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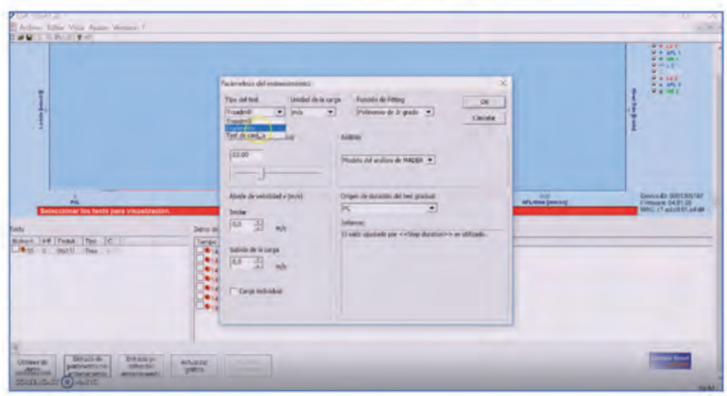

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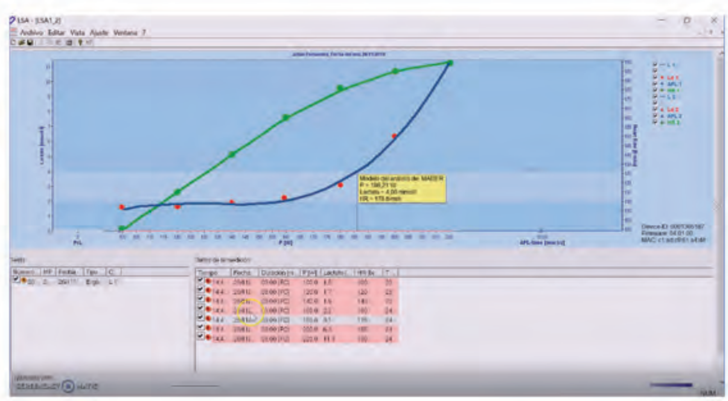

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Summary / Sumario

Do we really study the elite endurance athlete?

¿Realmente estudiamos al deportista de resistencia de élite?

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In the literature on endurance sports, many investigators indicate that an elite population has been studied. To mention an example, a simple search with the terms "elite athletic OR elite athlete AND endurance", shows a total of 2060 hits without limiting the position of any of the words in the document, 4 if they are in the title and 48 if they are located in the title or abstract. Limiting the search to 2018, there are 173, zero and 5, in any place in the text, in the abstract and in the abstract and title respectively.

The narrowing of the search to endurance sports is due to the fact that this is where the highest level of physiological integration occurs. Maximum oxygen consumption (VO_{2max}) is a key performance parameter in endurance sports. VO_{2max} is achieved when all the components of the Oxygen Delivery System (ODS)[1] are functioning at their maximum potential. Naturally, it must be recognised that this parameter is not decisive in winning an Olympic medal. However, in physiological terms, it is a paradigm of the integrated functioning of the body.

Can the athletes analysed in the various studies and investigations really be considered elite? It is our understanding that, to be considered elite, an endurance athlete must have a VO_{2max} of more than 60 ml/Kg/min. Considering marathon runners to represent a paradigm of endurance athletes, the values of these come within a range of 4.15-4.30 L/min or 68.4-80.2 ml/Kg/min. Even though they are unable to actually achieve all the criteria for VO_{2max}, and therefore be VO_{2peak}, the reality is that any athlete not achieving values close to those indicated cannot be considered to be elite.

To cite an example, of the 173 hits consulted in 2018, in some of the studies the sample is not characterised, so that it can hardly be regarded as an elite population. In other studies, given that no gruelling methodology is involved, the subjects may be elite athletes, although no reference is made to the physiological characteristics. These two considerations indicate the relevance of these studies, always strictly referring to whether or not they can contribute to the knowledge regarding the maximal physiological response of the body of an elite athlete. In no event are we downplaying the importance of the objectives of each of these studies. The fact is that, in the studies consulted, there is no adequate substantiation of an elite population.

What could be the reasons for not studying the elite athlete in an investigation? In my opinion, these are as follows:

Generally, the investigator does not provide the trainer with useful information with regard to the athlete's performance at the time of the study nor future prospects.

On occasions, when performing certain tests proposed by the investigator, the athlete may be at an increased risk of injury.

The training conditions of an elite athlete cannot and must not be altered by an investigative study.

When a specific goal (Olympics, world championships, European championships) is at stake for an endurance athlete, then all the reasons listed above make trainers shy away from any investigation proposal. Not even those trainers with sound training in exercise physiology, therefore making the study of interest to them, will authorise their athletes to take part in investigative studies. There is no "reward" whatsoever, particularly with regard to the risks involved for their athletes in taking part in an investigative study. The trainer and athlete would be interested in "physiologically" knowing the optimal physical condition in order to understand the changes caused by training. It is necessary to bear in mind that the optimal condition is reached in a very short

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space of time (20-30 days), however the difference lies in achieving it at just the right moment.

Only two conditions can determine whether or not endurance athletes form a study population: 1) risk to their health and 2) that it could hypothetically benefit performance. For example, with regard to sports cardiology, numerous studies are made with elite athletes in order to determine possible causes of sudden death and how to prevent such causes in sport, and studies to look at the physiopathological repercussion of intensive training. In any case, neither of these two conditions indicated conflict with any of the reasons given above for which I consider that elite athletes are not a study population.

1. The investigator does not provide the trainer with relevant information. The most common physiological parameters for evaluating performance in endurance sports are VO_{2max} and the aerobic-anaerobic transition. Two relevant questions are set out below: 1) Do elite endurance athletes show changes in these two parameters over a season or various seasons? and 2) Are the methods used to determine these two parameters sensitive enough to evaluate elite athletes?

In a review article, Benito *et al*[2] indicate that VO_{2max} shows a very slight variation over a season, although it is true that the highest values are to be found when athletes are "more trained". However, account should be taken of the fact that daily intra-individual variations in the VO_{2max} values can reach 4 to 15% depending on the intensity achieved and the sensitivity of the measuring devices. Therefore, the indication that a certain athlete has a high VO_{2max} value is of no importance to the trainer, given that the measuring methods do not discriminate between small variations in performance through an integration parameter. The trainer obtains more information on the athlete through simpler, but more practical methods such as running speed, critical power and the lactic threshold. All these parameters can be obtained without taking unnecessary risks. Today, technological development makes it possible to perform "effort tests", called "field trials" because they are performed in the athlete's own environment. Although they are unquestionably subject to the same problems as the desktop respiratory gas exchange instruments, they can provide some responses and solutions to the questions raised by trainers.

On the other hand, as indicated by Benito *et al*[2], the aerobic-anaerobic transition experiences a considerable fluctuation between the different training stages. In a review made by these authors, the ventilatory threshold 1 (VT1) ranged from 0.5% to 22% and ventilatory threshold 2 (VT2) from 2.5 to 12.8%. A greater variation was found in the lactic threshold (0% to 36.8%). These differences are attributed to the different process designation of the aerobic-anaerobic transition and to the methodology used to determine it. With regard to this review, particular mention should be made of the work conducted with professional cyclists3. The variation experienced between different periods measured was less than 2%. The relevant point of this doctoral thesis was that no significant differences were found between the optimal physical condition and that of a few months earlier, although there was a significant difference in relation to the situation at the start of the season.

2. Increased probability of injury and adaptation of the investigative study to the schedule Related to the argument above, elite athletes and trainers cannot risk injury by doing, for example, a maximal effort test. Thus, although there are treadmills adapted to athletes, none of these meet two obvious requirements: 1) assurance that an inadequate stride cannot cause an injury of varying severity and 2) the treadmill biomechanics differ considerably from what is performed in the field; in the first case, the supports are to prevent the runner from going backwards while, in reality, the supports are for moving forwards. From a neurophysiological point of view, in other words, the control of movement, there is a huge gulf.

To this problem, we need to add the specificity of the endurance sport. Swimming is the paradigm of specificity. A "specific ergometer" has been developed solely for swimming, known as the swimming flume. However, regardless of the high financial cost of this device, the biomechanical problem of the treadmill is even more evident. It is therefore not surprising that athletes do not maximise their performance when doing a given test and perform tests that are clearly submaximal. When an athlete undergoes an annual sports physical, which includes the effort test with an a respiratory gas exchange analysis, from the point of view of evaluating performance, it should be questioned whether the data provided are relevant to the athlete and his/her trainer when applying such data to training.

Any proposal to conduct an investigation on elite athletes will inevitably have to adapt to the seasonal schedule. So, for example, an athlete whose schedule includes training at altitude at a moderate training load, cannot undergo a study in which high intensity training is proposed. Likewise, when an athlete is in optimal physical condition, it is not advisable to conduct a maximum effort test. Therefore limited "physiological" data are available for athletes in optimal or very good condition.

To sum up, only under exceptional circumstances are the elite athlete population really the subject of an investigative study. From a physiological point of view, the scientific measuring instruments are not precise enough to characterise not only the Olympic or world champion but also any finalist. On the other hand, in methodological terms, once an elite athlete is in top condition, it is complicated to conduct an investigation. Moreover, the risk of injury or altering the schedule makes it practically unfeasible to "conduct a test with the elite". In summary, two examples have been engraved on my mind.

The extraordinary athlete Kenenisa Bekele did an impressive 10,000m race, at a high pace (13 min 40 sec at 5,000) but he was able to do the final kilometre in impressive time (2 min 30 sec). While watching the race on TV, I asked myself "where would he get the energy from to do this impressive change of pace? My next immediate thought was that, assuming that I had the utopian opportunity to study him "to do an effort test on him, even simulated at 10,000 would serve no purpose": It would neither clarify my doubts, nor would he or his trainer gain anything from it, by reducing my information to the banality that he was very good.

On the other hand, on one occasion I had the opportunity to evaluate a cyclist, who went on to win the Tour de France twice. I saw him when he was young, just 16. I can still recall the conversational remarks of his trainer - discoverer at the time. "Javier this boy is grand reserve". What "physiological" basis did the trainer have for affirming the cyclist's potential, if he hadn't even performed the effort test? Naturally, I could make no "physiological" contribution to back-up his trainer's "prediction". Logically, once he had become an elite athlete, I had no chance to make another assessment.

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Effects of three water-based resistance trainings on maximal strength, rapid strength and muscular endurance of sedentary and trained older women

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Summary

Water-based resistance training (WRT) increases strength in sedentary elderly. However, it is not known if this modality promotes strength gains in the trained elderly. In addition, as all the existing studies compared the WRT group with the control group, it is not yet known what the best WRT strategy to promote strength gains in the elderly. Therefore, the aim of this study was to compare the effects of three WRT on the maximal strength, rapid strength and muscular endurance of sedentary and trained elderly women. Twenty-six women were allocated in groups: simple set of 30 seconds (1x30s, 66±1 years), multiple sets of 10 seconds (3x10s, 67±2 years) and simple set of 10 seconds (1x10s, 65±1 years). Training lasted for 20 weeks (two weekly sessions). Assessments were performed after 12 and 20 weeks of training to assess sedentary and trained women, respectively. Maximal strength was assessed by the 1RM test in knee extension, knee flexion and elbow flexion exercises. In these same exercises, the muscular endurance was evaluated, for this, the individual should perform the maximal of repetitions with the load corresponding to 60% of 1RM. Finally, rapid force was assessed by the rate of force development during knee extension. After 12 weeks of training, all groups significantly increased the maximal strength, muscular endurance and rapid strength. However, the groups showed no increase in strength from week 12 to week 20. In conclusion, the three WRT promoted an improvement in strength of sedentary older women, however, they were not efficient in promoting adaptations in trained women.

Key words:
Exercise. Aging. Muscle strength.

Efectos de tres entrenamientos de fuerza en el medio acuático en la fuerza máxima, fuerza rápida y la resistencia muscular de mujeres mayores sedentarias y entrenadas

Resumen

El entrenamiento de fuerza en el medio acuático (WRT) aumenta la fuerza de mayores sedentarios. Sin embargo, no se sabe si esta modalidad promueve ganancias de fuerza en mayores entrenados. Además, como todos los estudios existentes compararon el grupo WRT con el grupo control, aún no se sabe cuál es la mejor estrategia WRT para promover ganancias de fuerza en los ancianos. Por lo tanto, el objetivo del presente estudio fue comparar los efectos de tres WRT en la fuerza máxima, fuerza rápida y resistencia muscular en mujeres mayores sedentarias y entrenadas. Veintiséis mujeres fueron distribuidas en los grupos: serie simple de 30 segundos (1x30s, 66±1 años), series múltiples de 10 segundos (3x10s, 67±2 años) y serie simple de 10 segundos (1x10s, 65±1 años). Los entrenamientos tuvieron una duración de 20 semanas (dos sesiones semanales). Las evaluaciones fueron realizadas después de 12 y 20 semanas de entrenamiento para evaluar mujeres sedentarias y entrenadas, respectivamente. La fuerza máxima se evaluó mediante la prueba de 1RM en ejercicios de extensión de rodilla, flexión de rodilla y flexión de codo. En estos mismos ejercicios, se evaluó la resistencia muscular, para ello, el individuo debe realizar el máximo de repeticiones con la carga correspondiente al 60% de 1RM. Finalmente, la fuerza rápida se evaluó por la tasa de desarrollo de la fuerza durante la extensión de la rodilla. Después de 12 semanas de entrenamiento, todos los grupos aumentaron significativamente la fuerza máxima, la resistencia muscular y la fuerza rápida. Sin embargo, los grupos no presentaron incremento en la fuerza de la semana 12 a la semana 20. En conclusión, los tres WRT promovieron incrementos en la fuerza de mujeres mayores sedentarias, sin embargo, no fueron efectivos en promover adaptaciones en mujeres entrenadas.

Palabras clave:
Ejercicio. Envejecimiento. Fuerza muscular.

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Introduction

Aging causes a decline in different manifestations of muscular strength (maximal strength, rapid strength and muscular endurance)[1-5], which is related to a decrease in functional independence[6-8], a higher risk of falls[9,10] and mortality[11]. Therefore, water-based resistance training (WRT) has been recommended for the elderly in order to soften the deleterious effects of advancing age[12]. The aquatic environment has beneficial characteristics for the training of this public, such as lower joint impact[13], less sympathetic activation and suppression of the renin angiotensin system[14], which reduces heart rate and blood pressure levels[14].

Currently, WRT has been prescribed, as a priority, for set execution time and exercises are performed at maximal execution speed[15-21]. In aquatic environment, the execution speed is the main determinant of the exercise intensity[22]. Thus, it is believed that the higher the execution speed, the greater the intensity of the exercise and, consequently, the greater the stimulus for the increase of muscle strength. In this sense, it is speculated that breaking a set of long duration in multiple sets of short duration will allow a greater speed during the exercise, due to the recovery interval, which can maximize the strength gains. However, this strategy increases the session time required for strength training and, currently, there is a tendency to identify time-efficient interventions because of the shorter time available for exercise. In this sense, it has already been demonstrated that performing one set promotes the same strength gains that perform three sets after 10 weeks of WRT[16,17].

Increases in muscle strength in the first weeks of training are primarily a result of neural factors, such as better recruitment of motor units, better intramuscular coordination and reduction in the coactivation of the antagonist muscles[23]. It is believed that, in the initial stage of training with sedentary individuals, low volume strength training promotes sufficient stimulation to improve these factors as well as high volume training[23]. For this reason, it seems that different training strategies promote the same increases in muscle strength due to the short intervention period and the initial conditioning of the individual, and this result can not be extrapolated to interventions with longer duration. In this sense, identifying the long-term response of a training in individuals already trained is fundamental, since this is the scenario of fitness clubs. However, no study was found comparing different training strategies after a period of more than 12 weeks. Thus, the objective of this study was to compare the effects of three WRT (1x30s, 3x10s, and 1x10s) on maximal strength, rapid strength and muscular endurance of elderly women after 12 and 20 weeks of training, corresponding to a previously sedentary and trained state, respectively.

Material and method

Experimental approach to the problem

This study is a quasi-experimental longitudinal study. To investigate the effects of different WRT on strength in older women, three trainings were performed. Fifteen individuals (67±1 years) were evaluated twice before the start of training (weeks –4 and 0, which served as control period) to test the stability and reliability of outcomes. During the four weeks control period, individuals were instructed to maintain their regular lifestyle habits and no intervention regarding the present study (ie, training session or assessments) was performed. This period served to test the stability and reproducibility of the dependent variables without the practice of physical exercise. All groups (i.e., 1x30s, 3x10s and 1x10s) trained during 20 weeks and each participant were evaluated before, after 12 and after 20 weeks (weeks 0, 13 and 21, respectively) the water-based resistance training. Participants completed all the evaluations within a week with an interval of 48 h between the tests. Each specific test at pre- and post-intervention was over seen by the same investigator (who was blinded to the training group of the subjects in maximal dynamic and muscular endurance tests) and was conducted on the same equipment with identical subject/equipment positioning. Throughout the training period, the water temperature was maintained at 31°C and the water depth in all individuals was fixed between the xiphoid process and shoulders.

Participants

Thirty women aged from 60 to 75 years old volunteered for the study. The participants volunteered for the present investigation following announcements in internet and in a widely read local newspaper. As inclusion criteria, women should not be practicing physical exercise for at least 3 months and present medical permission for exercise. The exclusion criteria included any history of neuromuscular, metabolic or hormonal diseases. The participants were not taking any medication that could influence their hormonal or neuromuscular metabolism and were advised to maintain their normal dietary intake throughout the study. The participants were residents of the city of Porto Alegre and metropolitan region. After pre-training evaluations, the participants were allocated by stratified randomization (randomization.com site) using a 1:1:1 ratio based on the maximum dynamic strength of knee extension to three groups: 30 seconds single set training group (1x30s; n=10), 10 seconds multiple set training group (3x10s; n=10) or 10 seconds single set training group (1x10s; n=10). The individuals were informed about the study and the possible risks and discomfort related to the procedures prior to signing an informed consent form. The study was conducted according to the Declaration of Helsinki and was approved by the research Ethics Committee at the Federal University of Rio Grande of Sul (protocol number 675.861).

After the training period, the 1x30s group showed no sample lost, three individuals were lost in 3x10s group (one due allergy problem, one because surgery was required and one due work) and one individual was lost in 1x10s group (due health problems). Therefore, twenty-six women completed the training: 10 in the 1x30s group, 7 in the 3x10s group and 9 in the 1x10s group.

Procedures

Physical characteristics

Heigth and body mass were measured using an Asimed stadiometer (resolution of 1mm) and Asimed analog scale (resolution of 0.1 kg), respectively. Body composition was assessed using the skinfold technique. A four-site skinfold equation was used to estimate body density[24] and body fat was subsequently calculated using the Siri equation[25].

Maximal dynamic strength (1RM)

Maximal dynamic strength was assessed using the one-repetition maximal test (1RM) on the bilateral knee extension (World-Esculptor, Porto Alegre, Brazil), knee flexion (Können Gym, Porto Alegre, Brazil) and elbow flexion (free weights). The order of the exercises was randomized, alternating upper and lower limbs exercise. The participants warmed up for 5 minutes on a cycle ergometer and performed specific movements for the exercise test. Each individual's maximal load was determined with no more than 5 attempts with a 5-min recovery between attempts. Performance time for each contraction (concentric and eccentric) was 2 seconds, controlled by a metronome (MA-30, KORG, Japan). The 1RM value was considered as the maximal load possible to exert at the concentric phase for a given exercise. Participants were familiarized with all procedures in two sessions one week prior to the test day. The test-retest reliability coefficient (intraclass correlation coefficient, ICC) was 0.93 for the knee extension 1RM, 0.90 for the knee flexion 1RM and 0.98 for the elbow flexion 1RM ($p<0.001$).

Muscular endurance

Muscular endurance was assessed during the bilateral knee extension, knee flexion and elbow flexion. In these test, the participants had to perform a maximum possible number of repetitions with a load equivalent to 60% of 1RM. Performance time for each contraction and the order of the tests was the same used in the 1RM test. In the post-training test, the same absolute load of the first evaluation was used.

Rate of force development

The rate of force development during isometric contraction of knee extension evaluated. The participants were positioned seated on a knee extension exercise machine (Taurus, Porto Alegre, Brazil) with 90° of hip flexion and 60° of knee flexion (0º to full extension) of the dominant member. Strength was evaluated using a load cell (ZX250 alpha) connected to a digital converter. The individuals were instructed to exert maximal strength possible as fast as was possible. Three attempts were performed, each lasting 5 seconds and with 3 minutes interval between them. During the tests, the researchers provided verbal encouragement so that the women would feel motivated to produce their maximal strength. Before the measurement session, a familiarization with the testing procedure was performed. The isometric force–time analysis on the absolute scale included the maximal rate of force development (RFD; N.s-1), defined as the greatest increase in the force (the largest increase in strength at fixed intervals of 20 milliseconds); and, the RFD at 50 and 100 ms, defined as the greatest increase in the force in the first period of 50 and 100 ms, respectively. The RFD variables were calculated from the force onset, which was considered the point that the force exceeded 2.5 times the standard deviations of the mean of the force signal at rest, and were determined using the MATLAB software. The ICC values were 0.95, 0.98 and 0.92 for maximal, 50 and 100 knee extension RFD.

Water-based resistance training

Before the start of the resistance training, individuals completed two familiarization sessions with the exercises they would further perform during the training period and with Borg Scale of Perceived Exertion (6-20). The trainings were performed twice a week, on nonconsecutive days, during 20 weeks. The resistance training was performed in circuit format: the pool was divided into 4 stations and in each station 3 exercises were performed, totalizing 12 exercises (Table 1). A passive interval of 2 minutes was conducted between stations. The participants performed each repetition at maximal effort (index 19 of Borg Scale of Perceived Exertion) and amplitude to achieve the greatest possible velocity of motion and, consequently, greater resistance. The difference between 3 groups was the amount of sets performed or time of execution by set: 1x30s group performed each exercise by 30 seconds once, 3x10s group performed three sets of each exercise for 10 seconds (with a passive interval of 2 minutes between sets) and 1x10s group performed each exercise during 10 seconds once. Verbal encouragement was provided by the instructor during all resistance exercises. Every session, women started training at a different station.

Table 1. Description of the exercises performed in each station.

Station 1	Unilateral hip flexion until 90° with knee extension and after hip extension with the knee extended (right leg) Unilateral hip flexion until 90° with knee extension and after hip extension with the knee extended (left leg) Flexion and extension horizontal of shoulders, simultaneous of both arms
Station 2	Simultaneous hip adduction and abduction of the 2 legs Unilateral elbow flexion and extension(right arm) Unilateral elbow flexion and extension (left arm)
Station 3	Unilateral knee flexion and extension (right leg) Unilateral knee flexion and extension (left leg) Flexion and extension of the shoulders simultaneous of both arms
Station 4	Unilateral hip adduction and abduction (right leg) Unilateral hip adduction and abduction (left leg) Flexion and extension of elbows with abducted shoulders, simultaneous of both arms

Each session was composed of a standard articular warm-up of 7 minutes, resistance training (13 minutes for 1x30s group, 28 minutes for 3x10s group and 9 minutes for 1x10s group) and final stretching (10min). In order to equalize 45 minutes session for the three groups, 1x30s and 1x10s groups performed a relaxation immersion after stretching. The same experienced instructor and monitor in practice of water-based exercises accompanied all the sessions for three groups.

Statistical analysis

To analyze the results, descriptive statistics were used (mean±standard error). Normal distribution and homogeneity parameters were checked using the Shapiro–Wilk and Levene tests, respectively. Baseline comparisons and training frequency were analyzed using one-way ANOVA. Statistical comparisons with the control period (from week – 4 to week 0) were performed using Student's paired t-test. The

ICC test was applied in order to verify the reliability of variables (test and retest) during control period. The training-related effects were assessed using Generalized Estimating Equation (GEE) and Bonferroni post hoc procedures were used to locate the pairwise differences. The adopted level of significance was α=0.05. The SPSS statistical software package was used to analyze all of the data.

Results

The physical characteristics of participants are shown in Table 2. Age, height, body mass, body mass index, fat mass and sum of skinfolds were similar between groups.

During the control period (i.e., between weeks –4 and 0), no significant differences were observed in all variables analyzed (Table 3). During the intervention, the training frequency showed no difference between groups (1x30s: 90.00±1.10%, 3x10s: 89.81±1.79%, 1x10s: 88.61±1.38%, p=0.471).

At baseline, there were no differences between groups in maximal dynamic strength (1RM). After 12 weeks of training, all groups similarly increased the knee extension 1RM (1x30s: 36.00 ± 2.94 to 46.2 ± 2.9 kg; 3x10s: 37.42 ± 3.49 to 43.71 ± 4.08 kg; 1x10s: 34.88 ± 2.99 to 46.00 ± 4.11 kg), knee flexion 1RM (1x30s: 33.80 ± 1.63 to 40.40 ± 2.76 kg; 3x10s: 34.85 ± 3.33 to 41.71 ± 3.04 kg; 1x10s: 33.88 ± 2.64 to 39.88 ±2.56 kg) and elbow flexion 1RM (1x30s: 16.90 ± 0.67 to 19.40 ± 0.83 kg; 3x10s: 15.71 ± 0.83 to 18.42 ± 0.90 kg; 1x10s: 16.66 ± 1.04 to 19.44 ± 1.10 kg). The results of 1RM at week 20 (knee extension: 1x30s: 48.2 ± 3.22 kg, 3x10s: 49.16 ± 3.91 kg, 1x10s: 48.55 ± 4.72; knee flexion: 1x30s: 43.00 ± 3.27 kg, 3x10s: 43.50 ± 2.73 kg, 1x10s: 40.00 ± 2.05 kg; elbow flexion: 1x30s: 19.60 ± 0.87 kg, 3x10s: 18.66 ± 0.45 kg, 1x10s: 20.66 ± 1.29 kg) were higher than pre-training, but did not differ from week 12. 1RM results are shown in Figure 1.

Table 3. Pre- and post-values during the control period (–4 and 0 weeks).

(n=15)	Week -4 Mean±SE	Week 0 Mean±SE	p
KE 1RM (kg)	35.86±2.40	34.93±2.18	0.280
KF 1RM (kg)	32.66±1.86	32.20±1.87	0.587
EF 1RM (kg)	15.86±0.56	15.73±0.51	0.164
KE ME (rep)	10±1	9±1	0.083
KF ME (rep)	11±1	10±1	0.950
EF ME (rep)	12±1	11±1	0.711
RFD 50 ms KE ($N.s^{-1}$)	96.22±35.78	98.18±35.99	0.778
RFD 100 ms KE ($N.s^{-1}$)	187.74±59.45	209.59±57.76	0.339
RFD maximal KE ($N.s^{-1}$)	736.15±191.49	680.55±201.60	0.339

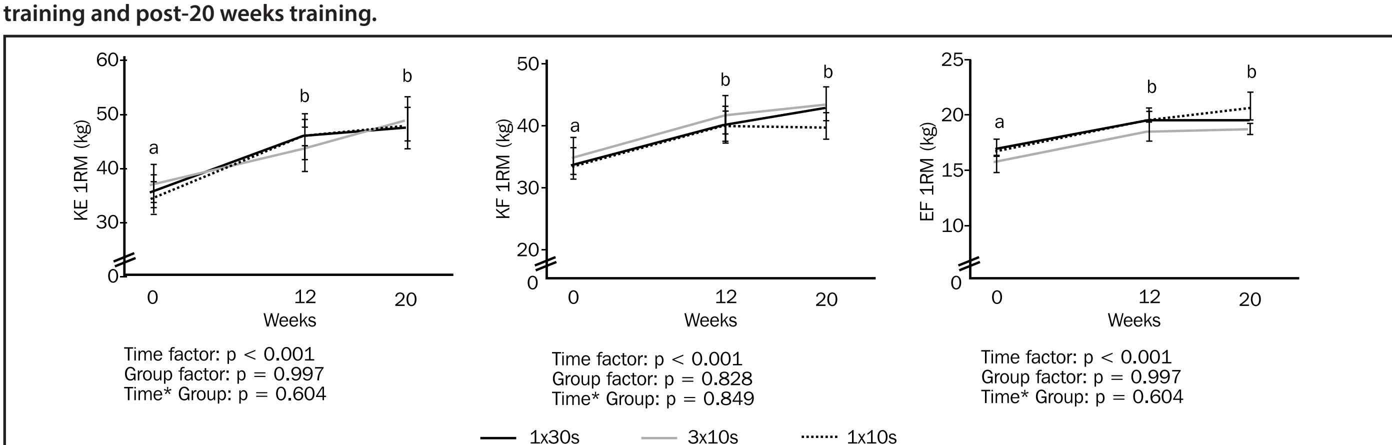
1RM: one maximal repetition, KE: knee extension, KF: knee flexion, EF: elbow flexion, ME: muscular endurance, rep: repetitions, RFD: rate of force development, ms: millisecond.

Table 2. Physical characteristics of participants.

	1x30s Group (n=10) Mean±SE	3x10s Group (n=7) Mean±SE	1x10s Group (n=9) Mean±SE	p
Age (years)	66 ± 1	67 ± 2	65 ± 1	0.683
Height (m)	1.57 ± 0.1	1.55 ± 0.01	1.61 ± 0.01	0.062
Body mass (kg)	68.36 ± 2.60	61.57 ± 3.20	71.08 ± 3.74	0.149
IMC ($kg.cm^{-2}$)	27.72 ± 1.25	25.36 ± 1.21	27.20 ± 1.41	0.463
Fat mass (%)	31.98 ± 1.40	30.68 ± 1.45	33.12 ± 1.18	0.491
∑ skinfolds (mm)	82.10 ± 4.25	77.30 ± 4.11	92.86 ± 6.17	0.212

∑: sum

Figure 1. Maximal dynamic strength of knee extension (KE 1RM), knee flexion (KF 1RM) and elbow flexion (EF 1RM) pre-, post-12 weeks training and post-20 weeks training.



Lowercase letters represent difference in the time factor.

Table 4. Rate of force development and muscular endurance pre-, post-12 weeks training and post-20 weeks training.

	Group (n)	Pre-training Mean±SE	Post-12 weeks Mean±SE	Post-20 weeks Mean±SE	Time	Group	Time* Group
KE RFD	1x30s (10)	136.10 ± 48.5^{a}	376.91 ± 156.16^{b}	401.15 ± 89.05^{b}	<0.001	0.113	0.289
50ms	3x10s (07)	175.55 ± 127.14^{a}	875.54 ± 306.60^{b}	755.27 ± 212.44^{b}			
($N.s^{-1}$)	1x10s (09)	154.75 ± 59.18^{a}	275.32 ± 91.91^{b}	391.29 ± 79.59^{b}			
KE RFD	1x30s (10)	177.17 ± 59.18^{a}	423.24 ± 124.61^{b}	541.00 ± 100.57^{b}	<0.001	0.093	0.240
100ms	3x10s (07)	312.99 ± 158.38^{a}	967.57 ± 257.60^{b}	769.07 ± 183.22^{b}			
($N.s^{-1}$)	1x10s (09)	232.36 ± 83.43^{a}	403.57 ± 136.42^{b}	454.37 ± 77.37^{b}			
KE RFD	1x30s (10)	858.40 ± 231.35^{AB}	862.39 ± 162.62^{AB}	1036.41 ± 177.90^{AB}	0.317	0.015	0.284
max	3x10s (07)	1465.97 ± 367.24^{B}	1721.85 ± 357.62^{B}	1133.71 ± 201.50^{B}			
($N.s^{-1}$)	1x10s (09)	548.09 ± 102.52^{A}	719.46 ± 185.33^{A}	618.18 ± 96.95^{A}			
KE ME	1x30s (10)	9 ± 1^{a}	12 ± 1^{b}	13 ± 1^{b}			
(rep)	3x10s (07)	12 ± 1^{a}	19 ± 4^{b}	14 ± 3^{b}	0.001	0.218	0.752
	1x10s (09)	10 ± 1^{a}	13 ± 2^{b}	13 ± 1^{b}			
KF ME	1x30s (10)	11 ± 2^{a}	15 ± 1^{b}	17 ± 1^{b}			
(rep)	3x10s (07)	12 ± 1^{a}	25 ± 8^{b}	14 ± 1^{b}	0.001	0.711	0.233
	1x10s (09)	13 ± 2^{a}	16 ± 1^{b}	15 ± 1^{b}			
EF ME	1x30s (10)	12 ± 1^{a}	19 ± 3^{b}	19 ± 3^{b}			
(rep)	3x10s (07)	12 ± 2^{a}	20 ± 2^{b}	21 ± 3^{b}	<0.001	0.822	0.622
	1x10s (09)	13 ± 1^{a}	19 ± 2^{b}	17 ± 2^{b}			

Note: KE: knee extension, RFD: rate of force development, ms: millisecond, ME: muscular endurance, KF: knee flexion, EF: elbow flexion, rep: repetitions. Lowercase letters represent difference in the time factor. Uppercase letters represent differences in the group factor.

Table 5. Percentages of significant increase observed in maximal strength, muscular endurance and rapid strength after 12 weeks of training.

	1 x 30 s	3 x 10 s	1 x 10 s
KE 1RM	28 %	17 %	32 %
KF 1RM	20 %	20 %	18 %
EF 1RM	15 %	17 %	17 %
KE RFD 50 ms	177 %	399 %	8 %
KE RFD 100 ms	139 %	209 %	4 %
KE ME	29 %	57 %	32 %
KF ME	40 %	115 %	30 %
EF ME	51 %	69 %	45 %

1RM: one maximal repetition, KE: knee extension, KF: knee flexion, EF: elbow flexion, ME: muscular endurance, rep: repetitions, RFD: rate of force development, ms: millisecond.

The results of RFD and muscular endurance are shown in Table 4. At baseline, there were no differences between groups in the RFD at 50 and 100 ms. There was a significant increase in the RFD at 50 and 100 ms in all groups after 12 weeks of training, and there was a maintenance of those values until the end of training. The maximal RFD showed no difference in the time factor and the 3x10 s group had higher values than the group 1x10 s during the intervention. Muscular endurance showed no difference between groups at baseline. After 12 weeks of training, knee extension, knee flexion and elbow flexion muscular endurance increased significantly in all groups and these values remained constant until the twentieth week of training.

Table 5 presents the percentages of significant increase observed in maximal strength, muscular endurance and rapid strength after 12 weeks of training.

Discussion

The main finding of the present study was that the three WRT promoted similar gains of maximal strength, muscular endurance and rapid strength after 12 weeks of training in previously sedentary older women. This result is important for the elderly population because the maximal strength is inversely associated with the risk of mortality whereas the improvement of the rapid strength and muscular endurance may reflect in a greater ability to perform activities of daily living, greater functional independence and lower risk of falls. However, no adaptation was observed from week 12 to 20, showing that WRT did not stimulate strength gains in previously trained older women.

The results of the present study after the initial 12 weeks of training corroborate other investigations that observed increases of maximal strength in elderly individuals after aquatic training[26-29]. The percentage increases observed in the present study are similar to the ones found by Tsourlou *et al.*[27] (knee extension 29%) after 24-weeks training and higher than those observed by Bento *et al.*[28] after 12-weeks training (knee extension 12 and knee flexion 13%). This divergence is possibly related to the fact that the aforementioned studies used submaximal velocities in WRT, which are not specific for the development of muscle strength, whereas the present study had always used the maximal velocity. In this way, Takeshima *et al*.[26] found increases in the maximal strength similar to the present study (knee flexion 13 to 40%, knee extension 8 to 27%) after a 12-weeks training performed always in maximal velocity. In addition, the maximal execution speed is essential to increase the RFD[30]. Only the study by Bento *et al*.[31] observed an increase in RFD of knee extension (11%), however, the observed increments are much lower than in the present study, which is also attributed to the submaximal velocity used in the cited study. The increment of the lower limbs RFD found in the present study could represent a better capacity of the elderly to perform their daily life activities, making them more independent and less susceptible to the care of others[31]. In addition, a greater capacity to produce strength in a short period of time could serve as a protective mechanism during a possible fall[10], since that the individuals would be able to restore balance more quickly[32].

To the best of our knowledge, this is the first study that investigated muscular endurance in elderly individuals after WRT. Schoenell *et al*.[16] found increases in muscular endurance of knee extension (9-13%), knee flexion (20-33%) and elbow flexion (33%) in young women after 10 weeks of WRT. These percentages of increases are lower than those observed in the present study, which could be attributed to the greater amplitude for improvement of the elderly population. The improvement of muscular endurance is of extreme importance for the older people, once it demonstrates a capacity to produce strength for a longer period and a better capacity to accomplish their daily life activities, like walking, climbing stairs and carrying objects, promoting functional independence to these individuals.

We believed that the 3x10 s group would perform the exercises at a higher execution speed when compared to the 1x30s group, due to the fractionation of the exercise in multiple sets and the recovery interval between them, which could promote greater strength gains. However, similar increments were observed after both WRT, suggesting that perhaps both groups performed the exercises at similar execution speeds, generating the same stimulus for strength development. Similar increases between the 3x10s and 1x10s groups after the initial 12 weeks of training were already expected and corroborate other studies with WRT[16,17].

The results of the present study also demonstrated that, surprisingly, no differences were observed in strength between week 12 and 20 of training. We believed that previously untrained older women who initiated a WRT would increase muscle strength, which would provide a higher execution speed during training in subsequent weeks. This higher execution speed would promote a greater training overload, generating new stimuli for increasing muscle strength. However, this hypothesis is not true, since no increase was observed in any investigated variable from week 12 to 20. However, this result should be interpreted with caution, since it does not mean that WRT does not promote strength increase in already trained individuals, but rather that the same periodization of training (ie, same volume and intensity) prescribed for untrained individuals is insufficient to promote increased muscle strength in trained individuals. Thus, it is speculated that there must be a progression of WRT after the initial weeks of intervention to promote strength gains in trained older women.

Possible limitations of the present study are the small n sample and the absence of neuromuscular and morphological evaluations. We highlight the strengths of the study methods such as randomizing participants between the groups, blinding of assessors to outcomes in maximal dynamic and muscular endurance tests, and description of losses and exclusions. Moreover, the main difference of the present study in relation to previous studies is the longer follow-up, which allowed to evaluate the effect of WRT in sedentary and trained elderly women, adding important information in the literature and contributing to a better prescription of WRT.

In conclusion, 1×30s, 3×10s, and 1×10s training models promote similar increments in maximal strength, rapid strength and muscular endurance after 12 weeks of intervention in previously sedentary older women. As a practical application, the results of the present study demonstrate that it is not necessary to fractionate a long duration set into multiple sets of shorter duration nor to perform multiple series to maximize the gains in strength of sedentary older women. However, after 12 weeks of intervention, the same prescription of volume and intensity in WRT do not promote strength improvements in trained women in already trained women, which shows the need to increase the training overload in this period.

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Conflict of interest

The authors do not declare a conflict of interest.

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Volume load and efficiency with different strength training methods

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Summary

This study compared differences in volume load (VL), efficiency and rating of perceived (RPE) exertion between four different workout methods. Twelve trained men selected by convenience (28.1 ± 4.8 years, 1.72 ± 0.6 cm, 72.2 ± 5.5 kg, 24.4 ± 1.4 body mass index) with at least three years' strength training experience performed the following exercises: biceps curl with a barbell (BC), triceps press using a pulley with a straight bar (TP), seated leg curl (LC), and seated leg extension (LE). Four different workout formats were performed, in a counterbalanced entrance: the traditional method (TM) - three successive sets of each exercise; the paired agonist-antagonist paired set method (APS) - three sets of each exercise alternating between agonist/antagonist muscles (BC/TP and LC/LE); the paired alternating limb method (PAL) - three sets of each exercise in an upper limb/lower limb interaction (BC/LC and TP/LE); and the circuit method (CM) - one set of each exercise repeated three times (BC, TP, LC, LE). The load was held constant at an absolute 15 repetition maximum previous tested, and with one-minute rest intervals between sets and exercises, characterized as an endurance training. Volume load (set x repetition x load), efficiency (VL/workout time) and RPE were recorded. Significantly higher VL and efficiency were observed for the CM versus the TM and APS ($p < 0.05$). The CM was not significantly different versus the PAL. The CM resulted in the best performance when compared to the other methods and can be a good alternative to improve workout volume and efficiency.

Key words:
Resistance training. Strength training. Exercise.

Carga de volumen y eficiencia con diferentes métodos de entrenamiento de fuerza

Resumen

Este estudio comparó las diferencias en la carga de volumen (CV), la eficiencia y la calificación del esfuerzo percibido (CEP) entre cuatro métodos de entrenamiento diferentes. Doce hombres entrenados, seleccionados por conveniencia (28,1 ± 4,8 años, 1,72 ± 0,6 cm, 72,2 ± 5,5 kg, índice de masa corporal 24,4 ± 1,4) con al menos tres años de experiencia en entrenamiento de fuerza realizaron los siguientes ejercicios: bíceps con barra recta (BC), tríceps presione usando una polea (TP), flexión de rodillas sentado (FR) y una extensión de pierna sentada (EX). Estos ejercicios se realizaron en cuatro formatos de entrenamiento diferentes, en una entrada contrapesada: el método tradicional (MT): tres series sucesivas de cada ejercicio; el método emparejado de conjunto agonista-antagonista emparejado (AA): tres conjuntos de cada ejercicio alternando entre músculos agonistas/antagonistas (BC/TP y FR/EX); el método de miembro alterno emparejado (AE): tres series de cada ejercicio en una interacción miembro superior / miembro inferior (BC/FR y TP/EX); y el método del circuito (MC): un juego de cada ejercicio repetido tres veces como un circuito (BC, TP, FR, EX). En todos los formatos de trabajo, la carga se estableció en un absoluto 15 repeticiones máximas antes de la prueba, y con un minuto de intervalo entre los sets y los ejercicios, como un entrenamiento de resistencia. Se registró la CV (series x repetición x carga), la eficiencia (CV/tiempo de entrenamiento) y la CEP. Se observó una CV y una eficacia significativamente mayores para el MC frente a MT y AA ($p < 0,05$). El MC no fue significativamente diferente frente al AE. El MC resultó en el mejor rendimiento en comparación con los otros métodos y puede ser una buena alternativa para mejorar el volumen y la eficiencia del entrenamiento.

Palabras clave:
Entrenamiento de resistencia. Entrenamiento de fuerza. Ejercicio.

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Introduction

Strength training (ST) has been recommended for athletes and practitioners to develop muscle strength, power, endurance, and hypertrophy[1,2]. Several ST prescriptive variables can be manipulated to optimize these outcomes, such as volume load, rest interval between sets, training frequency, load intensity, and exercise order[3]. In this sense, the manipulation and combination of these variables in ST are often expressed in different workout formats[4].Volume load (repetition x loads x sets) is one of the variables often adopted by practitioners to estimate the magnitude of mechanical stress during a ST session and can affect strength or hypertrophy outcomes[5]. Thus, it has been suggested that a higher volume load (VL) stimulates greater strength gains[5-7]. Conversely, training efficiency is the ability to perform a higher VL with reduced workout duration (VL/ workout time in minutes).

In this context, a few training methods have the objective of reducing the workout duration, without comprimising the VL[6,9]. For example, the agonist-antagonist paired set method (APS) is characterized by alternating sets of two exercises for muscle groups with an agonist-antagonist relationship[5.] Robbins *et al*.[6] investigated the effectiveness of the APS method, measuring the VL and efficiency versus the traditional method (TM). As a result, bench pull exercise (alternating bench pull with bench press), the APS method enabled higher VL and efficiency versus the TM (successive sets). In the bench press exercise, same behavior was observed, with higher VL and efficiency under the APS method versus the TM. Several studies have shown that the APS method is an interesting alternative to improve the VL in a time-efficient manner without compromising strength gains[4-9].

In addition, the circuit method (CM) is often adopted with the objective of reducing workout duration, without compromising workout performance[10]. The CM is traditionally characterized by performing sets of different exercises with relatively shorter rest intervals, lower loads, and higher repetitions per set[10]. However, alterations in the traditional CM has been investigated, as proposed by Alcaraz *et al*.[10] that compared the acute effects of the CM versus the TM with same relative load, using 6-RM loads. For the TM, subjects performed five sets of the bench press with a passive three-minute rest interval between sets. Conversely, in the CM, subjects performed one set of the leg extension and one set of the ankle extension during each bench press rest interval (three minutes), performing a total of five sets to failure. As a result, CM was a time-efficient method, presenting same training volume without compromising the duration of the workout.

However, there is still lack of evidence regarding the acute effect of different ST methods on performance and efficiency[5-13]. Additionally, set configuration is a possibility of manipulation in ST during the prescription, and different combinations can differ acute performance[13,14]. Successive sets, as proposed by TM, are generally prescribed in ST, however, alternating sets as proposed by APS and CM can optimize training volume without compromise session duration[5-12]. In this sense, evidence showing different alternating sets schemes of these training methods may contribute to the body of knowledge for both coaches and ST practitioners. Therefore, the purpose of this study was to compare the VL, training efficiecy (VL/ workout time), and rating of perceived exertion during ST sessions with differing training methods (TM, APS, paired alternating limb, and CM) in trained men. Is was hypothesized that alternating sets methods would result in greater performance with same workout time versus TM.

Material and method

Subjects

Twelve trained men volunteered to participate in this study (28.1 ± 4.8 years, 1.72 ± 0.6 cm, 72.2 ± 5.5 kg, 24.4 ± 1.4 body mass index) and selected by convenience. For the sample size calculation, we used the recommendation of Hopkins *et al*.[15], which considered the smallest and largest main effect (–0.06 and 0.06); and the Type 1 error at 5% and Type 2 error at 25%. Due to the small sample size, this study had internal validation, and the data obtained here should be considered for subjects with similar characteristics. All subjects had previous ST experience (5.5 ± 2.6 years). The anthropometrics measures were done on the first day of the study.

The inclusion criteria were: a) have at least three years of ST experience; and b) to have performed the same exercises required in the present study during their regular exercise program. The exclusion criteria were: a) if they had some positive item in the Physical Active Readiness Questionnaire (PAR-Q); b) reported any kind of injury that could preclude being able to execute the exercises used in this study; c) if they were consuming any kind of ergogenic aids such as creatine monohydrate or anabolic steroids. The conditions of the study were in accordance with the norms of the Brazilian National Health Council, under resolution no. 466/2012, referring to scientific research on human subjects and the Helsinki Declaration.

During the study, subjects were instructed to maintain their dietary habits, to remain properly hydrated and avoid any kind of exercise in the 48 hours prior to each session. All of them reported doing three to five days per week of ST, with one to two hours per session, doing both free weight and machine type exercises. At the time that they were recruited they were doing a hypertrophic phase in a periodized program; with 8-12 repetitions, approximately one-minute rest intervals between sets, three sets per exercise in a split-body routine[1,16] (Table 1).

Procedures

This study utilzed a within subjects repeated measures design, which consisted of a total of six visits on non-consecutive days with 48-72 hours recovery (e.g. Monday, Wednesday and Friday). The first two visits consisted of fifteen repetitions maximum (15-RM) test and retest trials. The last four visits involved performance of four different workout formats in a randomized counterbalanced design.

Table 1. Anthropometric measures of the subjects.

	Age (years)	Height (cm)	Weight (kg)	BMI
Mean ± SD	28.1 ± 4.8	172 ± 0.6 cm	72.2 ± 5.5	24.4 ± 1.4

SD: Standard deviation; BMI: body mass index

Fifteen repetition maximum (15-RM) testing

During the first two sessions, subjects underwent 15-RM test and retest trials to determine the training load for the following exercises in this order: biceps curl with barbell (BC), triceps press using a pulley with a straight bar (TP), seated leg curl (LC) and seated leg extension (LE). These exercises are generally present in training programs and can contribute for better practical applications. There were 48-72 hours interval between the test and retest trials. The 15-RM testing protocol was adapted from Miranda *et al*.[17]. The initial load was estimated based on the weight that the subjects frequently used in their training sessions. Before starting the test, one set was considered a warm-up with 50% of the estimated load. Three to five minutes rest interval was adopted between trials for a better recovery according to proposed by Miranda *et al*.[17]. Between exercises, the recovery period was 10 minutes, adopted to optimize the load for 15-RM. Each subject performed three attempts for each exercise. On the retest day, the same protocol was done to optimize the accuracy of the load achieved for 15-RM. The test was stopped at the moment the subject reached a failure in technique or a repetition maximum. The higher load obtained in both days was used in the experimental sessions.

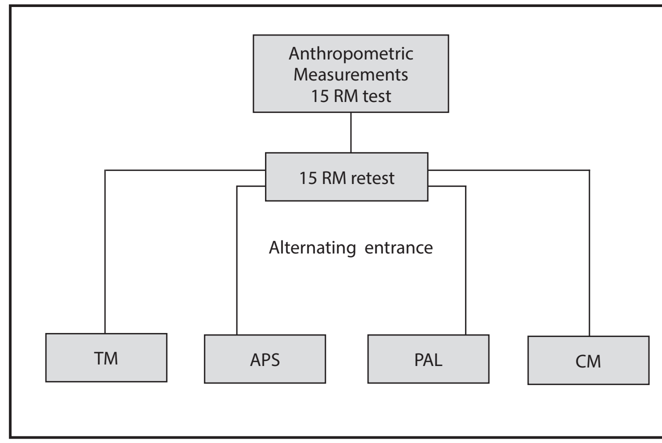
The following strategies were adopted in order to optimize results and reduce the margin of error in testing: 1) the explanation of the testing methodology; 2) standardization and guidance on exercise execution; 3) the researcher carefully monitored exercise execution; 4) verbal encouragement to motivate subjects.

In order to control the performance of each exercise, subjects were instructed to follow these exercise guidelines: the BC was executed with the arms extended along the body and the hands in a supinated position gripping a straight bar. During the concentric phase, subjects flexed their elbows and during the eccentric phase, extended their elbows back to the starting position. The TP was executed using a pulley for which the elbows were flexed statically at an initial elbow angle less than 90º at the starting point, and then fully extended during the concentric phase, and then flexed back to the staring positiong during the eccentric phase. The LC (Cybex International Inc.; Owatonna, Minnesota, EUA) was executed from a seated position with the hips flexed to approximately 90º and the knees extended to approximately 180º. During the concentric phase, subjects flexed the knees and during the eccentric phase, extended the knees back to the starting position. Subjects were instructed to touch the plates when extending the knees back to the start position. The LE (Cybex International Inc.; Owatonna, Minnesota, EUA) was executed from a seated position with the hips and knees flexed to appoximately 90º. Subjects fully extended their knees during the concentric phase and then flexed their knees to return to the start position.

Experimental session

During sessions three, four, five and six, subjects performed four different workout formats in a randomized crossover design with 48-72 hours recovery between sessions. Before starting all experimental sessions, a warm-up was done for the first exercise. In all protocols, the first exercise was the BC, and the warm-up consisted of 50% of the 15-RM for 15 repetitions with 30 seconds to one-minute rest interval before starting the protocol[17]. No attempt was made to control the exercise pace and subjects were instructed to mantain consistent and correct technique.

Figure 1. Schematic representation of the study.



15RM: 15 repetition maximum; TM: traditional method; APS: agonist-antagonist paired set method; PAL: paired alternating by limb method; CM: circuit method.

The following four workout formats were performed: the traditional method (TM)—three successive sets of each exercise; the agonist-antagonist paired set method (APS)—three sets of each exercise alternating between agonist/antagonist muscles (BC/TP and LC/LE); the paried alternating limb method (PAL)—three sets of each exercise in an upper limb/lower limb interaction (BC/LC and TP/LE); and the circuit method (CM)—one set of each exercise repeated three times as a circuit (BC, TP, LC, LE). In all workout formats, the load was held constant at an absolute 15-RM and with one-minute rest intervals between sets and exercises. The volume load (set x repetition x load), efficiency (VL/workout time, in minutes) and rating of perceived exertion (REP) using the OMNI scale were recorded following each protocol. For RPE, a previous orientation was made before starting protocol to familiarize the participants with the OMNI scale (Figure 1).

Statistical analysis

The statistical analysis was performed using SPSS software, version 20.0 (Chicago, IL, USA). The statistical analyses were initially performed using the Shapiro-Wilk normality test and homoscedasticity test (Barlett's criterion). All variables showed normal distribution and homoscedasticity. The intra class coeficient correlation (ICC = $(MS_b - MS_w)/[MS_b + \{k-1\}*Ms_w]$) was calculated to verify the reproducibility of the 15-RM test and retest, where MSb = mean-square between, Msw = mean-square within, and k = the average group size. The two-way ANOVA [protocol (4) x sets (3)] for repeated measures followed by Bonferroni post hoc tests was applied to determine if there were significant differences or interations in repetition performance between protocols and sets[1-3]. The two-way ANOVA for repeated measures followed by Bonferroni post hoc tests was used to determine if there were significant differences or interations between protocols for VL. The value of $p \leq 0.05$ was adopted for all interferential analyses to establish the significance between comparisons.

Results

The ICC for the 15-RM test and retest trials ranged between 0.90 to 0.98. The 15-RM training loads were: BC (10.7 ± 3.1kg), TP (24.4 ± 4.3kg), LC (114.5 ± 21.7kg), LE (155.8 ± 34.3kg).

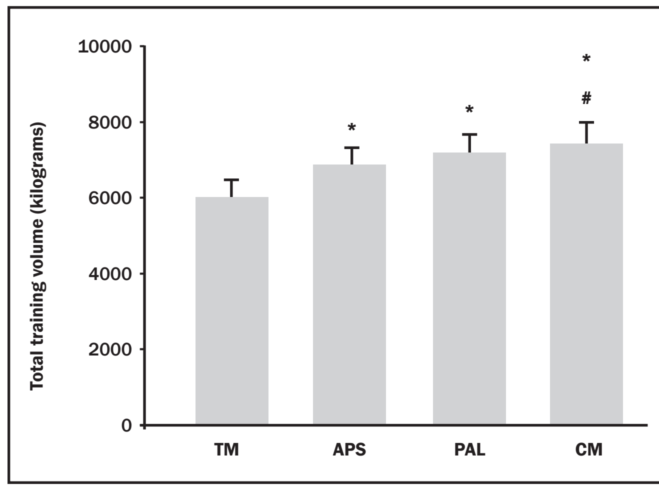
The two-way ANOVA showed significant differences between protocols in total repetitions for the BC (F = 18.264; p = 0.0001), TP (F = 18.992; p = 0.0001), LC (F = 11.966; p = 0.0001), and LE (F = 20.323; p = 0.0001; Table 2). When considering the repetition results for the BC exercise, higher repetition performance was noted under the APS (p = 0.012), PAL (p = 0.003), and CM (p = 0.000) protocols versus the TM protocol. The CM protocol also showed significant increases in total repetitions versus the APS (p = 0.023). For the TP exercise, greater total repetitions were noted under the APS (p = 0.006) and CM (p = 0.0001) protocols versus the TM protocol. The CM protocol also showed significant increases in total repetitions versus the PAL (p = 0.002) protocol. However, for the LC exercise, greater total repetitions were noted under the PAL (p = 0.006) and CM (p = 0.001) protocols versus the TM protocol. Conversely, the LE exercise showed higher total repetitions under the APS (p = 0.002), PAL (p = 0.000) and CM (p=0.000) protocols versus the TM protocol.

For the VL results, the two-way ANOVA showed significant differences between protocols for the BC (F = 16.868; p ≤ 0.0001); TP (F = 17.545; p = 0.0001); LC (F = 11.766; p = 0.0001); and LE (F = 16.193; p = 0.0001). When considering the VL results for the BC exercise, a higher VL was noted under the PAL (p = 0.007) and CM (p = 0.000) protocols versus the TM protocol. The CM protocol also showed a significant increase in VL versus the APS (p = 0.019) protocol. For the TP exercise, higher VL results were noted under the APS (p = 0.008) and CM (p = 0.000) protocols versus the TM protocol. The CM protocol showed significant increases versus the PAS (p = 0.004) protocol. For the LC protocol, higher VL results were noted under the PAL (p = 0.005) and CM (p = 0.002) protocol versus the TM protocol. However, for the LE exercise, higher VL results were shown in the APS (p = 0.004), PAL (p = 0.002) and CM (p = 0.000) protocols versus the TM protocol.

Regardless of these differences, when analyzing the session total training volume [(repetition * load * set) + all exercises)] for each protocol (Figure 2), there were significant differences between protocols (F = 28.477; p = 0.0001). Higher total training volume (TTV) was noted under the APS [6930.5 (±458.1) kg; p = 0.005] PAL [7239.2 (±458.1) kg; p = 0.0001] and CM [7507.9 (±501.8) p = 0.0001] protocols versus the TM [6092.5 (±433) kg] protocol. The CM protocol also showed significant differences versus the APS (p = 0.026) protocol.

When analyzing the efficiency (VL/workout time in minutes) of each method (Figure 3), there were significant difference between protocols.

Figure 2. Total training volume, in kilograms, in traditional method (TM), agonist-antagonist paired set method (APS), paired alternating by limb method (PAL) and circuit method (CM).



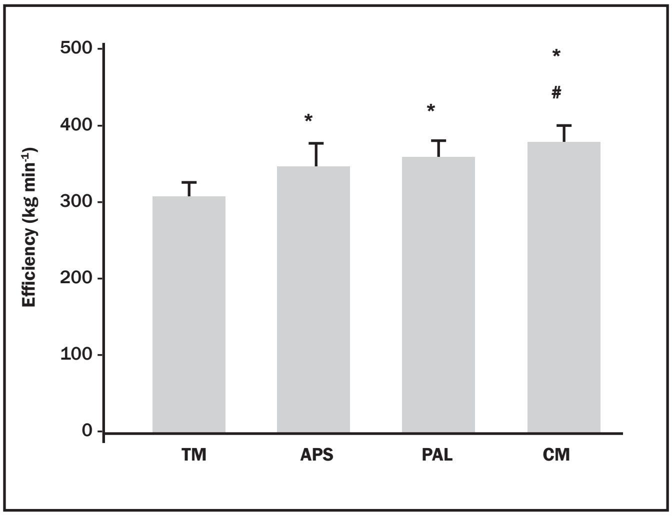
*significant difference for TM; #significant difference for APS.

Table 2. Total work (TW) in number of repetitions and volume load (VL) in kilograms of the traditional method (TM), agonist-antagonist paired set method (APS), paired alternating by limb method (PAL) and circuit method CM. Results expressed in mean (standard deviation).

	Biceps curl	Triceps press	Leg curl	Leg extension
Volume load (kilograms)				
TM	993.7 (290)	825.9 (158.9)	1860.5 (621.1)	2415.5 (732)
APS	1104.3 (235)	983.3 (180.6)*	2069.8 (613.3)	2773.1 (759.8)*
PAL	1149.1 (265.9)*	919 (136.6)	2336.2 (612.1)*	2835.0 (906.2)*
CM	1221.6 (255.1)*#	1074.1 (185.1)*&	2255.0 (722.3)*	2957.4 (847.6)*
Total Work (repetition)				
TM	34.7 (7.6)	34.2 (5.5)	35.2 (7.3)	33.8 (5.3)
APS	38.7 (5.8)*	40.5 (5.2)*	39.2 (7.4)	38.7 (4.4)*
PAL	40.1 (5.8)*	38.3 (6.7)	44.6 (8.4)*	39.3 (5.9)*
CM	42.8 (5.9)*#	44.4 (6.4)*&	42.5 (8.0)*	41.2 (4.5)*

*Significant difference for TM protocol (p ≤ 0.05); #significant difference for APS protocol (p ≤ 0.05). & significant difference for PAL protocol (p ≤ 0.05).

Figure 3. Training efficiency (total training volume/workout time in minutes) in traditional method (TM), agonist-antagonist paired set method (APS), paired alternating by limb method (PAL) and circuit method (CM).



*significant difference for TM; #significant difference for APS.

Higher results were noted under the APS ($p = 0.005$), PAL ($p = 0.000$) and CM ($p = 0.000$) protocols versus the TM protocol. The CM protocol also showed significant differences versus the APS ($p = 0.02$) protocol. The results of RPE, in median (minimum – maximum) for each protocol were: TM = 7.5 (5 – 10); APS = 8.0 (5 – 10); PAL = 8 (6 – 10); CM = 8.5 (8 – 10). No significant differences were observed between protocols ($p = 0.072$).

Discussion

The main finding of the current study was the higher TTV noted under the APS, PAL and CM protocols versus the TM [6092.5 (±433) kg] protocol. The CM protocol was also significantly greater versus the APS ($p = 0.026$) protocol. In summary, the TM protocol showed the lowest total TTV and efficiency, while the CM protocol showed the highest total TTV and efficiency (Figure 1 and 2).

In the present study, the recovery period between sets and exercises was similar between protocols; however, exercise order manipulation between training methods was crucial to promote changes in muscle endurance performance. In the TM protocol, the exercise sets were performed successively; conversely, during the APS, PAL, and CM protocols, the exercises were applied in an alternating manner. Higher repetition performance for the APS, PAL, and CM protocols may have been possible due to the greater recovery between like sets.

Previous studies indicated that repetition performance maintenance is impaired when shorter rest intervals (i.e., 30 s to one-min) are adopted between sets for the same exercise or muscle group, likely due to a decreasing concentration of creatine phosphate and elevated H+ concentrations due to rapid hydrolysis of ATP[18-20]. Therefore, performing paired exercise sets for muscle groups may improve muscle endurance performance due to a longer recovery period between like sets.

In a previous study, Schoenfeld *et al.*[21] compared different rest intervals between sets in an eight week periodized program in twenty-one recreationally trained men. The independent variable was the rest interval, where one group adopted shorter rest intervals (one minute) and the other group, longer rest intervals (three minutes) between exercise sets. The ST program was composed of seven different exercises for several muscle groups. Three sets of each exercise were performed for eight to 12 repetitions, and with 10-RM loads. At the beginning and end of the training period, muscle thickness was assessed via ultrasound for the elbow flexors, triceps branchii, and quadriceps femoris. Muscle strength (1-RM) and endurance (50% 1-RM to failure) in the bench press and back squat were also assessed. The authors noted that subjects which adopted the longer rest interval presented greater hypertrophic outcomes in the lower and upper limbs; and improved the 1-RM loads in both exercises tested versus the shorter rest interval group. These findings were attributed to higher VL performed in the longer rest interval training protocol. Although evident the importance of VL on training outcomes, the results of the present study should be carefully considered since only single joint exercises were used and only performance results of acute session were investigated.

Thus, rest interval between sets is important to improve performance, specially considering the VL of training session. In order to investigate different rest intervals, Scudese *et al.*[20] evaluated its effect on the repetition performance over five sets of the bench press exercise with 3-RM loads. Sixteen recreationally trained men performed four protocols with differents rest intervals between sets (one, two, three and five minutes). The protocols that used two, three and five minutes showed greater performance when compared to the one-minute rest interval. However, no significant differences were observed between two, three, and five minutes rest. The present study adopted same rest interval between sets in each method, however, the methods APS, PAL and CM provided longer recovery for the same muscle group. This can justify the findings of higher VL for these methods when compared to TM. Additionaly, this study implemented exercises for upper and lower limbs with an absolute load often prescribed to develop muscular endurance (15-RM), differing from Scudese *et al.*[20] that evalutated high-load training (i.e., 3-RM).

In this context, the APS method has been associated with a higher VL versus the TM. Paz *et al.*[9] compared VL and workout efficiency for the APS method versus the TM for the upper limb musculature in trained men. For the APS method, subjects performed alternating sets of bench press and a wide grip seated row, with two minutes between agonist-antagonist paired sets. In the TM, subjects performed three successive sets of the bench press and then three successive sets of the wide grip seated row, with two minutes of rest between exercise sets. The authors observed higher VL and efficiency under the APS method versus the TM. In the present study, considering the strength performance between methods, the APS method resulted in a significantly lower VL versus the PAL and CM. Important to consider that during lower body multijoint exercises, the APS method presents limitations since coactivation of agonists and antagonists muscles occurs, and PAL can be an alternative for prescription when both limbs were performed in the same training session.

Considering that all training methods investigated had same total sets performed and same rest interval between sets, all the training sessions were performed with the same duration (20 minutes). Thus, CM seems to be a good alternative for increasing the efficiency of ST sessions, perfoming higher VL with same training duration. In a previous study, Alcaraz *et al.*[22] compared the effects of the TM versus the CM over a period of eight months in 33 healthy men experienced in ST. The total session time for the TM was initially 105 minutes and by the end of the study was 125 minutes, since it followed a periodization scheme that increased the number of sets for each exercise. The CM followed the same periodization scheme, but the total session time was initially 55 minutes and at the end of the study was 78 minutes, being a time-efficient method since the VL was not different between protocols. The results showed no differences in strength development between protocols, measured with a 1-RM test for the upper and lower limb musculature in the bench press and half squat exercises, and the CM also showed a better result for body composition improvement. Thus, time-efficient methods can be a good alternative for practitioners that do not have too much time for training, but desire to improve strength and body composition.

The present study was limited by a small sample size. However, the procedures adopted in the current study had greater practical applications, since the exercises selected are generally prescribe in ST and the methods implemented in this study can be applied in gyms and training centers. However, only single joint exercises were performed, and future investigations should consider different exercises. Future studies should investigate the effect different training methods with a larger sample; novice and trained subjects; and assessing biochemical markers.

Conclusion

In conclusion, the TM condition resulted in the worst performance, and PAL and CM training systems promoted better results, considering the TTV and efficiency. When the goal is to achieve greater muscle endurance performance in a time-efficient manner, the PAL and CM may be a good alternative to be implemented by coaches and practitioners.

Conflict of interest

The authors do not declare a conflict of interest.

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Psychosocial, physical and anthropometric variables in chilean schoolchildren. A comparative study according to physical activity levels

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Summary

Introduction: Physical activity (PA) has multiple benefits for physical and mental health in different types of populations; however, there are no comprehensive evaluations in school population. On the other hand, levels of physical inactivity have generated an increase in childhood obesity worldwide and cardiovascular risk factors, affecting the overall development of children and their quality of life, in addition to a large number of psychosocial components. The purpose of the research was to compare according to levels of PA, psychosocial, anthropometric and physical variables in Chilean schoolchildren.
Method: 605 schoolchildren (272 women and 333 men) between 11 and 14 years of age participated. Self-esteem, body image, cardiorespiratory fitness, blood pressure and anthropometric parameters were evaluated.
Results: The girls presented higher body mass index (BMI) and percentage of body fat (BF), in addition they presented higher risk score of dissatisfaction with the corporal image (p = 0.03), in the self-esteem there were no differences (p> 0.05). PA was higher in children (p <0.001), as were values in systolic blood pressure (SBP) and diastolic blood pressure (DBP) (p <0.05). Children had a higher proportion of school children categorized with high PA (p <0.001). School children with lower levels of PA have higher anthropometric parameters (p <0.001), as well as a higher risk of body dissatisfaction (p = 0.009) and lower self-esteem (p <0.001) and cardiorespiratory fitness (p <0.001).
Conclusion: Schoolchildren with lower PA levels presented negative results in psychosocial variables such as body image and self-esteem, as well as a lower cardiorespiratory fitness and high anthropometric parameters.

Key words:
Obesity. Physical activity. Schoolchildren. Cardiorespiratory capacity.

Variables psicosociales, físicas y antropométrica en escolares chilenos. Un estudio comparativo según niveles de actividad física

Resumen

Introducción: La actividad física (AF) tiene múltiples beneficios para la salud física y mental en distintos tipos de poblaciones, sin embargo, no existen evaluaciones integrales en población escolar. Por otra parte los niveles de inactividad física han generado un incremento de la obesidad infantil en todo el mundo y de los factores de riesgo cardiovascular, afectando el desarrollo integral de los niños y su calidad de vida, además de un gran número de componentes psicosociales. El propósito de la investigación fue comparar según niveles de AF, variables psicosociales, antropométricas y físicas en escolares chilenos.
Método: Participaron 605 escolares (272 mujeres y 333 hombres) de entre 11 y 14 años de edad, se evaluó la autoestima, imagen corporal, capacidad cardiorrespiratoria, presión arterial y parámetros antropométricos.
Resultados: Las niñas presentaron mayor índice de masa corporal (IMC) y porcentaje de grasa corporal (GC), además presentaron mayor puntaje de riesgo de insatisfacción con la imagen corporal (p=0,03), en la autoestima no existieron diferencias (p>0,05). La AF fue superior en los niños (p<0,001), al igual que los valores en la presión arterial sistólica (PAS) y diastólica (PAD) (P<0,05). Los niños presentaron mayor proporción de escolares categorizados con AF alta (p<0,001). Los escolares con menores niveles de AF presentan parámetros antropométricos más elevados (p<0,001), así como también, presentan mayor riesgo de insatisfacción corporal (p=0,009), menor autoestima (p<0,001) y capacidad cardiorrespiratoria (p<0,001).
Conclusiones: Los escolares con menores niveles de AF presentan resultados negativos en variables psicosociales como la imagen corporal y autoestima, además de una menor capacidad cardiorrespiratoria y parámetros antropométricos elevados.

Palabras clave:
Obesidad. Actividad física. Escolares. Capacidad cardiorrespiratoria.

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Introduction

There are strong associations between physical activity (PA), obesity and cardiometabolic risk (CMR) factors in children[1,2] because the low levels of PA present today[3,4] have led to a rise in childhood obesity worldwide[5] and an increase in cardiovascular risk factors[6]. At the same time, they have also affected the overall development of children, their quality of life[7] and various psychosocial variables[8].

In general, the literature consistently shows a significant association between PA and different psychosocial variables and mental health, but the research designs are often weak and the effects either small or moderate[9], generating a vacuum in relation to PA levels and variables such as self-esteem and dissatisfaction with body image. These two psychosocial variables are of great importance to the development of schoolchildren, because body dissatisfaction is a good predictor of various mental health risks[9] and self-esteem is related to many positive aspects of mental health and academic achievement[8].

In physical health, blood pressure is an element used to assess the heart's response and high values are of predictive value for the later development of hypertension (HT)[10]. HT is often underdiagnosed in children[11] even though it is considered the most important cardiovascular risk factor in the world[12] and screening and detection in children and adolescents should be a priority.

Physical fitness is another important component of health because the cardiometabolic risk of those children and adolescents who have a higher level of cardiorespiratory fitness (CRF) is lower[13] and, therefore, their cardiovascular profiles are healthier[14]. Consequently, cardiorespiratory fitness is a key contributor to development in this stage of life[15] and assessment at early stages is paramount[16], since risk could be modified, chiefly by improving CRF[17] and also by increasing PA levels.

Most studies of the child population consist of isolated evaluations of physical, anthropometric and/or psychosocial variables relative to PA levels, there existing a vacuum in the literature where all these variables are compared within a school context to appreciate the real damage of low PA levels. For all these reasons, this research aimed to compare psychosocial, anthropometric and physical variables according to PA levels in Chilean schoolchildren.

Material and method

Participants

Participation in the study was voluntary and purposive sampling was applied. The first population included (n = 687) was a fi nite population from 19 academic year groups (approximately 35 students from each year group), all in the registration stage. After applying the inclusion/exclusion criteria, a total of (n = 82) were excluded for different reasons, but mainly because it was impossible to carry out the evaluations on some academic year groups for administrative reasons. In the end, 605 children (272 female and 333 male) from schools in the Chilean region of Araucanía took part.

The inclusion criteria included informed parental consent and the consent of the participant, enrolment in the schools and being between 11 and 14 years old. Due to the voluntary nature of the study, those children who did not meet the requirements were excluded from the research.

The exclusion criteria were: musculoskeletal conditions or any other known medical condition which could affect the performance and health of the participants during the physical evaluation stage; children with physical, sensory or intellectual disabilities were also excluded.

The research respected the agreements of the 2013 Helsinki Declaration and was approved by the bioethics committee of the University of Jaén, Spain. The programme and tests were verbally explained to all the participants before the start of the study.

Instruments

Anthropometric parameters

PBody mass (kg) was measured using a TANITA UM-028 Scale Plus (Tokyo, Japan) with the children barefoot and in underwear. Height (m) was measured with a Seca® 214 measuring rod (Hamburg, Germany), graduated in mm. Body mass index (BMI), understood as body weight divided by height in metres squared (kg/m^2), was used to estimate the degree of obesity, determining the body weight status of the participants using the following rating criteria according to percentile; BMI between p 85 and < p 95: Overweight, BMI > p 95[18]: Obese. Waist circumference (WC) was measured using a Seca® 201 tape measure (Hamburg, Germany) at the level of the umbilicus. The waist-height ratio (WHR) is calculated by dividing WC by height and was used as a means of estimating fat accumulation in the central area of the body, values >0.5 indicating cardiometabolic risk[19].

Cardiorespiratory fitness

Cardiorespiratory fitness (CRF) was measured using the 20m shuttle run test[20] (20mSRT). The participants had to run between two lines 20 m apart, while maintaining the rhythm of the beeps from a pre-recorded CD[20].

Blood pressure

Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured twice after 15 minutes of rest, using widely recognised rating standards for studies involving children and adolescents[12]. An Omron® HEM 7114 digital electronic monitor (Illinois, USA) was used for both measurements.

Physical Activity Levels

Levels of physical activity were measured using the PAQ-C questionnaire for children. The questionnaire has 10 questions and question No. 10 was excluded from the analysis because it asks about illness in the last week[21]. The minimum total score from all responses was 9 points and the maximum was 45; a higher score indicates a higher level of PA.

Self-esteem

Self-esteem was measured using the TAE-Alumno test[22]: a self-report self-esteem test for schoolchildren in years 3 to 8 of primary education in relation to a standard set for academic year and age. 1 point is given for each affirmative answer and 0 points for each negative answer. The raw score is converted into a T-score according to age and each child is classified into one of the following categories. Normal self-esteem: 40 points or higher. Low self-esteem: between 30 and 39 points. Very low self-esteem: 29 points or fewer. The internal consistency of the questionnaire with the current sample was Cronbach's alpha = 0.81.

Body image

The Body Shape Questionnaire designed by Cooper, Taylor, Cooper and Fairburn in 1987 was used to identify dissatisfaction with body image[23]. The questionnaire consists of 34 items which are answered using a six-point Likert scale, where: one = never, two = rarely, three = sometimes, four = often, five = very often and six = always. The maximum possible score is 204 points and the minimum is 34. The scores obtained are classified as follows: a) below 81, no dissatisfaction with body image; b) 81-110, slight dissatisfaction; c) 111-140, moderate dissatisfaction, and d) over 140, extreme dissatisfaction.

Procedures

The previously trained research assistants (evaluators) visited the schools selected during the 2017 Chilean school year and conducted evaluations of children who had parental consent and wished to take part. The evaluations took place in a favourable space provided by the school with optimum temperature and reliable privacy. The evaluations were conducted in the morning during physical education classes.

Statistical analysis

Statistical analysis was performed using STATA v13.0 software. The nominal qualitative variables were expressed as proportions and differences were calculated using the chi-squared test. The continuous variables showed nonparametric distributions and, consequently, were expressed as medians and 5th and 95th percentiles. Differences between groups were determined using the Mann-Whitney U and Kruskal Wallis tests. Spearman's rank correlation coefficient was used to establish the relationship between variables of cardiometabolic risk, physical activity and perceived physical exertion. P-values <0.05 were considered statistically significant.

Results

Table 1 shows a comparison by sex. The girls gave greater BMI and BF (%) values and also scored higher in terms of risk of dissatisfaction with body image than the boys (p=0.03). No differences were noted in self-esteem (p>0,05). PA was higher in the boys (p<0.001), as were the SBP and DBP values (p<0.05).

The proportion of children with higher PA scores was greater in the boys (p <0.001). No differences were observed in weight, CMR, body dissatisfaction and self-esteem (p>0.05) (Table 2).

Table 3 shows that the children with higher PA levels gave lower BMI, WC, WHR and BF values (p<0.001), exhibited a lower risk of dissatisfaction with body image (p=0.009), obtained higher self-esteem scores (p<0.001) and achieved better 20mSRT results (p<0.001).

Figure 1 reveals that those children categorised as having low PA levels were more dissatisfied with their body image (p = 0.009) and had lower self-esteem (p <0.001).

Discussion

This research aimed to compare psychosocial, anthropometric and physical variables according to PA levels in Chilean schoolchildren. The main finding of this study was that the results of those children with lower PA levels were more negative in the psychosocial, physical and anthropometric variables compared to those who did carry out PA. These results are important because they are physical and mental health indicators which affect the overall growth of schoolchildren.

The children evaluated in this research who reported lower PA levels obtained higher scores for dissatisfaction with body image and girls scored higher than boys. While research conducted with Spanish adolescents revealed that body dissatisfaction is negatively associated with PA in both sexes[24], a study with Brazilian schoolchildren showed the same association but with girls scoring significantly higher than boys[25], as did previous research with Chilean schoolchildren[26].

Table 1. Description of the study variables by sex.

Variables	Girls (n=272)	Boys (n=333)	p-value
Age (years)	12 (10-14)	12 (10-14)	0.08
Weight (kg)	50.4 (32.5-72)	49 (33.2-81.7)	0.66
Height (m)	1.53 (1.39-1.67)	1.55 (1.38-1.74)	0.009
BMI (kg/m^2)	21.31 (15.7-30.2)	20.2 (15.3-24.5)	0.05
WC (cm)	71 (59-95)	72 (57-98)	0.30
WHR ($WC/height^2$)	0.46 (0.38-0.61)	0.47 (0.38-0.6)	0.94
BF (%)	24.6 (13.9-35.8)	23.7 (10.5-37.9)	0.02
Body image (score)	48 (34-134)	45 (34-122)	0.03
Self-esteem (score)	52 (33-68)	50 (34-66)	0.73
20mSRT (min)	3 (2-7)	5 (2-10)	<0.001
Physical Activity (score)	31 (10-40)	34 (15-50)	<0.001
SBP (mmHg)	120 (88-135)	123 (96-141)	0.007
DBP(mmHg)	78.5 (54-98)	80 (57-110)	0.01

The data shown represent median and 5th-95th percentiles, p-value, Mann-Whitney U test. BMI: body mass index; WC: waist circumference; WHR: waist-height ratio; 20mSRT: 20m shuttle run test; SBP: systolic blood pressure; DBP: diastolic blood pressure.

Table 2. Frequency of cardiometabolic risk, physical activity and body perception parameters in Chilean schoolchildren.

Variables	Total n=605	Girls n=272	Boys n=333	p-value
Weight category n (%)				0.01
Normal weight	323 (53.4)	143 (52.6)	180 (54.1)	
Overweight	138 (22.8)	75 (27.6)	63 (18.9)	
Obesity	144 (23.8)	54 (19.8)	90 (27.0)	
CMR n (%)				**0.39**
No risk	496 (82.0)	227 (83.5)	269 (80.8)	
At risk	109 (18.0)	45 (16.5)	64 (19.2)	
Body dissatisfaction n (%)				**0.17**
None	525 (86.8)	228 (83.8)	297 (89.1)	
Slight	41 (6.8)	23 (8.5)	18 (5.4)	
Moderate	23 (3.8)	14 (5.2)	9 (2.7)	
Extreme	16 (2.6)	7 (2.6)	9 (2.7)	
Self-esteem n (%)				**0.17**
Normal	535 (88.4)	237 (87.1)	298 (89.5)	
Low	59 (9.8)	27 (9.9)	32 (9.6)	
Very low	11 (1.89)	8 (2.9)	3 (0.9)	
Physical activity n (%)				**<0.001**
≥ 40 high	95 (15.7)	24 (8.8)	71 (21.3)	
20-39 moderate	355 (58.7)	195 (71.7)	160 (48.1)	
<20 low	155 (25.6)	53 (19.5)	102 (30.6)	

The data shown represent number and proportions, p-value, Chi-squared test.

Table 3. Comparison of study variables by Physical Activity Level.

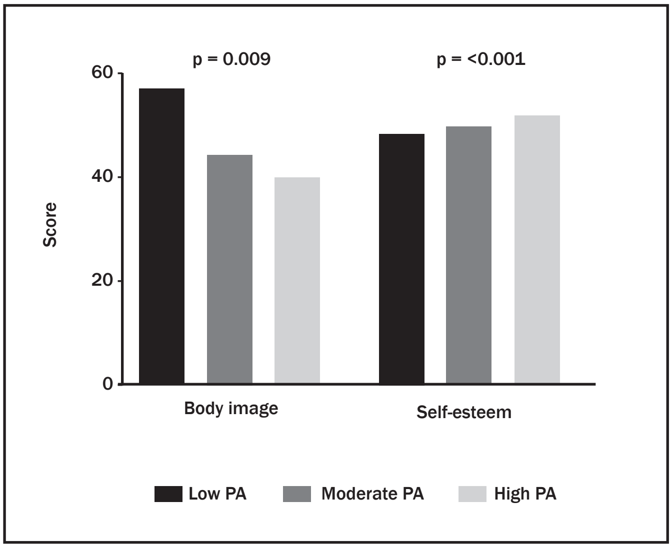
Variables	Low PA < 20	Moderate PA 20-39	High PA > 39	p-value
n (%)	155 (25.6)	297 (49.0)	153 (25.3)	
Age (years)	12 (10-14)	12 (10-14)	12 (10-14)	0.62
BMI (kg/m2)	25.8 (16.0-32.0)	20.46 (15.9-24.8)	19.2 (14.7-27.8)	<0.001
WC (cm)	81 (62- 102)	70 (59-86)	68 (55-90)	<0.001
WHR (WC/height2)	0.53 (0.39-0.64)	0.45 (0.39-0.57)	0.44 (0.37-0.58)	<0.001
BF (%)	26 (16.4-35.1)	23.5 (12.5-38)	22,9 (10.5-39)	<0.001
Body image (score)	57 (34-144)	45 (34-100)	40 (34-106)	0.009
Self-esteem (score)	48 (33-56)	50 (38-68)	52 (39-68)	<0.001
20mSRT	4 (2-7)	4 (2-9)	6 (2-11)	<0.001
SBP (mmHg)	123 (94-147)	121 (89-137)	122 (90-132)	0.41
DBP (mmHg)	80 (57-108)	79 (55-100)	79 (56-100)	0.86

The data shown represent median and 5^{th}-95^{th} percentiles, p-value, Kruskal-Wallis test. BMI: body mass index; WC: waist circumference; WHR: waist-height ratio; 20mSRT: 20m shuttle run test; SBP, systolic blood pressure; DBP: diastolic blood pressure.

The children with lower PA levels scored lower for self-esteem. This is worrying because low self-esteem has been associated with family problems, lower perceived social support and is even considered a predictor of higher suicide rates[27]. A significant association between PA and physical self-concept and its various subdomains has been consistently demonstrated in children and adolescents[9]. Research conducted with Chilean schoolchildren reported a positive relationship between PA levels and self-esteem[28]. Similarly, a systematic review showed that PA interventions led to improvements in self-concept and self-esteem in children and adolescents, and that the best place to carry out such interventions was at school[29].

PA can bring psychological benefits. Literature increasingly suggests that PA may improve aspects of mental health, including depression, anxiety and self-esteem[9]. It has been demonstrated that higher PA

Figure 1. Comparison of dissatisfaction with body image and self-esteem scores by physical activity level.



levels at the ages of 9 and 11 predict higher self-esteem at the ages 11 and 13[30], self-esteem being considered key to academic performance. These findings highlight the need to promote physical activity among adolescents as a way to encourage positive self-esteem.

The schoolchildren with lower PA levels also had lower CRF levels. International epidemiological reviews show that CRF is one of the physiological variables most subject to examination, particularly regarding functional capacity and human performance[31]. Meanwhile, a recent review focusing on adolescents found that certain factors are associated with low CRF levels, such as low PA levels, excessive screen time and excess body fat[32]. In the last three decades, CRF has established itself as a strong, independent predictor of mortality from both all causes and specific diseases, and as a marker for physical health, mental health and cognition[33].

In the sample studied, the children with low PA levels had elevated anthropometric parameters. This result is reinforced in several countries, where a lack of PA increases individual risk factors for developing overweight and obesity[34]. A major study which evaluated children aged 9 to 11 in 12 different countries reported that, along with other associated factors (insufficient sleep and hours of TV), a lack of PA is an important behavioural risk factor[35].

This research did not reveal any comparative differences in SBP and DBP according to PA levels, although it should be emphasised that PA has a beneficial effect on blood pressure in children[36]. One study reported an increased risk of hypertension in people with low PA levels combined with overweight or obesity[37]; these factors also increase the risk of developing diabetes, with higher levels of insulin in the circulation[38].

Finally, associations between PA and different psychosocial parameters can be defended[39]. Increasing PA among children should be a priority, because increasing it at early ages also increases self-esteem later on in life. However, it is also important to note that such interventions should equally emphasise the support of parents and their ability to promote PA in their children by providing positive feedback, serving as active models and facilitating participation in PA programmes[40]. Schools, therefore, would seem to be a favourable environment for such interventions because they are capable of joining up school, teachers, environment, guardians, parents and students.

Limitations and strengths

The main limitation of the study lay in measuring PA levels because this was done through a survey where each of the schoolchildren reported their own activity. One of the strengths of the study was that it was conducted in the school environment with a large sample, making it possible to supply the schools with information and contribute to the development of educational policies to increase PA.

Conclusion

In conclusion, we found that those schoolchildren with higher PA levels obtain better results in psychosocial variables such as body image and self-esteem, in CRF and in various anthropometric parameters. For this reason, it is necessary to encourage an increase in PA at schools, because this tends to improve biopsychosocial aspects, while low PA levels are associated with many negative aspects of health in schoolchildren.

Conflict of interest

The authors do not declare a conflict of interest.

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Original article

Interchangeability of two tracking systems to register physical demands in football: multiple camera video versus GPS technology

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Summary

The main aim of this investigation was to study the agreement between the distances covered at various speeds by professional soccer players in official matches using a Video-based system (VBS) and a Global Position System (GPS), and to create equations that predict distances from those obtained by other technologies. For these purposes twelve professional soccer (La Liga Santander) players' activities in official matches were registered simultaneously with a semi-automatic multiple-camera or VBS (TRACAB®, system offered by Mediacoach®) and GPS (GPEXE®, Exelio, Udine, Italia). The measured variables were the distance covered by the players at various speeds ranges such as: <7, from 7 to 14, from 14 to 21, from 21 to 24, and >24, (all in km•h^{-1}) and as well several time slots (15, 30 and 45 minutes) were considered. The agreement between the distance recorded by VBS and GPS was studied using the Bland-Altman method. Furthermore, calibration equations using linear regression models were calculated in order to allow interchangeability of data from VBS to GPS and viceversa. The results showed that the agreement between VBS and GPS was low due to elevated systematic (from 3.3 m to -164.4 m) and random error (from 29.3 m to 274.8 m). VBS measured systematically more distance that GPS and the difference between VBS and GPS tended significantly to rise as the distance increased. However, the calibration equations were significant ($p<0.05$) and predicted the distance from one system to another well (R^2= 0.55-0.90). In conclusion, the distance recorded by VBS and GPS cannot be used interchangeably and the calibration equations provided by this study should be used to compare or exchange distances between the two systems.

Key words:
External load. Match analysis. Agreement. Calibration equations. Elite.

Intercambiabilidad de dos sistemas de seguimiento para registrar las demandas físicas en el fútbol: video cámara múltiple versus tecnología GPS

Resumen

Los objetivos de este estudio han sido estudiar el grado de acuerdo entre las distancias recorridas a diferentes velocidades por jugadores profesionales del futbol (La Liga Santander) registradas por el sistema semiautomático de multi-cámara (VBS) y el Sistema de Posicionamiento Global (GPS), y encontrar ecuaciones de calibración entre los dos sistemas. Para ello se registraron las actividades de once jugadores profesionales de fútbol en partidos oficiales simultáneamente con el VBS (TRACAB®, system offered by Mediacoach®) y GPS (GPEXE®, Exelio, Udine, Italia). Las variables medidas fueron la distancia recorrida por los jugadores en diferentes rangos de velocidad, tales como: <7, de 7 a 14, de 14 a 21, de 21 a 24, y >24, (todos en km•h^{-1}) considerándose varios intervalos de tiempo (15, 30 y 45 minutos). El acuerdo entre la distancia registrada por VBS y GPS se estudió utilizando el método de Bland-Altman. Además, las ecuaciones de calibración, usando modelos de regresión lineal, se calcularon para permitir la intercambiabilidad de datos del sistema semiautomático a los GPS y viceversa. Los resultados mostraron que el acuerdo entre VBS y GPS fue bajo debido a un elevado error sistemático (de 3.3 m a -164.4 m) y aleatorio (de 29.3 m a 274.8 m). VBS midió sistemáticamente más distancia que GPS y la diferencia entre VBS y GPS tendió a aumentar significativamente a medida que aumentó la distancia recorrida. Sin embargo, las ecuaciones de calibración fueron significativas ($p<0.05$) y predijeron bien la distancia de un sistema a otro (R^2= 0.55-0.90). En conclusión, la distancia registrada por VBS y GPS no se puede utilizar de manera intercambiable y las ecuaciones de calibración proporcionadas por este estudio se podrían usar para comparar e intercambiar las distancias entre los dos sistemas.

Palabras clave:
Carga externa. Análisis de competición. Ecuaciones de calibración. Élite

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Introduction

Monitoring and management of the athletes' workloads has been in the spotlight in recent years[1]. It is important to monitor individual load during training sessions and matches for several reasons: improved performance, management of load distribution, injury prevention and coach feedback[2]. Athletes participating in elite sports are exposed to high workloads and increasingly saturated competition calendars, so poor load management is one of the major risk factors of injury[3].

The analysis of soccer player activity during matches and /or training sessions have been studied using different techniques and instruments[4]. If we refer to the level of human participation in the process of coding and recording the movements of athletes, we could talk about: a) manual technique, which include using pen and paper, accounting for strides, tape recorder usage, observation software or digitizing tablets carry out the recording with greater personal involvement[5]. This technique requires certain inference from the observer to encode and later register the physical variables[6]; b) A second technique, vision-based systems (VBS), using semi-automatic procedures for monitoring players, and where the support of video playback is indispensable and the interpretive work of the behaviour is largely reduced[7] and, finally; c) the third type, the one which uses radiofrequency or telemetry (such as, Global or Local Positioning Systems, GPS or LPS, respectively). This technique allows automatic tracking and monitoring of the movements of players without the intervention of 'intermediaries'. Technology such as GPS and other micro-technology (e.g., accelerometer, gyroscope and magnetometer) produces a plethora of variables enabling practitioners to quantify training load in more detail than ever before[8].

New technology and analytical methods have led to new possibilities on how to monitor load. Currently in high performance, the player activity analysis during matches and/or training sessions can be measured by different tracking technologies[9], such as GPS, LPS and VBS. The recent incorporation of GPS technology in other sports have also led researchers to study their reliability and validity in different settings[10]. The results of this studies showed that the reliability these devices is better in high frequencies[11] when the distance is linear, but not at maximum speeds[12]. Nevertheless, when movement involves high acceleration[13] and/or change of direction[14] patterns, the accuracy could be compromised. On the other hand, LPS uses infrastructure installed in the same place (usually in indoor) without satellites' connection need. This system has several advantages, e.g., high sampling rates, miniaturization of the devices, more accurately[15]. Finally, the VBS monitors the movements of every player and the ball by sampling activity for up to 25 times per second[7]. Although VBS has been used to study the demands of competition in numerous research studies, the reliability and validity of some semi-automatic tracking products has been scarcely and poorly studied[16]. Most of deficiencies of these studies are placed in the statistical analyses used to assess accuracy, reliability, and validity of the tracking systems[17,18].

Despite the fact that the use of GPS devices is currently allowed in official matches (FIFA, 2015)[19], the most players do not wear it as they feel is uncomfortable and might affect their performance (personal communication from professional players). Consequently, teams monitor training load and friendly matches using GPS technology, while the activity of official matches is monitored through VBS (usually is a company who offers the service, such as TRACAB® or ProZone®). Therefore, in order to carry out an adequate management of the workload we must be able to integrate both training and match load. For example, for an adequate use of the acute:chronic load ratio for a longitudinal assessment of workload it is necessary to introduce in the model both training and match loads[20], because load management is emerging as one of the main risk factors in no contact injuries[1]. This workload should be included in return to play decision-making process[21] so it is essential to be able to integrate and compare GPS and VBS data.

Increasingly national leagues have agreements with companies that analyze team´s match loads (TRACAB®, OPTA®, INSTAT®, ProZone®...) and the use of this type of technology will be accessible to all teams belonging to La Liga. Therefore, it becomes relevant to study the relationships between variables registered by different VBS and GPS systems. The interchangeability and comparison between systems would be also applicable in talent identification programs. When a sport club is interested to know the activity of a young athlete in competition (measured with GPS) and compare it with professional player´s activity (measured through VBS) interchangeability and comparability plays a key role.

For these reasons systems interchangeability could be a timely solution for fitness coaches. The agreement between semi-automatic VBS and GPS has been examined in different studies[22-24]. All of them showed that both systems do not adjust well enough and so the data interchangeability has to be done carefully and comparison of the outcomes. Randers *et al.*[24] and Buchheit *et al.*[22] compared four systems in friendly match and training tasks respectively, showing big differences in some variables such as total distance and distance covered at high speeds. The studies showed that there is less agreement in velocity than in distance, and that these difference tend to increase as the magnitude (distance and time) increases. The advantage of Buchheit *et al.*[22] is that they provided calibration equations that can be used to predict the results that could be expected with a given system from the data collected by another system.

Accordingly, the primary aim of this study was to determine the agreement between VBS and GPS quantifying the amount of systematic and random errors between the distances covered by professional soccer players at various speeds and time slots. We hypothesize the correlation between two systems will be adequate so, the second aim of this research was to create an equation that predicts the distances from VBS to GPS data and vice versa.

Material and method

Participants

Twelve professional male soccer players (25.0±4.0 y, 76.9±6.8 Kg, and 184.1±6.4 cm) from La Liga Santander, Spain's top soccer league were monitored during three official matches, placed in the middle of the first round of the championship, during the 2016-17 season. In total, 116 records of 15-minute slots, 52 of 30-minute slots and 15 of 45-minute slots were analysed. The study was conducted in accordance to the Declaration of Helsinki (2008), and the Ethics Committee of the

University of the Basque Country (CEISH) giving institutional approval for the study (CEISH/235).

Variables

Similar to previous works[25,26], the variables analyzed were the distances covered by players during official matches at various speed ranges: total distance (TD) and distance covered at less than 7.3 km•h^{-1} (0to7), between 7.3 to 14.0 km•h^{-1} (7to14), between 14.0 to 21.0 km•h^{-1} (14to21), between 21.0 to 24.0 km•h^{-1} (21to24), and at more than 24.0 km•h^{-1} (>24).

Both GPS and VBS systems registered the distance in 15-minute time slots (e.g., 0-15', 16-30', 31-45', 46-60', 61-75' and 76-90'). Only periods that the player completed were included in the analysis. The analysis performed in 15-minute, 30-minute and 45-minute time slots at the above-mentioned speeds that are commonly used in football match analysis to assess performance or fatigue[27-29].

Procedure

The players wore the same device of GPEXE PRO (Exelio, Udine, Italia, GPEXE®) and were also tracked using the TRACAB® system managed by Mediacoach® on each match. Each GPS unit was placed between shoulder blades using a specially designed vest. In accordance with the manufacturer's instructions, GPS devices were activated 15 min prior to the start of the match. At the end of the match, data from GPS was downloaded to a PC and processed using the software provided by GPEXE® (The Power Tracker for GPEXE). The GPS files were manually cut considering the starting point the displacement of the players at the beginning of the match. From this starting point, 15-minute time slots were stablished. No extra time was included for analysis. In order to assess the reliability of this procedure all GPS data was processed by two independent researchers. A high correlation coefficient (0.94) was found between the two and therefore the data from one of the researchers was included in the study. The VBS data was provided by TRACAB® (managed by Mediacoach®, Mediapro®, España).

Data analysis

To determine the agreement (the amount of systematic and random error) between VBS and GPS, the Bland and Altman method[30] was used. Repeatability coefficient (RC), bias or systematic error (SE), lower and upper limits of agreement (LOAs) and upper and lower confidence intervals at 95% for SE and LOAs were calculated. These results were accompanied with Bland-Altman plots. This analysis was performed using the MedCalc® program for Windows version 12.2.1.0 (Medcalc software, Mariakerke, Belgium). To determine whether the systematic error between devices was significant, a paired t-test was performed. In order to check that there was no relationship between the difference between systems (VBS *vs* GPS) and the magnitude (distance) Bland-Altman plots were checked and a linear regression was also performed[31]. In the regression analysis the difference between systems was defined as the dependent variable and the mean of both systems as the independent variable. The significance level for the t-test and the regression was set *a priori* at $p<0.05$.

In order to create an equation that would allow for predicting the distance from one system to another, linear regression equations were created. These equations would allow for converting the distance registered from GPS to VBS or vice versa.

$$GPS = a+b\,(VBS)$$

$$VBS = a+b\,(GPS)$$

The significance level for this regression analysis was set *a priori* at $p<0.05$. The typical error of the estimate (TEE) or the residual standard error and adjusted R square were also calculated. Paired t-test analyses and all regression analyses were conducted in R (3.3.3 version) using base package and R studio (1.0.136 version).

Results

Descriptive analysis

In the Table 1 it can see the descriptive values, mean and standard deviation (sd) in meters, for each time slot and tracking system (VBS and GPS) considering the different velocity ranges.

Agreement between VBS and GPS

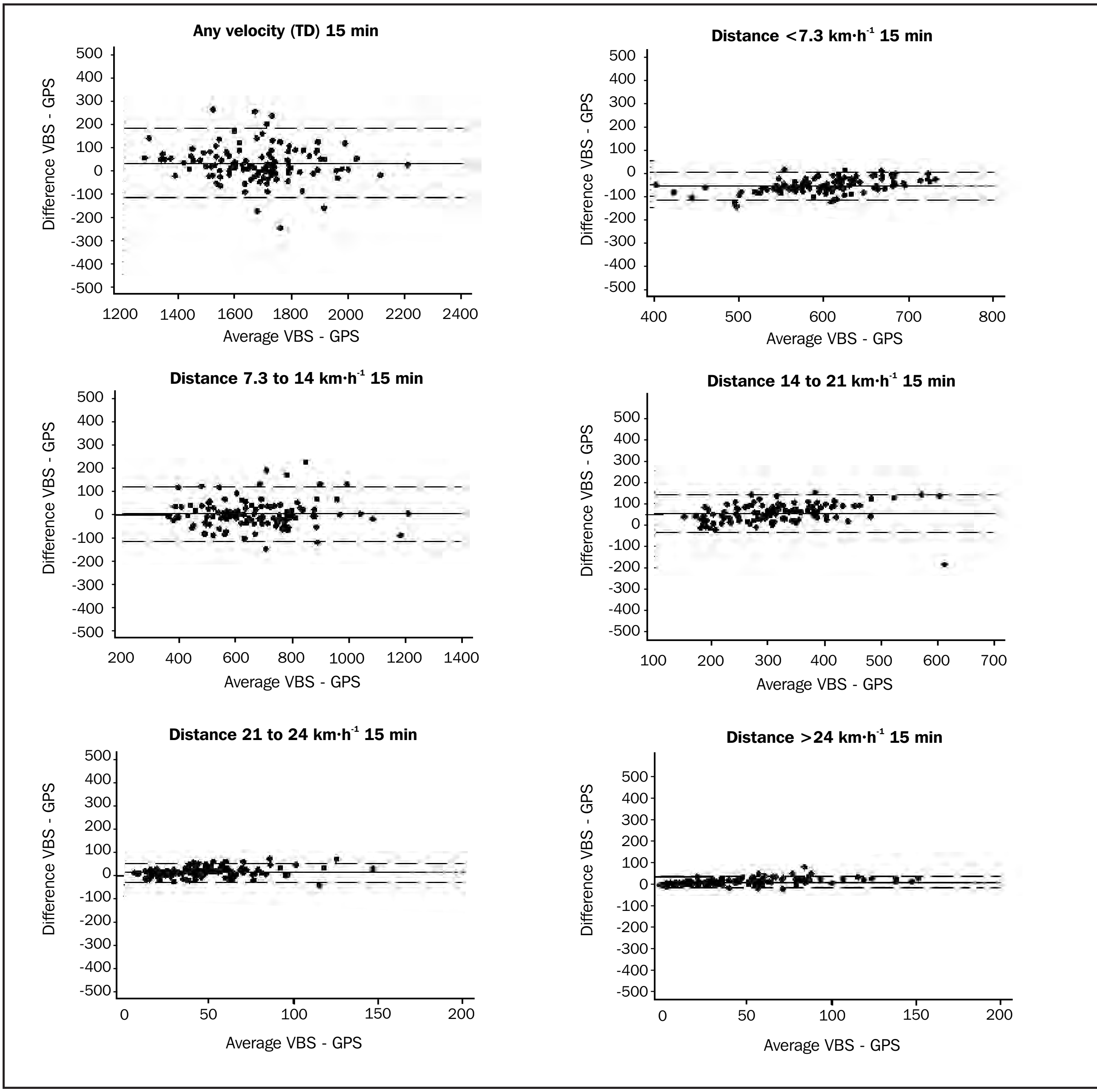
As for the systematic error, Bland-Altman analysis showed that VBS tends to measure systematically more distance that GPS at all speeds (except from 0 to 7.3 km•h^{-1} where GPS measure more than VSB) in the three time slots analysed in this study (Figures 1, 2 and 3). According to

Table 1. Descriptive values (mean and standard deviation, sd) in meters, for each time slot and tracking system (VBS and GPS) considering the different velocity ranges.

		VBS		GPS	
Time Slot	**Velocity range**	**mean**	**sd**	**mean**	**sd**
15 min	TD	1685.4	296.4	1663.4	316.2
	0to7	568.7	70.6	627.5	56.0
	7to14	678.2	170.3	663.1	168.6
	14to21	335.3	97.0	283.3	78.2
	21to24	48.9	30.9	45.6	25.6
	>24	52.6	39.0	38.6	32.0
30 min	TD	3399.2	296.4	3357.2	316.2
	0to7	1130.4	127.5	1250.3	98.2
	7to14	678.2	170.3	663.1	168.6
	14to21	335.3	97.0	283.3	78.2
	21to24	48.9	30.9	45.6	25.6
	>24	52.6	39.0	38.6	32.0
45 min	TD	5106.1	445.0	5079.3	447.9
	0to7	1743.0	172.9	1907.4	150.8
	7to14	678.2	170.3	663.1	168.6
	14to21	335.3	97.0	283.3	78.2
	21to24	48.9	30.9	45.6	25.6
	>24	52.6	39.0	38.6	32.0

VBS is video-based system (TRACAB®) and GPS is global position system (GPEXE®).

Figure 1. Bland-Altman plots VBS vs GPS at 15 minutes time slot.

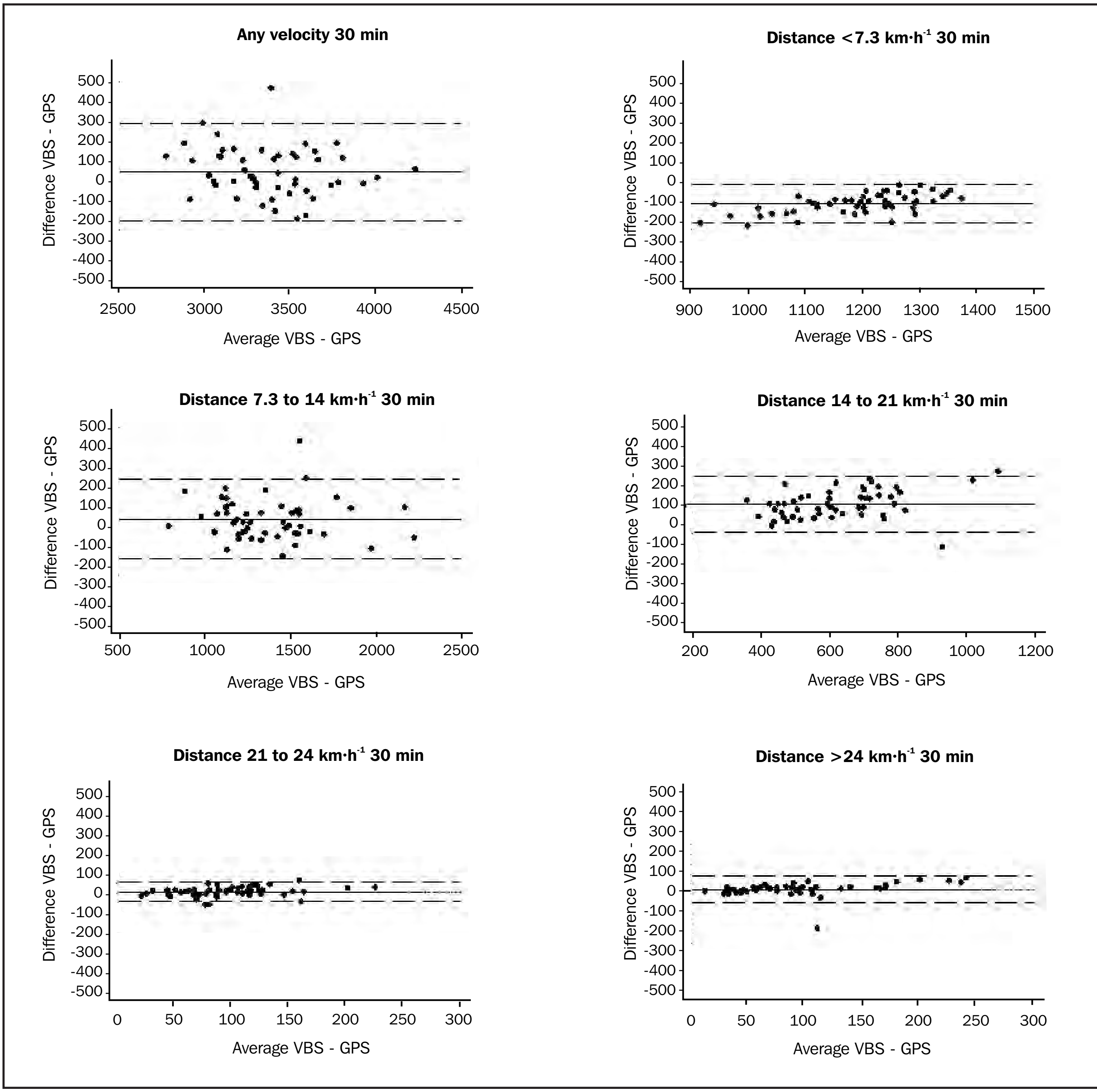


TD: Total distance.

paired t-test, this differences were all significant for the 30 *minute time slots and 5 out of 6 15-minute time-slot speeds* ($p<0.05$). In the 45-minute time slot two speeds had a significant systematic error, 0 to <7.3 km•h^{-1} and 14.0-21.0 km•h^{-1} (Table 2).

The random differences between VBS and GPS (Table 2) varied from 148.1 m (TD) to 29.3 m (>24 km•h^{-1}) in the 15-minute time slot. In the 30-minute time slot the random error (repeatability coefficient) varied from 246.4 m (TD) to 48.8 m (21to24 Km•h^{-1}). The repeatability coefficient was from 274.8 m (TD) to 55.9 m (21to24 km•h^{-1}) in the 45-minutes slot. Regression analyses demonstrated that there was a tendency in the differences between VBS and GPS to increase when the measured magnitude (distance) was bigger. This was more common in the 15-minute slot (4 out of 6 analyses) than in 45-minute slot (2 out of 6 analysis) (Table 2).

Figure 2. Bland-Altman plots VBS vs GPS at 30 minutes time slot.



TD: Total distance.

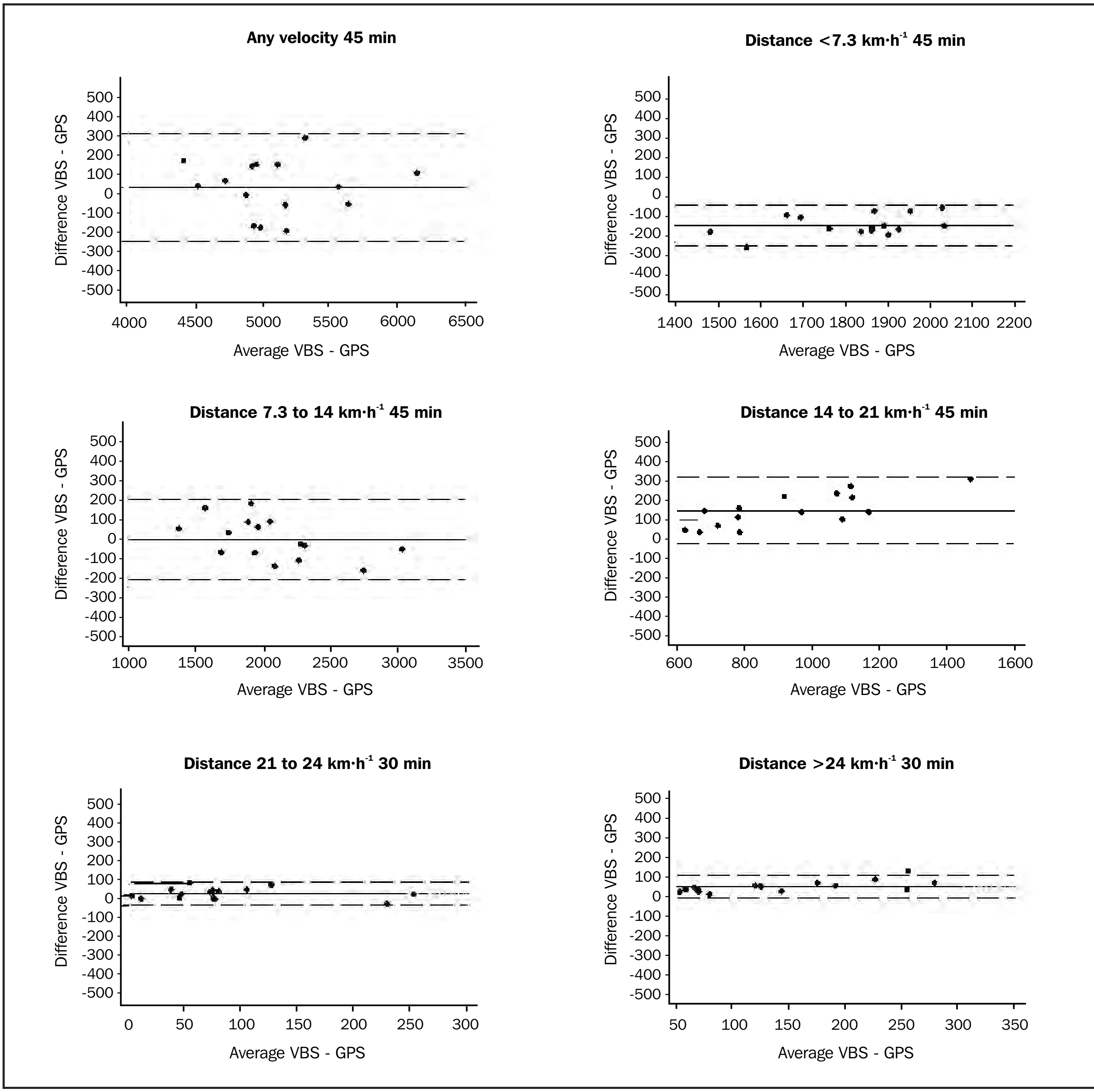
VBS and GPS prediction equations

All the prediction equations calculated in the present study are displayed in Table 3. The prediction equations calculated in this study appeared to be significant (Table 3). The adjusted R^2 was from 88% to 54% in the 15-minute time slot, 88% to 71% in the 30-minute time slot and from 95% to 84% in the 45-minute slot.

Discussion

The main aim of this investigation was to study the agreement between the distances covered at various speeds by professional soccer players in official matches using VBS and GPS, and create equations that predict distances from those obtained by other technologies. The results of the analysis showed that distances recorded by the two sys-

Figure 3. Bland-Altman plots VBS vs GPS at 45 minutes time slot.



TD: Total distance.

tems differed substantially and cannot be used in an interchangeable manner. However, prediction equations created in this study predicted the distance from one system to another.

As for the agreement between the systems, this study found that during official matches, the different metrics collected by the two systems differed substantially. These results are in line with other studies[22-24] that also indicated that the GPS measures less than the video-tracking. According to the analysis, the systematic error demonstrated that there is a tendency in VBS to measure more distance in all speeds and time slots than GPS, and these differences appeared to be significant in the majority of cases. It is important to mention that there was an exception to this rule in the 0 to 7 km•h^{-1} speed. In this case, GPS overestimates

Table 2. Agreement analysis between VSB and GPS.

Time Slot	Velocity range	Systematic error	Systematic error CI 95%	Paired t-test	Repeatability coefficient	LOA lower	LOA lower CI 95%	LOA upper	LOA upper CI 95%	Regression p-value
15 min	TD	22.0	8.1 to 35.9	0.002	148.1	-126.1	-149.9 to -102.3	170.1	146.3 to 193.9	NS
	0to7	-58.8	-64.3 to -53.3	0.000	58.5	-117.3	-126.7 to -107.9	-0.3	-9.7 to 9.1	0.000
	7to14	15.1	4.2 to 26.0	0.007	116.1	-100.9	-119.6 to -82.3	131.2	112.5 to 149.8	NS
	14to21	49.9	41.8 to 58.1	0.000	86.4	-36.4	-50.3 to -22.5	136.3	122.4 to 150.2	0.006
	21to24	3.3	-0.5 to 7.2	NS	41.0	-37.7	-44.3 to -31.1	44.3	37.7 to 50.9	0.004
	>24	14.1	11.3 to 16.8	0.000	29.3	-15.2	-19.9 to -10.5	43.3	38.6 to 48.0	0.000
30 min	TD	42.0	7.0 to 77.0	0.020	246.4	-204.4	-264.6 to -144.2	288.4	228.2 to 348.7	NS
	0to7	-119.9	-133.5 to -106.3	0.000	96.0	-215.9	-239.4 to -192.5	-23.9	-47.3 to -0.4	0.000
	7to14	33.7	5.0 to 62.5	0.022	202.3	-168.6	-218.0 to -119.2	236.0	186.6 to 285.5	NS
	14to21	97.2	77.3 to 117.1	0.000	140.1	-42.9	-77.2 to -8.7	237.3	203.1 to 271.5	0.010
	21to24	8.1	1.2 to 15.0	0.023	48.8	-40.7	-52.6 to -28.8	56.9	44.9 to 68.8	0.020
	>24	22.9	13.4 to 32.5	0.014	67.4	-44.4	-60.9 to -27.9	90.3	73.8 to 106.8	0.011
45 min	TD	26.80	-50.8 to 104.4	NS	274.8	-247.9	-383.7 to -112.2	301.6	165.8 to 437.4	NS
	0to7	-164.38	-194.1 to -134.7	0.000	105.1	-269.4	-321.3 to -217.5	-59.3	-111.2 to -7.4	NS
	7to14	-3.91	-61.9 to 54.1	NS	205.2	-209.1	-310.5 to -107.7	201.3	99.9 to 302.7	0.036
	14to21	144.02	96.8 to 191.2	0.013	167.1	-23.1	-105.7 to 59.5	311.1	228.6 to 393.7	NS
	21to24	6.77	-9.0 to 22.6	NS	55.9	-49.2	-76.8 to -21.5	62.7	35.1 to 90.3	NS
	>24	44.29	27.5 to 61.1	NS	59.4	-15.1	-44.4 to 14.3	103.7	74.3 to 133.0	0.007

CI 95%: confidence interval at 95%, LOA: limit of agreement, NS: Non-significant, TD: Total distance.

Table 3. Equations between the two different technologies (GPS and VBS) during official matches in all velocity ranges.

Time slot	Range of speed	VBS to GPS		GPS to VBS		Adjusted R^2	p-value
	($Km \cdot h^{-1}$)	Formula	TEE	Formula	TEE		
15 min	TD	G = 65.2+(V*0.948)	75.36	V = 230.6+(G*0.875)	72.38	0.83	0.001
	0to7	G = 215.0+(V*0.725)	22.78	V = (-154.7) + (G*1.153)	28.72	0.83	0.001
	7to14	G = 32.6+(V*0.930)	58.24	V = 49.3+(G*0.948)	58.83	0.88	0.001
	14to21	G = 19.6+(V*0.794)	39.31	V = 48.3+(G*1.006)	44.26	0.79	0.001
	21to24	G = 15.5+(V*0.615)	17.29	V = 8.2+(G*0.892)	20.82	0.55	0.001
	>24	G = (-1.6)+(V*0.763)	11.79	V = 8.9+(G*1.134)	14.37	0.86	0.001
30 min	TD	G = 29.7+(V*0.979)	126.80	V = 510.7+(G*0.860)	118.90	0.84	0.001
	0to7	G = 433.0+(V*0.723)	34.31	V = (-392.0)+(G*1.218)	44.52	0.88	0.001
	7to14	G = 24.5+(V*0.958)	103.50	V = 139.3+(G*0.922)	101.50	0.88	0.001
	14to21	G = 49.4+(V*0.783)	61.37	V = 60.3+(G*1.064)	71.55	0.83	0.001
	21to24	G = 20.2+(V*0.716)	21.08	V = 6.5+(G*1.017)	25.12	0.72	0.001
	>24	G = 9.0+(V*0.697)	28.50	V = 20.4 +(G*1.031)	34.67	0.71	0.001
45 min	TD	G = 192.6+(V*0.957)	144.10	V = 309.0+(G*0.944)	143.20	0.90	0.001
	0to7	G = 457.2+(V*0.832)	46.74	V = (-344.9)+(G*1.095)	53.61	0.90	0.001
	7to14	G = (-236.2)+(V*1.117)	97.13	V = 288.4+(G*0.858)	85.13	0.96	0.001
	14to21	G = 117.1+(V*0.740)	49.36	V = (-96.8)+(G*1.279)	64.92	0.94	0.001
	21to24	G = (-4.2)+(V*0.981)	29.58	V = 24.0+(G*0.868)	27.83	0.84	0.001
	>24	G = (-2.758)+(V*0.750)	20.70	V = 16.398+(G*1.229)	26.49	0.92	0.001

G: GPS; V: VBS; TEE: typical error estimated; TD: Total distance.

the distance provided by VBS in all time slots. This might be because the VBS speed range player needs to be running at least 1 second or 1 m in this range of speed before it starts measuring, while GPS devices are constantly receiving displacement when players move. It would be highly recommended (but unlikely) that companies who offer services to Clubs unify criteria to ease the researchers and coaches task when quantifying the workload.

As for the random error, the Bland-Altman analysis showed that the error associated with GPS and VBS was elevated. Moreover, this study also found that the differences between systems tend to increase significantly, when the measured magnitude (distance) increases. In other words, the bigger the distance measured, the bigger the differences between the distances recorded by the systems. This agrees with the fact that the repeatability coefficient increases in all speed ranges as the time slot increases.

Therefore, the distance provided by VBS and GPS are substantially different and cannot be compared directly. However, the prediction equation derived from linear regression analysis was significant with an elevated R^2. In other words, the equation explains well the changes in the dependent variable (one system) from the values in the independent variable (the other system). That means that having data from either GPS or VBS, one could predict the distance that the other system would register with high accuracy.

The use of different tracking systems by professional football clubs justifies the need of being able to exchange the information obtained through VBS and GPS. Converting the information obtained through the VBS into GPS data could be useful in the tracking and management of the workload, and to estimate, for example acute:chronic load. As well to assess if the demands of training tasks replicate the match demands[32,33]. The inverse conversion could also be interesting to know the time of the return to play of an athlete, or what would be the activity of a young club sportsman (measured through GPS technology) compared to a professional (measured through VBS).

In practice (just considering the variable TD), when staff members want to convert match running distances collected with GPS, e.g. 5,000 m in 45 minutes, to VBS-expected distances these equations can be used: if they had worn one of the GPS units the estimated distance should be 4,977.6 m (0.957 x 5,000 m + 192.6 m). Considering the same distance covered by the player (5,000 m), if we wanted to convert from VBS to GPS expected distances the equation should be this, 0.944 x 5000 m + 309.0 m for GPS device, that is, 5,029.0 m.

When comparing the equations proposed per Buchheit *et al.*[22] with the ones of the current study, the relation between both tracking systems is similar. Let's consider the same distance covered by one player that was 5,000 m. The following formulas could be used provided by Buchheit *et al.*[22], GPS = (1.01 x VBS)-70 m or VBS = (0.92 x GPS)+250 m, if VBS was used to register this distance or GPS system, respectively. The GPS-expected distance covered by the player would be 4,980 m (5,029 m in the current study), while the VBS-expected distance ran by the player would be 4,850 m (4,978 m in the current study). In this way, technicians could track the training and match loads considering distances at different speeds. However, other mechanical variables (e.g., acceleration, inertial movements) like level 2 and 3 proposed by Buchheit and Simpson[20] are still without possibilities of transformation due to videotracking systems do not provide information of this type of variables (e.g., inertial movement analysis).

The main limitation of this study is that only two systems were studied (VBS *vs*. GPS) among the vast amount of VBS and GPS systems that the market offers nowadays. However, the two systems studied are two of the most used tracking systems. On the other hand, VBS has stablished that player needs to be running at least 1 second or 1 m before it starts measuring (this is a rule that the company uses) and GPS devices are constantly receiving displacement at any movement. Furthermore, frequency is not the same for both systems. These facts might have affected the agreement between systems. Unfortunately, little can be done to correct this since companies make their decisions based on the market and not on the needs of researchers.

It would be interesting for further research to compare different VDS and GPS systems to help coaches, technical staff and researchers to understand the workload of players measured by different technologies. In the same line, studies in other sports and settings would also be interesting to seize workloads and demands of different sports to adjust properly the workloads and improve physical performance.

Conclusion

The main conclusions of the study are:

- VBS and GPS do not register the same amount of distance in any of the speeds or time slots studied (there was an elevated systematic and random error). Systematically, in most of the speed ranges, VBS register most distance than GPS system. This differences increases when the measured distance is bigger at any speed. The results from VBS and GPS cannot be used interchangeably.
- Prediction equations predict the distance from VBS to GPS and vice versa very well.

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Conflict of interest

The authors do not declare a conflict of interest.

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Original article

Effects of a proprioceptive physical exercise program on balance in young skaters aged between 11 to 15 years

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Summary

Introduction: Having an adequate state of body balance allows the skater to maintain an adequate technique and control in the execution of each sporting gesture, this may limit accessory movements that lead to an inadequate increase in joint stress, which can ultimately impact on the health status and performance of these athletes.
Aim: To determine the effects of a proprioceptive physical exercise program on balance in skaters between the ages of 11 and 15 years.
Methodology: A experimental study conducted in 58 skaters belonging to the Santander Skating League of Bucaramanga, who were randomized into two groups, one received proprioceptive training (n = 29) and the other group performed a conventional training (n = 29), both were developed for 12 weeks with a frequency of 3 times a week and a duration per session of 30 minutes.
Results: The dynamic balance assessed with the Star Excursion Balance Test (SEBT), showed changes in all directions after the intervention of both groups. In relation to the static balance determined with the Balance Error Scoring System (BESS) showed positive changes in the experimental group.
Conclusions: The proprioceptive training program produces results superior to the conventional one, in terms of the static and dynamic balance of the skaters evaluated.

Key words:
Postural balance. Skating. Propioception.

Efectos de un programa de ejercicio físico propioceptivo sobre el equilibrio en jóvenes patinadores entre los 11 y 15 años

Resumen

Introducción: Un estado de equilibrio corporal apropiado permite al patinador mantener el control y la técnica adecuada en la ejecución de cada gesto deportivo. Así, un buen estado reduce movimientos accesorios que llevan al deportista a un incremento del estrés articular, que finalmente puede repercutir en el estado de salud y el rendimiento de estos atletas.
Objetivo: Determinar el efecto de un programa de ejercicio físico propioceptivo sobre el equilibrio de patinadores en edades comprendidas entre los 11 a 15 años.
Material y método: Estudio experimental con dos grupos de intervención en paralelo, realizado en 58 deportistas pertenecientes a la Liga Santandereana de Patinaje de la ciudad de Bucaramanga, quienes fueron aleatorizados en dos grupos: Grupo Experimental (GE) (n=29) que recibió entrenamiento propioceptivo y Grupo Control (GC) (n=29) que recibió entrenamiento convencional. Ambos protocolos fueron desarrollados durante doce (12) semanas, con una frecuencia de tres veces por semana y una duración de treinta minutos en cada sesión. El equilibrio dinámico y estático fue evaluado antes y después de cada intervención mediante *Star Excursion Balance Test* (SEBT) y *Balance Error Scoring System* (BESS).
Resultados: Después de la intervención, ambos grupos mostraron cambios positivos en cuanto al equilibrio dinámico; éstos fueron superiores en el GE ($p<0.05$). En cuanto al equilibrio estático, los cambios fueron positivos y significativos en el grupo que recibió ejercicio propioceptivo ($p<0.05$). En contraste, el grupo que recibió tratamiento convencional no mostró cambios en esta variable.
Conclusión: El entrenamiento propioceptivo produce resultados superiores en el equilibrio estático y dinámico de los patinadores evaluados, en comparación con los resultados generados por el entrenamiento convencional.

Palabras clave:
Equilibrio postural. Patinaje. Propiocepción.

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Introduction

Skating requires athletes to adapt their body to a specific, unnatural movement, in which the point of support is reduced. Therefore, their support is based on four fixed, inline wheels that slide over a surface, drawing a straight line that is at an oblique angle to forward movement; this condition produces continuous changes of balance thereby causing a greater degree of instability compared to other sports[1].

Indeed, balance is the basic component in skating because it makes it possible to maintain an adequate technique and control in the execution of each sports gesture and, moreover, it limits the accessory movements that increase joint stress[1-4]. The correct technique for roller speed skating is based on achieving maximum effectiveness and efficiency of the forces applied to the skate during the push, slide and recovery phases[5,6]. Indeed, the lack of good postural balance may lead to the wasteful use of these forces due to inefficient movements that finally affect sporting performance[2,7-14].

Today, proprioceptive work is not always considered in sports training processes, particularly in speed skating; in most cases, its importance is stressed as a rehabilitation tool. Studies indicate that this type of work permits more effective movement and offers athletes a greater reaction capacity against competition demands. This fact may suggest that a proprioceptive exercise program is an important factor in the planning and methodological processes of sports training[15-17].

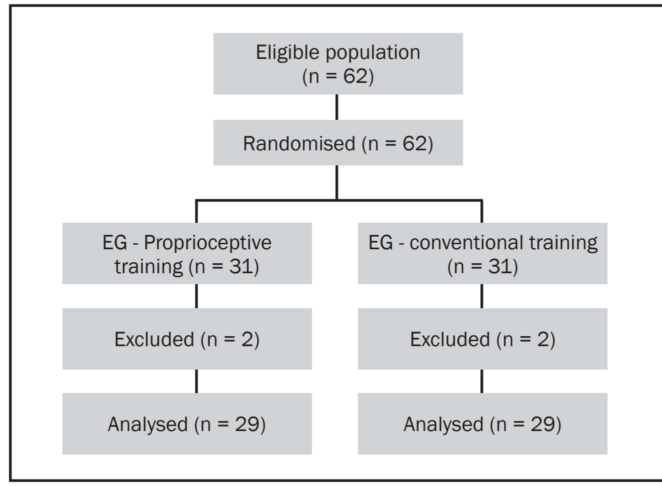
Added to the above, the little scientific evidence related to the effects of proprioceptive work on the balance of skaters, justifies the conduct of this study.

Material and method

This experimental study was conducted with two parallel intervention groups, comprising 58 skaters pertaining to the Santandereana Skating League of the city of Bucaramanga, aged between 11 to 15 years. The athletes were randomised into two groups: the first one, the Experimental Group (EG) received a proprioceptive physical exercise program; while the second one, the Control Group (CG) was given conventional training. The protocols for the two groups were implemented over 12 weeks with a frequency of 3 times per week and a duration of 30 minutes per session. On the other hand, the dynamic and static stability assessments were conducted before and after the exercise program. It should also be indicated that four subjects were excluded from the study, due to musculoskeletal injuries (Figure 1).

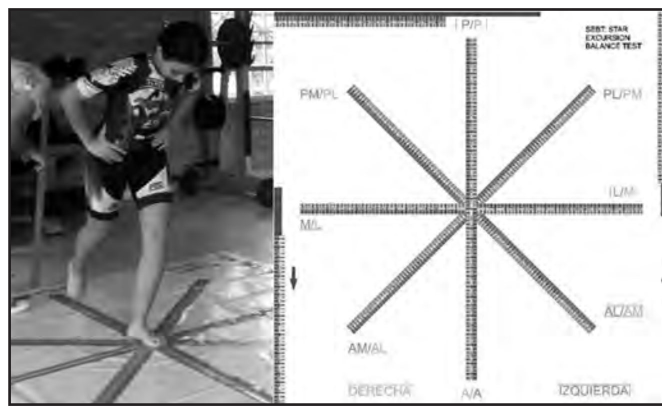
In relation to the dynamic balance evaluation, this was conducted with the aid of the *Star Excursion Balance Test* (SEBT) which has shown a reliability of between 0.85 and 0.96[18]. For this test, the subject stands in the middle of a 1.83 m x 1.83 m square marked out with tape on the floor and comprising 8 lines in the form of a star with an intersection angle of 45º between each line from the centre of the square[19]. These lines are named according to the direction of reach in relation to the stance leg:

Figure 1. Flow diagram, data collection.



Source: Compiled by author.

Figure 2. Star Excursion Balance Test.



(AL), anterior (A), anteromedial (AM), medial (M), posteromedial (PM), posterior (P), posterolateral (PL), y lateral (L)[20] (Figure 2).

In this test, the subject is positioned in the centre of the star, maintaining a single-leg stance. Immediately the unsupported leg must make a light touch for a 1 second duration as far as possible on each of the marked lines, in a clockwise direction for an unsupported right leg and in an anti-clockwise direction for the left leg. Three complete attempts were permitted with a 3 minute interval between each one. The distance achieved in each direction was the average of the 3 attempts[20].

On the other hand, the assessment of the static body balance was made with the *Balance Error Scoring System* (BESS), which has shown good reliability in paediatric and adolescent populations[21]. This comprises three stances on two different surfaces: one firm and the other foam. Subjects are barefoot and must place their hands on their iliac crests, and position themselves in three different stances, namely double-leg, single-leg and tandem (one foot behind the other)[22].

In the first stance, the feet must be resting on the surface and approximately hip-width distance apart, the single leg stance should be made with the non-dominant side with 20 degrees of hip flexion and 45 degrees of knee flexion. Finally, in the tandem stance, the subject must stand with the non-dominant foot at the back. Each stance must be held for 20 seconds with the eyes closed. The evaluator must count the athlete's errors or deviations from the correct stance as follows: 1) Hands lifted off the iliac crest 2) Opening eyes 3) Step, stumble or fall. 4) Moving hip into more than 30 degrees abduction. 5) Lifting forefoot or heel. 6) Remaining out of the test position more than 5 seconds. To record the result, the number of errors committed in each of the three stances are added together. The maximum total number of errors is 10. The greater the number of errors, the poorer the balance[23].

Interventions

Experimental group

The application of the proprioceptive exercise is based on the program proposed by Avalos, Mancera and Adalid[24-26], making some changes to tailor it to the demands of speed skating. The program was designed to be applied in a pre-competitive period and comprised single- and double-leg stances on stable and unstable surfaces with the eyes open and closed. With a 12-week duration, it comprised a general mesocycle of 5 weeks and a specific one of 7 weeks, to be performed three times a week with a duration of 30 minutes for each session.

At each session, a 10' warm-up was performed, followed by five proprioception exercises developed at 8 levels: for the first level, the subjects kept their eyes open, with a double leg stance on a firm, stable surface with a wide base of support. For the second level, their eyes must remain closed, the athletes remained in a double leg stance on a firm surface and with a reduced base of support. For the third level, the exercises were performed with their eyes open, single leg stance on an unstable, horizontally positioned board. For the fourth level, the exercises were performed with their eyes open, single leg stance on an unstable, vertically positioned board. For the fifth level, the single leg stance was maintained and the exercises were performed with their eyes closed on an unstable, horizontally positioned board. The sixth level corresponds to a single leg stance, eyes closed on an unstable, vertically positioned board. And, finally, for the seventh and eighth levels, the tests were conducted on skates with the eyes open and closed respectively.

From the third to the eighth levels, external disturbances were performed, including arm movements, simulating the movement made when skating, movement with a fellow athlete and the use of an air balloon. The dynamic stability exercise was performed with progressively higher jumps - first 5 centimetres, then 10 centimetres and finally 15 centimetres. Finally, a dynamic stretching routine was performed.

Control group

This group performed a conventional warm-up imposed by the skating trainer, at the start of the training session, consisting in continuous jogging, jumps at different heights and directions, as well as muscle stretching.

Statistical analysis

The data analysis was performed with the SPSS statistics program, version 20.0 licensed by the Universidad Autónoma de Manizales. The normality distribution was determined through the Kolmogorov – Smirnov test. This was then used to calculate the measures of the central tendency and dispersion for the quantitative variables, as well as the absolute and relative frequencies for the qualitative variables. The Student's t test for independent data was used to compare the difference between the measurements for the two groups. The comparison of the dynamic and static stability change, before and after the exercise program, was made according to the distribution of variables, by a Student *t* test or Wilcoxon rank test. In general, an alpha level of 5% was considered for the entire analysis.

Ethical considerations

The study was approved by the Ethics Committee of the Universidad Autónoma de Manizales. Participants gave their voluntary acceptance and signed the informed consent. Likewise, the study was classified as minimum risk according to resolution 008430 of 1993 of the Ministry of Heath of Colombia, in addition to the fact that the study observed the ethical principles of research on human beings.

Results

Table 1 shows that the mean age was 12.93±1.4 years and 13.21±1.3 for the Experimental and Control groups respectively. With regard to Body Mass Index (BMI), this was 18.25 kg/m^2 ± 2.1 kg/m^2, for the EG and 19.75 ± 4.0 kg/m^2 for the CG. 69% of the population studied were females and 67% were distance skaters.

Table 2 shows an improvement in the dynamic balance in all directions for both groups ($p<0.05$). The greatest differences were observed to be in the the following directions: left posterior (12.51 cm), right (11.79 cm) and left posteromedial (11.93 cm) of the EG.

After the intervention on the EG, an improvement was observed in the static balance averages on a firm, stable surface (Table 3). For its part, although the CG showed changes for both surfaces, the results are not statistically significant.

Discussion

The results of this study suggest that proprioceptive training, made with youth skaters, gives better static and dynamic balance results compared to those achieved with conventional training. These positive effects generated by proprioceptive training have principally been confirmed in other sports such as football, basketball and handball[3].

It should be pointed out that few investigations have been made in the field of roller skating and those that have been made are focussed on describing anthropometric characteristics and on the kinematic analysis of the push cycles in youth skaters[27-31]. On the other hand, studies have been made on speed or figure ice skating, which are also directed at

Table 1. Sociodemographic characteristics of the participants in the study.

Variables	Experimental Group (n=29)	Control Group (n=29)
Age	12.93 ± 1.4	13.21 ±1.3
Height (cm)	155.6 ± 10.38	158.3 ± 8.73
Weight (kg)	44.96 ± 7.4	48.27 ± 8.0
BMI (kg/m2)	18.25 ± 2.1	19.75 ± 4.0

		Experimental group (n=29)		Control group (n=29)	
		Frequency	Percentage	Frequency	Percentage
Sex	Male	12	41.4 %	6	20.7 %
	Female	17	58.6 %	23	79.3 %
Sports discipline	Speed	9	31 %	10	34.5 %
	Distance	20	69 %	19	65.5 %

Source: Compiled by author

Table 2. Initial and final dynamic balance in the experimental and control groups.

SEBT TEST								
Direction	Laterality	Group	Initial		Final		Dif.	p
			Average	(SD)	Average	(SD)		
Ant	Right	Experimental	69.45 cm	6.74	75.00 cm	6.87	5.55	0.000*
		Control	68.83 cm	6.43	74.28 cm	5.73	5.45	0.000*
	Left	Experimental	70.45 cm	7.24	76.07 cm	6.011	5.62	0.000*
		Control	69.59 cm	7.12	74.76 cm	6.71	5.17	0.000*
Ant-lat	Right	Experimental	72.17 cm	6.61	78.69 cm	6.69	6.52	0.000*
		Control	71.90 cm	7.78	77.21 cm	6.68	5.31	0.000*
	Left	Experimental	73.24 cm	8.42	79.31 cm	6.13	6.07	0.000*
		Control	73.48 cm	6.73	77.59 cm	7.36	4.11	0.000*
Lat	Right	Experimental	72.90 cm	8.80	81.62 cm	7.59	8.72	0.000*
		Control	73.00 cm	7.18	79.66 cm	7.75	6.66	0.000*
	Left	Experimental	74.38 cm	9.91	80.97 cm	7.34	6.59	0.000*
		Control	74.10 cm	7.82	79.69 cm	8.18	5.59	0.000*
Post-lat	Right	Experimental	73.48 cm	10.43	83.17 cm	8.64	9.69	0.000*
		Control	74.21 cm	7.97	81.66 cm	7.91	7.45	0.000*
	Left	Experimental	73.76 cm	12.06	83.28 cm	7.79	9.52	0.000*
		Control	74.69 cm	9.27	82.28 cm	8.13	7.59	0.000*
PostRight	Right	Experimental	70.83 cm	12.40	82.62 cm	9.64	11.79	0.000*
		Control	74.00 cm	10.20	83.03 cm	8.52	9.03	0.000*
	Left	Experimental	70.83 cm	12.97	83.34 cm	10.38	12.51	0.000*
		Control	73.76 cm	9.23	82.83 cm	8.13	9.07	0.000*
Post-med	Right	Experimental	66.62 cm	12.19	76.34 cm	10.26	9.72	0.000*
		Control	68.28 cm	8.78	74.21 cm	7.87	5.93	0.000*
	Left	Experimental	66.14 cm	13.70	78.07 cm	9.43	11.93	0.000*
		Control	68.45 cm	9.37	74.31 cm	8.58	5.86	0.000*
MedRight	Right	Experimental	60.45 cm	12.74	67.45 cm	10.44	7.00	0.000*
		Control	61.76 cm	8.58	67.00 cm	7.48	5.24	0.000*
	Left	Experimental	59.59 cm	12.34	69.14 cm	9.47	9.55	0.000*
		Control	60.72 cm	9.45	65.90 cm	7.87	5.18	0.000*
Ant-med	Right	Experimental	65.52 cm	7.98	70.79 cm	5.72	5.27	0.000*
		Control	65.62 cm	6.50	69.72 cm	5.87	4.10	0.001*
	Left	Experimental	66.55 cm	9.716	71.55 cm	5.18	5.00	0.001*
		Control	65.41 cm	6.31	69.72 cm	5.99	4.31	0.002*

Source: Compiled by author (*p <0.05)

Table 3. Initial and final static balance in the experimental and control groups.

Variable	Group	BESS TEST Initial Average	Initial SD	Final Average	Final SD	Dif.	p
BESS firm	Experimental	8.03 points	5.68	5.21 points	4.32	2.82	0.015*
	Control	6.14 points	4.31	5.24 points	4.65	0.9	0.455*
BESS foam	Experimental	14.69 points	4.84	11.97 points	5.14	2.72	0.040*
	Control	12.00 points	5.06	10.17 points	5.85	1.73	0.253*

Source: Compiled by author (*p <0.05)

showing the effect of proprioceptive training on postural control as well as physical performance and ankle stability[9,26,32-36].

The interest in analysing the influence of balance training on youth skaters is based on the fact that, at these ages, the skills of proprioception (sense of position) and praxis (sense of space) are immature. This characteristic causes these athletes to be more vulnerable to falls and injuries, primarily with regard to the ankle, where the resistance of the ligaments is physiologically reduced at this stage in life[37,38].

Brachman *et al.* consider some of the results of the studies showing the influence of proprioceptive training on physical performance, postural control and injury prevention to be controversial. However, Akahame *et al.* demonstrate that the training performed on unstable surfaces and even on the actual skates, as in our study, improves postural control and the strength of the lower limbs. In this way, these effects could reduce the risk of injury and increase the competitiveness of the athlete[2].

The work of Brachman *et al.* as well as that of Heitkamp *et al.* and Hrysomallis, conclude that the relationship between the athlete's level of balance, the number of injuries and sporting results, has not been sufficiently understood. This is due to the fact that there is no agreement between the results of the studies and there is no wide body of research in this area. Despite the above, the investigators suggest that proprioceptive training could manage to improve the competitiveness and reduce the risk of injury when it is adequately directed, even when combined with strength training it could manage to increase its effectiveness[2,3,14,34].

In their review, Brachman *et al.* conclude that the positive effect of proprioceptive training on athletes in different disciplines, aged between 7 and 30 years, was more effective when the exercise protocols had a duration of between 8 to 12 weeks, with a frequency of two sessions per week and a time of 45 minutes per session; this routine is similar to the one used in our study. On the other hand, most articles analysed by Brachman *et al.* use the SEBT and the BESS to assess balance, as in our study. These tests are considered to be versatile and with suitable psychometric properties in the child and youth population[18-21].

It should be pointed out that the results shown by Brachman *et al.* do not include any articles analysing speed skaters, they only include the study by Saunders *et al.* which analyses the effect of proprioceptive training on youth figure skaters. However, this does not show any significant changes following a program of three sessions per week over six weeks. This latter characteristic may be a reason for which the exercise protocol used does not evidence an improvement in corporal balance[26]. The above statement may be based on the results evidenced by Winter *et al.,* who found that a five session training program over twelve weeks, and not during six, creates changes in the speed skater's balance. However, Kovac *et al.* mention that a four week training schedule, with three proprioceptive exercise sessions can improve the postural control of young figure skaters[35-36].

With regard to the above, it is important to consider the complexity of establishing an appropriate training model for each sports discipline and type, including its characteristics and demands. Moreover, there are other factors that could affect the results obtained after the planned training. One of these is the balance level of the skater before starting training and which was not measured in all the studies[38].

Conclusion

This is the first experimental work conducted on speed roller skaters; here it is evidenced that proprioceptive training conducted three times a week with a duration of 30' per session, over twelve weeks, improves the dynamic and static balance of these athletes. This suggests the inclusion of exercises of this type as a key factor in the training planning and methodology for roller skaters. On the other hand, it is relevant to point out that this training must be differentiated and adapted to the specific type of sport, as was done in this study. Finally, we would suggest that future studies analyse the effect of this training routine on physical performance and the risk of injuries in subjects pertaining to the different categories and types of roller skating.

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Conflict of interest

The authors do not declare a conflict of interest.

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Proprioceptive training methods as a tool for the prevention of injuries in football players: a systematic review

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Summary

Introduction: Proprioceptive exercises have been used as a training method in the reduction of injuries' rate on soccer players. However, there is no certainty about the number of researches performed or the results of these methods.
Objective: Investigate out which the training methods were used in lower limbs to prevent soccer players' injuries between 2008 and 2018. The secondary objective was to describe the results of each research.
Material and method: This study is a Systematic Revision of research already published. Articles published between 2008 and 2018 that connected proprioception exercises to injury prevention were reviewed. The electronic search was performed through Web of Science, Scopus, Sport Discus, PubMed, and MedLine. All articles that presented proprioception as exercises to prevent injuries were included.
Results: 11 articles were found which used exercises connected to preventive programs in soccer players. Which were stratified according to the described aim: (i) Proprioceptive program, (ii) Balance training, (iii) Neuromuscular training, and (iv) Posture-control training.
Conclusion: Once the systematic review ended, several preventive programs were found for soccer players based on proprioception, balance, neuromuscular and posture-control. These training methods have proven to have good results in the prevention of injuries, especially in knees and ankles. For the above described, it is necessary to include injury prevention exercises in the training programs developed by soccer players.

Key words:
Prevention. Proprioception. Injuries. Football.

Métodos de entrenamiento propioceptivos como herramienta preventiva de lesiones en futbolistas: una revisión sistemática

Resumen

Introducción: Los ejercicios de propiocepción se han utilizado como método de entrenamiento para disminuir la tasa de lesiones de los jugadores de fútbol, pero no existe certeza de la cantidad de investigaciones existentes ni los resultados de estos métodos.
Objetivo: Investigar cuáles fueron los métodos de entrenamientos usados para la prevención de lesiones en las extremidades inferiores en futbolistas entre los años 2008 y 2018. El objetivo secundario fue describir los resultados obtenidos en cada uno de los estudios.
Material y método: El estudio corresponde a una revisión sistemática de estudios previamente publicados. Se evaluaron artículos publicados entre los años 2008 y 2018 que relacionaron ejercicios de propiocepción y prevención de lesiones. La búsqueda electrónica se realizó a través de Web of Science, Scopus, Sport Discus, PubMed, MedLine. Se incluyeron todos los artículos que utilizaron propiocepción como ejercicios para la prevención de lesiones.
Resultados: Fueron encontrados 11 artículos que utilizaron ejercicios de prevención en futbolistas. Los cuales fueron estratificados según el objetivo descrito: (i) Entrenamiento propioceptivo, (ii) Entrenamiento de equilibrio, (iii) Entrenamiento neuromuscular y (iv) Entrenamiento de control postural.
Conclusión: Al término de la revisión sistemática se hallaron programas de propiocepción, equilibrio, neuromuscular y control postural. Estos métodos de entrenamiento han demostrado tener buenos resultados en la prevención de lesiones, especialmente en rodillas y tobillos. Por lo anteriormente descrito, se precisa incluir ejercicios de prevención de lesiones en los programas de entrenamiento desarrollado por futbolistas.

Palabras clave:
Prevención. Propiocepción. Lesiones. Fútbol.

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Introduction

Football is a phenomenon involving mass social participation, prominent in recreational, training and competitive fields alike, and generating benefits including improved cardiovascular performance linked to the health and metabolism of players. It also helps prevent other illnesses such as diabetes and hypertension[1]. The mainstream nature of this sport has not only led to developments in physical, technical and tactical training, but also in methods to prevent injuries[2]. The latter development is due to the fact that all sporting activities entail a certain degree of risk of injury, which is why playing football requires the correct equipment, an optimum level of fitness, controlled training and a good technique in the sport[3]. The aforementioned is more evident in high-performing athletes, as they can increase skeletal-muscular energy with a greater probability of suffering from acute and chronic injuries[4].

Injuries in football occur much more frequently than expected, posing a limiting factor for these athletes[5]. In a study carried out by Carlos-Vivas *et al.*[6], it was concluded that the majority of injuries that occur are to the lower limbs, and are both muscular and articular, specifically the thighs, ankles, groin and knees, generating lengthy recovery times and long periods of leave for both professional and amateur athletes alike. Therefore, injury prevention programmes for footballers should be an integral component of all training sessions[7]. These exercises have led to the creation of programmes such as the FIFA 11+, which includes exercises focusing on running, strength and plyometrics[2]. Jones and Rocha[8], concluded that a major part of the components that make prevention programmes successful are the stretches, lower body muscle strengthening exercises, and increased aerobic capacity.

One of the important elements within prevention programmes, is proprioception[9]; this corresponds to the relationship between kinaesthetic components and movements of the body. Well developed proprioception ensures positive stimulus-response synchronisation, achieving good performance in joint stability so as to prevent injuries. Schiftan *et al.*[10] describe that when performing proprioceptive work, the joint must be able to deal with its capacity so that the afferent signals react to the joint position, meaning that each exercise that is performed, regardless of whether the work is active, passive, static or dynamic, achieves a response from the extremities.

Within the important factors, proprioception is fundamental for football players[9]. In a study, Daneshjoo *et al.*[9] reveal that a drop in proprioceptive function determines the prevalence of injuries. Consequently, it is important to obtain and assess information about the athlete to ensure the early detection of any shortcomings in the proprioceptive work; this way individual programmes can be created to meet the needs of each player.

In sporting training therefore, it is extremely important to prevent injuries with proprioceptive programmes, thus maintaining optimum physical condition. Unfortunately, the number of training programmes that have used proprioception to prevent injuries among athletes is not certain, which is why the main aim of this systematic review was to discover the training methods used to prevent injuries in the lower extremities of football players between 2008 and 2018. The secondary objective was to describe the results obtained in each of the studies.

Material and methods

Literary search

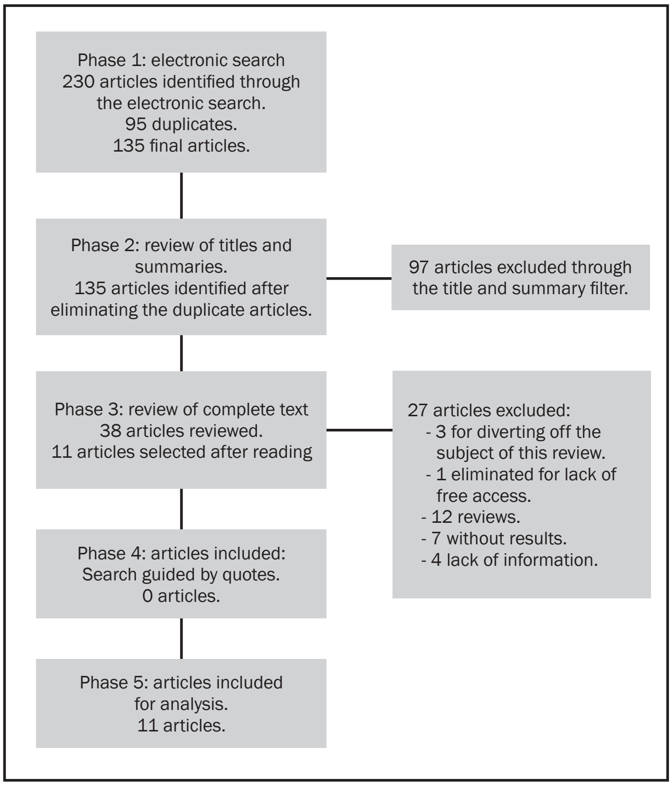
The development of this systematic review was performed using a rigorous search guided by references in different databases and electronic search engines. The combination of key words used for the electronic search can be found in Table 1. The electronic search was performed within the Web of Science (WOS), Scopus, Sport Discus, PubMed, Medline.

The search strategy was split into five stages. Stage one: electronic search of the different databases, identifying 230 articles. Next all

Table 1. Search strategy using selection and combination of key words.

Steps	Strategy	WOS	Scopus	Sport Discus	MedLine	PubMed
1	Proprioception training	4	7	53	83	4
2	Proprioception exercises	3	3	47	2	4468
3	Proprioception	3954	7449	1124	4364	15189
4	Proprioceptive	4325	5056	756	3464	3313
5	Proprioceptivity	2	4	0	1	1
6	#1 or #2 or #3 or #4 or #5	6994	9948	1614	34768	16757
7	Prevention	369112	476731	27917	716536	683295
8	Injury prevention	27906	38160	3868	11292	48732
9	#7 OR #8	369112	476731	27917	716536	683621
10	Soccer	14545	13819	7599	6362	6208
11	Football	16522	16156	10454	6909	6762
12	Soccer players	9319	6656	3756	3044	914
13	#10 OR #11 OR #12	26153	26086	14659	11087	10819
14	#6 AND #9 AND #13	64	41	27	40	58

Figure 1. Identification of studies in the systematic review.



duplicate articles were deleted (95 articles), leaving 135 articles. Stage two: filtering titles and summaries. Next the articles were eliminated using exclusion criteria (97 articles), leaving 38 articles. Stage three: reading and integral analysis of the 38 articles. After reviewing the 38 articles, 27 were eliminated, all for not meeting the inclusion criteria. Stage four: search for articles guided by the bibliography. In this phase no new studies were included. Thereby, the total amount of studies for the systematic review comprised 11 articles (Figure 1).

Inclusion and exclusion criteria

The search restrictions were: articles published in the last 10 years (January 2008 to July 2018), written in English, Spanish, French, Portuguese and German. Only experimental studies were included.

The importance of each study was assessed based on the inclusion criteria in Table 2. The studies that did not meet the inclusion criteria were excluded. Both the inclusion of articles and the discrepancies encountered were resolved through agreement between the three researchers that formed part of the systematic review team.

Assessment of the methodological quality

The Physiotherapy Evidence Database (PEDro) was used to assess the quality of the studies. The classification was performed based on three selection criteria (maximum four stars), comparability (maximum three stars) and results (maximum four stars). The articles with scores of eight to eleven were considered to be of high methodological quality, from four to seven moderate, and below four low.

With regards to the scores obtained for the articles using the PEDro scale, two studies received high scores, nine articles were qualified as moderate, and none of the studies were classed as low (Table 3).

Table 2. Inclusion criteria.

Study design	Experimental.
Demographic	Male and female football players (trained - not trained) between 14 and 30 years of age.
Intervention	Training session containing lower body proprioceptive exercises.
Comparator	Studies that generate a certain impact in proprioceptive exercises on preventing injuries.
Results	Incidence rate for injury, changes in sporting performance.
Language	English, Spanish, French, Portuguese and German.
Exclusion	Children and older adults. Studies with other sports. Upper body proprioceptive training. Training sessions that do not contain proprioceptive exercises.

Table 3. List of articles included with scoring based on the PEDro scale.

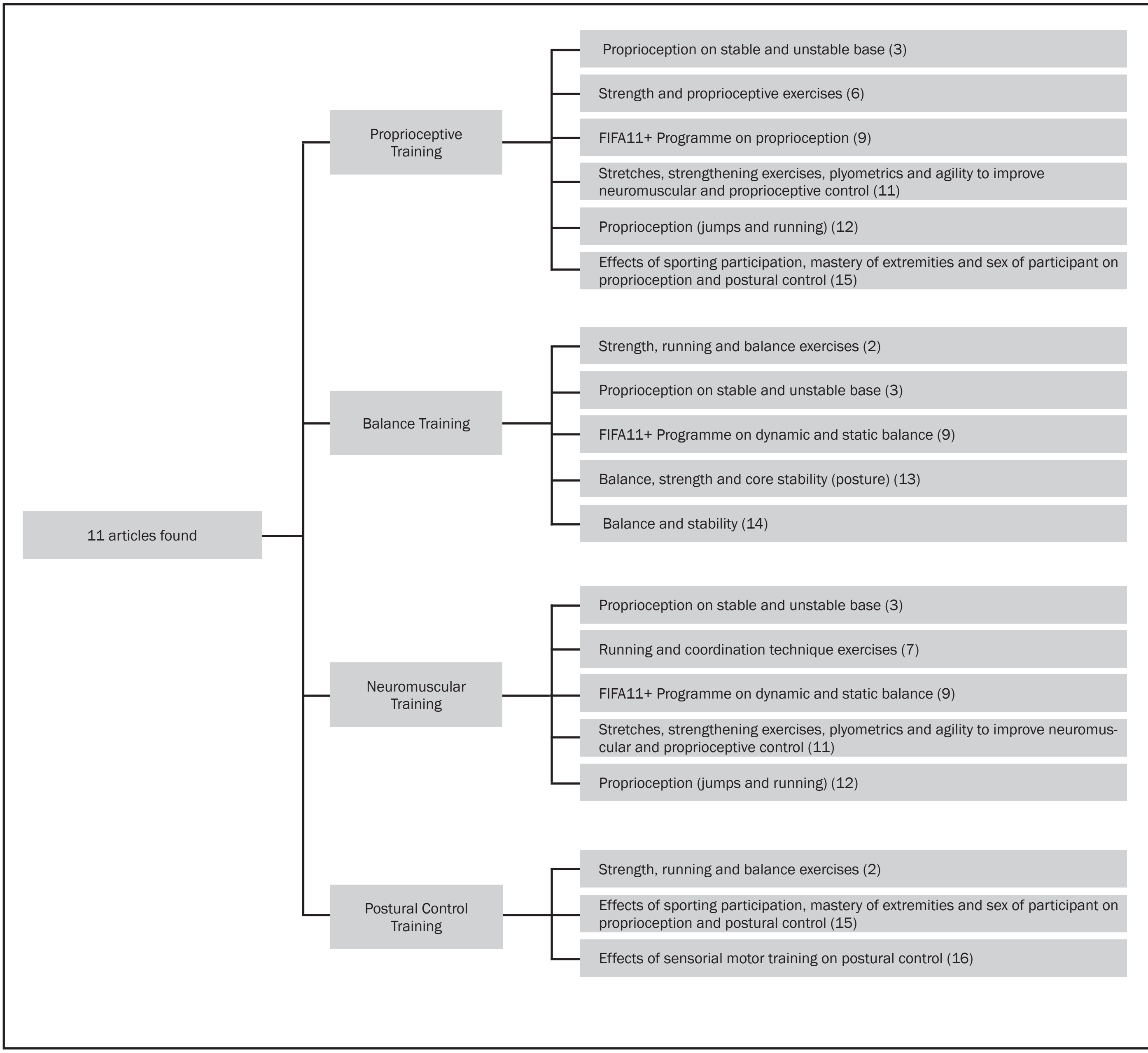
	Selection	Comparability	Results	Total
1 Gilchrist *et al.*[11]	***	****	7	
2 Cameron *et al.*[7]	***		****	7
3 Kraemer & Knobloch[12]	**		****	6
4 Daneshjoo *et al.*[9]	***		****	7
5 Daneshjoo *et al.*[2]	***		****	7
6 Owen *et al.* [13]	***		****	7
7 Donnelly *et al*[14]	****	***	****	11
8 Cug *et al.*[15]	***		****	7
9 González-Jurado *et al.*[3]	***		****	7
10 Heleno *et al.*[16]	****	**	****	10
11 Carlos-Vivas *et al.*[6]	**		****	6

Results

Amount of results available

In the electronic search, 230 articles were identified, of which 95 articles were duplicates. These 135 remaining articles were filtered by title and summaries, leaving 38 articles to be read and analysed thoroughly. After reviewing the 38 articles, 27 were eliminated for not meeting the inclusion criteria. In the search for articles guided by bibliographic

Figure 2. Stratification of the articles in the systematic review.



references, new studies were not included. Thereby, the total amount of studies for the systematic review comprised 11 articles. These articles were stratified depending on the type of intervention:

– Proprioceptive training.
– Balance training.
– Neuromuscular training.
– Postural control training (Table 4 and Figure 2).

It is important to mention that in this stratification, most of the studies found used more forms of training. Despite this, in the description of the programmes, proprioceptive training was reported as the main method used to prevent injuries [3,6,9,11,12,15], as well as balance training[2,3,9,13,14], neuromuscular[3,7,9,11,12] and postural control[2,15,16] (Figure 2).

Significance of the results available

Within the 11 studies selected, regardless of the type of training, sex, level of professionalism, active or sedentary participants, nine revealed significant results in preventing injuries[2,3,6,7,9,11,12,15,16], and in just two there were no significant changes in the prevalence of injuries[13,14].

Table 4. Characteristics and results of the preventive training methods in football players.

Reference	Year	Objectives	Subjects	Variables	Protocol	Results	Performance
Cameron *et al.*[7]	2009	Examine the effect of HamSprint Drills training and conventional Football warm-up on the neuromuscular control of the lower extremities.	M = 26 (EG = 13, CG = 13)	I: PP D: CP	CG: The warm-up performed only comprised stretches, speed work and Football exercises for 30 minutes. EG: During the warm-up, specific HamSprint Drills TP were performed, based on exercises to improve running technique and coordination.	EG ↑ *vs* CG in 0.115 in the area below the curve, equivalent to an improvement of 1.1 in the standard deviation of the programme.	↑
Cug *et al.*[15]	2016	Quantify the effects of sporting participation, the mastery of the extremities, the sex of the subject in postural control and the joint proprioception of the knee.	M = 38 (GFF = 19, GSF = 19) F = 35 (GWF = 17, GSF = 18)	n: TP D: DLA, NDLA, PC	They were assessed with the mSEBT for dynamic control, with 4 trial runs. Participants were asked to place their big toe on the centre of the star and stretch out as far as possible with the other foot, completing the exercise with just one touch. Biodex isokinetic dynamometer for the direction of the joint position at 30°, 45° and 60° from a 90° knee flex.	Within the mSEBT, the posterior medial direction was better in football players compared to sedentary individuals ($p = 0.006$). The anterior direction was better for sedentary individuals than for football players ($p = 0.04$). There were no differences found between sex or dominant extremity.	↑
Daneshjoo *et al.*[2]	2013	Examine the effects of the FIFA11+ and HarmoKnee programmes on performance measurements for professional football players.	M = 36 (EG1 = 12, EG2 = 12, CG = 12)	In:TP D: PhP, Speed, Agility	EG1 (FIFA11+): Exercises comprising 1st run, 2nd Strength, PC and Balance, 3rd advanced run, 3 times a week + normal training. EG2 (HarmoKnee): Exercises of (warm-up, strength, balance and muscle activation) 3 times a week + normal training. CG: Normal training.	EG1 and EG2 ↑ vs. CG in Speed, and Speed with and without ball and Illinois agility tests ($p < 0.005$). Therefore, EG1 improved in jumps, agility and football skill, whilst EG2 improved skills used in football.	↑
Daneshjoo *et al.*[9]	2012	Research the effects of FIFA11+ and HarmoKnee on proprioception and the dynamic and static balance of professional football players.	M = 36 (EG1 = 12, EG2 = 12, CG = 12)	In:TP D: Balance, Flexibility, Proprioception,	EG1 (FIFA11+): Exercises comprising 1st run, 2nd Strength, PC and Balance, 3rd advanced run. EG2 (HarmoKnee): Exercises of (warm-up, strength, balance and muscle activation). Both performed TP 3 times a week with 20 minutes of specific exercises. CG: regular training work. Biodex isokinetic dynamometer for the direction of the joint position at 30°, 45° and 60° from a 90° knee flex.	The proprioception error of the dominant leg ↓ in EG1, in knee flex of 2.8% and 1.7% compared to 3.0% and 2.1% in EG2. Static balance was significantly greater with the eyes open compared to with the eyes closed ($p < 0.000$). There are improvements in SEBT EG1 (12.4%) and EG2 (17.6%).	↑
Donnelly *et al.*[14]	2015	Establish if the technique and balance exercise implemented along with the footballer players' training influences the activation of the muscle that crosses the knee during a planned and unplanned side pass.	M = 28 (BTT = 12, ST = 16)	In: BT D: TE, T, Tec	The training interventions were employed for 20 minutes as a warm-up, twice a week for the first 18 weeks, then once a week until week 28. The BT included ball balance exercises using just one leg, balance discs, and Swiss stability balls.	Non-significant changes in the muscle activation of ST and BTT. At the end of the season, the knee extensor ($p = 0.023$) and semi-membranous muscle ($p = 0.006$) increased in both planned and unplanned muscle activation.	=
Gilchrist *et al.*[11]	2008	Examine if the use of an alternative warm-up improves neuromuscular and proprioceptive control and can reduce the number of ACL injuries.	M = 1435 (EG = 583, CG = 852)	In: PP D: I, %I, ACL	EG: They included an alternative warm-up to their work, which included (stretching, strength, polymetric exercises, agility), 3 times a week. CG: They only performed their regular warm-up.	The ACL injury rate was 1.7 times lower in the EG than in the CG (representing ↓ 41%). The non-contact ACL injury rate was 3.3 times lower in the EG than in the CG (representing ↓ 70%).	↑
González-Jurado *et al.*[3]	2016	Compare two proprioceptive training programmes on stable base (EG1) and unstable base (EG2)	M = 18 (EG1 = 9, EG2 = 9)	In: PT D: PC	EG1: Exercise with stable base. EG2: Exercises with unstable base, the same PP was followed, only the work base was changed. The SEBT was tested 3 times for 3 repetitions.	Differences were found in EG1 variables front left; front left side; posterior right and antero-medial right ($p < 0.005$). EG2 front right; front left; right medial posterior; left medial posterior and right medial ($p < 0.005$).	↑
Heleno *et al.*[16]	2016	Assess the benefits of a sensorial motor training programme lasting five weeks on the functional performance and postural control of young football players.	M = 22 (EG = 12, CG = 10	In: TP D: PC, agility, coordination	EG: Football training plus the sensorial motor programme for 5 weeks, 3 times a week (static support exercises for the legs, hops, moving position, exercises with a ball, work sequences and exercises on stable and unstable surfaces). CG: Normal training. Functional tests were carried out: SEBT, SHT and F8 as previous training.	EG obtained significant results in the postural control tests SEBT ($p > 0.05$), agility and coordination examined using the F8 and the SHT ($p > 0.5$ to 0.8) compared to the CG.	↑

(follow)

(continuation)

Reference	Year	Objectives	Subjects	Variables	Protocol	Results	Perfor-mance
Kraemer & Knobloch[12]	2009	Establish the effect of proprioceptive training on patella and Achilles tendinopathy	M = 24	In: TP D: I, IT	The first 2003/2004 season was the control period with normal training. In the second 2003/2004 season, BT was applied, consisting in jumping forwards on a base, an obstacle race forwards and back, an obstacle race, side jumps, hopping backwards, among others.	The hamstring injury rate without contact dropped from 22.4 to 8.2 / 1000 hours ($p = 0.021$), patella tendinopathy from 3.0 to 1.0 / 1000 hours ($p = 0.022$), and Achilles tendinopathy from 1.5 to 0.0 / 1000 hours ($p = 0.035$). + training, – general injury rate ($r = -0.185$, $p = 0.001$) lower body.	↑
Owen *et al.*[13]	2013	Assess the effectiveness of a muscular injury prevention programme and the total number of injuries in professional football.	M = 26 – 23 (1st season = 26, 2nd season = 23)	In: PP D: I, IT	1st season (2008-2009) with intervention: Multicomponent PP twice a week comprising 4 work stations (balance, functional strength, core stability and mobility). 2nd season: control, without PP.	Intervention season (n = 88 total injuries) > control season (n = 72 total injuries); there is no significance between them ($p = 0.21$).	=
Carlos-Vivas *et al.*[6]	2017	Verify the effectiveness of a prevention programme on reducing lower body injuries among Amateur Footballers	M = 84 (EG = 40, CG = 44)	In: PP D: T, IT	EG: PP after warm-up twice a week, including strength and proprioception exercises on the main leg muscle groups. CG: Regular practice.	↑ injuries in CG 82.9% vs. 17.1% in the EG, furthermore for every 1000 hours of play the EG obtained 8 injuries vs. 41 in the CG. PP after warm-up, ↓ risk of suffering injuries in the lower extremities.	↑

In: Independent; D: Dependent; M: Male; F: Female; PP: Prevention programme; I: Injury; %I: Percentage of injury; s: Significant; ns: Not significant; CG: Control group; EG: Experimental group; PC: Postural control; p: People; TP: Training programme; PhP: Physical performance; DLA: Dominant leg angle; NDLA: Non-dominant leg angle; NMT: Neuromuscular training; PT: Proprioception training; BT: Balance training; TE: Type of exercise; T: Time; IT: Injury time; Tec: Technical; ACL: Anterior Cruciate Ligament; SF: Sedentary female; SM: Sedentary male; ST: Simulated training; BTT: Balance and technique training; mSEBT: Modified Star Excursion Balance Test; SEBT: Star Excursion Balance Test; : Increase; ¯: Reduce; GMF: Group of male footballers; GSM: Group of sedentary males; GFF: Group of female footballers; GSF: Group of sedentary females; SHT: Side Hop Test; F8: Figure of 8.

Discussion

Prevention programmes

Upon finishing the systematic review, various prevention programmes were found. The vast majority of these programmes focused on the reduction of the injury rate in sport[17,18], especially for knees and ankles[19], but even though the majority of the programmes aimed to prevent injuries, each of the research studies consulted had a different approach[3,9,11,12,15]. As such, Schiftan *et al.*[10] concluded that proprioception training programmes are effective in reducing the rate of ankle sprains, whilst Owen *et al.*[13] recommended a preventive training programme entailing multiple components, which could be appropriate for reducing the amount of muscle injuries sustained in a season. However, and regardless of the detailed description given by the authors mentioned above, preventive programmes must be complemented by recording the movement, with feedback and with constant repetition of the works included in the session, as this set of methodological tools led to changes in the neuromuscular response of the athletes studied[7]. Consequently, some researchers have established that athletes should carry out this kind of training every day[13]. According to Ladenhauf *et al.*[20] and Hottenrott *et al.*[21], for preventive programmes to be successful they should include strength exercises, plyometrics, agility, proprioception, balance and neuromuscular training. In turn, Liebert[22] describes how these kinds of prevention programmes should last for between 15 to 20 minutes, how they should be low cost and easy to implement. According to Rahnama[23], by performing more research studies on the risk factors linked to football, solid advice could be given to players, the team's medical body, the coach and even the referees. This would help reduce injuries, keep players healthy and improve sporting performance. One example of the aforementioned is the FIFA11+ prevention programme (this warm-up methodology lasts for around 20 minutes and comprises three well-defined parts with a total of 15 exercises. It should be applied before training and competition); this prevention programme has proven to be effective in reducing injuries, demonstrating its positive effect on athletes[24].

Neuromuscular training

The main aim of this kind of training is to improve neuromuscular control, based on an increased stability of the joint, and producing muscle co-activation triggering greater stability in the joint[25,26]. It has been proven that neuromuscular programmes have a positive effect on preventing injuries and muscular imbalances. Furthermore, by integrating plyometrics, changes take place in the neural and muscular-skeletal system, increasing sporting performance[27]. Some researchers such as Huebscher *et al.*[28] and Acevedo *et al.*[29], have described how neuromuscular training should contain a combination of balance exercises, plyometrics, agility and strength in the specific sport, and these exercises should allow for feedback from the body mechanics. Adding to the previous description, Huebscher *et al.*[28] and Gilchrist *et al.*[11], mention that proprioception and neuromuscular training have an impact on athletes' injuries, which due to the continued adjustments through the trial-error repetition of the nervous system, have revealed promising results in terms of reducing injuries. Unfortunately, and based on existing evidence that present a large number of exercises and types of proprioceptive programmes that could be applied, it would be bold to suggest a single routine or proprioceptive programme to follow[11,28]. However, the proposal made by Ergen & Ulkar[30] allows exercises to be performed that do not pose any degree of complexity, for example, working on different surfaces open or closed eyes, and on alternate legs; these exercises - as they are complemented with stretches, muscle strengthening, plyometrics and agility works - could help reduce knee injuries.

Balance training

The core objective of these kinds of training sessions is to develop the athlete's capacity to maintain and control his/her centre of gravity[31]. In turn, postural balance is necessary for the harmonious and adequate development during the game; this is established as multi-sensorial integration[32]. On the other hand, balance training refers to exercises that improve postural stability and promote the mechanisms responsible for the contraction of agonist and antagonist muscles[32]. After finishing the systematic review, no training programmes were found that focused exclusively on the development of balance, rather a collection of preventive exercises that included work on different surfaces with varied degrees of stability[3,14,31], strength exercises, running and balance[2], the FIFA11+ programme on dynamic and static balance[9], balance, strength and core stability (posture)[13]. Once again, it would be bold to suggest a specific routine or balance programme to follow. However, and based on the results given by the authors of the FIFA11+ programme regarding dynamic and static balance[9], it appears to be a preventive training alternative.

Proprioceptive training

Proprioception is a process via which the body takes information provided by the nervous system through afferent and efferent channels[34,35], generating a motor response[36] and thus revealing consistent and unconscious effects on postural balance, stability and muscle sense[37]. Proprioceptive training can be analysed using two channels: the first is linked to the types of activities that can be done, including stretches, strengthening exercises, plyometrics and agility; the second analysis is that these kinds of exercises should be repetitive to achieve correct execution associated with the practice[30]. In this respect, Daneshjoo *et al.*[9] described proprioceptive programmes as a main component of prevention methods for football players, as by reducing the proprioceptive function there is an increased tendency to suffer injuries more easily, which is why it is key to assess and obtain information about the footballer to observe any shortcomings in proprioceptive work, and from that point create prevention programmes tailored to that player. Based on existing information, strength and proprioceptive exercises[6], the FIFA11+ programme on proprioception[9], and others such as stretches, strengthening exercises, plyometrics and agility to improve neuromuscular and proprioceptive control[11], are specific alternatives to be incorporated within preventive programmes for footballers. Unfortunately, not all proprioceptive training programmes have a significant effect on this variable[3]. In a study presented by González-Jurado *et al.*[3], it was reported that after five weeks of applying a training programme using an unstable and stable base, no significant differences were found in a football team ($p > 0.05$). Despite this, evidence reveals that incorporating specific exercises to prevent injuries in the lower extremities after a warm-up reduces the injury rate[6,9,11].

Postural control

Postural control refers to maintaining the centre of mass against the forces of gravity. Postural control is achieved via muscle contractions[38]. Postural control integrates three afferent channels: vestibular, visual and motor sensory[39]. These channels play a fundamental role in the athlete's activities, with particular emphasis on all movements that require keeping balance, which becomes important in the performance of the player[40]. Despite existing evidence not claiming specific tests for postural control, there are claims for an increase in agility, leg strength and football skills after incorporating the FIFA11+ programme as part of the warm-up for football players[2]. Furthermore, Heleno *et al.*[16] assessed the benefits of a motor sensorial training programme lasting five weeks on the functional performance and postural control of young football players. The tests used by the researchers were: the Star Excursion Balance Test (SEBT), the Side Hop Test (SHT) and the Figure-of-Eight Test (F8); after finishing the intervention, the experimental group improved in all the tests[16]. Consequently, postural training programmes revealed improvements in performance. They can also be implemented using readily available equipment and at a low cost.

Conclusion

Upon finishing the systematic review, it was clear that the main methods of preventing injuries in the lower extremities of football players, were proprioceptive training, balance training, neuromuscular training and postural control training. Within these programmes, proprioceptive training stands out as the main or secondary element in preventive programmes, which have been fundamental in reducing the injury rate and in rehabilitating football players following trauma. As such, evidence shows that preventive programmes are easy to apply, short in duration (15 to 20 minutes) and are not necessarily costly to perform[22]. For all the above, injury prevention exercises must be included within training programmes developed for football players.

Practical applications

- In practical terms, and having performed the systematic review, exercises to prevent injuries are a highly useful tool, and offer a wide variety of functions to reduce the risk of injuries in footballers. However, certain aspects must be taken into account:
- Integrate proprioceptive exercises into every preventive programme, as evidence proves that they have good results in preventing injuries, in particular in the knees and ankles of footballers.

- When it comes to implementing a prevention programme, the type of player, his/her history of injuries and the types of exercises that could be applied should be taken into account.
- If it is a proprioceptive preventive programme for a group of footballers, develop a methodological sequence that is suitable to generically cover all the team's needs. Likewise, the types of exercises used should be varied in different sessions.
- Each of the programmes that can be applied should have specialised personnel that possess the skill set needed in order to perform each of the exercises correctly, without risking the integrity of the player.
- Finally, researchers are encouraged to establish new preventive programmes, applying proprioception to the lower extremities of football players so as to reduce injury rates.

Conflict of interest

The authors do not declare a conflict of interest.

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Acute effects of heat on health variables during continuous exercise and their comparison with normal and cold conditions: A systematic review

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Summary

Background: There has been an increasing number of running practitioners in the last years. Although running activity involves several benefits for practitioners, it might also induce health problems when practicing under heat conditions.
Purpose: The main aim of this systematic review was to evaluate how high temperatures affect runner's health during continuous exercise.
Search strategy: The search for articles for this study was carried out in two different databases, Web of Science and Pubmed.
Study selection: The inclusion criteria were a) Studies that investigated the effects of endurance exercise, at least at 27º, on health variables, determining exercise intensity, indicating total time for exercise and presenting pre- and post-test results or compare with normal or cold conditions.
Results: 1336 articles were identified after the searching process. 333 runners were evaluated in fifteen articles that were included in the qualitative synthesis. High increases in heart rate, body and skin temperature, some urine and blood markers, blood pH, ventilation, rate of perceived exertion and sweat rate were identified during continuous activity under heat conditions, and also when comparing with normal or cold conditions. Lower values were found in body mass, eosinophil than those observed before the running activity. Lower values for oxygen consumption and plasma lactate may occur in hot conditions when comparing with normal conditions.
Conclusions: Studies analyzed conclude that an uncontrolled long-term activity in hot conditions may induce health problems related to high body and skin temperatures. Cooling strategies should be assessed after continuous exercise under hot conditions. In addition exercise in hot conditions produces greater increases in immune functions, heart rate, breathing stress, metabolic responses and rate of perceived exertion, also compared with normal and cold conditions.

Key words:
Heat. Endurance. Health. Hyperthermia.

Efectos agudos del calor sobre variables de salud durante el ejercicio continuo en comparación con condiciones normales y frías: una revisión sistemática

Resumen

Introducción: El número de corredores ha incrementado en los últimos años. Aunque la actividad de correr implica varios beneficios para los practicantes, también puede provocar problemas de salud cuando se practica en condiciones de calor.
Propósito: El objetivo de esta revisión fue evaluar cómo las altas temperaturas afectan la salud del corredor.
Estrategia de búsqueda: La búsqueda de artículos para este estudio se llevó a cabo en Web of Science y Pubmed.
Selección de estudios: Los criterios de inclusión fueron estudios que investigaron los efectos del ejercicio de resistencia, al menos a 27º, sobre variables de salud, determinando la intensidad y duración del ejercicio y se presentaron resultados previos y posteriores a la prueba o compararon con condiciones normales o frías.
Resultados: 1336 artículos fueron identificados después del proceso de búsqueda. 333 corredores fueron evaluados en quince artículos que fueron incluidos en la síntesis cualitativa. Durante la actividad en condiciones de calor, se identificaron incrementos elevados en la frecuencia cardíaca, la temperatura corporal y de la piel, algunos marcadores de orina y sangre, el pH sanguíneo, la ventilación, el esfuerzo percibido y la sudoración. Se encontraron valores más bajos de masa corporal y eosinófilos que los observados antes de la actividad de carrera. Valores más bajos de consumo de oxígeno y lactato aparecen en condiciones de calor cuando se comparan con las condiciones normales.
Conclusiones: Los estudios analizados concluyen que una actividad no controlada a largo plazo en condiciones de calor puede inducir problemas de salud relacionados con altas temperaturas corporales y de la piel. Además, el ejercicio en condiciones de calor produce mayores incrementos en las funciones inmunitarias, la frecuencia cardíaca, el estrés respiratorio, las respuestas metabólicas y el esfuerzo percibido, también en comparación con las condiciones normales y frías.

Palabras clave:
Calor. Resistencia. Salud. Hipertermia.

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Introduction

Nowadays there has been an increase in open running races where anyone can participate, even without a medical examination.

Endurance activity has several benefits on health according to a recent meta-analysis[1] that highlighted some advantages in body composition, resting heart rate (HR), maximal oxygen consumption (VO_{2max}), triglycerides or high density lipoproteins in sedentary people. Contrarily, the practice of running in hot conditions (HC) or cold conditions (CC) and high or low relative humidity can incur performance and health problems[2-5].

The American College of Sports Medicine considers a hot environment when temperature exceeds 27 centigrade degrees (ºC)[6]. Practicing sport under heat conditions affects negatively to aerobic performance[7]. After studying 28 marathons, positive correlations were found among non-finished runners and environmental temperature, and also between temperature and time needed to finish the races[8]. Hyperthermia, defined as an internal body temperature higher than 39.5ºC[9] may reduce VO_{2max} values up to 16% and increase heart rate (HR) between 15 and 20 beats per minute at the same intensity compared to cooler temperatures. This is due to the vasodilation process whose objective is to reduce skin temperature[10]. Fatigue might also occur as a consequence of high body temperatures even in trained subjects during prolonged exercise[11]. Although resting values for body temperature are lower in trained athletes, aerobically trained subjects can reach higher body temperatures than untrained ones when exercising at maximal intensities[12]. Skin temperature depends more on environmental conditions (temperature and relative humidity) while body internal temperature depends more on exercise intensity[13].

During sweating, a runner may lose a huge quantity of electrolytes such as sodium or potassium, inducing hyponatremia. However, hyponatremia could be also consequence of hyperhydration or a big loose of body mass (BM)[14], that ultimately might provoke death cases[7,15-17].

During exercise with high temperature exposure, there is a higher predominance of glycogen over lipid metabolism and also higher concentrations of plasma lactate[18], which induce greater fatigue. Heat acclimation can reduce muscle glycogen rate of utilization even to 50% and 60%, reducing fatigue[19]. Other benefits of heat acclimation involve greater arterial elasticity[20] or reductions of heart rate in high temperature conditions[21].

Body composition might be an important factor in exercise at different temperatures. The higher subcutaneous fat, the more efficient heat conservation is in cold environments due to a low thermic conductivity observed by fat mass[22].

Humidity is another determining factor since sweat evaporation becomes more inefficient in a heat environment making body internal temperature difficult to reduce[23]. During running, convection is less efficient in heat dissipation at lower running speeds, so this factor is identified as important in exercise intensity[23].

Continuous activity in hot conditions has less increases than variable-intensity exercise in heat storage, cardiovascular and metabolic stress[24]. Therefore, the main aim of the present systematic review was to evaluate how high temperatures affect runner's health during continuous exercise.

Method

Search strategy

Two databases were used for the searching process, PubMed and Web of Science following the search terms "Heat" AND "endurance" AND "run"; "Heat" AND "Marathon"; and "Heat" AND "endurance" AND "Cycle". The process was undertaken from May to June of 2018 and no papers were excluded based on publication date or language.

Inclusion criteria

The inclusion criteria for the studies were: a) investigating the effects of endurance exercise on health variables, at least, at 27º C; b) determining the intensity of exercise or if it was self-paced; c) indicating the value for total time of exercise when no criteria of exercise conclusion were established by the researchers (until fatigue or reaching certain body temperature). If it was necessary, authors were contacted for getting this value and d) presenting pre- and post-exercise results in hot conditions or comparing it with normal conditions (NC) or cold conditions.

Exclusion criteria

Studies that did not investigate the relationship between health variables and exercise parameters were not included. Articles were excluded if the physical activity followed by the participants was not continuous (when different activities were undertaken, only continuous exercises were taken into consideration). Those that had an animal sample were not included either. No articles were included if they only focused on performance parameters. Investigations about the effects of any substance intake were excluded as well as the post-test results of an intervention program. Previous reviews and studies where heat effects on health variables variation were not measured or were not interesting for the review were also excluded. Additionally, studies measuring races and competitions, such as ultramarathon with race times longer than five hours were excluded due to intense temperature variations. Triathlon research was excluded because of water temperature effects. Last exclusion criteria included research with unhealthy participants.

Results

A flow chart for the article identification after the searching process is presented in Figure 1. Number of records identified, screened and those chosen for eligibility and included ones are shown.

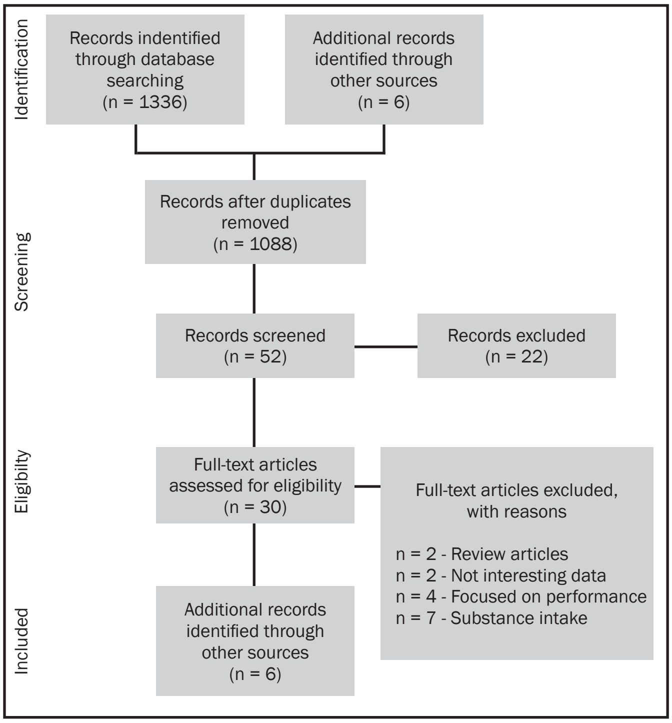
Table 1 shows an overview of articles included in the qualitative synthesis, showing the number of participants, age, exposure time to HC and its temperature and outcome measurements for each article.

A total of 333 runners (295 males and 38 females) were evaluated in the 15 articles included in the qualitative analysis once selection process concluded.

Discussion

Exposure to high ambient temperatures, reaching values of 40 ºC in core temperature can induce heat stroke[39]. This consequence can be

Figure 1. Flow chart showing the search method.



n: number of articles.

due to a high intensity exercise[40]. Aerobic fitness adaptations, related to heat dissipation, are not necessarily associated to a less health risks about body temperature[12]. Otherwise, fluid intake is an effective form to maintain lower levels of body temperature, mostly in aerobically trained athletes[41], also heat acclimation produces significant reductions in body temperature[42]. After 107.12 ± 8.85 min of exercise in HC, it was found a body temperature (BT) of 39.6 ± 0.6ºC[29], 40.1 ± 0.3ºC after 58.8 ± 3.3 min and 39.8±0,4 ºC after 59.7±2.0 min of self-paced exercise. These values were significantly higher than self-paced exercise in NC[32]. 39.2 ± 0.1ºC was the temperature reached during race-walking in HC at 10.9 $Km•h^{-1}$ for 60 min, being 38.4 ± 0.1ºC when running at the same velocity and time, but this difference were not noticeable at skin level[28]. The increase in BT after a 30 minutes self-paced run went from 37.42 ± 0.28ºC to 39.20 ± 0.12ºC for men while for women in follicular phase it ranged from 37.42 ± 0.28ºC to 39.30 ± 0.10ºC and from 37.7ºC to 39.20 ± 0.01ºC in luteal phase[36]. At 80% and 100% of VO_{2max} intensity in cycle exercise, higher BT than CC was observed in HC[31]. Increases of 0.13 ± 0.03 $ºC•min^{-1}$ for HC and 0.06 ± 0.03 $ºC•min^{-1}$ for CC were detected at 80% of VO_{2max} intensity until exhaustion, considering that the time to exhaustion was approximately twice longer for CC[31]. The increases at the same conditions for a 100% of VO_{2max} intensity were 0.22 ± 0.05 $ºC•min^{-1}$ for HC and 0.13 ± 0.03 $ºC•min^{-1}$ for CC. At 70% of peak treadmill running speed, BT was higher for HC at 30 minutes after the start of the exercise when comparing with NC, the same difference appeared during a maximum intensity run[27]. In the same study, it was observed how the skin temperature stays always significantly higher when practicing the same exercise in HC than in NC[27]. In fact, during exercise in NC, skin temperature tends to decrease (from 30.5 ± 0.1 to 25.8 ± 0.1ºC), while in HC the skin temperature remains between 33.5 ± 0.1ºC and 34.1 ± 0.2[27]. At 75% of VO_{2max} intensity of 30 minutes running, BT was significantly higher for HC than NC[25]. Higher values for BT occurs in the first 45 minutes for HC than NC when cycling at 55% of VO_{2max}, remaining these values until the end of the 75 minutes exercise[33]. Comparing HC with CC, significant differences in BT were determined only in the first 30 minutes of cycle activity at a 65% of max power (W_{max}), but higher and significant differences were determined appear in skin temperature values from the beginning until the end of the exercise (40 minutes)[34]. Cycling at 65% of VO_{2max} in HC produced significant increases in BT during all the exercise time, being higher when practicing in the evening than in the morning, where similar results were also observed in skin temperature values[37]. A comparison between HC and NC was conducted by Lafrenz *et al.*,[38] identifying significant higher values in body and skin temperature for HC in both submaximal and maximal intensity exercises.

After an 80% and 100% of VO_{2max} intensity during cycling exercise higher blood pH under HC than CC was observed, a difference that remained along the recovery time at 80% of VO_{2ma}[31]. There were not significant lactate concentration differences between HC and CC after cycling exercise until exhaustion at 80% of VO_{2max} intensity[31]. However, at a 65% of W_{max} significant differences in lactate concentrations were observed in the first 20 and 40 minutes of cycling when comparing between the same conditions[34]. Additionally, differences in lactate concentration were found after 60 minutes of race-walking and running at same VO_{2max} percentage, but not when running at same speed in HC[28]. In the present study, there were not differences in plasma volume after any of these trials. After a 30 minutes of 70% of peak treadmill running speed, urate were higher for HC when comparing with NC[27]. After running at maximum effort, there were also higher values for plasma ammonia concentrations in HC, but lower values in lactate concentrations[27]. Anyway, the difference between pre-exercise urate concentrations in these three variables compared to those observed after running at maximum effort showed significant increases. Furthermore, there were not any significant differences in plasma volume and lactate in submaximal cycling exercise when comparing HC to NC, observing same results for plasma volume in maximal intensity, but lower values in plasma lactate in HC comparing with NC[38].

According to the research about immune system, at the end of 78 minutes of a self-paced race[6], there were significant increases of total leucocytes number (from $5.52x10^3 \pm 0.2x10^3$ cell/μL to $9.31x10^3 \pm 2.4x10^3$ cell/μL), neutrophils (from $2.90x10^3 \pm 0.6x10^3$ cell/μL to $7.64x10^3 \pm 3.4x10^3$ cell/μL) and hematocrit percentage (from 43.16 ± 3.0 to 46.68 ± 3.2). At the same time, there were significant decreases in lymphocytes (from $1.67x10^3 \pm 0.3x10^3$ cell/μL to $1.34x10^3 \pm 0.3x10^3$ cell/μL) and eosinophil ($0.36x10^3 \pm 0.2x10^3$ cell/μL to $0.22x10^3 \pm 0.1x10^3$ cell/μL). Data obtained after a mean time of 107.12 ± 8.85 min of self-paced running in HC, revealed that leucocyte count and plasma Lipopolysaccharides increased by 66.2% and 31.6% respectively, as well as granulocyte, which increased from $4.1x10^9 \pm 1.0x10^9$/L to $9.0 \pm 3.2x10^9$/L. Same authors[29] also observed a significant increase in cytokines (IL-6, IL-10 and IL-1ra) after a running competition. On the other hand, lymphocyte count decreased 25% after running activity. In addition, no significant changes before and after the race in TNF-α and IL-1β were identified[29]. After a Marathon race with a mean time of 229 ± 38 minutes in HC, increases

Table 1. Overview of articles included in the review.

Author	N	Age (years)	Exposure time (minutes)	Outcome measures	T (ºC)
Al-Nawaiesh, *et al.* (2013)[26]	10 M	17.75±0.68	5, 10, 15, 20, 25 and 30	Body Temperature, Glycaemia, Rating of Perceived Exertion, Blood Pressure, HR, Sodium and Potassium	40
Del Coso, *et al*. (2013)[27]	114M 24F	39±8	229	Leg power, Body Mass, Urine Haematites, Leuko-cytes, Proteins, Ketones, Myoglobin and Bilirubin.	28
Marino, *et al*. (2001)[28]	9M	25 ± 1	31,3 ± 1,2	Body Temperature, Skin Temperature, Heart Rate, Plasma Lactate and Ammonium, Respiratory Exchange Ratio.	35
Mora-Rodríguez , Ortega and Hamouti (2011)[29]	4M 5F	22 ± 5	8, 15, 25, 30, 40, 45, 55 and 60	Oxygen Consumption, Body Temperature, Skin Temperature, Heart Rate, Rate of Perceived Exertion, Sweat Rate, Plasma Lactate.	30
Ng, *et al.* (2008)[30]	32 M	25.0 ± 3.2	107,12 ± 8,85	Leukocyte, Lipopolysaccharides and Cytokines, Body Temperature and Heart Rate.	27
Lim, *et al.* (2009)[31]	18 M (2G)	33.8 ± 7.1 33.0 ± 7.0	Until reaching 39.5ºC of BT	Lipopolysaccharides, Body Temperature, Cytokines, Ant-LPS Antibodies (IgG and IgM), Heart Rate, Sweat Rate.	35
Mitchell, *et al.* (2014)[32]	11 M	32.6 ± 4.4	To exhaustion	Oxygen consumption, Heart rate, Ventilation, Body Temperature, Blood PH, Plasma Lactate.	37
Silva-Filho, *et al*. (2016)[7]	14 M	41 ± 10	78	Body Mass, Hematocrit, Leukocyte, Neutrophils, Lymphocyte, Monocyte, Basophils, Eosinophil and Monocytes.	38,75
Viveiros, *et al.* (2012)[33]	7 M 7 M	54 ± 2 28 ± 1	58,8 59,7	Oxygen consumption, Heart Rate, Body Temperature and Sweat rate.	40
Mitchell, *et al*. (2002)[34]	10 M	24.7 ± 6.6	75	Body Temperature, Heart Rate, Glucose, Cortisol, Neutrophil, Lymphocyte and Leukocyte,	38
Romer, *et al.* (2003)[35]	7M	21.7 ± 0.8	2, 30 and 60	Body Temperature, Skin Temperature, Plasma Lactate, Heart Rate and Rate of Perceived Exertion	35
Luk, *et al.* (2016)[36]	28M 4F	49 ± 8 42 ± 12	384 ± 60	Leukocytes, Neutrophils, Monocytes and Lymphocytes	35.3 ± 5.0
Wright, *et al*. (2002)[37]	5M 5F	20.6 ± 0.8 25.0 ± 1.6	21.7 ± 1.75 20.6 ± 0.87	Body Temperature, Heart Rate, Rate of Perceived Exertion and Sweat Rate.	30
Hobson, *et al*. (2008)[38]	9M	24 ± 2	45.8 ± 10.7 40.5 ± 9.0	Body Temperature, Skin Temperature, Heart Rate, Plasma Volume, Sweat Electrolytes and Rate of perceived exertion.	35
Lafrenz, *et al.* (2008)[39]	10M	23 ± 3	15 and 45	Oxygen consumption, Plasma Lactate and Volume, Heart Rate, Body Temperature, Skin Temperature, Rate of perceived Exertion.	35

M: Male; F: Female; 2G: Two different groups; DS: Different samples

were found for hematite, leukocytes, proteins, ketones and bilirubin values through urine concentration analysis, not finding significant values in post-race pH concentrations and specific gravity[26]. Romer, Bridge, McConell & Jones[34] investigated immune cells function in HC observing significant increases of 134% in total leukocytes, 319% in neutrophils, 24% in monocytes and 53% in lymphocytes after a self-paced cycle race. A running activity in HC at 70% of VO_{2max} until reaching volitional status or a BT of 39.5ºC was conducted to examine blood markers by Lim *et al.*[30]. There were increases of 71% and 92% on plasma lipopolysaccharides concentration in two different groups. Additionally, these authors[30] did not find significant differences between pre-exercise and post-exercise in anti-LPS IgG antibodies concentrations. Similar results were found for anti-LPS IgM antibodies concentration, except for the significant increase identified between pre-exercise and 90 minutes post-exercise rest in this anti-LPS antibodies concentration. Regarding cytokines concentration, no differences between pre- and post-exercise in TNF-α and IL-1β, were detected whereas, on the contrary, increases in both IL-6 and IL-10 concentrations between pre- and post-exercise and between pre-exercise and 90 minutes post-exercise in both groups were determined[30]. Greater loss of plasma volume in HC than NC and also higher number of circulating lymphocyte (CD3, CD4 and CD8), leukocyte and neutrophil number at the end of exercise occurred when cycling at a 55% of VO_{2max}, maintaining these differences in leukocyte and neutrophil cells two hours after the exercise[33].

When HC and NC were compared, a significant difference in blood sugar was detected in the first 5 minutes of exercise at 75% of VO_{2max}, that was maintained until the end of the activity (30 minutes)[25]. Similar results were observed after 75 minutes of cycling exercise in blood sugar and cortisol at a 55% of VO_{2max}[33]. In HC, sodium concentration was significantly higher after 5, 10 and 15 minutes, but lower after 20 and 25 minutes of exercise than in NC, not being significantly different after 30 minutes of exercise[25]. No significant differences were identified in sodium concentrations after 45 minutes in HC of cycling at 65 of VO_{2max}, but these differences were determined, instead, in potassium and chloride concentrations[37].

During exercise in the heat, body mass loss can induce an increase of HR[43]. Variables as HR variability decay faster than other adaptations like BT after heat acclimation during non-exposure to heat[42]. During exercise at 75% of VO_{2max}, HR significantly increases every 5 minutes in both HC and NC, observing a significant differences between both conditions at 10 and 15 minutes[25]. At 70% of peak treadmill running speed, heart rate was observed to be higher for HC from the first 10 minutes until the end of the run (30 minutes) when comparing with NC, observing similar results in the first 10 minutes during running at maximum effort[27]. After 60 minutes of 90% of self-paced running speed exercise, there were significant differences between NC and HC in HR values in young (28 ± 1 years), and middle-aged adults (54 ± 2 years)[32]. Significant higher values were identified in HR in 60 minutes of race-walking at 10.9 Km • h^{-1} in HC than running at the same conditions of velocity and time[28]. No significant differences were found between HC and CC at 80% and 100% of VO_{2max} in HR in cycling exercise[31]. Significant differences were observed in HR in the first 15 minutes when exercising at 75% of VO_{2max} that remain until the end of the 75 minutes activity, same differences from the first 10 minutes until the end of exercise (40 minutes) when comparing HC and CC at a 65% of W_{max}[34]. Cycling in HC at 65 of VO_{2max} produces significant increases of HR during the entire exercise time, being higher when practicing in the evening than in the morning[37]. When cycling at submaximal intensities, HR was affected by temperature, since higher values for HC than NC were observed. However, this difference was not determined at maximal intensity[38].

While in trained subjects, blood pressure values return to baseline, hypotension status appears post-exercise in trained athletes in HC[44]. Diastolic blood pressure increases with decreases of environmental temperature among elderly men[45]. Diastolic blood pressure was lower in HC than NC after 5, 10 and 15 minutes of exercise at 75% ofVO_{2max}, not being significantly different after the first 20 minutes[25]. Systolic blood pressure (SBP) was also higher in NC during the first 5, 10 and 15 minutes while after 20, 25 and 30 minutes of exercise higher values for SBP in HC were detected[25]. In submaximal intensity cycling exercise, there were not significant differences in mean arterial pressure when comparing HC with NC[38].

During cycling at 80% and 100% of VO_{2max} intensity, higher levels of ventilation in HC than CC at the exhaustion time were determined (148.74 ± 20.88 L•min^{-1} and 127.81 ± 15.75 L•min^{-1} for 80% of VO_{2max} and 164.29 ± 12.92 L•min^{-1} and 151.59 ± 17.39 L•min^{-1} for 100% of VO_{2max} in HC and CC respectively)[31]. This difference were not observed when performing at 65% of VO_{2max} cycling intensity[38].

Respiratory exchange ratios (R) were significantly higher under HC than NC at 70% of peak treadmill running speed. In HC R value was always close to 1 (1.0 ± 0.01 for the first 10 minutes; 0.99 ± 0.01 for 20 minutes; and 0.99 ± 0.01 for 30 minutes), while at the same intensity in lower values were determined (0.96 ± 0.01 at 10 min; 0.95 ± 0.02 for 20 min; and 0.93 ± 0.02 for 30 min)[27]. There were no significant differences among VO_2 parameters. In addition, significant differences were not found in R when comparing HC (0.97 ± 0.03) with NC (1.05 ± 0.04) at maximal cycling exercise[38].

Comparing a 60 min self-paced run in HC with 50 min in NC, $VO_{2Absolute}$ and VO_{2max} were significantly higher in young and middle-aged runners[32]. $VO_{2Absolute}$ values were also significantly higher for submaximal cycling exercise in HC comparing with NC, but lower for $VO_{2Absolute}$ and VO_{2max} at maximum effort[38].

Although body mass tends to fall during endurance exercise, it is not related to decreases in performance or health troubles[46-49]. At the end of 78 minutes of a self-paced race in HC, a reduction of BM of 3,48% occurred[6]. Similarly, after a marathon race, a loss of 2.22 ± 1.2% of BW was identified when comparing to pre-race values, registering decreasing values up to 6%[26].

Regarding sweat rate, it was observed higher values when practicing exercise in HC than in NC, in both self-paced and 90% of self-paced running intensity. This results were in agreement with those observed for young and middle-aged adults[32]. Lim *et al.*[30] described a sweat rate of 2.56 ± 0.52 L•h^{-1} and 2.40 ± 0.48 L•h^{-1} when running at 70% of VO_{2max}. Sweat rate was significantly greater for men than for women in HC after 30 minutes of self-paced exercise[36].

No significant differences were found in RPE in HC before and after heat acclimation[50]. Four studies reported RPE values in HC[25,27,34,38]. There were significantly higher values for RPE in HC than NC and CC when running at 75% of VO_{2max} at 5, 10, 20 and 25 minutes of exercise[25]. Similar results were observed at 70% of VO_{2max} while running, also observing these values at maximum intensity run[27] and at a 65% of W_{max} cycle[34]. Furthermore, RPE was significantly higher in HC at submaximal cycling intensity, but not significantly different at maximal intensity[38].

Conclusions

Practicing exercise in hot conditions, produces higher values in body temperature than in normal or in cold conditions. Absolute values after exercise typically reach 39.5ºC, which means that physical activity in hot conditions induces hyperthermia. Thus, we observed that hyperthermia may occur independently of exercise intensity in hot conditions. It has been observed that skin temperate is always higher in hot conditions when comparing to normal and cold conditions, even in normal and cold conditions skin temperature can be reduced during exercise. Therefore, we conclude that an uncontrolled long-term activity in hot conditions may induce health problems related to high body and skin temperatures. Cooling strategies should be assessed after continuous exercise under hot conditions.

It has been observed that plasma lactate does not tend to be higher when the exercise is under hot conditions after identifying higher concentrations in normal conditions. Plasma volume was not affected by different temperatures. Conversely, urate and ammonia concentrations appear to be higher in hot conditions than in normal conditions. The main finding of the current review was the values attributed to immune functions. Although sometimes lymphocyte cell number tends to fell instead of increase, exercise in hot conditions typically produces great increases in cell counts. Findings on blood sugar support the meaningful increases after the exercise in hot conditions, even comparing with normal conditions.

As for heart rate, higher values in hot than in normal conditions are observed. This fact must be taken into consideration during endurance training in a hotter ambient than 27ºC if the intensity of exercise are proposed in function of percentages of maximal heart rate. It could be interesting to study how high temperatures during exercise affect to those that intake beta-blockers drugs. Similarly, in Sports Science there were few studies to conclude how temperature affects blood pressure during exercise

Although there were not many articles that investigated the effects of heat on breathing variables. Ventilation, respiratory exchange ratios and oxygen consumption present greater values in hot conditions than in normal conditions when practicing exercise.

Finally, similar results for rate of perceived exertion during exercise when comparing heat to normal conditions. We conclude that RPE is always higher for hot conditions. Thus, these findings might be interesting for those whose training programs are based on subjective effort, knowing that at same intensity greater effort is demanded when practicing in higher temperatures.

Conflict of interest

The authors do not declare a any conflict of interest.

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LA PREPARACIÓN FÍSICA PARA EL JUDO

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Todo judoca que quiera progresar debería realizar una buena preparación física, tanto preventiva como para el rendimiento, sobre todo mediante ejercicios que deben ser específicos o, incluso estar integrados en su entrenamiento habitual. Este libro es el fruto de muchos años de trabajo y experiencia como judoca de su autor. Éste, de forma didáctica y clara, explica las técnicas de preparación física y la forma de integrarlas en el entrenamiento.

Trata todos los aspectos fundamentales: fortalecimiento muscular específico, planificación, resistencia específica y, prevención y recuperación. Es una obra de referencia en el mundo del judo y los deportes de combate, escrita por un especialista en la materia, con la participación de atletas de talla mundial. Incluye numerosos ejercicios y pruebas con y sin material adicional. Una lectura accesible tanto para el practicante debutante como para el cinturón negro con experiencia que utiliza muchas situaciones que se dan en los entrenamientos.

KAYAK DE RESCATE

Por: Daniel J. Aragón
Edita: Ediciones Tutor. Editorial El Drac.
Impresores 20. P.E. Prado del Espino. 28660 Boadilla del Monte. Madrid.
Telf.: 915 599 832 – Fax: 915 410 235
E-mail: info@edicionestutor.com Web: www.edicionestutor.com
Madrid 2019. 144 páginas. P.V.P.: 25 euros

Cada vez es más habitual ver a socorristas utilizando el kayak en sus jornadas de vigilancia en playas. Por su versatilidad y seguridad para estos fines, el llamado kayak autovaciable *(sit on top)* es el protagonista de este manual. El libro, con más de 120 fotografías, detalla las posibilidades de uso del kayak autovaciable para tareas de prevención, rescate y salvamento en playas.

En sus 144 páginas profusamente ilustradas y a color, incluye: la elección del kayak adecuado; las técnicas básicas de formación en piragüismo; el análisis de las técnicas de rescate; los protocolos de actuación con víctimas activas y pasivas; el conocimiento del medio; el programa formativo para socorristas acuáticos; y el mantenimiento, cuidados y reparación del kayak. Además, las técnicas descritas en este manual servirán para mejorar la seguridad de pescadores que usan el kayak y la de kayakistas de recreo o aventura que en sus salidas pueden verse sorprendidos por una situación de emergencia.

VALORACIÓN DEL RENDIMIENTO DEL DEPORTISTA EN EL LABORATORIO

Por: José Naranjo Orellana, Alfredo Santalla Hernández, Pedro Manonelles Marqueta
Edita: Esmon Publicidad. S.A.
Balmes 206, 3º 2ª. 08006 Barcelona
Telf.: 932159034 – E-mail: redaccion@esmon.es
Barcelona, 2013. 560 páginas. P.V.P.: 70 euros

El rendimiento deportivo es el resultado de la interacción del entrenamiento y de factores genéticos. Potenciar al máximo la capacidad y las cualidades del deportista a través del entrenamiento posibilita al éste a alcanzar el éxito en la competición. La valoración funcional es una especialización científica, enmarcada en el contexto multidisciplinar de las ciencias aplicadas al deporte, que abarca sistemas y técnicas basadas en la fisiología, la medicina del deporte, la ergometría, la biomecánica, la antropometría, la bioquímica y otras áreas de investigación; y, está muy vinculada al proceso global del entrenamiento físico y al rendimiento deportivo.

La obra se estructura en siete capítulos: Introducción; Valoración muscular; Valoración del metabolismo anaeróbico; Valoración del metabolismo aeróbico; Valoración cardiovascular; Valoración respiratoria; Supuestos prácticos.

SMD
Sociedad Española de Medicina del Deporte

AJUNTAMENT DE REUS

VIII JORNADAS NACIONALES DE MEDICINA DEL DEPORTE

MEDICINA DEL BALONCESTO

22-23 DE NOVIEMBRE DE 2019

SOCIEDAD ESPAÑOLA DE MEDICINA DEL DEPORTE (SEMED)
REGIDORÍA D'ESPORTS / AJUNTAMENT DE REUS

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Esports

REUS és ESPORT

CIUTAT DEL BÀSQUET CATALÀ
REUS
2019

COMITÉ ORGANIZADOR

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PROGRAMA CIENTÍFICO (PRELIMINAR)

DÍA 22 DE NOVIEMBRE, VIERNES

09.00-10.30 **PONENCIA: La Medicina del Deporte en el Baloncesto.**
Moderador: ***Francisco Javier Rubio Pérez***

Baloncesto femenino. ***Silvia Treviño Monjas***

Organización y control médico en Selecciones Españolas. ***Pilar Doñoro Cuevas***

Baloncesto en la discapacidad – baloncesto en silla de ruedas. ***Josep Oriol Martínez Ferrer***

11.00 -12.30 **PONENCIA: Lesiones y Baloncesto**
Moderador: ***Alfredo Rodríguez Gangoso***

La rodilla. ***Jaume Perramon Llavina***

El tobillo. ***Cristóbal Rodríguez Hernández***

Músculo y tendón. ***Javier Valle López***

12.30 -13.30 **CONFERENCIA INAUGURAL**
Presentación: ***Luis Franco Bonafonte***

La historia del dopaje en el deporte olímpico ***Eduardo Henrique De Rose***

15.30 -17.00 **PONENCIA: Muerte Súbita y Deporte**
Moderador: ***J. María Alegret Colomé***

Recomendaciones sobre participación deportiva en la cardiopatía isquémica. ***Mats Borjesson***

El electrocardiograma en la prevención de la muerte súbita del deportista. ***Gonzalo Grazioli***

Arritmias y muerte súbita del deportista. ***Xavier Viñolas Prat***

17.30 -19.00 **TALLER**
Electrocardiograma en deportistas.
Emilio Luengo Fernández

DÍA 23 DE NOVIEMBRE, SÁBADO

10.00 -11.30 **PONENCIA: Controversias: Nutrición - Ayudas Ergogénicas. Los mitos de la alimentación en el deporte.**
Moderador: ***Mónica Bulló***

¿Influye el tipo de dieta en la microbiota y el rendimiento deportivo? ***Teresa Gaztañaga Aurrekoetxea***

Dietas détox y antioxidantes alimentarios en la práctica deportiva. ***Nuria Rosique***

Ayudas ergogénicas, realidad o mito. ***Begoña Manuz González***

12.00 – 13.00 **PONENCIA: Manejo del dolor en Medicina del Deporte.**
Moderador: ***Isabel Tello Galindo***

Bloqueos nerviosos en lesiones del aparato locomotor en Medicina del Deporte. ***Eduardo Marco Sánchez***

Distrofia Simpático Refleja y Lumbalgia – Síndrome facetario en deportistas. ¿Qué ofrece la Unidad de Dolor? ***Guillem Bujosa Portells***

13.00 -13.45 **CONFERENCIA DE CLAUSURA**
Presentación: ***Pedro Manonelles Marqueta***

Actualización en dopaje. ***José Luis Terreros Blanco***

COMUNICACIONES CIENTIFICAS

El Comité Científico invita a todos los participantes a remitir comunicaciones científicas (comunicaciones orales y póster-presentación interactiva) a las VIII Jornadas Nacionales de la Sociedad Española de Medicina del Deporte.

Temas para presentación de Comunicaciones Científicas:

- Medicina del deporte.
- Entrenamiento y mejora del rendimiento.
- Biomecánica.
- Cardiología del deporte.
- Fisiología del esfuerzo.
- Nutrición y ayudas ergogénicas.
- Cineantropometría.
- Lesiones deportivas: diagnóstico, prevención y tratamiento.
- Actividad física y salud.

INFORMACIÓN GENERAL

22-23 de noviembre de 2019

Lugar
Auditorio y aulas
Hospital Universitari Sant Joan de Reus
Av. del Dr. Josep Laporte, 1
43204 – Reus (Tarragona)
Tfno: 977310300
Unidad de Medicina del Deporte.
Tfno: 977308305
Fax: 977337753
Correo electrónico: lfranco@grupsagessa.com
Localización del hospital: http://www.hospitalsantjoan.cat/contacteu/

Secretaría Científica
Sociedad Española de Medicina del Deporte
Dirección: Apartado de correos 1207. 31080 Pamplona
Teléfono: +34 948 26 77 06
Fax: +34 948 17 14 31
Correo electrónico: congresos@femede.es
http://www.femede.es/page.php?/interno/OtrasActividades

Secretaría Técnica
Viajes El Corte Inglés S.A.
División Eventos Deportivos
C/ Tarifa, nº 8. 41002 Sevilla
Teléfono: + 34 954 50 66 23
Correo electrónico: areaeventos@viajeseci.es
Personas de contacto: Silvia Herreros

Derechos de inscripción	Antes del 18-7-2019	Del 18-7-2019 al 19-9-2019	Desde 27-9-19 y en sede Jornadas
Cuota general	125 euros	150 euros	200 euros
Miembros ARAMEDE/ FEMEDE	100 euros	125 euros	175 euros
Médicos MIR*	60 euros	75 euros	125 euros
Estudiantes**	30 euros	30 euros	30 euros

*Es necesaria acreditación.
**Grados, Licenciaturas y Diplomaturas: Medicina, CC Actividad Física y Deporte, CC de la Salud...). Es necesaria acreditación. No se considera estudiantes los profesionales que cursen estudios, ni a graduados, licenciados y/o diplomados.

2019		
VIII Congreso Iberoamericano de Nutrición	3-5 Julio Pamplona	web: http://www.academianutricionydietetica.org/congreso.php?id=7#
24th Annual Congress of the European College of Sport Science	3-6 Julio Praga (Rep. Checa)	E-mail: office@sport-science.org
II Congreso Mexicano de Medicina del Deporte	3-6 Julio Mérida-Yucatán (México)	web: https://comede.mx/
13th Congreso Mundial de la International Society of Physical and Rehabilitation Medicine	9-13 Julio Kobe (Japón)	web: http://www.isprm.org
2nd International Conference on Physical Education, Sports Medicine and Doping Studies	15-16 Julio Sídney (Australia)	web: https://sportsmedicine.conferenceseries.com/
15th European Congress of Sport and Exercise Psychology	15-20 Julio Münster (Alemania)	web: https://www.fepsac2019.eu
Congreso colombiano de nutrición y dietética y II Internacional en alimentación y nutrición	15-17 Agosto Manizales (Colombia)	web: https://acodin.org/congreso-2019/
Sports Nutrition Summit Europe 2019	4-6 Septiembre Amsterdam (Países Bajos)	web: www.sportsnutritionsummit-europe.com
9th VISTA Conference	4-7 Septiembre Amsterdam (Países Bajos)	web: www.paralympic.org/news/amsterdam-host-vista-2019
Congress on Healthy and Active Children	11-14 Septiembre Verona (Italia)	web: http://i-mdrc.com/fourth-assembly/
Euro Global Conference On Food Science & Nutrition 2019	17-18 Septiembre París (Francia)	web: http://foodscience.jacobsconferences.com/
4th International Conference on Nutrition	17-18 Septiembre San Diego (EE.UU.)	web: https://www.meetingsint.com/conferences/nutrition
14th International Congress of shoulder and elbow surgery (ICSES)	17-20 Septiembre Buenos Aires (Argentina)	web: www.icses2019.org
Congreso Sdad. Francesa de Medicina del Deporte	19-21 Septiembre Reims (Francia)	web: https://www.congres-sfmes-sfts.com/fr/
8th European Exercise is Medicine Congress	20-21 Septiembre Amsterdam (Países Bajos)	Información: Lisa Kempter E-mail: lisa.kempter@uniklinik-ulm.de
56° Congreso SECOT	25-27 Septiembre Zaragoza	web: www.secot.es
1° Congreso Mundial de Educación Física (FIEP)	30 Septiembre - 4 Octubre Santiago del Estero (Argentina)	web: http://www.fiepargentinaoficial.com/
IX Congreso de la Sociedad Cubana de Medicina Física y Rehabilitación	1-4 Octubre La Habana (Cuba)	web: http://www.rehabilitacioncuba.com
11th European Congress on Sports Medicine	3-5 Octubre Portorose (Eslovenia)	web: http://www.efsma.eu

I Congreso de Reeducación Funcional Deportiva CERS-INEFC	4-5 Octubre Barcelona	Web: http://inefc.gencat.cat/ca/inefc/jornades_congressos/congres-cers-2019/informacio
6th Annual Congress on Medicine & Science in Ultra-Endurance Sports	11-13 Octubre Cape Town (Sudáfrica)	web: https://ultrasportsscience.us/congress/
13th European Nutrition Conference On Malnutrition In An Obese World	15-18 Octubre Dublín (Irlanda)	web: www.fens2019.org
50 Congreso Nacional de Podología y VI Encuentro Iberoamericano	18-19 Octubre Santander	web: https://50congresopodologia.com/
World Congress of Tennis Medicine and Sports Science	18-19 Octubre Estocolmo (Suecia)	web: www.shh.se/stmswc2019
Congreso Internacional de Fisioterapia	25-26 Octubre Toledo	web: congreso@coficam.org
10th International Physical Education and Sports Teaching Congress	31 Octubre-3 Noviembre Antalya (Turquía)	web: https://2019.tubed.org.tr/en/
5th World Conference on Doping in Sport	5-7 Noviembre Katowice (Polonia)	web: http://www.wada-ama.org
15º Congreso Internacional de Ciencias del Deporte y la Salud	8-9 Noviembre Pontevedra	web: www.victorarufe.com
Jornadas Andaluzas de Podología	8-9 Noviembre Sevilla	web: www.colegiopodologosandalucia.org
26th Word Congress TAFISA	13-17 Noviembre Tokyo (Japón)	web: www.tafisa.org
2019 FIP World Congress of Podiatry	14-16 Noviembre Miami (EEUU)	web: www.podiatry2019.org
VIII Jornadas Nacionales de Medicina del Deporte: "Medicina del Baloncesto"	22-23 Noviembre Reus (Tarragona)	E-mail: femede@femede.es web: www.femede.es
10th Annual International Conference: Physical Education Sport & Health	23-24 Noviembre Pitesti (Rumanía)	web: http://sportconference.ro/
7th World Congress on Physiotherapy and Rehabilitation	26-27 Noviembre Abu Dhabi (Emiratos Árabes)	web:https://physiotherapy.conferenceseries.com/middleeast/
56 Congreso Argentino de COT	28 Noviembre-1Diciembre Buenos Aires (Argentina)	web: www.congresoaaot.org.ar
2020		
V Congreso Internacional de Readaptación y Prevención de Lesiones en la Actividad Física y el Deporte	Enero Valencia	web: https://congresojam.com/
I Congreso actividad física, deporte y nutrición	28 Febrero-1 Marzo Valencia	Web: http://congresodeporte.es/
14th ISPRM World Congress – ISPRM 2020	4-9 Marzo Orlando (EE.UU.)	web: http://www.isprm.org/congress/14th-isprm-world-congress
Congreso FESNAD	11-13 Marzo Zaragoza	web: http://www.fesnad.org/

IOC World Conference Prevention of Injury & Illness in Sport	12-14 Marzo Mónaco (Principado de Mónaco)	web: http://ioc-preventionconference.org/
I Congreso actividad física, deporte y nutrición	27-29 Marzo Sevilla	web: http://congresodeporte.es/
37º Congress International Society for Snowsports Medicine-SITEMSH	1-3 Abril Andorra la Vella (Principat d'Andorra)	E-mail: andorra2020@sitemnsh.org
9º Congrés Societat Catalana de Medicina de l'Esport-SCME	3-4 Abril Andorra la Vella (Principat d'Andorra)	E-mail: andorra2020@sitemnsh.org
25th Annual Congress of the European College of Sport Science	1-4 Julio Sevilla	E-mail: office@sport-science.org
32nd FIEP World Congress / 12th International Seminar for Physical Education Teachers /15th FIEP European Congress	2-8 Agosto Jyväskylä (Finlandia)	Información: Branislav Antala E-mail: antala@fsport.uniba.sk
2020 Yokohama Sport Conference	8-12 Septiembre Yokohama (Japón)	web http://yokohama2020.jp/overview.html
International Congress of Dietetics	15-18 Septiembre Cape Town (Sudáfrica)	web: http://www.icda2020.com/
XXXVI Congreso Mundial de Medicina del Deporte	24-27 Septiembre Atenas (Grecia)	https://www.fims2020.com/
VIII Congreso HISPAMEF	15-17 Octubre Cartagena de Indias (Colombia)	web: http://hispamef.com/viii-congreso-hispamef-15-17-de-2020/
XXIX Isokinetic Medical Group Conference: Football Medicine	24-26 Octubre Lyon (Francia)	web: www.footballmedicinestrategies.com
26th TAFISA World Congress	13-17 Noviembre Tokyo (Japón)	web: www.icsspe.org/sites/default/files/e9_TAFISA%20World%20Congress%202019_Flyer.pdf
XVIII Congreso Internacional SEMED-FEMEDE	Murcia	web: www.femede.es
2021		
Congreso Mundial de Psicología del Deporte	1-5 Julio Taipei (Taiwan)	web: https://www.issponline.org/index.php/events/next-world-congress
26th Annual Congress of the European College of Sport Science	7-10 Julio Glasgow (Reino Unido)	E-mail: office@sport-science.org
22nd International Congress of Nutrition (ICN)	14-19 Septiembre Tokyo (Japón)	web: http://icn2021.org/
European Federation of Sports Medicine Associations (EFSMA) Conference 2021	28-30 Octubre Budapest (Hungría)	web: http://efsma.eu/
Congreso Mundial de Podología	Barcelona	web: www.fip-ifp.org
2022		
8th IWG World Conference on Women and Sport	5-8 Mayo Auckland (N. Zelanda)	web: http://iwgwomenandsport.org/world-conference/
XXXVII Congreso Mundial de Medicina del Deporte FIMS	Septiembre Guadalajara (México)	web: www.femmede.com.mx

Cursos *on-line* SEMED-FEMEDE

Curso "ENTRENAMIENTO, RENDIMIENTO, PREVENCIÓN Y PATOLOGÍA DEL CICLISMO"

Curso dirigido a los titulados de las diferentes profesiones sanitarias y a los titulados en ciencias de la actividad física y el deporte, destinado al conocimiento de las prestaciones y rendimiento del deportista, para que cumpla con sus expectativas competitivas y de prolongación de su práctica deportiva, y para que la práctica deportiva minimice las consecuencias que puede tener para su salud, tanto desde el punto de vista médico como lesional.

Curso "ELECTROCARDIOGRAFÍA PARA MEDICINA DEL DEPORTE"

ACREDITADO POR LA COMISIÓN DE FORMACIÓN CONTINUADA (ON-LINE 1/5/2018 A 1/5/2019) CON 2,93 CRÉDITOS

Curso dirigido a médicos destinado a proporcionar los conocimientos específicos para el estudio del sistema cardiocirculatorio desde el punto de vista del electrocardiograma (ECG).

Curso "FISIOLOGÍA Y VALORACIÓN FUNCIONAL EN EL CICLISMO"

Curso dirigido a los titulados de las diferentes profesiones sanitarias y a los titulados en ciencias de la actividad física y el deporte, destinado al conocimiento profundo de los aspectos fisiológicos y de valoración funcional del ciclismo.

Curso "AYUDAS ERGOGÉNICAS"

Curso abierto a todos los interesados en el tema que quieren conocer las ayudas ergogénicas y su utilización en el deporte.

Curso "CARDIOLOGÍA DEL DEPORTE"

ACREDITADO POR LA COMISIÓN DE FORMACIÓN CONTINUADA (ON-LINE 1/5/2018 A 1/5/2019) CON 6,60 CRÉDITOS

Curso dirigido a médicos destinado a proporcionar los conocimientos específicos para el estudio del sistema cardiocirculatorio desde el punto de vista de la actividad física y deportiva, para diagnosticar los problemas cardiovasculares que pueden afectar al deportista, conocer la aptitud cardiológica para la práctica deportiva, realizar la prescripción de ejercicio y conocer y diagnosticar las enfermedades cardiovasculares susceptibles de provocar la muerte súbita del deportista y prevenir su aparición.

Curso "ALIMENTACIÓN, NUTRICIÓN E HIDRATACIÓN EN EL DEPORTE"

Curso dirigido a médicos destinado a facilitar al médico relacionado con la actividad física y el deporte la formación precisa para conocer los elementos necesarios para la obtención de los elementos energéticos necesarios para el esfuerzo físico y para prescribir una adecuada alimentación del deportista.

Curso "ALIMENTACIÓN Y NUTRICIÓN EN EL DEPORTE"

Curso dirigido a los titulados de las diferentes profesiones sanitarias (existe un curso específico para médicos) y para los titulados en ciencias de la actividad física y el deporte, dirigido a facilitar a los profesionales relacionados con la actividad física y el deporte la formación precisa para conocer los elementos necesarios para la obtención de los elementos energéticos necesarios para el esfuerzo físico y para conocer la adecuada alimentación del deportista.

Curso "ALIMENTACIÓN Y NUTRICIÓN EN EL DEPORTE" Para Diplomados y Graduados en Enfermería

ACREDITADO POR LA COMISIÓN DE FORMACIÓN CONTINUADA (NO PRESENCIAL 15/12/2015 A 15/12/2016) CON 10,18 CRÉDITOS

Curso dirigido a facilitar a los Diplomados y Graduados en Enfermería la formación precisa para conocer los elementos necesarios para la obtención de los elementos energéticos necesarios para el esfuerzo físico y para conocer la adecuada alimentación del deportista.

Curso "CINEANTROPOMETRÍA PARA SANITARIOS"

Curso dirigido a sanitarios destinado a adquirir los conocimientos necesarios para conocer los fundamentos de la cineantropometría (puntos anatómicos de referencia, material antropométrico, protocolo de medición, error de medición, composición corporal, somatotipo, proporcionalidad) y la relación entre la antropometría y el rendimiento deportivo.

Curso "CINEANTROPOMETRÍA"

Curso dirigido a todas aquellas personas interesadas en este campo en las Ciencias del Deporte y alumnos de último año de grado, destinado a adquirir los conocimientos necesarios para conocer los fundamentos de la cineantropometría (puntos anatómicos de referencia, material antropométrico, protocolo de medición, error de medición, composición corporal, somatotipo, proporcionalidad) y la relación entre la antropometría y el rendimiento deportivo.

Más información:
www.femede.es

Guidelines of publication Archives of Sports Medicine

The ARCHIVES OF SPORTS MEDICINE Journal (Arch Med Deporte) with ISSN 0212-8799 is the official publication of the Spanish Federation of Sports Medicine. This journal publishes original works about all the features related to Medicine and Sports Sciences from 1984. This title has been working uninterruptedly with a frequency of three months until 1995 and two months after this date. Arch Med Deporte works fundamentally with the system of external review carried out by two experts (peer review). It includes regularly articles about clinical or basic research, reviews, articles or publishing commentaries, brief communications and letters to the publisher. The articles may be published in both SPANISH and ENGLISH. The submission of papers in English writing will be particularly valued.

Occasionally oral communications accepted for presentation in the Federation's Congresses will be published.

The Editorial papers will only be published after an Editor requirement.

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Submit of manuscripts

1. The papers must be submitted at the Editor in Chief's attention, written in double space in a DIN A4 sheet and numbered in the top right corner. It is recommended to use Word format, Times New Roman and font size 12. They must be sent by e-mail to FEMEDE's e-mail address: femede@femede.es.
2. On the first page exclusively it should include: title (Spanish and English), authors' first name, initial of the second name (if applicable), surname and optionally the second one; Main official and academic qualifications, workplace, full address and corresponding author e-mail. Supports received in order to accomplish the study – such as grants, equipments, medicaments, etc- have to be included.
   A letter in which the first author on behalf of all signatories of the study, the assignment of the rights for total or partial reproduction of the article, once accepted for publication shall be attached.
   Furthermore, the main author will propose up to four reviewers to the editor. According to the reviewers, at least one must be from a different nationality than the main author. Reviewers from the same institutions as the authors, will not be accepted.
3. On the second page the abstract of the work will appear both in Spanish and English, and will have an extension of 250-300 words. It will include the intention of the work (aims of the research), methodology, the most out-standing results and the main conclusions. It must be written in such a way to allow the understanding of the essence of the article without reading it completely or partially. After the abstract, from three to ten key words will be specified in Spanish and English, derived from the Medical Subject Headings (MeSH) of the National Library of Medicine (available in: http://www.nlm.nih. gov/mesh/MBrowser.html).
4. The extension of the text will change according to the section applicable:
   a. Original research: maximum 5.000 words, 6 figures and 6 tables.
   b. Review articles: maximum 5.000 words, 5 figures and 4 tables. In case of needing a wider extension it is recommended to contact the journal Editor.
   c. Editorials: they will be written by Editorial Board request.
   d. Letters to the Editor: maximum 1.000 words.
5. Structure of the text: it will change according to the section applicable:
   a. **ORIGINALS RESEARCH**: It will contain an introduction, which must be brief and will contain the aim of the work, written in such a way that the reader can understand the following text.
   Material and method: the material used in the work will be exposed, as well as its characte¬ristics, selection criteria and used techniques, facilitating the necessary data in order to allow the reader to repeat the experience shown. The statistical methods will be detailed described.
   Results: Results must report and not describe the observations made with the material and method used. This information can be published in detail in the text or using tables and figures. Information given in the tables or figures must not be repeated in the text.
   Discussion: The authors will expose their opinions about the results, their possible interpretation, relating the observations to the results obtained by other authors in similar publications, suggestions for future works on the topic, etc. Connect the conclusions with the aims of the study, avoiding free affirmations and conclusions not supported by the information of the work.
   The acknowledgments will appear at the end of the text.

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