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Evaluation of Body Composition Changes by Bioelectrical Impedance Vector Analysis in Volleyball Athletes Following Mediterranean Diet Recommendations during Italian Championship: A Pilot Study

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Abstract: In a volleyball team, an optimal body composition might be reachable by monitoring both training plan and nutritional habits to obtain success in competitions. The Mediterranean Diet (MD) may represent a good choice to cover the nutritional needs of those practicing competitive sports. The aim of this study was to monitor body composition changes through bioelectrical impedance vector analysis (BIVA) during pre-season training sessions (P), the championship (C), and the play-off period, in volleyball players following MD recommendations. Our data showed that athletes maintained an optimal MD adherence over the study period. In the total population, we observed an upward and leftward shift of the vector on the resistance (Rz)/reactance (Xc) graph within the specific tolerance ellipses for the volleyball players. Using Hotelling's T^2 test, we found significant changes in BIVA parameters from P to C of the entire team, due to reduction in Rz/height (H) and increase in Xc/H, along with an increase in phase angle, body cell mass index, and skeletal muscle mass. Our findings support BIVA as a useful tool to monitor body adaptations of athletes and the MD as an optimal dietary pattern in sport setting to allow good performance in athletes.

Keywords: Mediterranean diet; volleyball athletes; body composition; bioelectrical impedance vector analysis; performance

1. Introduction

In sports, the monitoring of body composition is a key factor and its variation over time can affect the athletes' performance [1]. Indeed, to obtain success in sport competitions, it is mandatory to achieve an optimal body composition in athletes through the careful adjustments of their training and nutritional habits according to specific sports demands. In the context of healthy eating habits, it has been documented that a higher adherence to the Mediterranean Diet (MD) boosts sports performance [2,3], suggesting that MD represents a valid pattern for preventing a good health status in the human population that practice physical activity [4–8]. Hence, it has been reported that adjustments to the MD plan should be made in athletes according to sport nutrition practices to optimize sport performance [9,10].

To measure and monitor the body composition of athletes during pre- and post-competition, different methods are currently available, including the bioelectrical impedance analysis (BIA), which represents the most used non-invasive tool. BIA, by detecting resistance (Rz) and reactance (Xc) along with impedance (Z), as the resultant from Rz and Xc, allows to evaluate body composition parameters and cell hydration status [11]. From these raw measurements, using prediction equations, several body composition parameters, such as free fat mass (FFM), fat mass (FM), total body water (TBW), and intracellular and extracellular water (ICW and ECW), are calculated. Among the bioimpedance parameters measured with BIA, the phase angle (PhA) is one of the most clinically important parameters, which is used as an indicator of cellular health, quality of cells, cell function, and membrane integrity [12–14]. PhA values between 5° and 7° indicate good cell structure and a good membrane integrity, lower values of PhA are related to fluid accumulation and loss of membrane integrity, while higher values are related to dehydration. Thus, the evaluation of the PhA is a qualitative approach included in the analysis of the body composition through BIA.

In previous decades, technological improvements have made the BIA a more reliable and, therefore, more acceptable way of measuring body composition through the qualitative analysis bioelectrical impedance vector analysis (BIVA), which consists of the interpretation of the raw parameters recorded in BIA and plotting them as a vector within a graph. Of note, avoiding the use of regression equations, BIVA shows the vector position within tolerance ellipses drawn for each specific population. Indeed, tolerance ellipses reflect the percentile in body composition parameters and can be useful to identify the specific athlete's profile for each sport [15] to create a reference target zone for each sport and each competitive level [16]. Specifically, the analysis through a rightward or leftward displacement of the BIVA vector to the major axis may represent a decrease or increase in the ICW/ECW ratio and the amount of TBW [17]. In addition, the vector migration laterally to the left with respect to the major axis indicates a greater cell mass, while displacements to the right with respect to the major axis indicate a smaller amount of cell mass [18]. The vectorial approach appears to be more efficient, since it considers both variables, PhA and vector length. Indeed, in groups of individuals characterized by identical PhA, but different vector lengths, and showing different body fluids or % FM [19], qualitative analysis may be used to monitor changes in bioelectrical parameters and in body composition. BIVA is useful to compare data with population-specific references in physiological conditions, such as in athletic subjects or in the elderly, and in pathological conditions such as in obesity [20]. Moreover, vector displacement by BIVA can indicate changes in soft tissues and body fluids in response to changing eating habits, use of supplements, and training programs or competitions [15,16].

Overall, the aim of this study is to evaluate the variation in the bioelectrical impedance vector analysis of 11 male volleyball players, following appropriate dietary recommendations based on MD associated with a specific integration protocol, during the competitive season. Importantly, BIVA provides information to optimize the competitive performance of volleyball players over the entire championship.

2. Material and Methods

2.1. Participants and Study Design

This pilot longitudinal study included a sample of 11 men, aged 19 to 37 years (27 ± 6.033, as mean and SD), and recruited from the Italian volleyball team in the volleyball division of the Serie A championship located in the Calabria Region, Italy (Corigliano Caffè Aiello Volley). The data were collected over a period of about 8 months, starting from enrollment, the day of the rally, to the end of the sporting championship, including the play-off phase during 2014–2015 sporting season. We divided the following phases: "P" (pre-season training session) refers to the data of enrollment and pre-season training session times (T) from T0 to T2. "C" (championship) refers to the data from T3 to T7, over the championship period. "PO" (play-off) refers to the data from T8 and T9, over the play-off period. During each check, we evaluated the anthropometric and electrical bioimpedance parameters for each athlete. This study was approved by Caffè Aiello Corigliano Feder-Volley, which gave permission, along with the regional sports council. The study followed the ethical recommendations of the Declaration of Helsinki for the study of humans. All subjects were informed of the study objectives and characteristics and signed informed consent forms.

2.2. Anthropometric Parameters

During the study period, an individual athlete's standing height was measured before each match, using a validated protocol [21]. Briefly, the measurement was performed without shoes in an upright position by taking the head orientation according to the Frankfort plane; the heels, buttocks, shoulder blades and nape of the examined subject come in contact with the graduated rod of the telescopic altimeter, which has an accuracy of 1 mm (1 mm) (Model 206, Seca Deutschland, Hamburg, Germany). Body weight was measured using a high precision mechanical scale (Model 756 Seca Deutschland, Hamburg, Germany), daily calibrated, with a maximum capacity up to 200 kg. The detection was carried out wearing very light clothing and barefoot or with very thin socks, distributing the weight equally on both legs, with arms on sides and in an upright position, remaining motionless so as not to distort the result. Each parameter detected during the checks was standardized as much as possible in order not to incur measurement errors. The checks were always carried out on the same day of the week (Tuesday morning) and, at the same time, also the time elapsed between the survey and the match previously supported by the athletes (at least 24 h apart).

2.3. Bioelectrical Impedance Analysis

The electrical bioimpedance parameters were detected by inducing an alternating current at the frequency of 50 kHz (single analyzer pole), using a phase sensitive instrument (RJL Systems®) (https://www.rjlsystems.com/about/validations-of-bia/, accessed on 8 June 2022), daily calibrated following the manufacturer's instructions, which was carried out to evaluate resistance, reactance, and phase angle (PhA). Derived body composition parameters such as total body water (TBW), body cell mass (BCM), free fat mass (FFM), fat mass (FM), body cell mass index (BCMI), fat-free mass/height (FFM/H), extracellular mass (ECM), extracellular water (ECW), intracellular water (ICW), lean dry mass (LDM), lean soft tissue (LST), and skeletal muscle mass (SMM) were calculated using predictive equations for athletes provided by the RJL Systems® software. The athletes were asked to settle in a supine position, on an insulating bed, a few minutes before the detection, in order to allow an optimal distribution of body fluids. The lower limbs were spread apart at a right angle with respect to the midline of the body, and the same was performed for the upper limb with respect to the abdominal trunk. Two injector electrodes were placed proximally on the hand and foot of the right part of the body, and two sensor electrodes were placed distally five centimeters away from the previous ones were applied, for a total of four electrodes. The BIVA vectors were analyzed through the BIVA Software 2002 [22].

2.4. Dietary Recommendations and Nutritional Supplementation

The athletes were asked to fill in a weekly food diary by entering, with the utmost precision and truthfulness, the times and types of meals before and after the nutrition education program (NEP). NEP, provided by a team of nutritionists, consisted of seminars and interactive lectures structured to cover knowledge of food sources of macro- and micronutrients typical of the MD pattern and correlation between nutrition and physical performance.

After a careful evaluation of the athlete's food diaries, the MD score from different MD questionnaires validated for adults was calculated [23,24], showing that our population of professional athletes already had good eating habits. To assess the MD adherence of our sample, the results of the Mediterranean Diet Adherence Screener (MEDAS) questionnaire were reported. The 14-item MEDAS questionnaire was scored with either a 0 or 1, with the overall score within the three following categories: poor (≤5), moderate (6–9), and optimal adherence (≥10).

With regards to the nutritional approach, each athlete followed a personalized diet that included monthly changes and adjustments. The dietary plan, according to the MD, model provided a balanced amount of macronutrients (proteins, carbohydrates, fats) equal to 45–60% of total calories that were represented by carbohydrates, preferably complex and rich in fiber; an amount of 20–35% of calories were made up of fat, and about 15–20% of calories came from protein. The personalized redistribution of macro and micronutrients took place according to the different daily energy expenditure (TDEE) of each subject as recommended by the Italian Society of Human Nutrition (https://sinu.it/, accessed on 9 June 2022). The distribution of some macronutrients such as proteins (ranged from 1 to 1.5 g/day) was also customized according to their physical activity level. Moreover, we recommended supplements such as sport drinks, creatine monohydrate, essential amino acids, beta-alanine, balanced recovery drinks (containing whey protein and glucose, or vitargo and, possibly, glutamine), multivitamins, and liquid or capsule fish oil (Omega 3). Dietary plans were designed using MetaDieta software, version 4.2.1 (Meteda S.r.l, Roma, Italy).

2.5. Training Methods

Participants received a personalized training plan by an athletic trainer. During the first 3–4 days, they followed a general organic workout based on muscle strengthening and basic endurance. In particular, the weekly training hours were 5 h a day, 6 days a week, with one match day and one rest day, for a total of about 30 h a week of time of sports experience. After that, the workout consisted of the development of rapidity and sprint, speed, fast and maximum strength, dynamics, jumping resistance, power, and explosive strength, considering the initial fitness of the individual athletes. Different types of tests were carried out and were repeated at various times during the championship season. The tests included: squat jump (from a standstill 90° to the knee); counter jump (movement for explosive–elastic strength); 15″ of continuous jumps (for alactacid anaerobic power); shuttle adapted to volleyball (Yo-Yo test); 8 m with standing start (for shooting ability); 15 m run (for running speed); 20 m from standstill (for acceleration capability); and 6 balls (for the specific ability to break and restart). The duration of the pre-championship period (pre-season training session phase) was 7 weeks overall. During the competitive season, the weekly work was set as follows (typical week):

- Monday: Recovery.
- Tuesday: Double Morning Weights, Afternoon Spec. Prep., and T.T. (technique training).
- Wednesday: Afternoon Spec. Prep. and T.T.
- Thursday: Double Morning Weights, Afternoon Spec. Prep., and T.T.
- Friday: T.T.
- Saturday: T.T.

As for the Tuesday work dedicated to strength, the following succession criterion developed in 4 weeks was generally as reported:

I. Maximum Strength (12/10/8/6).
II. Maximum Strength (12 + 2 × 6 − 3 × 6 − 4 × 6).
III. Maximum Strength (3 × 8 at 70%–75%–80%).
IV. Unloading Week (2 × 12).

In regard to the Thursday work dedicated to potency, the following succession criterion developed in 4 weeks was generally as reported:

I. Maximum Dynamic Force (4 × 6 (3 at 90° + 3 At 120°)).
II. Bulgarian Method (1 × 12 + 3 × 10 To 70% + 10 To 35%).
III. Bulgarian Method (1 × 12 + 3 × 10 To 80% + 10 To 40%).
IV. Week of Unloading.

The typical week represented a preordained pattern that has undergone variations based on different criteria such as the state of form of the athletes and the need to intervene in other training elements.

2.6. Statistical Analysis

The data collected during the entire competitive season were subjected to statistical analysis. Values were expressed as mean ± standard deviation (SD) or error standard (SEM) and *p*-value. Post hoc power analysis was performed by the software G*Power, version 3.1.9.7 (University of Heinrich-Heine, Düsseldorf, Germany), to evaluate the adequacy of the analyzed sample; the sample size was calculated on a website (http://powerandsamplesize.com/Calculators/Compare-2-Means/2-Sample-Equality, accessed on 8 June 2022) with the mean values and standard deviation obtained at P and PO for PhA (sample size = 11; type I error alpha= 5%; power = 0.9076). The data analysis of the entire team of athletes, in dissimilar time intervals, was calculated using the Kruskal–Wallis one-way ANOVA nonparametric test, post hoc test, and linear trend, with the significance level $p < 0.05$. The software Graphpad, version 8.0.2, was used.

The paired, one-sample Hotelling's T2 test was performed to evaluate the displacements in the mean group vectors. The tolerance ellipses for (50%, 75%, 95%) were generated using the software BIVA 2002, adopting specific tolerance ellipses for volleyball players provided by Campa et al. [25].

3. Results

Analysis of Body Composition, Bioelectrical Parameters Changes, and MD Adherence in Total Team of Volleyball Players

The anthropometric characteristics, bioelectrical parameters, and MD adherence assessed by the MEDAS score of the volleyball athletes studied are shown in Table 1.

Table 1. Anthropometric, bioimpedance parameters, and MEDAS score in the total team of volleyball athletes at enrollment (T0).

	Total Team (*n* = 11)
	Mean ± SD
Height (cm)	191 ± 9
Weight (Kg)	89.2 ± 13.7
BMI (kg/m^2)	24.2 ± 1.9
Rz (Ohm)	476.6 ± 30.7
Xc (Ohm)	57.9± 5.7
PhA (°)	6.9 ± 0.6
FM (kg)	12.9 ± 3.3
FFM (kg)	76.6 ± 10.7
BCM (kg)	40.3 ± 4.1
BCMI (Kg/m^2)	11 ± 0.5
ECM (kg)	31.3 ± 5.7

Table 1. *Cont.*

	Total Team (n = 11)
	Mean ± SD
SMM (kg)	37.5 ± 4.2
TBW (kg)	51.7 ± 6.7
ECW (kg)	22.6 ± 3.6
ICW (kg)	29.2 ± 3.1
Na/K	0.7 ± 0.1
BMR (Kcal)	2310.4 ± 295.7
MEDAS Score	9.8 ± 1.1

BMI, body mass index; Rz, resistance; Xc: reactance; PhA, phase angle; FM, fat mass; FFM, fat-free mass; BCM, body cell mass; BCMI, body cell mass index; ECM: extracellular mass; SMM, skeletal muscle mass; TBW, total body water; ECW, extracellular water; ICW, intracellular water; Na/K: Sodium/Potassium rate; BMR, basal metabolic rate. MEDAS (Mediterranean Diet Adherence Screener).

In the whole team, all data were reported in three "key times" referring to pre-season training session (P), championship (C), and play-off (PO) periods and are shown in Table 2. We found statistically significant improvements in all parameters except for Rz, Xc, BCM, ICW, and ECW when analyzed by ANOVA. Similarly, significant changes between P vs. C and C vs. PO were observed, while no differences between P vs. PO were displayed by the post hoc test. Regarding the MEDAS score, high adherence to the MD in all players was maintained over the study period (Table 2).

Table 2. Anthropometric, bioelectrical parameters and MEDAS score referring to "Key times" selected from the entire study period in total population.

	P	C	PO	ANOVA	Post Hoc		
	Mean ± SD	**Mean ± SD**	**Mean ± SD**		**P vs. C**	**C vs. PO**	**P vs. PO**
BMI (kg/m^2)	24.5 ± 0.3	25.3 ± 0.3	25.7 ± 0.6	**0.002**	**0.011**	**0.004**	ns
Rz (Ohm)	459.2 ± 15.2	447.3 ± 2.4	447.4 ± 0.3	ns	ns	ns	ns
Xc (Ohm)	55.6 ± 2.0	59.4 ± 1.8	59.9 ± 0	**ns**	**0.045**	ns	ns
PhA (°)	6.9 ± 0.5	7.4 ± 0.5	7.6 ± 0.5	**<0.0001**	**0.003**	**0.001**	ns
FM (kg)	12.8 ± 0.3	13.6 ± 0.4	14.2 ± 0.1	**0.002**	**0.024**	**0.004**	ns
FFM (kg)	77.6± 0.9	79.7 ± 0.7	80.6 ± 0.2	**0.006**	**0.009**	**0.008**	ns
BCM (kg)	40.6 ± 0.4	43.5 ± 2.7	44.0 ± 0.	ns	ns	ns	ns

Table 2. *Cont.*

	P	C	PO	ANOVA	Post Hoc		
	Mean ± SD	Mean ± SD	Mean ± SD		P vs. C	C vs. PO	P vs. PO
BCMI (kg/m^2)	11.1 ± 0.1	11.8 ± 0.3	12 ± 0.02	**0.024**	**0.003**	**0.004**	ns
ECM (kg)	31.4 ± 0.4	30 ± 0.5	29.7 ± 0.4	**0.025**	**0.013**	**0.013**	ns
SMM (kg)	37.9 ± 0.5	41.0 ± 0.9	41.4 ± 0.1	**0.033**	**0.003**	**0.004**	ns
TBW (kg)	53.2 ± 1.3	54.8 ± 0.4	55.0 ± 0.1	**0.024**	ns	ns	ns
ECW (kg)	23.4 ± 0.7	23.8 ± 0.1	23.9± 0.1	ns	ns	ns	ns
ICW (kg)	30.2 ± 1.0	30.9± 0.3	31.1 ± 0.1	ns	ns	ns	ns
Na/K	0.8 ± 0.1	0.7 ± 0.02	0.7 ± 0.0	**0.033**	**0.036**	ns	ns
BMR (Kcal)	2338 ± 25.7	2402 ± 22.6	2415 ± 5.6	**0.008**	**0.013**	**0.015**	ns
MEDAS Score	10 ± 0.2	10.3 ± 0.1	10.2 ± 0.1	**ns**	ns	ns	ns

BMI, body mass index; Rz, resistance; Xc: reactance; PhA, phase angle; FM, fat mass; FFM, fat-free mass; BCM, body cell mass; BCMI, body cell mass index; ECM: extracellular mass; SMM, skeletal muscle mass; TBW, total body water; ECW, extracellular water; ICW, intracellular water; Na/K: Sodium/Potassium rate; BMR, basal metabolic rate; MEDAS (Mediterranean Diet Adherence Screener). Data obtained by Kruskal–Wallis one-way ANOVA. Statistically significant differences among pre-season training session (P), championship (C), and play-off (PO) periods were calculated by post hoc test for multivariable analysis. ns, not significant.

We also graphically represented the most relevant parameters regarding the body composition and MEDAS score over study period in total population using the linear trends, showing that these parameters improved in a time-dependent manner with constant training (Supplementary Figure S1). These data fit with the vector displacement reported in the Rz–Xc graph over the key times. Regarding MD adherence, even in slight increases, no statistical changes were found (Supplementary Figure S1).

Results from the MEDAS questionnaire at T0 in the total team demonstrated that athletes with optimal, moderate, and poor adherence to the MD were 73% (n = 8), 27% (n = 3), and 0%, respectively. It is worth noting that most athletes had good eating habits consuming typically Mediterranean foods, such as whole grain cereals, vegetables, fruits, nuts, fish, legumes, and white meats dressed with extra-virgin olive oil. Moreover, the percentage of optimal, moderate, and poor MD adherence of the sample referring to "Key times" is reported in Table 3, confirming that most athletes followed principles of MD recommendations over the entire study period.

Table 3. Percentage of MEDAS (Mediterranean Diet Adherence Screener) score referring to "Key times" selected from the entire study period in total population.

Mediterranean Diet Adherence by MEDAS Score (%)	P (n = 11)	C (n = 11)	PO (n = 11)	p-Value
Optimal (≥10)	73 (n = 8)	64 (n = 7)	73 (n = 8)	ns
Moderate (6–9)	27 (n = 3)	36 (n = 4)	27 (n = 3)	ns
Poor (≤5)	0 (n = 0)	0 (n = 0)	0 (n = 0)	ns

MEDAS (Mediterranean Diet Adherence Screener); pre-season training session (P), championship (C), and play-off (PO) periods; n, number of participants; ns, not significant.

Using specific tolerance ellipses for volleyball players, we reported the BIVA graphical representation of vector changes in "Key times" selected from the entire study period (Figure 1). The BIVA graph displays the body composition changes as reported in Table 2.

Moreover, we observed that the mean vector displacement from P to C was statistically significant by the Hotelling's T^2 test, ($p < 0.001$) (Figure 2). Data show significant changes in the BIVA pattern due to the reduction in Rz/H and the increase in Xc/H from P to C. No differences were found from P to PO by the Hotelling's T^2 test.

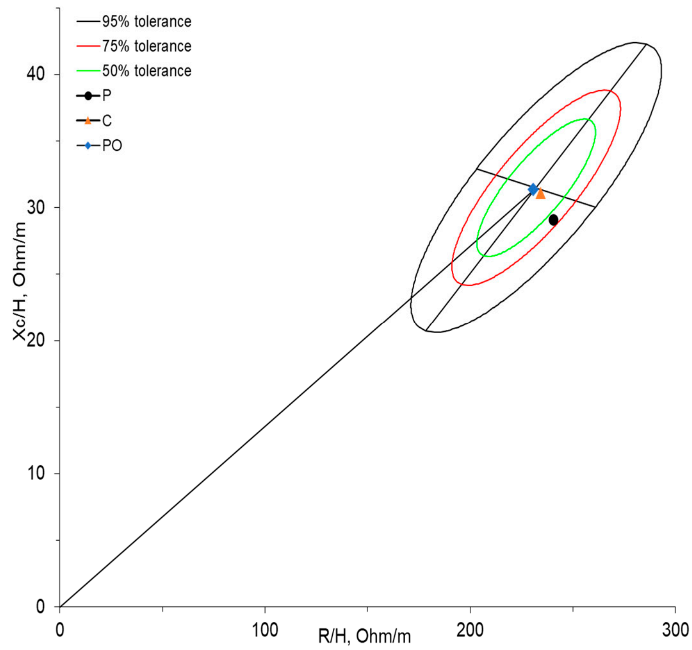

Figure 1. BIVA graphical representation of vector changes in "Key times" selected from the entire study period, using specific tolerance ellipses for volleyball players. Rz/H: Resistance/Height; Xc/H: Reactance/Height; Black circle: pre-season training session (P); Orange triangle: championship (C); Blue rhombus: play-off (PO) periods.

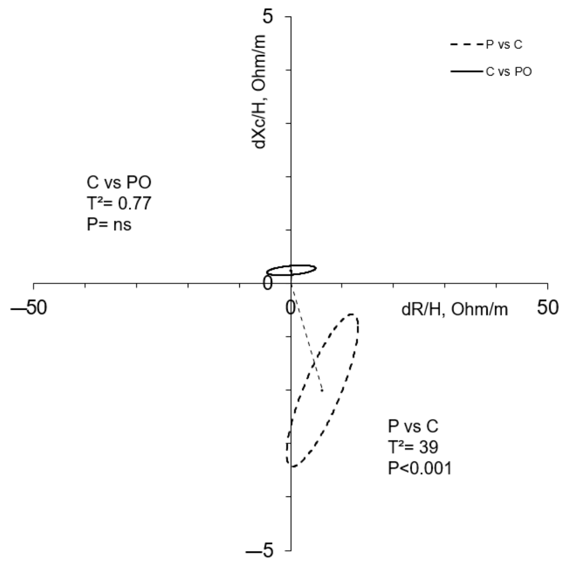

Figure 2. Mean displacements vector and Hotelling's T^2 test results of total population.

We also compared the anthropometric characteristics, bioelectrical parameters, and MEDAS score of the studied population at T0 with the two times of the P (T1 and T2) (Supplementary Table S1), among the times of C (from T3 to T7) (Supplementary Table S2), and between the times of PO (T8 and T9) (Supplementary Table S3). No significant statistical differences were found among the intervals of the "Key times" in the total population.

4. Discussion

According to our current knowledge, this is the first study in which body composition changes were monitored over a period of about 8 months including the pre-season sport training session, the entire competitive championship, as well as the play-off in 11 athletes of the volleyball team. It is worth underlining that all players had an optimal adherence to the MD, which was maintained over the entire study period, likely contributing to the improvement in their body composition. These findings are in accordance with previous studies in which a personalized Mediterranean dietary plan that included monthly changes and adjustments in elite athletes lead to optimal eating habits and health status [26,27].

Conversely, Caparello et al. [6] showed that the adult population had an average adherence to the MD in the same Mediterranean area, thus underlining that the general population is less compliant to the MD pattern compared to elite athletes. However, regarding the assessment on the MD adherence among professional athletes, data are different especially if the attention is focused on the differences between female and male athletes, as well as if different types of sports are compared. Moreover, adherence to the MD is not always correlated with body composition and, consequently, to athletic performance [28,29]. Santos-Sánchez et al. [30] in a cross-sectional study indicated that monitoring the body composition and the adherence to the MD could help to optimize the sports performance of professional players. Tomas et al. [31] showed that appropriate nutrition is essential for athletes, and diet should be adequate in both quality and quantity to avoid deficiencies, limit fatigue, and replenish energy reserves, as well as to store energy substrates useful for power muscle contraction, particularly for elite athletes. Furthermore, the MD potentially assures an optimal supply of antioxidants, such as tocopherols, carotenoids, and polyphenols [32] that improve antioxidant defense and counteract oxidative stress induced by intense and prolonged physical exercise [33]. Therefore, providing athletes with a nutritional education about the beneficial effects of MD, along with a training plan and the monitoring body composition and hydration status may be a useful strategy to improve athletes' health and physical performance.

In our volleyball athletes, with optimal adherence to the MD, we obtained an improvement of body composition parameters that were correlated to their performance. This suggested that the MD model could be properly considered a healthy dietary pattern in sport nutrition.

The positive correlation between physical activity and the MD [34] could explain how athletes would strive towards this dietary model to improve both health and sport results [35]. According to data from the studies [36,37], we recommended the combination of training programs other than with a specific dietary protocol, also with the conscious use of supplements, which allowed the athletes to improve the bioelectrical and body composition parameters over the entire competitive season. Our data revealed that lean mass was preserved and increased in all volleyball players, emphasizing, along with physical activity, the role of adequate nutritional intake to improve recovery, ameliorate muscle damage, and maintain muscle mass, as previously reported [38].

Importantly, measuring and monitoring body composition through the BIVA provides essential information on the needs of volleyball players over the entire championship. The generation of BIVA reference data for male competitive volleyball athletes allows differentiation of the athletic population from the general healthy population. Using the tolerance ellipses for volleyball players provided by Campa et al. [25], we showed that our sample fits perfectly with the volleyball population. According with the data showing that the vector displacement indicates an increase in BCM and a change in the ICW/ECW ratio with a decrease in FM [20], we found a significant increase in BCMI, FFM, and SMM in the entire team when comparing pre-season training sessions with the championship. In the specific case of our volleyball players, by applying the Hotelling's T^2 test, we showed significant changes in the BIVA pattern due to the reduction in Rz/H and the increase in Xc/H from P to C. The graphical representation also showed a continuous increase in the PhA with an increased mass and physical structure of the volleyball players. These data are in accordance with another study that analyzed body composition parameters in athletes [39]. However, it has been reported that the increased PhA is not always an index of improvement in body structure, as it also differs within a sport by player position and role by the athletes [40,41]. In the entire volleyball team, we found an increased PhA, BCMI, and SMM evaluated from P to C, along with the vector displacements within the R/Xc graph, confirming a practical way to evaluate the somatic maturation of athletes across the competitive season as well as the possibility to monitor their body composition and, consequently, their performance. Moreover, BMR was increased in our athletes over the study period, confirming the significant effect of sports training on metabolic rate [42]. However, further studies are needed to evaluate the contribution of diet and exercise to maintain body composition and BMR [43]. Interestingly, we observed in our athletes a reduced sodium potassium exchange that could suggest an increased activity of the Na+–K+ pumps and a decreased accumulation of interstitial potassium leading to a successful sport performance. Accordingly, previous findings highlighted the effects of high-intensity intermittent training on potassium kinetics and the performance in human skeletal muscle, supporting the hypothesis that accumulation of potassium in muscle during exercise may cause fatigue [44].

The first limitation of the study included a small sample size, related to the volleyball team composition rules, thus, considering the small size of our sample, we did not report the body composition parameters by dividing the sample into the play roles. Another limitation is related to the lack of information on the load of the P, since our athletes performed a general organic workout based on muscle strengthening and basic endurance. Moreover, we did not observe any correlation between the MD adherence and body composition parameters, since most volleyball athletes had an optimal MD adherence, which was maintained over the study period. Lastly, limitations are related to the lack of evaluation of the impact of supplements consumption on competitive players.

5. Conclusions

Overall, our findings demonstrate that the BIVA can be used as a useful tool to provide information on volleyball athletes' body adaptations and their general health status, helping to monitor the modifications in body composition in each player and suggesting the proper training along with adequate dietary recommendations. In the context of healthy eating habits, the MD, with its balanced distribution of macro- and micro-nutrients, should be recommended to optimize health and performance in elite athletes, representing an efficient way to maintain good health status during training.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/app13052794/s1, Figure S1. Linear Trend of body composition parameters and MEDAS score in total population. Linear trend estimation of phase angle (PhA) (A), body cell mass (BCM) (B), body cell mass index (BCMI) (C), fat mass (FM) (D), fat-free mass (FFM) (E), extracellular mass (ECM) (F), skeletal muscle mass (SMM) (G), total body water (TBW) (H), extracellular water (ECW) (I), intracellular water (ICW) (J), and Mediterranean Diet Adherence Screener (MEDAS) (K) over the Pre-season training session (P), Championship (C), and Play-Off (PO) periods in total population. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; **** $p < 0.0001$. Table S1. Team anthropometric measurements, bioimpedance parameters and MEDAS score from enrollment (T0) to sport pre-season training session (T1 and T2). Table S2. Anthropometric measurements, bioimpedance parameters and MEDAS score of the team during the championship (from T3 to T7). Table S3. Anthropometric measurements, bioimpedance parameters and MEDAS score of the team during the play-off period (T8 and T9).

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