 (n = 12)	t	%Δ	p	η^2_p	Magnitude of change	Probabilistic inference
SJ (cm)	29.3 ± 4.6	32.8 ± 5.2	2.201	12.4 ± 16.6	0.029	0.546	Medium	Almost certain beneficial
CMJ (cm)	29.4 ± 5.4	32.6 ± 4.3		12.6 ± 16.5	0.136	0.629	Medium	Almost certain beneficial
ABK (cm)	34.0 ± 3.9	3369 ± 4.0		−1.4 ± 7.9	0.699	0.833	Large	Possibly harmful
DJ (cm)	29.2 ± 4.8	33.0 ± 5.2		14.0 ± 16.6	0.638	0.645	Medium	Almost certain beneficial
MBT (m)	7.1 ± 1.0	7.7 ± 1.0		5.9 ± 8.2	0.303	0.820	Large	Probably beneficial
20 m (s)	3.6 ± 0.2	3.4 ± 0.2		−1.5 ± 5.9	0.466	0.428	Small	Possibly beneficial
RSA (s)	8.0 ± 0.4	7.8 ± 0.3		−2.1 ± 3.7	0.282	0.725	Medium	Possibly beneficial
Illinois (s)	18.6 ± 0.8	18.9 ± 0.7		1.8 ± 4.3	0.308	0.344	Small	Possibly harmful
Yo-yo (m)	401.7 ± 387.7	500.0 ± 271.3		120.5 ± 115.6	0.678	0.712	Medium	Almost certain beneficial
EFVPs								
	T1 (n = 12)	T2 (n = 11)	t	%Δ	p	η^2_p	Magnitude of change	Probabilistic inference
SJ (cm)	26.0 ± 3.2	25.0 ± 1.2	2.228	−3.0 ± 11.3	0.335	−0.022	Small	Probably harmful
CMJ (cm)	30.3 ± 3.6	31.2 ± 4.0		3.0 ± 2.2	0.0019	0.986	Large	Probably beneficial
ABK (cm)	34.3 ± 5.0	34.8 ± 3.4		2.4 ± 3.1	0.0276	0.972	Large	Possibly beneficial
DJ (cm)	26.1 ± 3.9	27.1 ± 40.5		3.8 ± 6.6	0.1031	0.886	Large	Probably beneficial
MBT (m)	7.3 ± 1.0	7.2 ± 1.1		1.0 ± 11.0	0.8234	0.685	Medium	Probably trivial
20 m (s)	3.6 ± 0.2	3.5 ± 0.2		−1.8 ± 6.2	0.3257	0.465	Small	Possibly beneficial
RSA (s)	8.5 ± 0.8	8.6 ± 0.8		0.9 ± 6.3	0.7579	0.749	Medium	Probably trivial
Illinois (s)	186.6 ± 0.9	18.9 ± 1.1		1.9 ± 3.8	0.1488	0.733	Medium	Possibly harmful
Yo-yo (m)	389.1 ± 208.0	656.7 ± 247.4		29.6 ± 42.6	0.0181	0.860	Large	Almost certain beneficial

SJ squat jump, *CMJ* countermovement jump, *ABK* Abalakov jump, *DJ* drop jump, *MBT* medicine ball throwing test, *20 m* speed test without changes of direction, *RSA* sprint repeat ability with change of direction, *Illinois* Illinois COD agility test, *Yo-yo* Yo-yo intermittent endurance test, *t* t de Student, *%Δ* percentage change, *p* p-value, *η2p* effect size

relationships fell into the magnitude category of a small to very high relationship (r = 0.194/−0.809) for EFVPs and moderately to highly (r = 0.449/−0.561) for EFBPs players.

Discussion

The primary objective of this research was to analyse the specific dietary intake of elite female basketball and volleyball players and to assess the impact of specific energy intake and its relationship to sport performance in their respective disciplines, as well as their BC during the first 16 weeks of the competition season. A secondary objective was to compare total energy intake and macronutrient distribution with established, but non-sex-specific, recommendations [2]. Our main results did not conclusively support our hypothesis that (i) adherence to a well-defined specific training protocol would improve measures of BC (i.e., body fat percentage, fat mass, and muscle mass and somatotype categorisation) during the competition season; and (ii) that female participants would significantly improve athletic performance despite observed dietary intakes that were far from established recommendations.

Although the current approach is novel, adequate nutrition is necessary to optimise performance outcomes, ensuring that the athlete consumes sufficient calories to ensure the energy expenditure produced during their sporting activity [2]. Both basketball and volleyball, being classified as sports disciplines in which athletes perform high volume levels of intense training (3–6 h·day^{-1} of intense training in 1–2 training sessions over 5–6 days·week^{-1}), are disciplines that can result in a caloric expenditure of 600–1200 kcal/h or more per session [1]. This is why their caloric needs can approach 40–70 kcal·kg·day (2000–7000 kcal·day for 50–100 kg athletes) [37]. In the case of elite athletes, energy expenditure during intense training or competition will exceed these levels even further [64].

As a result, recommendations have been made for these athletes to consume between 50 and 80 kcal·kg^{-1}·day^{-1} or 2500–8000 kcal·day^{-1} for 50–100 kg participants [2].

In our case, in both disciplines, 100% of the participants consumed less total energy than the existing guidelines

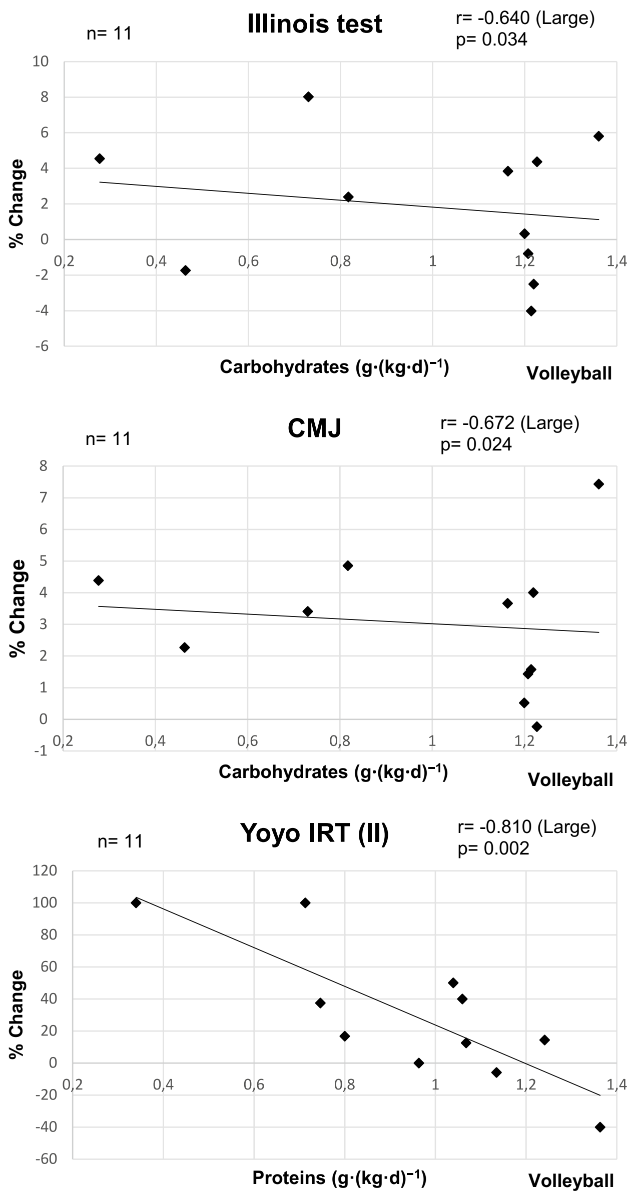

Fig. 5 Significant bivariate correlations (strong, greater than 0.5 and very strong, greater than 0.7) between dietary intake and percentage change in performance by EFBPs and EFVPs over the 16 weeks of the study. *r* correlation coefficient, *p* *p*-value, *n* population size

indicate, while also 100% of the participants had a CHO intake below the recommended levels [65]. In terms of protein and fat intake, 82.61% of the players consumed protein below the established recommendations and 56.52% consumed less fat than recommended. The mean total daily energy intake of the participants in the present study was 1477.0 ± 342.6 kcal·day^{-1}, with a relative value of 20.2 ± 4.3 kcal·kg^{-1}·day^{-1}, which is lower to previous recommendations and far from the latest research in both disciplines [66, 67]. In addition, athletes with insufficient energy intake to balance the energy expended during exercise are at risk of developing low energy availability (LEA), which is the cornerstone of a condition called relative energy deficiency in sport (RED-s) [68].

Importantly, the present study observed in female volleyball players a negative correlation between total energy intake and performance in the intermittent endurance test (Fig. 4). The implications of this result are that higher total energy intake appears to be related to greater endurance strength. The fact that the recommendations for this type of athlete are not sex-specific, requires the consideration of alternative proposals for energy intake, more specific or current energy intake proposals [69], suggesting a total caloric intake of 39–44 kcal·kg^{-1}·day^{-1} or that [14] ± 45 kcal·kg^{-1}·day^{-1} to maintain optimal health and performance, as well as adequate BC.

Regarding the distribution of macronutrients, the EFBPs ($n = 12$) consumed less CHO (2.4 ± 0.7 g·kg^{-1}·day^{-1}; range: 1.1–3.7 g·kg^{-1}·day^{-1}) than the established recommendations for this sport population [70], 100% ($n = 12$) of the EFBPs consumed less than the established CHO recommendations for athletes [71]. In relation to CHO, female basketball players showed a significant and negative correlation between CHO intake and changes in CMJ (Fig. 4). For the EFVPs ($n = 11$), the same percentage of CHO consumption is observed and there was also a significant and negative correlation between CHO intake and changes in CMJ (Fig. 4). In volleyball players, a strong negative correlation between CHO intake and agility test can also be observed. These inverse relationships suggest from our data that it is certainly beneficial for athletes involved in high-intensity activities to have an adequate intake of CHO and that this intake will be related to performance [72, 73]. However, further analysis reveals that the mean percentage increase for CMJ among EFBPs was 12.53% ± 16.5% and 3.03% ± 2.2% for EFVPs. Thus, although there was a negative relationship between CHO intake and CMJ, there was a significant increase in this test in all 23 participants [72].

The right choice of nutrition can improve performance in physical activity by combining different macronutrients during training [74]. Therefore, it is important to keep in mind that training and nutrition can vary according to the individual needs of the athlete and can significantly affect the physiological response to training [75].

In the agility test, we can see that all participating athletes ($n = 23$) presented a negative result between data collection occasions with a resulting time increase in this test of 1.76% ± 4.3% for basketball and 1.84% ± 3.8% for volleyball. Thus, it would be reasonable to suggest that consuming less CHO than the stated recommendations may be beneficial overall and that, at some point, increasing CHO intake without increased energy expenditure may produce diminishing returns, especially in this test [76]. Therefore, by adjusting nutritional intake, it is possible to promote adaptations to training. Several strategies have been developed for this purpose, some more supported by evidence than others. The most common approaches are high carbohydrate availability training (high training) and low carbohydrate availability training (low training), with several variations of each. The choice of the appropriate method depends on one's specific goals, as there is no one-size-fits-all approach. Therefore, the optimal practical application lies in the combination of different nutritional training methods [77]. Indeed, it has been suggested that women are less dependent on glycogen during exercise and less sensitive to CHO-mediated glycogen synthesis during recovery [78] and therefore, compared to men, women may require a lower total CHO intake for exercise. This is supported by data showing that CHO intake in female athletes does not increase maximal or average power or improve agility [79].

Furthermore, in the present study, favourable BC results were observed along with improved performance, suggesting that further research is warranted to compile sex-specific CHO recommendations that consider the variation in substrate utilisation between men and women [80].

Regarding total dietary fat intake, it is recommended that athletes consume at least 20% of their calories in the form of fat [65]; failure to do so may result in deficiencies of essential fatty acids and fat-soluble vitamins (vitamins A, D, E and K), as well as high caloric insufficiency [81]. Contrary to popular opinion, increased fat intake has not been shown to lead to increased adiposity in athletes [82]. Currently, to our knowledge, there are no specific recommendations for female athletes for intake of different types of fatty acids [22], and in the absence of sex-specific recommendations for fat intake and composition, it is recommended that female athletes consume the established 20% of their total calorie intake in the form of fat from various sources to ensure repletion of different types of fatty acids [22]. Specifically, EFBPs were observed to consume a range of 8.60%–21.25% of their total calories from fat, with a mean intake (16.4% ± 3.2% of total kcal) below the above recommendation.

Furthermore, 91.6% ($n = 11$) of EFBPs consumed less than the recommended fat intake, while 8.3% ($n = 1$) of female athletes met the fat intake recommendations (Table 2). The EFVPs, consumed a range of 24.79%–91.69% of their total calories from fat, with a mean intake (24.6% ± 6.5% of total kcal) above the above recommendation [65]. Specifically, 18.18% ($n = 2$) of the EFVPs consumed less than the recommended fat intake, while 81.81% ($n = 9$) of the female athletes met the fat recommendations (Table 2). Lack of fat can be a problem because if not enough fat is consumed, IMTG can be depleted for up to 48 h after exercise, limiting performance [83]. In addition, because women do not utilise muscle glycogen to the same extent as men, the female population may be more dependent on IMTG during exercise, increasing the importance of IMTG replenishment in women [78]. Fat intake in terms of percentage of total energy was lower in the present study than in previous research with female basketball [71] and volleyball players [84]. The values observed in the EFBPs appear adequate, and possibly even beneficial, as despite fat intake being below recommended levels, body fat percentage remained virtually stable (−1.5% ± 9.2%) throughout the 16 weeks. However, in the EFVBs, there was an increase in fat percentage over this period (3.0% ± 16.4%), which may influence the strong negative correlation (Fig. 4) between this value and the intermittent endurance test in having to mobilise greater fat mass. Additional measures of BC, including fat mass, muscle mass (%), absolute muscle mass and somatotype, showed slight improvements in EFBPs despite fat energy intake being lower than traditional recommendations, as in EFVPs, although in EFVPs, % fat mass and endomorphic values worsened slightly, all in relation to changes in body mass and hence BMI. Consequently, these results suggest that a low-moderate fat intake is beneficial in high-intensity athletes to supplement IMTG-derived energy production and increase circulating lipids [76], which is distinct from women's specific substrate utilisation needs [85].

Related to protein pool, EFBPs consumed less protein (1.1 ± 0.2 ($g \cdot kg^{-1} \cdot d^{-1}$) than the established guidelines [65]. This fact may be related to the strong negative correlation (Fig. 4) that has been established with the upper body strength test of medicine ball throwing. Strong negative correlations (Fig. 4) have also been established with this test and with the intermittent endurance test (Fig. 4) in the EFVPs. This may be related to the low protein intake in these athletes (1.0 ± 0.3 $g \cdot kg^{-1} \cdot d^{-1}$), values far from the established guidelines [86]. It has been postulated that accelerated catabolism due to insufficient protein intake during periods of repeated intense exercise (i.e., competition season) may inhibit recovery, leading to poor performance [87]. Moreover, given that female athletes may require, as discussed above, a higher CHO intake, a higher protein intake would be justified and thus compensate for the lower CHO intake [88]. In addition, the protein intake observed in EFBPs was lower than protein intake in other studies [71], which contrasts with EFVPs [84]. It is true that female athletes require higher protein intake to maintain a positive nitrogen balance and promote muscle protein synthesis [89], to help improve skeletal muscle adaptations and to improve mitochondrial size [90].

However, either one or the other, no need for both—caution and care—must be exercised, as combining excessive protein intake with muscle glycogen depletion could lead to elevated ketone body levels [91] and thus dehydration and reduced muscle performance.

It is important to highlight two aspects of the work, one is the limitation in the data collection at a nutritional level, as only valid data was available for one measurement, which means that a valid statistical analysis cannot be made in this regard, and secondly, that, although participants having different energy intakes for each variable (total calories, CHO, protein, and fat) compared to traditional recommendations established for the male gender, a fact that makes these measures not entirely extrapolated to women, since the fact that our athletes do not comply with them does not mean that they are in any way at risk, BC and performance values were significantly improved or maintained across the board for almost all parameters measured over the 16 weeks of the study. This is noteworthy, as previous research has established total calorie and macronutrient recommendations for athletes based on the amount and intensity of exercise performed; however, many of the established recommendations lack gender specificity, as energy and macronutrient intake should be tailored according to gender and the specific demands of sport and time of year [2]. Furthermore, to maximise performance, both periodised training and control of dietary intake must occur synchronously, as low energy availability can lead to a host of negative physiological reactions due to inadequate nutrition. Although this request is announced at the end of many research articles, the complexity of female physiology has meant that this aspect has not yet been thoroughly investigated. Thus, female athletes are subjected to potentially unhelpful recommendations from their immediate environment due to the misapplication of results obtained in studies of the male population.

On the other hand, the limited scope of our study and the controlled conditions of the tasks performed restrict the general applicability of our findings. In addition, all participants were physically active, making it difficult to determine whether the changes found were due to high levels of physical activity in general or to sports performance specifically. Another limitation is the lack of information on participants' sleep and diet, which could help explain the observed differences.

Despite the limitations noted above, this work highlights several positive aspects, such as (i) the extensive monitoring of elite volleyball athletes over a 16 week competitive season prior to a championship and (ii) the integrated approach that analysed physiological and performance indicators at both the individual and team levels.

On a practical level, from the results obtained, it was found that monitoring hormonal responses during season planning can provide valuable information on the level of stress generated by sports training and competitions, as well as on the ways in which athletes adapt to the stress induced by sporting activities. This information can be used to manage training load and plan training cycles more effectively throughout the competitive season.

Conclusions

In conclusion, dietary monitoring in elite female basketball and volleyball players while the competitive season showed lower intakes of total energy, CHO, and protein. One could consider the fact of not having a control group as a limitation of the study, but as this is a non-randomly selected elite group, it does not make much methodological sense to have a control group. On the other hand, the fact of not having a second valid data collection at nutritional level to be able to develop a correct statistical analysis is another of the limitations of the work. However, even though the participants' actual intake was lower relative to the recommendations, the athletes did not experience a decline in their athletic performance, indeed, they showed, albeit slight, overall improvements in performance and BC during the first 16 weeks of the season, as these recommendations are based on the male gender. Therefore, these results suggest that high-intensity athletes may experience beneficial changes in physical performance with dietary intake significantly different from the recommended intake. However, current nutritional recommendations for female athletes are generic and not sex-specific, so they may not consider differences in substrate utilization between the sexes. Finally, the present data suggest that, although a cause–effect relationship between dietary intake and BC-performance cannot be determined, elite female players in these sports disciplines may experience beneficial outcomes with lower intakes of total energy, CHO, protein, and fat than previously recommended.

Author contributions All authors contributed to the conception and design of the study. Material preparation, data collection and analysis were carried out by Álvaro Miguel-Ortega, Julio Calleja-González and Juan Mielgo-Ayuso. The first draft of the manuscript was written by Álvaro Miguel-Ortega and all authors commented on earlier versions of the manuscript. All authors read and approved the final manuscript.

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Data availability To promote transparency of the data supporting the results reported in the article, the authors have established the data availability statement. The data associated with this article are not publicly available but are available from the corresponding author upon reasonable request.

Declarations

Conflict of interest The authors declare no conflict of interest.

Ethical approval It is important to note that the data collected have been treated with the utmost confidentiality and scientific rigour, in accordance with the guidelines of the respective research projects following the required scientific methodology. Likewise, these procedures comply with the provisions of Organic Law 15/1999, of 13 December, on the Protection of Personal Data (LOPD). Furthermore, the ethical criteria established by the Responsible Committee for Human Experimentation have been strictly followed, as established in the law 14/2007 (published in the OSG number 159).

Informed consent Prior to participation, each participant received a thorough explanation of the risks and benefits associated with the experimental procedures. To ensure informed consent, each player signed a written consent form.

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