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Summary / Sumario

Editorial

Macromolecular Antioxidants: Importance in Health and Perspectives

Antioxidantes macromoleculares: importancia en salud y perspectivas

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Antioxidants

Antioxidants are dietary constituents that play an essential role in the prevention of chronic diseases (neurological, cardiovascular, cancer) and processes associated with aging ((insulin resistance, increase in inflammation, cognitive and memory decline, aorta thicker and less flexible, deterioration of the skin and others).

The antioxidants in the diet are a complex mixture of hydrophilic and lipophilic substances, consisting mainly of three vitamins (A, C, E), a few dozens of carotenoids (beta-carotene, lycopene, lutein, zeaxnthin,...) and several hundred of polyphenols (flavonoids, anthocyanins, resveratrol, hydroxytyrosol, quercetin, phenolic acids….).They are characterized by their ability to protect from oxidative damage to DNA, proteins and lipids, and to prevent the pathogenesis of numerous risk factors associated with chronic diseases (oxidative stress, inflammation, hypertension, hyperglycemia, dyslipidemia). Its mechanisms of action are complex, including free radical counteraction, modulation of gene expression, modulation of the colonic microbiota and strengthening of the endogenous antioxidant system.

The natural source of antioxidants are foods and beverages of vegetable origin, which usual and abundant consumption provides the amount and variety of antioxidants adequate to maintain a suitable antioxidant status. It should be take into account that the positive effects of antioxidants result not from a particular antioxidant but from the synergistic and additive action of a high number of substances, including vitamins A, C and E, carotenoids and polyphenols. A good antioxidant status contributes significantly to protecting health and achieving quality-of-life aging.

It should be take into account that the positive effects of antioxidants result not from a particular antioxidant but from the synergistic and additive action of vitamins A, C and E and from a high number of carotenoids and polyphenols. A good antioxidant status contributes significantly to protecting health and achieving a healhty aging.

Macromolecular antioxidants[1]

The strong scientific evidence of health effects of antioxidants has been established through biological and medical research exclusively focused on the small molecular size or low weight antioxidants (mA) mentioned above: (Vitamins A.C and E, carotenoids and polyphenols).

However, recent findings has shown that plant foods - in addition to mA - contain abundant amounts of other type of high molecular weight antioxidants, named macromolecular antioxidants (MA). They are high molecular weight proanthocyanidins and tannins and polymeric structures of low molecular weight polyphenols and carotenoids bound to polysaccharides and proteins

MA have so far been ignored due to the fact that it is not possible to extract them from the plant material using the current technologies and, in addition, they are not detected by the usual methods of analysis of antioxidants. That is why the scientific community has focused research exclusively on mA, ignoring MA. However, we ingest significant amounts of both mA and MA daily.

It should be noted that the daily intake of MA in our usual diet is higher than to that of mA.Therefore, it is very possible that in all the health effects currently attributed exclusively to Am there is a major contribution of MA.

Macromolecular antioxidants have a high biological and antioxidant activity and they exhibit promising health related properties. Their greater molecular size confers them some specific physiological characteristics and mechanisms of action, which differentiates them from mA.

Most Am are absorbed in the small intestine during digestion and pass to the blood stream between 0.5 and 2 hours after intaking, producing an increase in antioxidant status (blood antioxidant concentration) and being distributed to target cells and organs Contrary, MA crosses intact the stomach and small intestine and reaches the colon where they interact with the colonic microbiota in a fermentative process that breaks the macromolecules, resulting a high intestinal antioxidant status

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and the production of antioxidant metabolites. These metabolites are absorbed through the colonic mucosa and reach the bloodstream about eight hours after ingestion, being distributed to cells and tissues where they may have systemic effects. This indicates that MA may increase and prolong antioxidant status and the health effects associated to dietary antioxidant intake.

Several biological assays, animal experiments and clinical studies have been carried out, obtaining positive results indicating that macromolecular antioxidants may play an important role in gastrointestinal health - especially in relation to prevention of colon cancer - derived from increased antioxidant status and also in protection against various risk factors for chronic diseases due to metabolites absorbed through the colonic mucosa

The publications resulting from this research have had a high impact in recent years, as shown by the high number of references and by the recognized research impact indicators published in the Web of Science (WOS).

Current research focuses on the development of clinical trials to study the potential effect of macromolecular antioxidants in the prevention of metabolic syndrome. This syndrome is one of the major public health problems and occurs in people who have several of the most common risk factors in Western countries (hypertension, obesity, hyperglycemia, abdominal obesity, hypercholesterolemia).

Nevertheless, they are preliminary studies that require a great increase of research at national and international level for its consolidation. We must bear in mind that the scientific evidence of the effects of low molecular weight antioxidants has been established by hundreds of research teams over a century of work and even this topic has been awarded with several Nobel Prizes, while there are still very few research groups working on macromolecular antioxidants. The increase of number of researchers in this field along with the extraordinary advances in experimental methodologies and technological equipments, can allow the establishment of a complete knowledge of the properties and healt effects of macromolecular antioxidants in a few years

Technological studies are also being carried out to obtain macromolecular antioxidants and the development of applications as a new type of ingredient for the food and pharmaceutical industries. In fact there are already in the international market some products with MA.

Perspectives in nutrition sports

There is a growing market for antioxidant supplements to prevent muscle damage resulting from the intensive and strenuous exercise of sportsmen, produced by free radicals and inflammation and prolonged days after workouts and competitions. The most commonly used supplements are drinks or products rich in several types of low molecular weight polyphenols (mA), obtained from fruits or herbs rich in polyphenols (blueberries, pomegranate, ginger, green tea, etc.).

The use of MA in sports medicine would allow a more complete and balanced intake of antioxidants, currently focused exclusively on Am. Some positive effects in general wellness and in protection of muscle damage could be expected, derived from the specific characteristics of MA, previously mentioned: longer antioxidant action and strengthening of intestinal health resulting from its interaction with the colonic microbiota.

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Original article

Isokinetic performance of knee extensors and flexor muscles in adolescent basketball players

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Summary

Background: Basketball is one of the most popular and most practiced sports in the world, being played by 450 million people worldwide, and the knee is the most commonly injured region of the body involving adolescent male basketball players. Isokinetic dynamometry is generally considered the best protocol for dynamic strength measurements, which are important for preventing musculoskeletal injuries. Therefore, the objective of the present study was to analyze the muscular performance, the unilateral differences and relationships between the knee extensor and flexor muscles in adolescent male basketball players.
Method: The information provided by database concerning the isokinetic evaluation of the knee extensor and flexor muscles from 21 male basketball players under the age of 15 were analyzed. The isokinetic dynamometer was used in a concentric-concentric mode for the knee extensor and flexor muscles at angular velocities of 60°/s, 120°/s, 180°/s, and 240°/s.
Results: The results demonstrated no statistically significant differences between the dominant limb and the nondominant limb at the considered velocities, whether for mean peak torque values or for the flexor/extensor ratio. Another important result showed flexor/extensor ratios within normal values for knee joints.
Conclusions: This study demonstrated that lower-limb dominance does not interfere in the muscular concentric isokinetic performance of the knee extensor and flexor muscles in adolescent male basketball players. We believe that the short time spent in basketball's practice (mean time was 2.46 years) appears to be responsible for these results because the adolescent athletes evaluated in this study did not show differences between limbs, in contrast to studies involving older male basketball players.

Key words:
Muscle strength. Knee. Basketball.

Valoración isocinética de los extensores y flexores de la rodilla de jugadores de baloncesto adolescentes

Resumen

Introducción: El baloncesto es uno de los deportes más populares y más practicado en el mundo, siendo jugado por 450 millones de personas alrededor del mundo. La rodilla es la región del cuerpo más comúnmente lesionada en jugadores de baloncesto adolescentes. La dinamometría isocinética es generalmente considerado el mejor protocolo para medir la fuerza dinámica, que es importante en la prevención de lesiones musculoesqueléticas así como para el seguimiento del entrenamiento deportivo. Por lo tanto, el objetivo del presente estudio fue analizar el rendimiento muscular, las diferencias unilaterales y relaciones entre los músculos extensores y flexores de rodilla de jugadores de baloncesto adolescentes.
Métodos: Se analizó la información de una base de datos en la evaluación isocinética de los músculos extensores y flexores de rodilla de 21 atletas de baloncesto masculino menores de 15 años. El dinamómetro isocinético fue utilizado en modo concéntrico-concéntrico para los músculos flexores y extensores de la rodilla en las velocidades angular de 60°/s, 120°/s, 180°/s y 240°/s.
Resultados: Los resultados no mostraron ninguna diferencia estadísticamente significativa entre el miembro dominante y el miembro no dominante en las velocidades consideradas, tanto para los valores promedio de los pico torque, como para la relación flexores/extensores. Otro resultado importante es que la ratio flexores/extensores mostro valores normales para la articulación de la rodilla de nuestros deportistas.
Conclusiones: El estudio ha demostrado que no hay diferencias entre la extremidad dominante y la no dominante en los valores obtenidos de fuerza isocinética concéntrica de los extensores y flexores de la rodilla de los jugadores de baloncesto adolescentes. Creemos que el poco tiempo empleado en la práctica de baloncesto (el tiempo medio fue de 2,46 años) parece ser responsable de estos resultados, dado que los atletas adolescentes evaluados en este estudio no mostraron diferencias entre los miembros, en contraste con estudios realizados en atletas mayores de baloncesto.

Palabras clave:
Fuerza muscular. Rodilla. Baloncesto.

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Introduction

Basketball is one of the most popular and most practiced sports around the world, being played by 450 million people worldwide[1]. This sport is characterized by sprinting, changes of direction, lateral movement, jumping, and landing[2] as well as repetitive motor actions and excessive-joint load[3]. The large number of injuries in basketball players is linked to running, rapid shifts of movement, and jumping[4,5]. Children and adolescents may be particularly at risk because of their improper technique, poor proprioception, muscle weakness[6], and high volume of intesive trainning[7]. Since the basketball has explosive actions (such as sprints, jumps and innings), knee flexors/extensors force indexes (flexors/extensors ratio or hamstrings/quadriceps ratio) based on the rate of torque development may be useful in assessing joint stability.

Ligament sprains are the most common injury on children[6-8] and adolescent[6,7,9,10] basketball players, and the knee is the most commonli injured region on their bodies[10-14]. This occurs mainly because the demands on the knee from specific sports practices cause specific muscular adaptations and, consequently, imbalances in strength that affect the joint[15]. The quadriceps femoral muscle plays a key role in performing jumps, whereas the hamstrings control running activity and stabilize the knee in situations that involve shifts of direction or attempting a turnover[16].

One of the most active fields of sports medicine research is to determine proper muscular balance – important for preventing injuries – and to specify clear criteria for a return after an injury[17]. Isokinetic dynamometer technology is helping muscular behavior researchers by enabling them to investigate kinetic profiles on athletes. The evaluation of the muscular force is exerted dynamically, at a constant speed and in a certain range of movement. Through a well-structured protocol, it is possible to compare the assessed participants, their normative data, and the generated curves[18]. The results can be used to adjust training techniques in an attempt to prevent traumatic and overuse injuries[19]. Because of a lack of studies related to the evaluation of concentric isokinetic parameters, new research is therefore necessary on a national level regarding adolescent male basketball players. Therefore, the main objective of the present study was to use information from a database to analyse the muscular performance and the unilateral differences and relationships between the knee extensor and flexor muscles of the dominant and nondominant limbs in adolescent basketball players.

Material and method

This is a quantitative, cross-sectional, and retrospective study conducted at the Instituto de Medicina do Esporte e Ciências Aplicadas ao Movimento Humano of the University of Caxias do Sul (IME-UCS), in the city of Caxias do Sul, Rio Grande do Sul, Brazil. It has been approved (protocol number 967.527) by the Ethical Research Committee of the Faculdade Cenecista Bento Gonçalves (Bento Gonçalves, Rio Grande do Sul, Brazil) and conducted according to the 2012 Law N 466 of the National Health Council, which approves the guidelines and rules for research involving human beings.

The information provided by the IME-UCS database concerning the concentric isokinetic evaluation of the knee extensor and flexor muscles from 21 male basketball players under age 15 from a local team were part of this study sample. The number of participants was conveniently established and, therefore, determined intentionally and not by probability according to the number of available evaluations in the IME-UCS database. Furthermore, were included evaluations with paternal informed consent of the risks associated with the experimental procedures; which the respective IME-UCS consent term had been authorized by their responsible and by the athletes and athletes with more than 2 years of basketball practice. Were excluded athletes that had the last training on the same day of the test and athletes who reported injuries of lower limbs or acute illness that could disturbed the evaluation.

A questionnaire regarding age, height, weight, dominance, practice time and prevalence of injuries was previously presented to the athletes. The mean age of the athletes was 14.35 years (±0.81), mean height was 1.72 meters (±0.61) and mean weight was 66.78 kilograms (±12.36). With respect to dominance, 19 athletes reported a dominance of the right limb for game movements and only 2 reported dominance of the left limb and the mean time of basketball practice 2.46 years (±1.10). Of all the players, 15 had not sustained injuries in the 45 days prior to the isokinetic evaluation, whereas 6 had suffered injuries both in practice and in competition, particularly involving the knee joints (meniscal and Osgood Schlatter injuries), calf (distension and contusion), ankle (sprain), and foot (fracture). It is also important to observe that only 4 athletes evaluated in the sample practiced regular muscular strengthening activities (weightlifting).

The evaluations were made with the institution's isokinetic dynamometer (Biodex System 4®, Biodex Medical Systems, Shieley, New York, USA). The chosen samples were made between November 2014 and December 2014, in a concentric-concentric mode, for the knee's extensor and flexor muscles at angular velocities of 60°/s, 120°/s, 180°/s, and 240°/s. The athletes first underwent warmup exercises on a stationary bicycle for 8 min with no resistance at moderate velocity (70–80 rounds per minute)".

We believe that it is better to talk a little beat more about the velocity. The athletes were then leaded through the isokinetic dynamometer. The athletes sat on the dynamometer chair with their torsos leaning at 85°, stabilized with belts around the torso, pelvis, and thigh (1/3 distal) to avoid compensatory movements, with the motor axis aligned to the knee joint axis. Tests were first performed on the dominant limb (DL) and next on the nondominant limb (NDL). The athletes performed three sub-maximal repetitions and a previous maximal for each test on all four velocities to familiarize themselves with the procedures and warmup. Protocol during the test demanded 5, 10, 15, and 20 maximal repetitions of knee extension and flexion in concentric-concentric mode on an angular velocity of 60°/s, 120°/s, 180°/s, and 240°/s. A 1-minute rest period was set between evaluations of different velocities, and a 3-minute rest period between DL and NDL evaluations. The athletes were tested by the same examiner with the use of verbal incentives to stimulate them throughout the process and to encourage the maximum use of their strength potential.

Isokinetic variables – peak torque (PT, N/m) to know the function and the flexor/extensor ratio (%) to detect possible deficits of strength and muscular imbalances – were used for the analysis. The means values for PT and the flexor/extensor ratio for the knee joint musculature were evaluated statistically on the SPSS 17.0 software (Statistical Package to Social Science for Windows). To verify the normality of the data distribution, the Shapiro-Wilk test was used, and the mean values for the DL and NDL evaluations were submitted to Student's t test with a resultant level of significance of 0.05.

Results

The concentric isokinetic data results of the PT of the DL and NDL are presented in Table 1. At an angular velocity of 60°/s, 120°/s, 180°/s, and 240°/s, the average values for PT knee extensor and flexor muscles showed no significant differences between the limbs.

Table 2 shows that there was no significant difference between the DL and NDL average value results of the flexor/extensor ratio for the angular velocities of 60°/s, 120°/s, 180°/s, and 240°/s. No relevant disparity was observed on any of the four evaluated velocities for either the DL or the NDL.

Discussion

Isokinetic testing provides precise evaluation of muscle performance. Nevertheless, for the basketball athletes' evaluation, the fixation of the axes limits the evaluation of a real functional gesture, since in the basketball gestures includes several axes. This sport has explosive actions (such as sprints, jumps and innings), for which good joint stability is desirable. Despite this, the isokinetic dynamometer is very useful for the comparison between the limb strength and the agonistic and antagonistic balance relationship during concentric muscle contraction[19,20]. Over the years, several works concerning a broad set of sports studied the bilateral muscle imbalance and the agonistic and antagonistic ratio (flexor/extensor ratios) of knee joints to provide data about the correct muscular balance of such joints. However, studies on adolescent basketball players specifically are uncommon even though the participants are more vulnerable to the injuries caused by the precocious practice of the sport, are still undergoing neurobiological maturation and growth spurts, and are inserted in a competitive and selective scenario. As several previous studies had already reported, musculoskeletal injuries before isokinetic evaluations demonstrated that the knee was the most commonly injured region[10-14]. According to Louw *et al.*[21], the prevalence of such knee injuries is due to the poor landing mechanism once it is a task that demands good coordination, dynamic muscular control, and flexibility, especially for teenagers whose capabilities are not fully matured. This result indicated that isokinetic evaluation is important for adolescent basketball players and highlights the risk for those injuries and for the optimization of the training process[22].

According to isokinetic analysis, the results of this study were in agreement with those of others adolescent basketball isokinetic studies, demonstrating that at low velocities there are higher PT than at high velocities[23-26]. The evaluations of the muscular PT at low velocities (60°/s) represent the strength capacity a muscle has, whereas high velocities show their muscular potential[26]. By considering both velocities, many times the observation of athletes' muscular performance is better at high velocities because they are equivalent to the sport's practice. The

Table 1. Mean standard deviation values for PT of the extensor and flexor musculatures of the dominant limb and the knee of the non-dominant limb.

Angular velocities	PT knee extensors (N/m)			PT knee flexors (N/m)		
	DL	NDL	*p*	DL	NDL	*p*
60º/s	138.37 (±47.20)	139.20 (±49.73)	0.83	76.29 (±22.18)	76.12 (±22.80)	0.92
120°/s	143.62 (±31.93)	141.97 (±30.53)	0.58	73.40 (±18.57)	75.63 (±18.95)	0.09
180º/s	123.69 (±28.38)	121.90 (±29.54)	0.51	70.60 (±17.38)	67.35 (±20.38)	0.10
240°/s	106.22 (±25.20)	103.44 (±25.19)	0.33	62.56 (±14.37)	63.31 (±18.17)	0.70

DL: dominant limb; NDL: non-dominant limb; PT: peak torque.

Table 2. Mean and standard deviation values for the flexor/extensor ratio of the dominant limb and the knee of the nondominant limb.

Angular velocities	Flexor/extensor ratio (%)		
	DL	NDL	*p*
60º/s	56.45 (±8.78)	56.64 (±10.91)	0.92
120°/s	55.87 (±9.15)	54.29 (±11. 60)	0.41
180º/s	57.94 (±10.51)	56.28 (±14.64)	0.42
240°/s	59.77 (±10.02)	62.10 (±12.83)	0.31

DL: dominant limb; NDL: non-dominant limb.

comparison between DL and NDL showed no significant differences in the mean PT values for the extensor and flexor musculature and in the flexor/extensor ratios. Other studies demonstrated that bilateral asymmetry did not exist in the knee muscle performance of adolescent male basketball players[24,26], whereas bilateral asymmetry was seen in older male basketball players[18,26-30]. Dominance of one limb over the other is a controversial subject[30]. Dominance may be directly associated with the characteristics of each sport, and muscular imbalances may occur when analyzing the flexor and extensor groups bilaterally; however, when considering DL and NDL, strength values of less than 10% are considered normal, and a percentage higher than that indicates a deficit. Many sports require unilateral action during such movements as jumping and changing direction and these movements can develop asymmetric neuromuscular adaptations in the lower extremities[31]. These movements can induce a marked increase in strength on the dominant limb and, consequently, a bilateral difference with the nondominant limb[30]. However, basketball is a sport that requires bilateralism, and bilateral training focuses on training both limbs equally. Consequently, there is a bilateral motor increment. However, the significant differences between limbs in older basketball players can be explained by unilateral jumping over the years[18,31], whereas Schiltz *et al.*[18] claimed that even after years of intense basketball practice, the preferential use of a lower limb for jumping did not induce a bilateral muscle imbalance of the knee. Rosene *et al.*[23] justify that during adolescent athlete training, for the most part, the specific loads upon the lower limbs are sufficient to maintain similar strength on both sides, even unilateral sports like volleyball[16] and soccer[32]. The synergistic action of the involved muscle groups (flexors and extensors of the knee) is necessary for standing, since all activity in load supposes a proportional increase of the force of the agonist-antagonist pair. We really believe that the short time of basketball practice (the mean time of basketball practice was 2.46 years) may help to explain the similar results between the DL and NDL. The comparison between the limbs is extremely important because it provide insights related to injury prevention, performance, and rehabilitation[33]. Previous studies have linked bilateral strength imbalance with a great risk of injury in basketball players[33] and the most appropriate strategy for reducing the injury risk is the identification and understanding the muscular performance[34]. If not identified, the bilateral limb imbalance can affect the athletic performance[34] through the changes in the biomechanical of movement and posture[35].

In relation to knee joint flexor/extensor ratio analysis, no significant differences were observed between DL and NDL, and its mean values vary very little from one to the other. Studies by Buchanan and Vardaxis[24] and by Hadžić *et al.*[26] also demonstrated no flexor/extensor ratio differences between DL and NDL in young male basketball players. The evaluations of the knee's functional capacity and the knee joint's muscular balance are provided by the flexor/extensor ratio that, according to the studies, is approximately 60%[36,37]. Santos *et al.*[38] state that values under this percentage, when in lower velocities, shall make the athlete more prone to developing some kind of injury. However, this study's results showed that, as velocities increased, so did the flexor/extensor ratio. Since the performance of the flexors are higher at medium-high velocities because of its greater percentage of muscular fibers type II than the extensors of the knee. During activities performed at high velocities, muscular stability is crucial; at lower velocities, instability is actually well balanced, whereas compensation decreases as velocities increase. Knee's flexors and extensors strength indices (flexor/extensor ratio) based on the PT of the concentric contraction have traditionally been used to describe the possible destabilization of the knee joint. Most likely in the basketball practice, which has the explosive actions cited, analyze the flexor/extensor ratio in high velocities are interest in order to assess joint stability. Also of important is that imbalance in the flexor/extensor PT ratio is correlated with a greater incidence of lower-extremity injury[39] and is an important parameter for choosing the correct intervention by health professionals involved with the athletes[38]. These results allow our group of athletes to insist on the need to strengthen the flexors muscles, since they do not reach 60% although they are close.

This study demonstrated that there are no differences between the mean DL and the NDL values for knee extensor and flexor PT and flexor/extensor ratios in adolescent basketball players, with the mean values obtained on the isokinetic evaluation being varied very little between both knees. This study also showed strength balance between flexor and extensor PT, demonstrated through the flexor/extensor ratio analysis. We believe that the time spent practicing appears (mean time was 2.46 years) to be responsible for these results because the adolescent athletes evaluated in this study did not show differences between limbs, unlike studies with older male basketball players. This study is important because there are few studies[24,26] that evaluate adolescent male basketball players, male basketball playeirs, and that ones, evaluates just, differently of our study that utilized 4 different angular velocities. Another important factor is that the literature do not present normal parameters for the most utilized velocities in different ages, sports practices and types of contractions and our study can collaborate with this lack of literature. Therefore, the absence of consensus related to athletes from different sports means that isokinetic studies concerning the specificities of basketball might provide a deeper and more complete muscular description of this selected population. However, we suggest that future studies should be conducted to expand knowledge related to isokinetic muscular function evaluation on adolescent male and female basketball players, using different angular velocities, and isokinetic eccentric and isometric contractions for a better knowledge of the muscular balance of the joints of the basketball athletes.

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Effects of different automatic filters on the analysis of heart rate variability with Kubios HRV software

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Summary

Background and objective: Heart rate variability (HRV) can provide useful information on different physiological situations. The aim of this study was to analyse heart rate variability (HRV) indices following the application of different filters included in a widely used analysis program.
Material and method: 30 measurements were recorded of the heart rate signal of professional footballers. HRV was recorded in a sitting position, early morning and fasting. The HR monitor Firstbeat Bodyguard recorded HR data for 10 minutes during every measurement and Kubios® software imported and analysed all RR intervals. Each recording was analysed without a filter (none) and subsequently with each of the five different filters (very low=0.45 sec. low=0.35 sec. medium=0.25 sec. strong=0.15 sec. very strong=0.05 sec). The variables analysed pertained to time domain (standard deviation of RR intervals (SDNN), the square root of the mean of the squares of the differences between adjacent RR intervals (rMSSD) and the number of pairs of adjacent RR intervals that differ by over 50ms in the whole recording, divided by the total number of RR intervals and expressed as a percentage (pNN50)); frequency domain (high frequency HF, low frequency LF, very low frequency VLF, both in terms of power and peak frequency); the diameters of the Poincaré plot (SD1 and SD2); as well as the internal complexity of the signal, Detrended Fluctuation Analysis (α1 and α2) and approximate and sample entropy (ApEn and SampEn).
Results: A significant difference was only found for rMSSD, pNN50, LF power and HF power and SD1 when comparing the analysis of the no filter recording with the very strong filter.
Conclusion: The filtering system provided by the Kubios® software to treat the artefacts did not affect the values of the HRV indices analysed, except when the "very strong" filter was applied.

Key words:
Heart rate variability. Filter system. Kubios®.

Efecto de los diferentes filtros automáticos en el análisis de la variabilidad de la frecuencia cardiaca con el software Kubios HRV

Resumen

Introducción y objetivo: La Variabilidad de la Frecuencia Cardiaca (VFC) puede proporcionar información útil sobre diferentes situaciones fisiológicas. El objetivo de este estudio fue analizar los índices de variabilidad de la frecuencia cardiaca (VFC) tras la aplicación de diferentes filtros incluidos en un programa de análisis utilizado.
Material y método: Se registraron 30 mediciones de la señal del rimo cardíaco, pertenecientes a futbolistas profesionales. La VFC se registró en una posición sentada, por la mañana y en ayunas. Se realizó un registro de 10 min de duración con el monitor de ritmo cardiaco Firstbeat Bodyguard y todos las series de intervalos RR fue importada y analizada con el software Kubios®. Cada serie de tiempo se analizó sin un filtro (ninguno) y posteriormente con cada uno de los cinco filtros diferentes (Muy bajo = 0,45 seg. Bajo = 0,35 seg. Medio = 0,25 seg. Fuerte = 0,15 seg. = Muy fuerte 0,05 seg). Las variables analizadas pertenecen al dominio de tiempo (desviación estándar de los intervalos RR (SDNN), la raíz cuadrada de la media de los cuadrados de las diferencias entre intervalos adyacentes RR (rMSSD) y el número de pares de intervalos RR adyacentes que difieren en más de 50 ms en toda la grabación, dividido por el número total de intervalos RR y expresada como un porcentaje (pNN50)); al dominio de la frecuencia (HF: alta frecuencia, LF: baja frecuencia y VLF: muy baja frecuencia, tanto en términos de potencia y la frecuencia de pico); los diámetros del gráfico de Poincaré (SD1 y SD2); así como la complejidad interna de la señal, con el análisis de la fluctuaciones sin tendencias (α1 y α2) y entropía aproximada y muestral (ApEn y SampEn).
Resultados: Se encontró sólo diferencia significativa en rMSSD, pNN50, HF y LF en términos de potencia y SD1 cuando se compararon los registros al aplicar el filtro muy fuerte con sin filtro.
Conclusión: El sistema de filtrado proporcionada por el software Kubios® para tratar los artefactos no afectó a los valores de los índices de VFC analizados, excepto cuando se aplicó el filtro "muy fuerte".

Palabras clave:
Variabilidad de la frecuencia cardiaca. Sistema de filtro. Kubios®.

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Introduction

Heart rate variability (HRV) is the variation that occurs in the series of time interval measured between two consecutive heartbeats (RR interval)[1,2]. HRV is a non-invasive method that enables us to evaluate the interaction between the sympathetic and parasympathetic nervous system, reflecting the heart's capacity to adapt to changing physiological conditions. In fact, a lower HRV indicates a predominance of sympathetic activity and an augmented HRV indicates a predominance of parasympathetic activity on the sino-auricular (SA) node[1].

HRV has been widely studied in cardiac patients[1,3-6] as well as athletes[7,8], among other areas. Different devices have been used for this purpose, from a holter to different heart rate monitors. In many cases, however, it is hard to get a good HRV measurement owing to the appearance of artefacts in the signal. This could be caused by technical factors (including missed beats) or by the appearance of ectopic beats. Technical causes can pertain to poor placement of the electrodes during measurement or to the movement of the subject during the test, particularly during long recordings or when the subject is asleep. Ectopic beats can be normal and relatively common in healthy subjects[1,9].

For some authors, the presence of ectopic beats can modify the values of the HRV indices by up to 50% of the final results[9]. Hence, artefacts in the signal must be treated following HRV measurement in order to obtain suitable results[10,11]. Many methods and algorithms for editing or correcting dubious R–R intervals have been developed and evaluated. Some of the common artifact correction and editing techniques involve deletion, interpolation of degree zero, interpolation of degree one (linear interpolation), and cubic spline interpolation. Interpolation methods replace the non-normal R–R intervals with new interpolated R–R intervals. Unlike the deletion method, interpolation methods preserve the initial number of samples. Most interpolation methods can be considered to serve as low-pass filters with different filtering capacities. Interpolation of degree zero substitutes the abnormal R–R intervals with an average value that is computed from the neighbouring normal R–R intervals. In interpolation of degree one, called linear interpolation, a straight line is fitted over the abnormal R–R intervals to obtain new values. One popular spline interpolation method is a cubic spline interpolation, where smooth curves are estimated through a number of data points by fitting a third degree polynomial. It has been recommended to use interpolation methods when R–R interval time series contain occasional ectopic beats and artefacts. This especially concerns the power spectrum HR variability analysis[12]. In addition, several other methods have been proposed for artefact correction such as comparing and merging method[13], the predictive autocorrelation method[14], non-linear predictive interpolation[15], exclusion of R–R interval segments with divergent duration[16,17], impulse rejection[18], the integral pulse frequency model[19,20], the sliding window average filter[21], non-linear filtering combined with wavelet based trend removal[22], and threshold filtering also with wavelet based trend removal[23].

Some studies have compared the impact of editing methods on the results of HRV analysis[8,14,15,24-27]. However, although these studies yield different results depending on the type of study, the message was the same: filtering methods affect HRV analysis. The differences between the results could be attributable to the type of study population used, the length of the R-R interval time series, the editing method, the number of samples edited, etc.

Furthermore, there is an increasingly widespread use of commercial software that by default previously filters the signal without the user knowing exactly what has been done, or in the best case scenario, software that allows the user to apply different types of filter discretionally. Anyway, automatic filters that exclude some intervals from the original RR sequence should not replace manual editing because they are known to behave unsatisfactorily and to have undesirable effects leading potentially to errors.

Moreover, in commercial software that offer the possibility of choosing different filter levels, this choice is subjective by the examiner. Therefore, given a specific number of artifacts, we do not know if the result would be the same if the time series is subjected to a type of filter or other. This is what happens to Kubios, one of the commercial programs more often are being used in recent times in the analysis of HRV. It offers five levels of filtering that users will choose based on their inspection of the track.

The aim of this study was to analyse HRV indices for a group of athletes in all the domains following the application of different filters included in a commonly used analysis software.

Material and method

Study samples

30 heart rate signal recordings were analysed, belonging to high level professional athletes (aged 25.22 ±3.41 years old; weight 74.42±7.31 Kg; height 178.85±7.83 cm). The Local Ethics Board approved the study, which followed all the principles set out in the Declaration of Helsinki. All subjects signed an informed written consent to participate in this study.

Method

HRV was recorded along 10 minutes in a sitting position, early morning and fasting. The subjects were seated for 10 minutes before recording to explain the conditions. They were asked to remain in the same position without speaking during the recording time.

The HR monitor Firstbeat Bodyguard (Firstbeat Technologies; Jyväskylä. Finland) recorded HR data for 10 minutes during each recording. This two channel monitor acquires RR intervals with 1 ms resolution and a sampling rate of 256 Hz. Firstbeat Uploader (Firstbeat Technologies; Jyväskylä, Finland) software downloaded the data from the devices to the computer and Kubios® software[28] (Kubios HRV. 2.1, Biosignal Analysis and Medical Imaging Group, Kuopio, Finland) imported and analysed all RR series. Following the manufacturer's instructions in order to avoid the interference of artefacts, the time series were manually checked for artefacts before the analysis[28,29].

Kubios® (Finland) is a widely used free software for HRV analysis and it includes artefact correction options that can be used to correct artefacts from a corrupted RR interval series[28,29]. The user can select between very low, low, medium, strong, and very strong correction levels. In addition, a custom level in seconds can be set. The different correction levels define thresholds (very low=0.45 sec, low=0.35 sec, medium=0.25 sec, strong=0.15 sec, very strong=0.05 sec) for detecting RR intervals differing "abnormally" from the local average RR interval. For example, the "medium" correction level will identify all RR intervals that are larger/smaller than 0.25 seconds compared to the local average. Furthermore, the above correction thresholds are for 60 beats/min heart rate; for higher heart rates the thresholds are smaller (because the variability is expected to decrease when HR increases). The corrections to be made on the RR series are displayed on the RR interval axis. A piecewise cubic spline interpolation method is used in the corrections[28].

Each recording was analysed without a filter (none) and then subsequently with each of the five different filters (very low, low, medium, strong and very strong).

The variables analysed were: in the time domain[1], the standard deviation of RR intervals (SDNN), the square root of the mean of the squares of the differences between adjacent RR intervals (rMSSD) and the number of pairs of adjacent RR intervals that differ by over 50ms in the whole recording, divided by the total number of RR intervals and expressed as a percentage (pNN50). In the frequency domain[1], high frequency (HF: 0.15-0.4 Hz), along with low frequency (LF: 0.04-0.15 Hz) and very low frequency (VLF: 0.0033-0.04 Hz) oscillations were analysed both in terms of power (ms^2) and peak frequency (Hz). In terms of the Poincaré graph[30], the longitudinal (SD2) and transversal (SD1)[31] axes were analysed. To study the complex structure of the signal, two tools were used. Firstly, a Detrended Fluctuation Analysis (DFA)[32,33] was conducted, measuring the correlation between data at different time scales through short and long term fluctuations that are characterised by slopes $\alpha 1$ and $\alpha 2$, respectively. And secondly, the irregularity of the signal was measured by means of approximate entropy (ApEn)[34] and sample entropy (SampEn)[35].

Statistical analysis

A descriptive study was carried out of all the variables, determining their average values and standard deviation. The normality of distributions was assessed with the Shapiro-Wilk test. The contrast of hypothesis was carried out with the test of Kruskal-Wallis for the non-normal variables (VLF, LF and HF, both in Hz and ms^2) and a repeated measures ANOVA was used with the normal variables. The Bonferroni test was done as a test post-hoc and the significance threshold was set at $p < 0.05$.

Results

Table 1 shows the average values and standard deviations for the measurements taken with each of the filters (none; very low; low; medium; strong and very strong) for each of the HRV parameters analysed. Significant differences were only found for RMSSD, pNN50, power LF, power HF and SD1 when comparing the measurement taken without a filter to the very strong filter.

Table 2 shows the filter with which the first change is detected in each domine: Time Domine, Frequency Domine, Poincaré plot and Nonlineal values. Most subjects present changes with very low filter and no subject showed the first change with the VS filter. In other words, no subject reached the very strong filter without the record showed a change in some variable.

Discussion

The main contribution made by this paper was that the use of a filtering system provided by the Kubios® software for the treatment of artefacts did not affect the values of the HRV indices when they are analysed in group, with the exception of when the "very strong" filter was applied. The variables obtained by means of non-linear analysis methods were not even altered by the strongest filter on the signal filtering system of this software.

In an ideal situation, HRV analysis is conducted with a series of RR intervals including only pure SA beats (NN interval). However, the series of RR intervals obtained on the basis of ECG recordings in ambulatory measurements or portable devices within the world of sport (heart rate monitors) are in most cases imperfect, so they are not without artefacts. However, when working with cardiac patients there can also be added alterations caused by cardiac arrhythmia that can be present in up to 90-95% of patients with acute myocardial infarction[12]. Hence the importance of editing the RR series before analysing it, a task that is often missed when working quickly with commercial software. It is common engineering practice to resample the time series as well as the use of several smoothing models[36,37]. For Buchheit[8], the presence of a single ectopic beat during a 5-min recording can modify HRV indices by up to 50% and for Thuraisingham[22] ectopic beats cause erroneously high values in the standard deviation of the R-R intervals (SDNN). Ectopic beats can be common events, especially among patients with cardiovascular disease, but they can also be present in healthy subjects[12]. In addition to physiological artefacts, there can also be errors attributable to technical aspects when taking measurements or the software used to detect R-R artefacts. For example, the detection algorithm can be faulty if the R-R interval detection threshold is too low or too high. Therefore, artefacts and ectopic beats represent a problem that must be taken into account when measuring HRV since they could impact the reliability of the result. However, in general there is very little information about the filters used by different analysis software and the equations they apply.

This study found no significant modifications in the HRV measurements regardless of the filtering level used, with the exception of the very strong filter on the variables mentioned previously. This might be due to the use of measurements taken from top athletes, who present high variability that is probably less sensitive to the interpolations made for the filter. As for the changes observed when comparing the gross signal (no filter) with the very strong filter level, this could be due to the fact that the threshold established for this filtering level (0.05 s) is so demanding that what it actually does it intensely smoothes the signal that alters the results for some indices in the time and frequency domains, although without affecting the complex structure of the signal as demonstrated by the absence of changes in the non-linear parameters.

As can be seen in Table 1, the rMSSD is the only variable that apparently shows a progressive decrease of the mean values as the filtering intensity increases, although the difference is not significant until using the VS filter. All other variables have apparently stable mean values until reaching the VS filter where they show a large change that

Table 1. Average and standard deviation for each measurement and each of the filters.

	Filter	None	Very low	Low	Medium	Strong	Very strong
SDNN (ms)	Average	135.81	136.79	133.05	131.06	121.41	98.76
	SD	55.83	56.30	54.47	51.39	48.54	38.51
RMSSD (ms)	Average	96.98	90.55	84.44	76.09	59.90	25.76 (*)
	SD	56.42	49.70	43.63	36.13	23.43	4.96
pNN50 (%)	Average	39.50	39.96	39.83	39.01	33.91	5.53 (*)
	SD	22.33	22.07	22.04	21.51	18.05	3.12
VLF (Hz)	Average	0.01	0.01	0.01	0.01	0.01	0.01
	SD	0.01	0.01	0.01	0.01	0.01	0.00
LF (Hz)	Average	0.07	0.08	0.07	0.09	0.07	0.06
	SD	0.02	0.02	0.02	0.09	0.02	0.01
HF (Hz)	Average	0.20	0.20	0.20	0.20	0.19	0.25
	SD	0.05	0.05	0.05	0.05	0.04	0.38
VLF (ms2)	Average	9,964.63	11,059.90	10,888.94	11,356.78	10,109.38	8,024.69
	SD	8,282.29	10,324.11	10,256.56	11,414.19	10,009.39	7,119.34
LF (ms2)	Average	5,968.57	5,802.70	5,491.25	4,793.61	3,458.68	987.40(*)
	SD	4,625.82	4,265.79	3,935.40	2,998.78	2,037.96	389.75
HF (ms2)	Average	2,853.30	2,585.98	2,304.20	1,829.54	1,023.63	117.95(*)
	SD	3,060.02	2,641.39	2,228.81	1,604.62	753.70	60.34
SD1	Average	69.24	64.10	59.76	53.85	40.62	18.23(*)
	SD	39.89	35.19	30.89	25.58	17.81	3.52
SD2	Average	178.12	181.55	179.56	176.73	165.69	138.11
	SD	70.82	73.31	72.95	69.32	67.95	54.75
DFA alpha 1	Average	1.19	1.22	1.25	1.27	1.31	1.55
	SD	0.25	0.23	0.21	0.19	0.19	0.11
DFA alpha 2	Average	0.99	1.00	1.00	0.99	1.07	1.26
	SD	0.10	0.10	0.10	0.20	0.11	0.14
ApEn	Average	1.15	1.16	1.16	1.16	1.14	0.82
	SD	0.10	0.10	0.10	0.10	0.12	0.18
SampEn	Average	1.29	1.30	1.31	1.32	1.29	0.80
	SD	0.26	0.26	0.27	0.28	0.28	0.22

Average values and standard deviation for each measurement and each of the filters (none; very low; low; medium; strong. very strong) for each of the HRV parameters analysed. (*) $p < 0.001$. ApEn, approximate entropy; SampEn, sample entropy; DFA, detrended fluctuation analysis; HF, high frequency; LF, low frequency; pNN50, number of pairs of adjacent RR intervals that differ by over 50ms in the whole recording, divided by the total number of RR intervals and expressed as a percentage; rMSSD: square root of the mean of the squares of the differences between adjacent RR intervals; SDNN: standard deviation of RR intervals; SD1: transversal diameter; SD2: longitudinal diameter; VLF: very low frequency.

in some variables becomes statistically significant. Although in each individual record a progressive reduction of HRV can be observed from the filter that causes the first change (Table 2), in a group analysis no significant change is evident until reaching the VS filter because each record corrects its artifacts with a different level of filtering, but none of them reaches the VS filter.

These results have an interesting application for those studies of athletes in which these variables are analyzed in group[38].

Sitting position is not standard for HRV analysis, although it is commonly used for short records in sports population[6,38]. However, this can be neglected in this study since this is only data acquisition for further technical analysis.

The duration of recordings (10 minutes) is in accordance with the guidelines of the Task Force[1] which states that in studies researching HRV, the duration of recording is dictated by the nature of each investigation. In this case, our preoccupation was to provide enough data for nonlinear analysis and according to Pincus[34] N for ApEn should be between 100 and 900 data (for m=2). A 10 min recording contains about 600 data. For SampEn and DFA the N needed is similar[39,40].

Conclusions

In conclusion, there are no significant differences between the results obtained by subjecting a series of data taken from top athletes to the different filters provided by Kubios® software, except the strongest one.

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Table 2. Filter that produced the first change.

Subject	Time domain	Frequency domain	Poincaré plot	Nonlineal variables	Total
1	VL	VL	VL	VL	VL
2	M	M	M	M	M
3	VL	VL	VL	VL	VL
4	VL	VL	VL	VL	VL
5	M	L	L	M	L
6	M	M	M	M	M
7	S	S	S	S	S
8	VL	VL	VL	VL	VL
9	VL	VL	VL	VL	VL
10	M	M	M	M	M
11	VL	VL	VL	VL	VL
12	VL	VL	VL	VL	VL
13	S	M	M	M	M
14	L	M	L	L	L
15	S	S	S	S	S
16	S	S	S	S	S
17	L	L	L	L	L
18	M	M	M	M	M
19	S	S	S	M	M
20	L	VL	L	VL	VL
21	VL	VL	VL	VL	VL
22	M	M	M	M	M
23	VL	VL	VL	VL	VL
24	VL	VL	VL	VL	VL
25	VL	VL	VL	VL	VL
26	VL	VL	VL	VL	VL
27	L	L	VL	VL	VL
28	VL	VL	VL	VL	VL
29	VL	VL	VL	VL	VL
30	VL	VL	L	VL	VL

Filter with which the first change is detected in Time Domain, Frequency Domain, Poincaré plot and Nonlineal variables (VL: very low; L: low; M: medium; S: strong). No subject showed the first change with the VS filter. The last column ("Total") shows the first filter with which the first change is observed in any variables.

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Excess weight and health-related quality of life in Latin American adolescents

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Summary

The purpose of the study was to identify differences in the components of health-related quality of life (HRQL) across weight status in samples of adolescents from three cities in Argentina, Brazil, and Chile. The *Kidscreen-52* questionnaire was administered to 1357 adolescents between 12 and 17 years of age (48.6% of them male) in selected samples in the three countries. To define the weight status (eutrophic, overweight, obesity) we used the gender-and-age-specific body mass index cut-offs recommended by the *International Obesity Task Force – IOFT.* Analysis of covariance was used to make comparisons between strata formed by controlling the scores associated with the city/country of origin, sex and age. Considering all adolescents in the study, 35.2% of girls and 28.6% of boys were overweight, of which 6.4% and 4.7%, respectively, showed to be obese. Magnitude of the prevalence increases with age, being these values more pronounced among the boys. Compared to eutrophic adolescents, the obese adolescents presented scores significantly more injured in the ten components of HRQL. The overweight adolescents showed significantly lower values than eutrophic adolescents in the components equivalent to *Physical Well-being, Psychological Well-being, Moods and Emotions, Self-Perceptions, Social Support and Peers, School Environment, and Social Acceptance/Bullying*. In addition, the comparison between overweight and obese adolescents showed statistically significant differences for the components of *Physical Well-being, Self-Perceptions, and Social Acceptance/Bullying*. Therefore the evidences found indicate to the importance of monitoring and intervening in HRQOL components related to the proposed programs for the reversal of overweight/obesity and weight control.

Key words:
Health education. Overweight. Obesity. Adolescent health. Latin America.

Exceso de peso corporal y calidad de vida relacionada con la salud de adolescentes latino-americanos

Resumen

El objetivo del estudio fue identificar diferencias en los componentes de la calidad de vida relacionada con la salud (CVRS) según el estado ponderal en una muestra de adolescentes de tres ciudades localizadas en Argentina, Brasil y Chile. Se aplicó el cuestionario *Kidscreen-52* a 1.357 adolescentes con edades comprendidas entre 12 y 17 años (48,6% chicos) en muestras seleccionadas en los tres países. El estado ponderal (eutrófico, sobrepeso y obesidad) fue definido mediante el índice de masa corporal, utilizándose los puntos de corte sugeridos por la *International Obesity Task Force.* Para establecer comparaciones entre los estratos formados, se utilizó el análisis de covarianza mediante el control de las puntuaciones asociadas a la ciudad/país de origen, sexo y edad. Considerando la totalidad de los adolescentes reunidos en el estudio, el 35,2% de las chicas y el 28,6% de los chicos presentaron exceso de peso corporal, de los cuales, 6,4% y el 4,7% respectivamente, mostraron ser obesos. Se observó aumento en las prevalencias de sobrepeso y obesidad con la edad, sobretodo en el grupo de los chicos. En comparación con los adolescentes eutróficos, los adolescentes obesos obtuvieron puntuaciones significativamente más comprometidas en los diez componentes de CVRS. Los adolescentes con sobrepeso mostraron valores significativamente menores que los adolescentes eutróficos en los componentes de *Bienestar Físico, Bienestar Psicológico, Estado de Ánimo y Emociones, Autopercepción, Amigos y Apoyo Social, Entorno Escolar y Rechazo Social/Bullying.* Además, en la comparación entre adolescentes con sobrepeso y obesos, las diferencias demostraron estadísticamente significativas para los componentes de *Bienestar Físico, Autopercepción y Rechazo Social/Bullying*. Por consiguiente, las evidencias encontradas apuntan hacia la importancia de monitorizar e intervenir en los componentes de CVRS relacionados con la propuesta de programas dirigidos la reversión del sobrepeso/obesidad y al control del peso corporal.

Palabras clave:
Educación en salud. Sobrepeso. Obesidad. Salud del adolescente. América Latina.

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Introduction

Over the past few decades, the prevalence of excess weight and obesity in young demographics has become established as a worldwide epidemic[1]. Despite more developed countries recently revealing a stabilising trend in the amount of young people with excess body weight[2], in Latin American countries cases of children and adolescents with excess weight and obesity continue to grow at an alarming rate[3]. Available literary data suggests that there are currently between 42.5 and 51.8 million young people aged up to 19 years living in Latin America that are overweight or obese, which corresponds to approximately 20-25% of the total of this demographic[4].

Excess body weight has an immediate repercussion on the metabolic health of young people, which is the case of dyslipidemia, hypertension and glucose intolerance, therefore defining the metabolic syndrome[5]. Having a heavier body weight also increases the risk of the appearance and development of cardiovascular, respiratory, endocrine, hepatic, gastrointestinal, orthopaedic and neurological disorders[6]. Other consequences of excess weight and obesity are psychosocial aspects, including low self-esteem, a negative self-image, discrimination, stigmatisation, social exclusion and depression[7]. Worse still, it is estimated that depending on the age of the onset and magnitude of the excess body weight, approximately 30% to 80% of young overweight or obese people can become obese adults[8].

As well as the co-morbidities and the psychosocial consequences linked to excess body weight specific to early ages, with serious immediate and future risks to the young people concerned, their family members and society in general, another issue highlighted by researchers in this field refers to the influence that the condition of excess weight/obesity can have on the perception of health-related quality of life components (HRQL). In this respect, it has been confirmed that the relationship between excess weight/obesity and the eventual deterioration of HRQL is sufficiently established in adults[9] and young obese people undergoing clinical treatment[10]. However, few studies have been found that aim to research the relationship between HRQL components and the weight condition in a demographic of young people, and fewer still in Latin American countries. The few studies available in literature reveal data from English-speaking cultures, and in some cases they use different measurement instruments to identify the HRQL components, with contradictory results[11,12].

The aim of this study was to identify differences between the different HRQL components in alignment with the weight condition (eutrophic, excess weight and obesity) in a sample of adolescents from three cities, located in Argentina, Brazil and Chile. From the very outset, the hypothesis was established that adolescents with excess weight and obesity would reveal more affected equivalent HRQL components than their eutrophic peers.

Material and method

A transverse descriptive study was carried out on a population of adolescents, that during 2009 were studying between sixth grade and tenth grade in three different Latin American urban state schools. The cities chosen for the study were San Miguel de Tucumán, located in the province with the same name in the north west of Argentina; Londrina, located in the region of Paraná, in southern Brazil; and Valparaíso, which is in province of the same name in central Chile. According to data from the Head of Statistics of the Education Secretaries from the three cities, at the time the studies were carried out, around 38, 70 and 53 thousand students respectively were registered for these levels of studies.

The intervention protocols used were approved by the Research Ethics Committee of the State University of Londrina, Brazil (Decree no. 073/2007) and followed the regulations of Ruling 196/96 of the National Health Council of Brazil regarding research involving humans.

Sample and selection of subjects

With regards to the sample size, a confidence interval of 95% was taken into account, an unknown success prevalence (p = 50%), a design effect of 1% and precision effect of 3%. Despite a size of 1,320 subjects being calculated, the final sample comprised 1,357 adolescents aged from 12 to 17 years (698 girls and 659 boys), distributed proportionally in accordance with the school year of each of the three cities/countries studied. A random selection was made of four schools in each city/country, and a probability sample procedure was used by conglomerates to select the adolescents in the schools, using the number of students as references in terms of sex, age and school level (Table 1).

The adolescents selected for the sample were informed of the nature and objectives of the study, under the principle of anonymity and non-influence of school performance. Consent was given by all participants and their tutors. The study inclusion criteria were: to be aged between 12 and 17 years, to be able to read and fill out the questionnaire, and to be present in class on the day indicated for data collection.

Table 1. Composition of the sample selected in the study considering the three classification criteria: cities/countries, sex and age (n = 1357).

Age	Tucumán, Argentina (n=327)		Londrina, Brazil (n=588)		Valparaíso, Chile (n=442)	
	Girls (n=168)	Boys (n=159)	Girls (n=303)	Boys (n=285)	Girls (n=227)	Boys (n=215)
12-13 years (n=443)	55	52	99	93	74	70
14-15 years (n=525)	65	62	117	110	88	83
16-17 years (n=389)	48	45	87	82	65	62

Data collection

The data collection in the three Latin American cities/countries followed the same procedures and was undertaken from May to September 2009. The indicators of excess weight and obesity were defined based on the body mass index (BMI), by dividing the body weight measurements in kilograms by the height in square metres (kg/m^2), using the cut points for sex and age suggested by the *International Obesity Task Force* – IOFT[13].

To establish the averages corresponding to body weight, an anthropometric scale was used with a precision of 100 grammes, which was checked after every ten weighs. To carry out the height measurements, an aluminium stadiometer was used with a 1 mm scale, following the procedures suggested by the World Health Organisation[14].

The HRQL components were identified and scaled by applying the *Kidscreen-52* questionnaire[15]. In the specific case of Argentinian and Chilean adolescents, a translated and transculturally adapted Spanish-language version of *Kidscreen-52* was used[16]. For the Brazilian adolescents, a translated and adapted *Kidscreen-52* version for the South American Portuguese language was used[17].

The *Kidscreen-52* questionnaire consists of 52 questions orientated towards the perception of 10 HRQL components in children and adolescents (Table 2). The responses to these questions are recorded using a Likert-type scale from one to five points (with the extremities being from "not at all" to "a lot" or from "never" to "always"), with the aim of identifying the frequency of behaviours/feelings or, in some cases, the intensity of specific attitudes, in the period of the week prior to filling out the questionnaire. The results of each component are counted using a syntax, which takes into account the responses of a group of questions that make up each field, with the questions being equally weighted. The final equivalent markers from each component are recoded into a measurement scale, with a variation between 0 and 100, with 0 being the least perception and 100 being the greatest perception of HRQL of the component in question[15].

The *Kidscreen-52* questionnaire was applied on just one occasion, individually for each student, by a single researcher in each Latin American city/country, in the school centre and during class time. The study participants received the questionnaire with instructions and recommendations so they could fill it out with no time limit. The participants' queries were clarified by the researcher present for the data collection. The average time taken to fill out the questionnaire was 30 minutes. In terms of the reliability of the questionnaire used for the adolescents from the three selected cities, the internal consistency values via the Cronbach co-efficient α varied between 0.71 in the *Self-perception* component, and 0.89 in the *Economic Resources* component, with an average overall value of 0.82.

Statistical analysis

The statistical handling of the data was carried out using the IT package *Statistical Package for the Social Science,* version 21. With regards to the equivalent indicators of excess weight and obesity, the stratified point proportions were estimated in accordance with the sex (boys and girls), age (12 to 13 years, 14 to 15 years and 16 to 17 years) and city/country of origin of the adolescents (Tucumán-Argentina, Londrina-Brazil, Valparaíso-Chile).

In terms of the data referring to the HRQL components, initially the frequency distribution was analysed via the Kolmogorov-Smirnov test. Considering that the data revealed a normal frequency distribution, parametric statistic resources were used, by calculating the average and standard deviation. Later, to establish comparisons between the scores given to the HRQL components associated with the presence of excess weight and obesity, the co-variance analysis was used (ANCOVA), adjusted by sex, age and city/country of origin of the adolescents, accompanied by the Scheffe multiple comparison test to identify the specific differences.

Table 2. Components of the *Kidscreen-52.*

Components	Items	Brief description of the content
1. Physical well-being	5	Participation in physical activity, energy and physical aptitude.
2. Psychological well-being	6	Positive feelings and satisfaction with life.
3. Mood and emotions	7	Depressing and stressful emotions.
4. Self-perception	5	Self-perception and satisfaction with bodily appearance.
5. Autonomy	5	Opportunities to create and manage their social and leisure time.
6. Relationship with parents and family life	6	Quality of the relationship with their parents and in the family environment.
7. Friends and social support	6	Nature of relationships with others.
8. School environment	6	Satisfaction regarding their competence and school performance.
9. Social rejection/bullying	3	Aspects regarding feelings of rejection by peers.
10. Economic resources	3	Perception in terms of the quality of available economic resources.

Results

Figure 1 reveals the prevalence of excess body weight (excess weight + obesity) estimated in the sample of adolescents analysed. Considering the total number of adolescents participating in the study, 35.2% of the girls and 28.6% of the boys displayed values of excess body weight, of which 6.4% and 4.7% respectively displayed obesity values. When the different ages were taken into account, the trends of increasing excess weight and obesity were confirmed with the passing of years, especially in the group of boys. In relation to the cities/countries of origin of the adolescents, the lowest percentages of girls and boys with excess weight and obesity were observed in San Miguel de Tucumán/Argentina, and the highest were identified in adolescents from Valparaíso/Chile.

Table 3 displays the information associated with the multi-variable analysis of the scores given to the HRQL components depending on weight, adjusted by city/country of origin, sex and age. In comparison to eutrophic adolescents, it has been revealed that obese adolescents display considerably more adversely affected scores in the ten HRQL components. In the case of adolescents with excess weight, they revealed significantly lower values than eutrophic adolescents in the components relating to *Physical well-being, Psychological well-being, Mood and emotions, Self-perception, Friends and social support, School environment* and *Social rejection/bullying*. Furthermore, in the comparison of adolescents with excess weight and obesity, the differences turned out to be statistically significant for the *Physical well-being, Self-perception* and *Social rejection/bullying* components.

Discussion

This study analysed the scores given to the HRQL components in adolescents from three Latin American cities/countries, classified in accordance with weight. The importance of the study is due to the possibility of considering, for the first time, the HRQL components of a multi-cultural sample of over-weight and obese adolescents using an internationally accepted instrument *(Kidscreen-52)*, which can verify the urgent need to intervene, in that it is added to the traditional argument regarding the concern for subjective aspects linked to quality of life.

The results found revealed that, using the specific cut points for sex and age proposed by the IOTF, it is estimated that the prevalence of excess body weight (excess weight + obesity) in the sample analysed

Figure 1. Prevalence of excess body weight (excess weight + obesity) stratified in accordance with cities/countries, sex and age of a sample of Latin American adolescents.

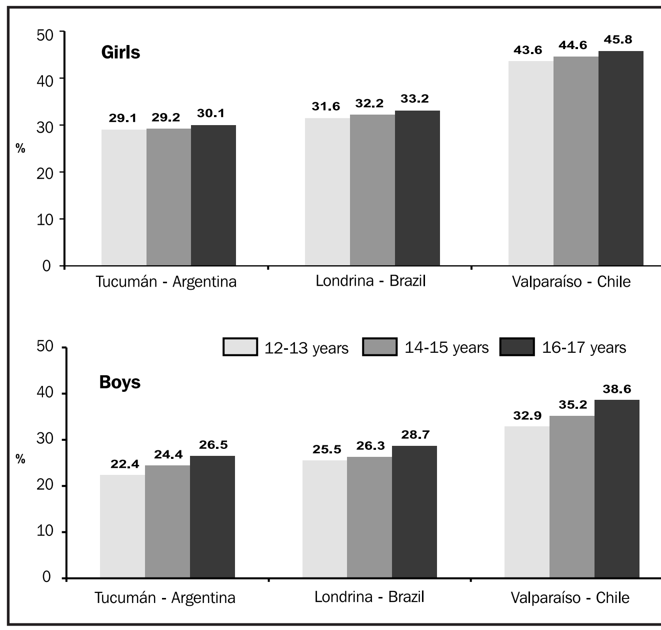

Table 3. Average, standard deviation and F test of the scores equivalent to the health-related quality of life components of the adolescents surveyed depending on their weight.

Quality of life components	Weight			F test	*Post-Hoc Scheffé*
	Eutrophic (a)	Excess weight (b)	Obesity (c)		
Physical well-being	78.65±17.85	69.58±16.98	57.79±15.65	45.218 (p < 0,001)	a > b > c
Psychological well-being	79.53±20.23	73.92±19.87	72.17±19.11	9.814 (p < 0,001)	b < a > c
Mood and emotionss	86.03±19.54	78.31±18.14	77.89±18.87	10.492 (p < 0,001)	b < a > c
Self-perception	80.78±17.11	71.17±16.53	64.35±15.58	31.566 (p < 0,001)	a > b > c
Autonomy	81.34±21.38	77.85±20.46	74.54±19.93	8.738 (p = 0,001)	a > c
Relationship with parents and family life	80.89±22.19	77.96±21.79	73.77±20.81	8.195 (p = 0,001)	a > c
Friends and social support	86.47±20.65	78.78±19.32	77.24±19.65	10.093 (p < 0,001)	b < a > c
School environment	75.14±19.47	66.24±18.25	63.13±19.43	13.651 (p < 0,001)	b < a > c
Social rejection/bullying	76.18±19.72	65.02±18.51	58.51±16.72	40.382 (p < 0,001)	a > b > c
Economic resources	79.95±21.90	75.57±20.84	72.80±22.19	7.879 (p = 0,001)	a > c

Co-variance analysis through the control of points associated with the city/country of origin, sex and age.

(31.9%) was approximately four times greater than that found in studies carried out on a young demographic in China (7.7%)[18], and on the other hand quite similar to that found in the United States (32.6%)[19].

The prevalences of excess weight and obesity were not evenly distributed in the sample analysed in this study. The sex, age and city/country of origin of the adolescents revealed different implications in the identification of excess weight and obesity. Coinciding with data from other studies[20], a larger number of girls presented greater excess body weight. Added to all of this, in this case, the excessive accumulation of body weight remained practically stable from 12 to 17 years. In terms of the boys, the prevalences of excess weight and obesity rose as the age increased. According to information available in specialised literature, only the studies that displayed the greatest prevalences of excess weight and obesity revealed similar trends[4,19]. In the other studies that were accessed, both boys and girls displayed greater prevalences of excess weight and obesity at younger ages[18, 20].

Supporting the different information previously available in literature[11, 12, 21-25], the findings from this study point to the major negative influence that excess body weight can have on HRQL components. The adolescents classified as obese revealed lower scores in all the quality of life components present in the *Kidscreen-52*, compared to their eutrophic peers, thereby suggesting that the impact of this condition is global and must occur in the different parts of the daily life of adolescents. Despite the HRQL components not being projected to monitor all the areas that are specifically related to excess body weight[26], their weighting may bring together important information, such as how young people with excess weight or obesity perceive their health and well-being. In this particular field, the dimensions of the HRQL components translate as outstanding health aspects, which are not detected using traditional biological and clinical dimensions.

The condition of excess weight and obesity frequently causes teasing by classmates with lower body weight. The strong influence of the surroundings, along with the perception of irony, increases personal insecurity, damages self-esteem and emotional well-being, and hinders interpersonal relationships[27]. As they get older, young people become increasingly aware of their surroundings, they perceive interpersonal differences more clearly, they make comparisons, prioritise self-criticism, and negative self-perception and personal dissatisfaction emerge[28]. The reduction in self-esteem determines a greater influence of peers and a perception of less social acceptance, which can lead to a more introverted character[24], as well as, according to that revealed with the results found in this study, adversely affected psycho-social elements that deteriorate HRQL components.

On the other hand, the data from this study reveals that, in relation to the quality of life components equivalent to *Physical well-being, Mood and emotions, Self-perception* and *Social rejection/bullying,* even greater adverse effects are revealed in obese adolescents, whilst *Autonomy, Relationship with parents and family life* and *Economic resources* are components that reveal similar scores among eutrophic and over-weight adolescents. These findings back up some suggestions from previous studies[23] that some HRQL components may be more affected than others as a result of excess body weight at a young age, with particular emphasis on physical, emotional and social aspects.

In the *Kidscreen-52* these fields consider items related to participation in physical activity, energy and physical aptitude, depressing and stressful situations, self-perception and satisfaction with bodily appearance, the nature of relationships with peers and feelings or rejection, i.e. issues that may eventually hinder participation in body weight control programmes, therefore establishing a vicious circle: greater accumulation of body weight - adversely affected HRQL components - less participation in intervention programmes - greater accumulation of body weight. Experimental studies that specifically involve clinical samples have proved this phenomenon[29,30].

Among the HRQL components included in *Kidscreen-52,* the greatest differences identified between eutrophic adolescents and those with excess body weight were in the physical area. This could be due to the difficulty reported by the adolescents with excess weight or obesity in participating in some kind of physical or sporting activity, related to metabolic limitations and orthopaedic problems, consequently inducing restrictions in possibilities of moving about. Less availability of energy and poor alignment of the lower limbs, accompanied by excessive over-loading generated by a greater body weight, are typical characteristics of young people with excess weight or obesity[6], which decisively contribute to greater cardio-metabolic and muscular-skeletal discomfort, in general converting the performing of physical exercise into a great sacrifice.

This study is not extent of limitations. For example, it is important to indicate that the data equivalent to the HRQL components was self-reported by the adolescents themselves. Likewise, self-reporting is a habitual procedure in studies of this nature, as it is the most viable way of obtaining data related to quality of life in wide demographics. On the other hand, the vast sample size in some way enabled the eventual imprecision of calculated estimates to be minimised. Furthermore, the transverse approach of the data could have limited the identification of differences, without formulating the possibility of there being an inverse causality. Another limitation was the presence of possible un-diagnosed co-morbidities associated with excess weight and obesity, which could have interfered in the quality of life of the adolescents with excess body weight.

To conclude, the results of this study suggest that adolescents with excess weight and obesity reveal more adversely affected specific HRQL components than their eutrophic peers. Even so, finding from this study indicate the importance of monitoring and intervening in HRQL components that target the proposal of programmes aimed at reducing excess weight/obesity and controlling body weight. Initiatives in this respect may be useful as references in assessing the effectiveness and actions established in intervention programmes, as well as helping understand the consequences of excess body weight for adolescents and conditioning public policies that specifically target this demographic.

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Original article

Body composition analysis using bioelectrical parameters in the Cuban sporting population

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Summary

Objectives: The purpose of this study is to provide data on bioelectrical parameters in Cuban sport population, particularly: resistance (R), reactance (Xc), impedance (Z), impedance vector component according to bioelectrical impedance vector analysis (BIVA) and phase angle (PhA), establishing references values on athletes of high performance level.
Material and method: We performed bioelectrical impedance analysis (BIA) in 943 Cuban athletes (620 male, 323 female) of 26 sports modalities. Bioelectric parameters R, Xc, Z and PhA were obtained at 50-kHz frequency and multi-frequency from 1 to 1000 kHz using a multi-frequency measuring device. From these parameters, five bioimpedance ratios were calculated (R/Height, Xc/ Height, Z/ Height, the reactance paralate, and resistence paralate) at 50 kHz. Bioelectrical impedance vectors analysis (BIVA) and Cole-Cole modeled were performed. Once R/Height and Xc/Height were estimated, the BIVA was performed. Mean and standard deviations were calculated for all variables. Unpaired t-test was used to detect differences between sexes. BIVA vectors were compared using Hotelling's T^2 test. To eliminate a null hypothesis about the equality of the examined parameters, we used the level of probability of $p < 0.05$.
Results: Compared to male population, female population had higher R, R/ Height, Xc, Xc/ Height, Z, Z/ Height and lower PhA. The accuracy of specific BIVA was different in the two sexes ($p<0.05$) and according to the Body Mass Index (≤25 and >25). Differences between sports were found in order to Z and PhA.
Conclusions: The study showed that variability of R, Xc, Z and PhA measures depends on gender, body mass characteristics of the study population, and sport.

Key words:
Bioelectrical parameters. Bioelectrical impedance vector analysis. Phase angle. Cole-Cole model.

Análisis de la composición corporal empleando parámetros bioeléctricos en la población deportiva cubana

Resumen

Objetivos: La propuesta de este estudio es proveer datos de parámetros bioeléctricos de la población deportiva cubana, particularmente: resistencia (R), reactancia (Xc), impedancia (Z), ángulo de fase (AF), y los componentes del vector impedancia de acuerdo al análisis del vector bioeléctrico (BIVA), estableciendo valores de referencia en atletas de alto rendimiento.
Material y método: Se les realizó el análisis de bioimpedancia eléctrica (BIA) a 943 deportistas cubanos (620 masculinos, 323 femeninos) de 26 deportes diferentes. Los parámetros bioeléctricos R, Xc, Z y PA fueron obtenidos a una frecuencia de 50-kHz y en la gama de 1 a 1.000 kHz usando un analizador multifrecuencia. De estos parámetros, fueron calculados cinco índices (R/Estatura, Xc/ Estatura, Z/Estatura, reactancia en paralelo, y resistencia en paralelo) a 50 kHz. Se obtuvo el análisis del vector de bioimpedancia eléctrica (BIVA) y se realizó un modelado Cole-Cole. Una vez estimado R/Estatura y Xc/Estatura, fue realizado el análisis de BIVA. La media y la desviación estándar fueron calculadas para todas las variables. *La prueba t fue usada para detectar las diferencias entre ambos sexos.* Los BIVA fueron comparados usando la T^2 de Hotelling. Para contrastar la hipótesis nula de igualdad entre los parámetros examinados, se empleó el nivel de significación de $p < 0{,}05$.
Resultados: En comparación a la población masculina, la población femenina tuvo mayor R, R/*Estatura*, Xc, Xc/*Estatura*, Z, Z/*Estatura* y menor PA ($p<0{,}05$). La precisión de BIVA fue diferente entre los sexos ($p < 0{,}05$) y de acuerdo al índice de masa corporal (≤25 y >25). Las diferencias entre deportes estuvieron relacionadas al valor de Z y AF.
Conclusiones: El estudio mostró que la variabilidad de R, Xc, Z y AF dependió del género, de las características de la masa corporal de la población estudiada, y del deporte.

Palabras clave:
Parámetros bioeléctricos. Análisis del vector impedancia bioeléctrica. Ángulo de fase. Modelo Cole-Cole.

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Introduction

The Bioelectrical Impedance Analysis (BIA) is an indirect method of estimating body composition (BC) based on a simple, quick and non-invasive diagnosis procedure that has been used from a clinical perspective as well as for research into molecular, cellular and tissue exploration in humans[1].

Body impedance (Z) is a 2-component function: resistance (R) and reactance (Xc). R represents the resistance of the tissues as an electrical current passes through, and depends on the hydration of the tissues, whilst Xc is the additional opposition due to the capacitance of those tissues and the cell membranes; it is a fundamental parameter for differentiating extra and intracellular liquid as well as the state of cell membranes[1]. The phase angle (PA) is a quality of life indicator; it is the tangent arc (Xc/R) x 180º/π. High PA values are interpreted as cell membranes in a good state, with correct osmotic pressure and ion concentration and a high cell mass[2].

The result of the graphic representation of Xc *vs.* R in the entire range of frequencies (1kHz-1MHz) is a semi-circle with its centre under the real axis corresponding to the model called Cole-Cole[3]. The semi-circle characterises the tissue bioimpedance in 4 parameters known as: resistance to frequency 0 (R_0), resistance in the infinite (R∞), constant characteristic of time (τ) and measurement of the depression of the semi-circular arc below the real axis (α). Based on the experimental model used, R_0 corresponds to extracellular resistance and R∞ to intracellular resistance[3,4].

On the other hand, the graphic analysis of the R, Xc relationship, standardised by the height, enables an assessment of the body composition of a subject to be carried out, classifying the state of hydration and variation of the soft tissue. This is known as the bioimpedance vector analysis (BIVA)[5,6].

Based on a number of demographic research studies carried out, there is a growing international acceptance of the use of PA and of BIVA for the tissue and molecular analysis of the BC. Many of these studies have proven the relationship between certain values and different pathological states in the general population[5-9]. However, Llames *et al*[2] suggested that the lack of reference values for the PA have limited its use in clinical and epidemiological situations, whilst Peine *et al*[10] suggested the need to establish the BIVA and PA characteristics for the different demographics, as their use may be limited by age, sex, ethnic origin, body mass index level, among other factors.

It has been demonstrated that the sporting population constitutes a wide segment of physiological variability that can reveal similar PA and BIVA values to people with abnormal pathological states, but in their case these are considered normal adaptations to the sport[11,12]. In turn, in literature specialising in athletes, the demographic characteristics of the BC bioelectrical parameters are not well documented, which could contribute to the study of the limits reached by these indicators and their more rational use in the field of nutritional assessment and of the biomedical control of training.

Based on the previous approaches, the authors proposed: 1) establishing the general characteristics of the bioelectrical parameters in elite Cuban athletes of both sexes at the frequency of 50Hz and the characteristic frequency, 2) establishing the characteristics of the BIVA vector in relation to the sex and body mass index, 3) establishing the demographic differences for the phase angle between the demographic studied and a reference one, and 4) comparing the sports assessed using the body Impedance and the Phase Angle parameters.

Material and method

Type of study and universe

A descriptive and prospective research study was carried out between 14th March and 20th October 2013. The population studied comprised 936 people, which made up the Cuban adult national selection in 26 sports. 620 male subjects and 323 females subjects were assessed, the distribution of which can be seen in Table 1. The average age of participants was 22.75±4.11 and 22.38±3,53 years for males and females respectively.

Methods and procedures

Before starting the study, all the subjects were informed and gave their consent to participate. The study was approved by the Cuban Sports Medicine Institute ethics committee.

Table 1. Sample composition according to sex and sport.

	Male	Female	Total
Basketball	27	54	81
Handball	36	15	51
Baseball	47	0	47
Boxing	25	0	25
Boating	38	11	49
Fencing	37	32	69
Football	63	13	76
Artistic gymnastics	13	1	14
Rhythmic gymnastics	0	12	12
Weight lifting	31	13	44
Grass hockey	22	17	39
Judo	18	25	37
Greek-Roman wrestling	36	0	36
Free-style wrestling	46	27	73
Figure skating	2	2	4
Speed skating	10	2	12
Basque pelota	5	5	10
Modern pentathlon	7	4	11
Water polo	13	0	13
Rowing	53	18	71
Table tennis	3	5	8
Sport shooting	8	8	8
Triathlon	7	4	11
Sailing	15	6	21
Volleyball	47	41	88
Beach volleyball	11	8	19
Total	620	323	943

The study was carried out in the morning by trained personnel, in an air-conditioned premises at 23ºC. To ensure validity and reliability, a protocol was designed which considered the following: 1) not to use diuretics within the previous week, 2) not to drink alcohol in the 48 hours prior to the exam, 3) not to carry out intense exercise at least 12 hours before, 4) not to consume food or drink 4 hours prior to the start of the tests, 5) to urinate/defecate for the last time 30 minutes before starting the programmed tests, 6) in the case of women, the phase of the menstrual cycle was taken into account, only performing the assessment during the oestrogenic phase.

To establish the Bioimpedance, the multifrequency analyser mBCA 514/515 was used *(medical Body Composition Analyser)* made in Germany (Seca 514/515 GmbH & co. kg, Hamburg) (Figure 1A), which was coupled to two units with wireless communication comprising a PC with a Seca Analytics mBCA 115 software (Figure 1B) and a wireless transmission stadiometer 360° Wireless Seca 284 (Seca GmbH & co. kg, Hamburg) (Figure 1C). The units had a precision of 50 g and 1 mm for the weight and height measurements, respectively.

Once the general data was entered into the PC (ID number, age ethnic origin, sport) the height was measured (H) in the wireless transmission stadiometer 360º Wireless Seca 284 (Seca GmbH & co. kg. Hamburg) and was transferred to the analyser using a switch. The height was assessed according to the requirements of the International Society for the Advancement of Kinanthropometry[13]: the subject stood barefoot on the stadiometer base with heels together, the medial borders of the feet at a 60º angle, the back side of the gluteus and the back part of the back touching the stadiometer. The head was positioned in the Frankfurt plane angle, with a slight tilt upwards as the subject breathed in.

Figure 1. Wireless units used to undertake the research.

Next, the individuals stood in an upright position on the analyser with a scapular-humeral joint flex of 30º. The analyser is composed of a pair of electrodes that make contact with the feet (metatarsal-calcaneus) and three pairs on the railings that are at different heights and are adjusted to the height of each subject. In this position the body weight and the body mass were analysed, a 100 µA current was introduced via the stimulating electrodes, whilst the voltage drop (V) was detected by the sensor electrodes, in accordance with Ohm's law (Z=Voltage/Intensity of the current).

The BIA measurements were assessed at the frequencies 1, 1.5, 2, 3, 5, 7.5, 10, 15, 20, 30, 50, 75, 100, 150, 200, 300, 500, 750 and 1,000 kHz. The 19 frequencies were used for the Cole-Cole arc model to establish resistance when the frequency tends towards infinity (R∞), resistance when the frequency tends towards zero (R_0), the characteristic frequency (Cf) and the depression angle, so that based on the values obtained the following were estimated: the membrane capacity (Mc), the extracellular (R_0) and intracellular resistances (R∞) and the arc radius (r), the area below the curve. To obtain the average values of R/H, Xc/H, Z/H, Rp/H, Xcp/H and PA, the 50 kHz frequency was used, while for R0/H, R∞/H, Mc/H, and PA, the Cf of the Cole-Cole model was used. The resistance and reactance in parallel (Rp and Xcp) and the membrane capacity (Mc) were estimated using the following formulas:

$$Rp = R + \frac{Xc^2}{R}$$

$$Xcp = Xc + \frac{R^2}{Xc}$$

$$Cm = Xc + \frac{1}{2\,\pi\,Fc\,x\ \ X\,Cp}$$

The graphs for the BIVA analysis were obtained using the software designed by Picolli and Patori (2002) and to process the BIVA analysis (Piccoli A, Pastori G: BIVA software. Department of Medical and Surgical Sciences, University of Padova, Padova, Italy, 2002 (available from: E-mail: apiccoli@unipd.it).

Statistical analysis

The demographic data obtained from the analysis was first exported to an Excel sheet then to the statistics package IBM-SPSS 20.0 for Windows, where the descriptive statistics were carried out.

After performing an exploratory analysis, the absolute and height-related average values (X) and the standard deviation (SD) of R, Xc, Z, Rp, Xcp and PA were obtained at the frequency of 50 kHz, whilst for R0, R∞, Mc, Z and PA, they were obtained at the Cf frequency.

The Student t test for independent samples was used to check the hypothesis of equality of averages between sexes for each of the bioelectrical indicators studied, following verification of the statistical assumptions of normality and homogeneity of variance.

The comparison between the BIVA vectors of different Body Mass categories (BM I≤25Kg/m² *vs* BMI >25Kg/m²) and between sexes was established using the Hotelling T^2 test, following verification of the statistical assumptions of normality and homogeneity of variance.

The level of significance used to rule out the zero-equality hypothesis of averages or of vectors for the checks was $p < 0.05$.

The normal distribution of the PA was verified using the plotting of the quantiles on the Q-Q graph and through the visual inspection based on the exploratory analysis carried out. The overlap of normal distributions of the demographic studied and that of the German reference study[10] were compared, and the overlap area was determined to establish the demographic similarities, adapting the Bivariate Overlap Zone by Norton & Olds[14].

For the description of the results by sports, the percentile distribution was established for Z and the PA, in the percentiles (p) 5, 10, 25, 50, 75, 90 and 95. From these, the following channels emerged: C1 (<5p), C2 (5-10p), C3 (10-25p), C4 (25-50p), C5 (50-75p), C6 (75-90p), C7 (90-95p), C8 (>95p).

To establish the central trend of the Phase Angle, the Body Impedance and the BMI for each sport, the average (X) was used, and the variability index used was the coefficient of variation (CV).

Results

Anthropometric characteristics and bioelectrical parameters (50Hz)

Table 2 displays the descriptive statistics of the anthropometric characteristics and bioelectrical parameters subdivided by sex.

Male athletes had a significantly higher average height and weight than female athletes (p = 0.00), proving that weight-height dimorphism does exist in both parameters. The body mass index revealed similar average values, but significantly different between both sexes (p = 0.00).

The bioelectrical parameters of the sporting demographic studied, at the frequency of 50Hz, were represented by a significantly lower resistance upon passing the current for males (506.2Ω <628.0 Ω) compared to females (p = 0.00). The Xc revealed higher opposition upon passing the current, due to the capacitance of these tissues and the cell membranes in females (63.7Ω >58.9Ω) (p = 0.00). These differences had a repercussion on the R/H, Xc/H, Z/H, Rp, Xcp, Rp/H, Xcp/E values, which revealed significantly higher average values of resistance, reactance and impedance for females (p = 0.00). The male PA (6.7º) was significantly greater to that found for females (5.8º), revealing greater relative cell mass (p = 0.00).

Table 2. Estimated values of bio-electric parameters at 50KHz (X±SD).

	Male	Female
Weight (kg)	81.0±14.0**	68.0±11.0
Height (cm)	180.0±10.0**	171.0±10.0
BMI (Kg/m²)	24.0±3.0**	23.0±2.0
R (Ω)	506.2±60.7	628.0±69.1**
Xc (Ω)	58.9±6.7	63.7±7.2**
Z	509.6±60.8	632.2±69.0**
R/Height (Ω/m)	280.6±34.7	367.7±41.9**
Xc/Height (Ω/m)	32.7±4.6	37.3±4.8**
Z/Height (Ω/m)	282.6±34.9	369.0±42.0**
PA (º)	6.7±0.6**	5.8±0.6
Rp (Ω)	513.0±61.0	635.0±69.3**
Xcp (Ω)	4444.4±782.0	6334.7±1133.0**
Rp/Height (Ω/m)	284.5±85.1	3716.0±42.2**
Xcp/Height (Ω/m)	2457.7±400.0	3699.7±655.0**

*Significant (p < 0.05); **Very significant (p<0.01)

Results of the parameters based on the Cole-Cole model

These same parameters were also established on the base of the characteristic frequency (Table 3), in order to better characterise the population, and in this case the results were similar to those of 50 kHz.

In the data obtained following the Cole-Cole model (Table 3), it was established that resistance when the frequency tends towards infinite (R∞), resistance when the frequency tends towards zero (R_0) and intracellular resistance (intraR) had significantly lower averages in males (p = 0.00). Also the difference in resistances between both extremes of Cole's arc (ΔR), the radius (r) and the area below the curve were significantly lower for males at the characteristic frequency (p =

Table 3. Values estimated according to the Cole-Cole model in the Cuban athletic demographic of both sexes, established at the characteristic frequency (X±SD).

Variables	Male	Female
R∞(Ω)	446,9±43,0	567,9±46,7**
Rº(Ω)	665,1±43,0	810,1±46,7**
intraR(Ω)	1429,1±272,1	1980,6±402,0**
Mc(nF)	6,9±1,50**	5,3±2,50
Cf (KHz)	44,89±3,9*	43,02±4,6
Z(Ω)559,3±60,0	692,4±73,0**	
PA(º)	6,26±0,61**	5,7±0,70
Depression angle α(º)	0,51±0,17	0,52±0,18*
ΔR(Ω)	209,1±21,7	232,8±24,2**
r(Ω)	84,7±53,1	93,8±57,8**
Area(Ω²)	9857,2±2155,0	11205,9±2305,8**
R∞/H(Ω/m)	369,5±23,9	473,7±27,3**
Rº/H(Ω/m)	247,5±23,9	332,1±27,3**
intraR/H(Ω/m)	793,9±151,2	1158,2±235,1**
Mc/H(nF/m)	3,8±7,0**	3,1±6,5
Z/H(Ω/m)	310,7±40,8	404,9±47,0**

*Significant (p < 0.05); **Very significant (p<0.01)

Figure 2. Differences in the arc of the Cole-Cole model for females (a) and males (b) through the experimental dependence Xc-R.

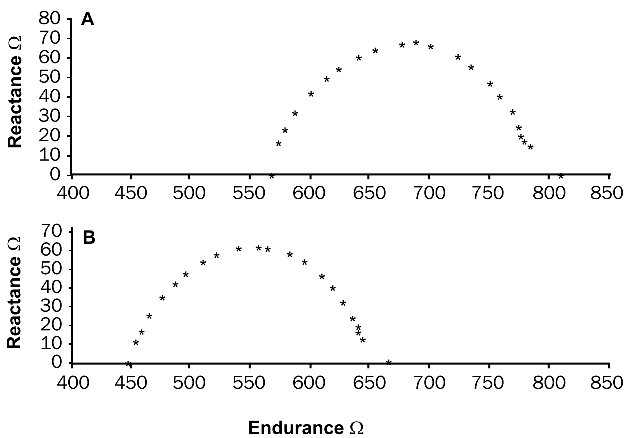
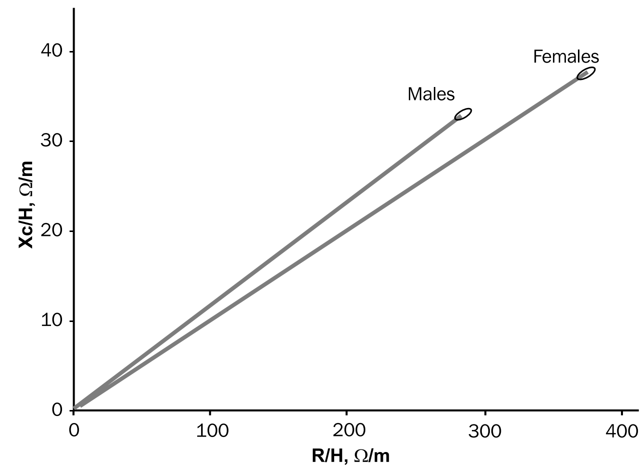


Figure 3. Impedance vector and reliability ellipse at 95% of the Cuban sporting population of both sexes.



0.00). These characteristics increased at the relative indicators R∞/H, Rº/H, intraR/H, Z/H (Ω/m), which revealed significant differences (p = 0.00). Both the PA as well as the membrane capacity in its absolute (Mc) and relative value (Mc/H) revealed significant and higher average values in males (p = 0.00).

The graphic analysis of the Cole-Cole model (Figure 2) revealed differences between male and female resistances: The R∞ value was lower for males, whilst the Xc was maximal, coinciding with the R∞ value for females. On the other hand, the Rº values proved to be considerably greater in females, whilst the maximum Xc value, at the critical frequency, reached much higher ohmic resistance values.

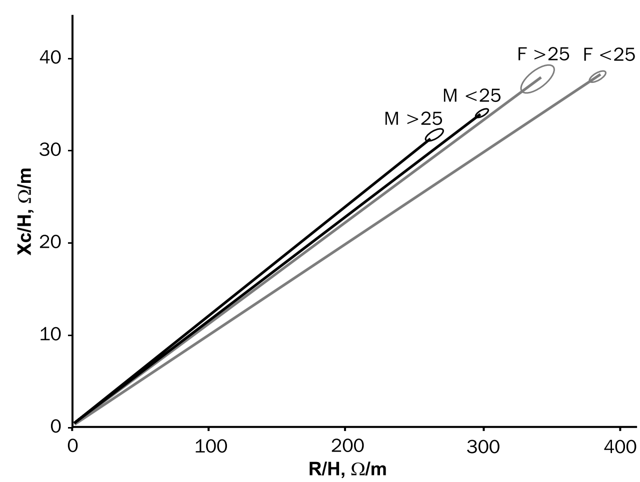
Characteristics of the BIVA vector on a demographic population and in relation to the BMI

The result of the graphic analysis of the BIVA is displayed in Figure 3. This displays the graphs that form the R/H *vs* Ex/H pairs for each sex, in which the average length of the vectors and the confidence ellipse reflect the characteristics of the body composition in the demographic assessed.

Upon analysing the figure, the BIVA vector was longer and had a smaller angle regarding the abscissas for females. The separation of the confidence ellipses between both sexes confirmed the significant differences between then upon establishing the Hotelling T^2 contrast (p = 0.00). The female athletes, in comparison to the male athletes, revealed a larger ellipse, which reflected great heterogeneity in the BIVA characteristics.

The average BMI values for the BMI>25 Kg/m^2 categories were 27.0±2.0 and 28.0±5.08 kg/m^2 for males and females respectively. For the BMI≤25 kg/m^2 category they were 22.0±1.8 and 21.6±2.1 kg/m^2 for the same order of sexes.

Figure 4. Impedance vector and reliability ellipse at 95% of the Cuban sporting population of both sexes, by body mass index groups.



When the effect of the BMI on the BIVA vector characteristics was examined visually (Figure 4), males revealed a shorter length, regardless of the BMI category (M >25, M ≤25) upon comparison with females (F ≤25 and F >25). In males, the vector length was lower for those with a BMI higher than 25 kg/m^2 (M >25), whilst it was slightly higher in females in the same category (F >25).

When the confidence ellipses that form the R/H *vs* Xc/H pairs for each sex were compared, significant differences were found between the BIVA using for the T^2 Hotelling test (p = 0,00). Male athletes revealed

Figure 5. Plotting of the normal phase angle comparing the phase angle values to the normal standard distribution for male subjects (to the left) and female subjects (to the right).

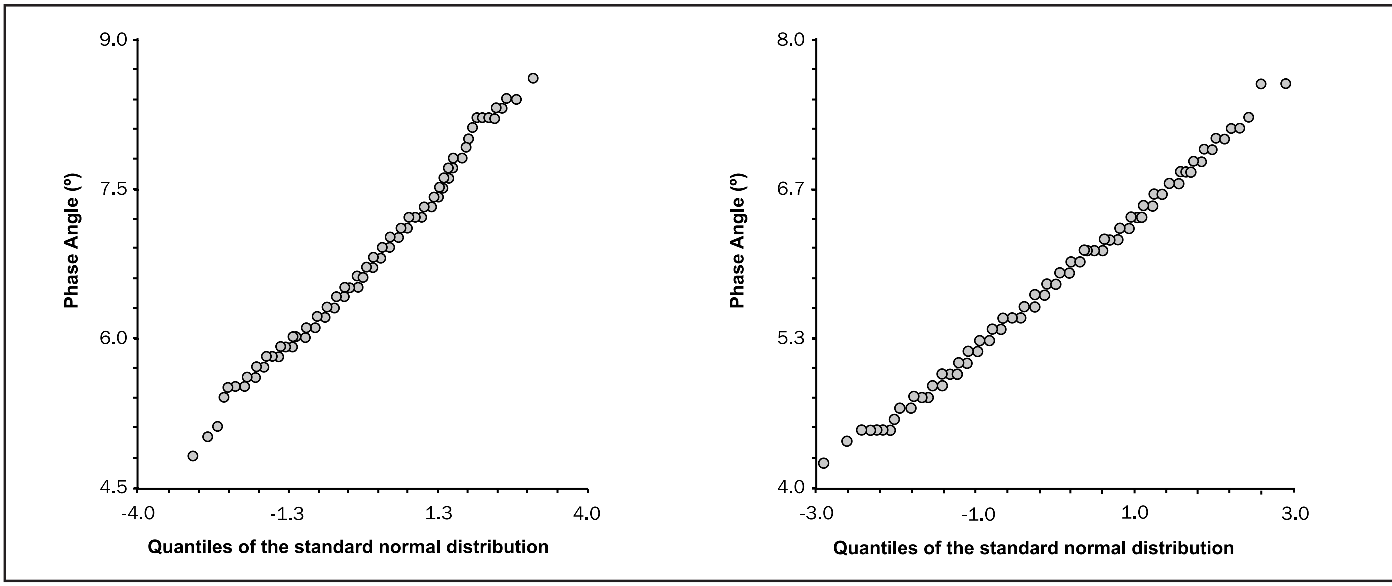
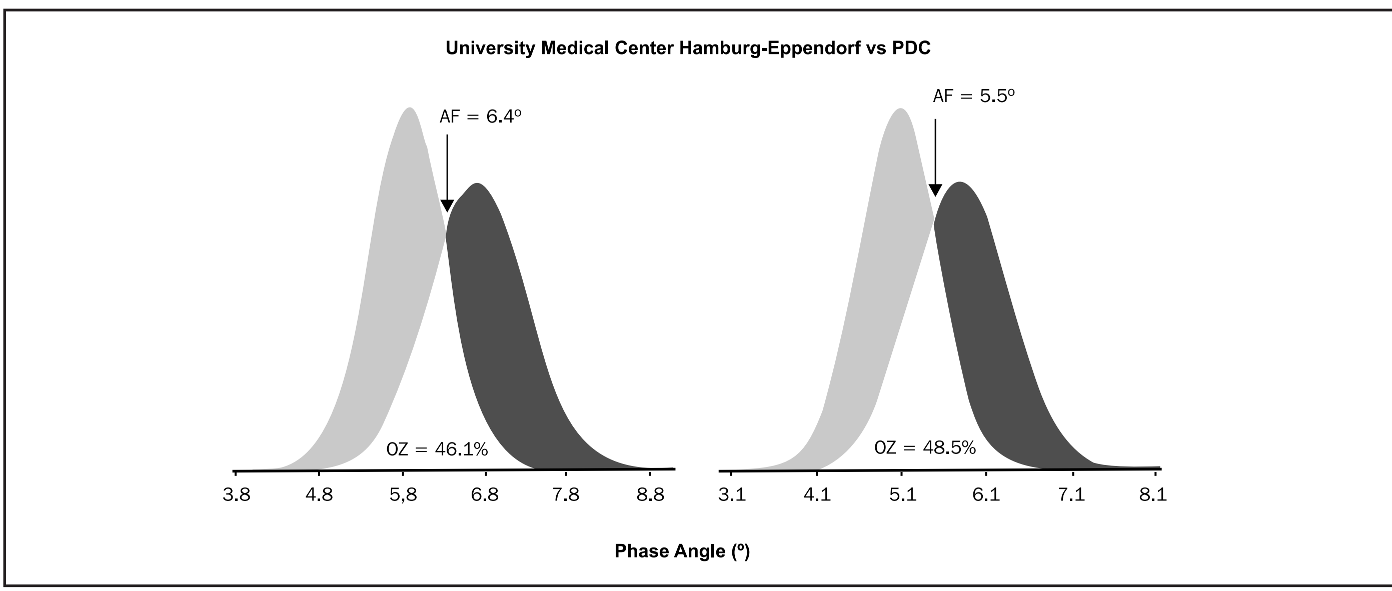


Figure 6. Overlap Zone (OZ) between the sample from the study by the University Medical Center Hamburg-Eppendorf and the PDC. The graph on the left shows the male demographic and the one on the right, the female demographic for both studies.



significant differences between the BMI categories (p = 0.00), whilst differences were found between females athletes from one BMI category to another (p = 0.00).

Demographic characteristics of the phase angle

The average PA value for the male demographic studied (6.7±0.6°) was significantly higher than that of the females (5.8±0.6°)(p <0.05), whilst the quantiles 25, 50 and 75 for males (6.2°-6.70°-7.1°) revealed a wider range than the range for females (5.5°-5.8°-6.2°).

Upon contrasting the average PA values for males with that of the reference male German population (n= 528, PA =5.9±0.5º) significant differences were found (p = 0.00), whilst females revealed the same qualitative result when the Cuban and German populations were compared (n = 518, PA = 5.0±0.5º) (P = 0.00).

Once the normal PA distribution had been verified, in accordance with the Q-Q plotting displayed in Figure 5, the analysis of the demographic overlap between the compared demographics was reflected (Figure 6).

Table 4. Percentiles for the impedance vector and the phase angle in the Cuban sporting population of both sexes.

			X±SD	5	10	25	50	75	90	95
Z	Male	Ω	509.6±60.8	416.7	434.9	476.2	512.3	558.2	602.6	625.3
	Female	Ω	632.2±69.0	512.4	549.1	596.3	634.3	684.1	724.6	768.1
PA	Male	°	6.70±0.6	5.7	5.9	6.2	6.70	7.1	7.3	7.6
	Female	°	5.80±0.6	4.8	5.0	5.5	5.80	6.2	6.6	6.9

Table 5. Descriptive statistic of the impedance vector and the phase angle by sport (X [CV]).

Sport	Male				Female			
	BMI (Kg/m²)	Z (Ω)	PA (°)	EVA	BMI (Kg/m²)	Z (Ω)	PA (°)	EVA
Basketball	24.7 (10.6)	520.3 (7.9)	6.5 (7.4)	C5>C4	24.1 (10.7)	640.6 (7.9)	5.8 (8.2)	C5>C4
Handball	25.6 (11.4)	496.8 (12.7)	6.4 (7.2)	C3<C4	23.2 (9.6)	634.0 (10.7)	5.8 (8.8)	C4=C4
Baseball	27.1 (13.5)	528.6 (14.1)	6.6 (11.0)	C5>C4	-	-	-	-
Boxing	23.5 (12.0)	542.7 (10.9)	6.7 (7.4)	C5>C4	-	-	-	.
Boating	25.1 (6.2)	490.4 (7.8)	7.0 (5.7)	C4<C5	23.8 (7.8)	574.6 (10.3)	6.5 (4.8)	C3<C7
Fencing	23.2 (9.2)	546.7 (9.5)	6.4 (8.5)	C5>C4	22.5 (9.7)	678.9 (7.5)	5.7 (8.5)	C5>C4
Football	23.1 (7.1)	547.0 (8.6)	6.4 (7.3)	C5>C4	22.6 (8.4)	648.7 (11.5)	5.3 (10.4)	C5>C3
Artistic gymnastics	22.8 (5.5)	494.2 (11.4)	7.0 (7.8)	C4<C5	21.2 (0.3)	668.6 (5.1)	7.0 (1.3)	C5<C8
Rhythmic gymnastics	-	-	-	-	18.7 (5.1)	738.6 (8.5)	5.1 (6.8)	C7>C3
Weight lifting	29.5 (15.2)	423.8 (10.6)	7.7 (7.6)	C2<C8	27.0 (16.4)	554.7 (10.0)	6.8 (7.1)	C3<C7
Hockey	23.4 (8.3)	538.6 (8.0)	6.6 (8.5)	C5>C4	22.3 (7.7)	639.4 (7.3)	5.6 (8.9)	C5>C4
Judo	27.6 (23.2)	471.5 (9.9)	6.8 (8.5)	C3<C5	25.3 (19.1)	550.2 (9.6)	6.2 (8.8)	C3<C5
Wresting	26.6 (8.2)	464.1 (8.9)	7.0 (6.9)	C3<C5	24.9 (8.7)	565.1 (9.5)	6.2 (8.0)	C3<C5
Synchronised swimming	-	-	-	-	19.1 (8,5)	703.3 (6.6)	5.6 (6.2)	C6>C4
Figure skating	23.3 (2.4)	483.5 (5.2)	6.8 (2.6)	C3<C5	23.0 (5.0)	628.3 (6.0)	5.0 (5.7)	C4>C2
Speed skating	22.4 (8.2)	542.0 (6.9)	6.7 (6.5)	C5>C4	22.6 (0.3)	670.0 (4.3)	6.1 (9.1)	C5=C5
Basque pelota	25.0 (9.8)	512.8 (7.0)	6.6 (9.3)	C5>C4	23.8 (10.2)	645.2 (8.9)	5.7 (6.8)	C5>C4
Pentathlon	22.7 (10.6)	543.5 (9.9)	6.5 (9.9)	C5>C4	22.4 (4.4)	663.2 (8.6)	6.0 (9.9)	C5=C5
Water polo	25.6 (7.7)	498.7 (9.4)	6.5 (7.0)	C4=C4	-	-	-	
Rowing	24.7 (8.0)	504.9 (7.3)	6.6 (7.8)	C4=C4	22.1 (7.1)	625.3 (6.7)	5.8 (7.0)	C4=C4
Table tennis	24.4 (11.6)	554.2 (14.8)	6.6 (8.0)	C5>C4	22.8 (4.8)	650.4 (7.0)	5.7 (9.5)	C5>C4
Sport shooting	25.6 (13.4)	554.6 (12.4)	6.2 (8.7)	C5>C3	23.8 (13.9)	707.4 (7.9)	5.0 (11.4)	C6>C2
Triathlon	23.9 (7.0)	482.6 (7.0)	7.8 (4.2)	C4<C8	21.4 (6.6)	625.3 (3.2)	5.9 (2.6)	C4<C5
Sailing	22.3 (8.3)	558.4 (11.0)	6.5 (6.1)	C6>C4	22.8 (7.0)	596.0 (9.0)	5.7 (11.2)	C3<C4
Volleyball	22.7 (8.0)	550.3 (8.3)	6.3 (6.3)	C5>C4	20.6 (6.6)	667.8 (8.0)	5.6 (5.3)	C5>C4
Beach volleyball	22.8 (10.8)	550.5 (9.1)	6.3 (7.5)	C5>C4	22.2 (6.9)	642.7 (4.9)	6.0 (8.0)	C5=C5

Males revealed a lower degree of overlap in terms of the reference distribution (46.1%) than females (48.5%), however, the distribution for the sporting populations was to the right of the reference values, with the coincidence values of both distributions 6.4 and 5.5º coinciding with the 25th percentile of the distributions of both males and females, respectively.

Reference values for the body impedance vector and the phase angle by sports

Table 4 reflects the percentile range of Z and the PA on a demographic level. The differences between sexes appear reflected descriptively in each percentile of the range.

Table 5 displays the descriptive statistic of the BMI, the Z vector and of the PA, as well as the assessment corresponding to its percentile distribution by sport in accordance with Table 4.

From a descriptive perspective, male athletes specialising in weightlifting, judo, baseball, wrestling, water polo, handball and boating revealed higher average BMI values, whilst female athletes revealed higher average values in weightlifting, judo, wrestling, basketball and boating.

On the other hand, athletes specialising in weightlifting, wrestling, judo, skating, triathlon, artistic gymnastics and boating revealed a more modest Z vector average value than the other sports among males. Coincidently, athletes specialising in triathlon, boating, artistic gymnastics wrestling, judo, figure skating and weightlifting had higher average PA values than athletes from other sports.

Upon establishing the individual characteristics of the Z and PA parameters, in accordance with the standards in Table 4, athletes specialising in weightlifting and triathlon were positioned in the C2 and C4 percentile channels for Z length, and C8 for the estimated phase angle average (Table 5).

For females, athletes specialising in weightlifting, wrestling, judo, triathlon and boating revealed a more modest Z vector average value than the other sports. Coincidently, athletes from boating, artistic gymnastics, wrestling, judo and weightlifting had higher average values for the PA.

The percentile distribution of the average estimated value for each sport produced more extreme Z and PA values, and weightlifting and boating were positioned in the C3 channel for Z length, and C7 for the estimated average PA value, whilst the distribution of those of rhythmic gymnastics was opposite. Athletes from artistic gymnastics revealed a C5<C8 distribution (Table 5).

Discussion

This research promotes the use of bioelectrical parameters of the body composition via BIA. This establishes the standards in a specific, previously unstudied demographic using this technology.

A clear sexual dimorphism was discovered in the parameters studied, as well as differences between subjects with different levels of Body Mass Index and belonging to different sports. This aligns with that found in specialised literature for healthy subjects[15,16].

Upon comparing the values obtained for each sex, the absolute and relative differences found in the R and the Xc reflected that there was sexual dimorphism, based on the parameters studied. Núñez *et al*[16] considered that a lower R favours a higher blood supply, facilitating a better conduction of the current, both in the extracellular and intracellular environment.

On the other hand, these authors16 indicate that a greater membrane capacity reflects a higher volume of muscle fibres, due to the fact that this parameter is related to the area and thickness of the body's cell membranes, whilst the lower value of the area below the curve, coincidentally with the R and the radius, could be due to a greater number of mitochondria for producing energy; with the result that the muscle is provided with a more efficient oxidative metabolism, and allowing, by performing to a greater measure, the optimisation of performance in males.

Likewise, the graphic representation of the phenomenon, using the Cole-Cole diagram, facilitated the understanding of dimorphism, providing information about how a lower extracellular and intracellular resistance in males refers to a greater hydration of the extra and intracellular compartments of this sex[16].

Hyper-hydration or dehydration can be assessed based on the shortening or lengthening of the impedance vector, whilst the variation of the amount of soft tissues can be assessed via the variation of the phase angle[5,15,17]. In this respect, greater hydration was observed among males, regardless of the BMI value. This indicator also predicted the state of hydration by establishing that those with a higher BMI were more hydrated, regardless of the sex.

On the other hand, with the BIVA vector analysis, the differences in the body composition between both sexes were confirmed. The shorter vector, associated with a high BMI value, suggested less fatty mass, whilst the ellipse of the smaller size indicated greater uniformity in the body composition for males in any of the graphic representations carried out.

The average values found for the PA in this study (6.7º and 5.8º) were much lower than those reported by Barbosa-Silva *et al*[18] for the American population of males (8.02º) and females (6.98º), whilst the values found in the German population[19] for males (6.89º) and females (5.98º) were similar to the estimates obtained in this study. Kyle *et al*[20] reported values of 7.5º and 6.6º for the Swiss population of males and females, respectively. The values found in this research study coincided with those reported among the American demographic for the third age, and with those found among the German and Swiss population aged between 50 and 60 years, approximately[18].

In the sporting population, few values relating to the PA have been reported. One of the studies found reported values of 6.62º and 6.28º for volleyball players from the Czech Republic and the Russian Federation that were higher than those found for Cuban volleyball players of the same level in this research study (5.6º)[11]. Another research study reported values of 7.0º and 7.7º for pre-juvenile and juvenile Spanish athletes in synchronised swimming[21].

Although a high value for the phase angle reveals development of the cell mass and a good nutritional state, the authors consider that the differences found on a demographic level in the literature prove that this is a good discriminant between individuals of different ethnic origin and physical constitution[7,8,15-17]. Therefore, the differences discovered between the volleyball players studied - the Russians and the Czechs - are not defining in this analysis. Likewise, the same occurs for Spanish synchronised swimmers, who revealed values that were considerably higher than the majority of Cuban athletes[21].

The comparison made with the matrix study by the University Medical Center Hamburg-Eppendorf proved that there are demographic differences for the assessment of the phase angle. Whilst in the German population the normal ranges were between 5.03-6.73º and 4.28-5.82º for the assessment of males and females[14], this research study produced values between 6.02-7.1º and 5.5-6.2º. This suggests that the cut-off points of the analysers like SECA mBCA are specific to the German reference population and overestimate the qualitative assessment of the sporting population.

On an individual level, it was proven that a suitable discrimination can be made with the Z-PA relationship of the state of hydration and nutritional level presented. In the analysis of extreme cases such as rhythmic gymnastics and weightlifting in females, it has been shown that for female rhythmic gymnasts a Z vector located in one of the highest channels (C7) and a PA located in the lowest channels (C3) represent low levels of hydration and cell mass, supported by the low BMI value present. For weightlifting, there was a high hydration and cell quality, based on a greater cell mass and hydrophilic interstitial structure proteins, or a better nutritional state, which suggests that the high BMI can reflect hypertrophy and not obesity. In males, weightlifting revealed the same result as for their female counterparts, whilst sailing athletes revealed an average PA (C4) with a larger Z vector, which reflects the lower quantity of body fluids in this demographic.

The results found on an individual level correspond to those described by Kim *et al*.[17], who were able to establish the relationship between the Z vector and the PA with the body type estimated using the somatotype and the BMI. For this author, low R values and high PA values are associated with artistic gymnasts, whilst low PA and high R values correspond to rhythmic gymnasts, dancers and ballet dancers.

The main limitation posed by this research study radiates in the fact that the results were not compared to those of the general public, which prevents the limits of adaptation to the practice of the sports in the researched environment from being determined. On the other hand, given the extension of the research study, the impact of the sporting factor on the BIVA vector characteristics could not be specified, which would have provided more details about the tissue, cell and molecular characteristics of the body composition under the different training regimes.

Despite that indicated, the research provides results that can be used as references in the clinical and medical-sporting practice, as well as in research studies that require greater reliability than when they use indirect equations available in analysers, as these are extent of assumptions for their determination.

Conclusions

Through the reference values provided it was possible to assess the discriminatory power of the bioelectrical parameters of Bioimpedance, as well as their usefulness in analysing the body composition of the sporting population. The study revealed that the variability of the bioelectrical parameters of Body Impedance, Resistance, Reactance, Phase Angle and the Bioimpedance Vector Analysis depended on the sex, on the body mass characteristics of the demographic studied, and on the sport.

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