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Exercise physiology and nutritional perspectives of elite soccer refereeing.

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Abstract

Referees are an integral part of soccer and their performance is fundamental for regular match flow, irrespective of the competition level or age classes. So far, scientific interest was mainly limited to aspects of exercise physiology and match performance of soccer referees, whereas recommendations for nutrition were adopted from active professional soccer. In contrast to elite soccer players most referees are non-professional and engaged in different occupations. Furthermore, elite referees and soccer players differ in regard to age, body composition, aerobic capacity and training load. Thus, referees' caloric needs and recommended daily carbohydrate intake may generally be lower compared to active soccer players, with higher intakes limited to periods of increased training load and match days or for referees engaged in physical demanding occupations. With respect to fluid intake, pre-match and in-match hydration strategies generally valid in sports are recommended also for referees to avoid cognitive and physical performance loss, especially when officiating in extreme climates and altitude. In contrast to elite soccer, professional assistance concerning nutrition and training is rarely available for national elite referees of most countries. Therefore, special attention on education about adequate nutrition and fluid intake, about the dietary prevention of deficiencies (iron in female referees, vitamin D

irrespective of sex and age) and basic precautions for travels abroad is warranted. In conclusion, the simple adoption of nutritional considerations from active soccer for referees may not be appropriate. Recommendations should respect gender differences, population specific physical characteristics and demands just as well as individual characteristics and special needs.

Introduction

Soccer (European "football") is one of the most popular sports worldwide. The official Fédération Internationale de Football Association (FIFA) survey "Big count 2006" documented 207 member associations and 265 million people involved in this sport. The increasing number of active players, representing a 21 % and 54 % increase in registered male and female players respectively, from 2000 to 2006, further emphasizes the popularity and economic importance of national and international soccer championships [1].

Match officials are an indispensable and inseparable part of soccer, independently of competition level or age classes. According to the laws of the game, a field referee (FR), two assistant referees (AR), and a fourth official are mandatory to control official matches [2]. In 2006, there were 840,000 registered referees, of which 10 % were women [1].

From the 1980's on scientific investigations began to provide background information of match officiating, applying the technical possibilities of the respective time and placing the main focus on the activity profile [3] and the physiological demands [4-6] of mainly male field referees, followed soon by specific studies about assistant referees [7] and finally of female match officials [8]. Castagna, Abt, and D'Ottavio published an extensive scientific review of the activity profile, exercise physiology and testing protocols in soccer refereeing [9], and an update on the subject, further including medical aspects, has recently been provided [10]. With respect to nutritional

aspects, Reilly and Gregson, Teixeira et al., Martinez Renon and Collado were among the first to present nutritional considerations based on the characteristics and performance of soccer referees[11-13]. These nutritional recommendations are mainly adopted from professional soccer barely considering differences and peculiarities regarding gender, age, anthropometry, training habits and exercise capacity of referees.

In this multi-disciplinary narrative review, we intend to present a somewhat atypical mixture of previously published data and actual measurement values collected in course of the pre-competition medical and physical assessment of top-class referees in preparation for the FIFA world cups.

The first part of this review will address the physical demands of soccer refereeing, referees physiological and anthropometrical characteristics. Where data are available, differences between male and female, field and assistant referees are presented, and a comparison with professional soccer players is drawn. In the second part, nutritional aspects and recommendation paucities will be discussed on the basis of the limited scientific literature and on data of the FIFA referees' world cup selection in 2012/13 (used with permission of FIFA Medical Assessment and Research Centre, F-MARC).

Age and anthropometric profile of elite soccer referees

This paragraph will shortly outline the anthropometrical profile of soccer referees. Body composition is an important factor in physical fitness according to the demands of a specific sport. Age and body composition determine the resting metabolic rate and the energy expenditure during physical activity and both were found to affect injury susceptibility [14, 15]. The career of many match officials may have started as active players. After first refereeing

experiences in youth or amateur soccer leagues, match officials must advance in grade in order to referee higher level matches. Finally, candidates for the annual FIFA Refereeing International List are nominated by the member associations if at least 25 (field referee) and 23 years old (assistants) in order to guarantee a minimal experience level [16].

Consequently, the mean age of field referees participating in the FIFA World Cup selections 2012/2013 of 37.7±3.3 and 37.3±4.0 years for male field and assistant referees respectively (range, 28-43 years), and of 33.7±3.5 years for female referees (range 26-42 years) (FIFA's World Cup referees selection, 2013, unpublished data) reflects a long career and qualification background. The age of 45 years for forced retirement is still valid at international and some national levels but is currently under discussion.

Table 1 summarizes the main anthropometrical data of elite FIFA referees in 2012/2013 (FIFA's World Cup referees selection, 2013, unpublished data). 106 male (52 FR, 104 AR respectively) and 42 female match officials participated in the pre-participation medical assessment. The differences concerning physique and body composition between FR and AR may not be accidental but reflect a selection by the role-specific requirements. In accordance with the presented data, Stulp et al. documented a significant height difference exceeding 4.0 cm between FR and AR engaged in the first French league and in the FIFA World Cup 2010, and interestingly found an association between referees' height and their authority in the field[17]. Average body mass index (BMI) values of Premier League referees reported by Reilly and Gregson [11] are significantly higher than those of current elite FIFA referees (27.1±5.3 kg/m^2 vs. 23.4±1.7 kg/m^2). Accordingly, Casajús and Gonzalez-Aguero reported a trend toward a more athletic body composition in elite Spanish referees over the last decade, presumably as a consequence of the increased physical demand and the more and more professional assistance in

teaching and training of match officials [18]. Moreover, a case study on the evolution of a top-level referee over 8 years showed a decreased body fat mass (sum of skinfolds: 53.6 vs. 42.2 mm) and improvements in running speed (12.0 vs. 14.0 km/h) and economy at the lactate threshold (43.4 vs. 37.3 ml/min/kg) [19].

Body weight and composition are of importance because excessive body weight and fat mass reduce the relative aerobic capacity and increase physical strain and susceptibility to fatigue [20]. The physical capacity and performance of match officials are fundamental for good positioning, and right decision-making. From a psychological point of view, an athletic physique emphasizes this ability to keep up with the play and may further help when asserting authority on the field.

Performance profile of soccer referees

This paragraph will give a short overview of the soccer referees performance profile to better understand the peculiarities of this population, as well as special needs in regard to education and training, nutrition and injury prevention. The paragraph is not intended to extensively review the literature on this topic and the interested reader is referred to recent review articles on the subject [9, 10, 21]. Field and assistant referees must keep up with the pace of the game and follow play closely in order to be in the right position to judge whether players' actions conform to the rules. There are numerous studies analyzing the activity pattern of match officials at a national and international level. Data on total distance covered by the FR during a soccer match (90 minutes + overtime) are comparable to field soccer players [22] but may vary widely between matches [23, 24] and between countries, with reports of 9,438±707 m for the English Premier League [4], 10,070±130 m for elite Danish referees [6], and 11,496±983 m to 12,956±548 m for FR officiating Italian Serie A matches [5, 25, 26]. Weston et al. reported inter-individual variations in the total

distance covered by referees and a correlation with the distance covered by players during the match[27, 28]. According to their analysis, the inconsistently reported decline in running distance between first and second halves [29-31] may derive to some extent form changes in patterns of play and tactics adopted by the teams rather than being solely a sign of accumulated fatigue [24, 28]. Analyses about performance constancy and changes of the referees activity pattern during match progress report equivocal findings [25, 29, 30, 32], but upcoming fatigue in match officials is of indisputable relevance and deserves particular attention. Beside the tactical approach of the soccer teams, the referees' physical fitness may influence their performance. In fact, Castagna and D'Ottavio found a strong negative relationship between aerobic capacity and duration of standing during the match[33], which accounts for 13.6-29.9 % of match time for male referees [32]. Similarly, the running speed attained at a blood lactate concentration of 4 mmol/L in an exercise test correlated positively with the distance covered during a match [34]. With respect to sprinting, Barbero-Álvarez et al. reported a sprinting distance, evaluated by GPS data acquisition, of approximately 700 ± 300 m during the game with peak sprint velocities of 19.15±0.61 km/h [35]. Although a major proportion of match time consists of low and moderate intensity activities such as standing, walking, trotting, running at low and moderate speeds, and running backwards, high-speed running and sprinting is considered crucial to follow the match closely. D'Ottavio and Castagna reported a count of 1,268 activities per match, representing a change in activity every 4.3 seconds on average and reflecting a highly intermittent activity pattern that demands both aerobic capacity and anaerobic resistance[26]. As for running distance these data may vary considerable from one match to another [24] and are comparable to field soccer players with reported 1000-1400 different short activities during a game [22].

Match distances of AR were reported to be 5,819±381 m during the America's Cup [35], 6137±539 m during the 2003 U-17 World Championship [31] and 5,752±554 m at the FIFA Confederations Cup 2005, with sideways movements accounting for 29.7±4.7 % of the total distance [36]. Krustrup et al. registered activity changes every 4-5 seconds and 110 high-intensity running activities per match with a mean duration of 2 seconds for top-class assistant referees [7].

Mallo et al. presented the only data currently available on top-class female FR, who covered an average distance of 10,032±300 m per match, composed of 25.7±3.7 % walking, 21.1±1.7 % jogging, 9.5±1.1 % cruising, 5.6±0.9 % high-intensity running, and 38.1±3.5 % of the time standing still[37]. Gender differences may reflect match strategies of the soccer teams and differing intensity patterns in male and female soccer.

Weston et al. demonstrated an age-related decline in the physical match performances of elite-level soccer referees[38]. The total distance and the amount of high-intensity running and sprinting were found to decrease with increasing age of the referee. However, the mean distance from the ball and the mean distance from fouls were not affected by age, indicating equal refereeing quality and maybe even a higher effectiveness of match activities in older and more experienced referees [38]. In fact, adequate exercise capacity is only one of the essential requisites for referees. Top-class soccer referees must also be well-versed in game rules, maintain concentration independently from match flow and make decisions quickly.

In addition to motion analysis to quantify the physical demands of soccer refereeing, alternative approaches have been used to obtain information about energy metabolism and expenditure during soccer refereeing. Repeated capillary lactate analyses are of limited value because serum lactate only reflects the intensity of the most recent activities. Additionally, continuous heart rate monitoring was frequently used to establish exercise intensity in soccer refereeing [29, 35, 36, 39, 40].

The average oxygen uptake during a match for both, top-class players and elite field referees, was reported to amount similarly to 68 % [41] and 70 % of the individual VO_{2max} [42], with the maximal oxygen uptake differing decisively between the groups.

Training and Testing

The following paragraph shortly outlines the training habits of the referees. Additionally, testing outcomes are presented that will give some insight on training outcomes and referees fitness level.

Very few data exist on the frequency and structure of physical training in referees, and the variation may be marked depending on refereeing level and role. The few full-time professional referees are restricted to some European and Latin-American countries and the majority of male, and almost all female, referees are semi-professional or officiate at an amateur level for free or for a small allowance. Assistance regarding physical training and theoretical education is provided by national and continental soccer associations as well as by FIFA that also organizes courses for training instructors. Female and male FIFA referees reported similar training hours per week during pre-season (7.5±3.1 vs. 7.1±3.4 hours/week, female vs. male) and in-season (6.0±2.9 vs. 6.1±2.4 hours/week, female vs. male). Fewer female than male referees reported to get instruction by a qualified person (64 % women vs. 84 % men) [8, 43]. The main reported targets of physical workouts are aerobic and intermittent exercise capacity, repeated sprint ability, and agility, but basic international standards for training structure and modality are lacking. In consideration of the increasing match demands and related injury risk, prevention programs have been advocated for FR and AR [10], and with the concept "FIFA 11+ Referee" recently a specific warm-up and prevention program has been implemented.

In regard to testing, FIFA since 1989 suggested the application of a battery of physical tests to evaluate the fitness level of referees, which initially consisted of a 12-minute Cooper running test, two 50 m and two 200 m runs, and a 4 × 10 m agility test. Since 2007, FIFA referee testing has included a standardized 6 × 40 m sprints and a repeated 150 m test, with specific minimum performance limits for male and female field and assistant referees [16]. The specificity of these tests is argument of discussion with respect to the referees' intermittent activity profile consisting of a predominant aerobic involvement and occasional sprints that are rarely longer than 30 m [44]. While Mallo et al. did not find an association between the test battery outcomes and match activities [31], some fitness test outcome parameters (i.e. mainly the repeated sprint tests outcomes) were found to be related to the match performance by others [45, 46], and were shown to discriminate between different competitive levels [47] and age groups [48].

Regarding the activity profile of assistant referees, a specific intermittent endurance test (ARIET) was designed and proven to be reproducible and valid [49].

In the course of the pre-participation screenings 2012/2013, a maximal cardiopulmonary exercise test on a treadmill was performed. The average VO_{2max} reported for male field and assistant referees was 51.9±4.2 ml/kg/min and 50.3±4.0 ml/kg/min, respectively; female referees attained 48.1±4.4 ml/kg/min (range 40.0-57.3) (FIFA's World Cup referees' selection, 2013, unpublished data). Casajus and Castagna documented somewhat higher VO_{2max} values of 55.3±3.3 ml/kg/min in 45 top-class Spanish referees following the same test protocol and without age-related differences[50], whereas maximal oxygen consumption in Italian elite-standard assistant referees was significantly lower with 44.5±5.8 ml/kg/min [49].

Medical blood analysis for female referees was performed to identify deficits of iron, folic acid, vitamin B12, and vitamin D, all of which are known to be frequent in pre-menopausal women and to impact cell regeneration and health. Among 42 female referees, 48 % had low levels of ferritin (cut off <25 mcg/l), 10 had low vitamin B12 (cut off <150 pmol/l) and two-thirds had 25(OH)-vitamin D levels <75 nmol/l. Elevated LDL cholesterol levels (>3.10 mmol/l) were found in 47 % of male and 14 % of female referees, with mean values equal to 3.07 ± 0.81 mmol/l (range 1.3-6.4) and 2.57±0.58 (range 1.7-3.9) (FIFA's World Cup referees's selection, 2013, unpublished data).

Elite soccer referees vs. top-class soccer players

As consequence of their education and training program, of national grading systems and of the minimal age limit of 25 and 23 years for field referees and assistants required by FIFA [51], international soccer referees are on average 10 to 15 years older than their playing counterparts [9, 52]. Beside the undisputed positive effects regarding authority and recognition attended by experience and age, changes in hormonal status affect the metabolism and induces noticeable transformation regarding body composition and exercise capacity. In fact, elite referees (FIFA referees) body fat percentage and body cell mass (BCM) that defines the compartment of metabolically active tissue in the bioimpedance based body composition analysis, were 20.4±3.6 % and 33.8±3.5 kg, respectively, while top-class soccer players from Italy and Austria, tested with the same BIA 101 ASE device (Akern, Florence, Italy), showed on average a body fat mass percentage of only 16.1±2.0 and 16.3±2.1 % in combination with a significantly higher body cell mass of 40.5±3.1 and 39.7±3.1 kg [53, 54].

Among further causes of these differences a differing energy availability (EA) must be emphasized. The combination of a lower body cell mass, a lower basal metabolic rate and a lower training load must be counterbalanced with a proportionally lower caloric intake to avoid a relative energy excess that is leading to an increase of fat mass. For body mass maintenance, an EA of 35-40 kcal/ kg fat free mass is recommended. The energy consumption during physical work and training is added to define the overall daily caloric need.

To be competitive, the athletic and sport specific preparation program of top-class soccer players contains 8 training sessions per week [55], while referees on average perform 3-4 weekly training sessions that have to be matched with job engagement in most cases of non- or semi-professional referees [12, 24, 52]. Further, despite the equivalent running distance over 90 minutes, the mean relative oxygen consumption (VO_2) of 68 % [41] and 70 % of an unequal VO_{2max} [42] in soccer players and referees during the match, indicate differences regarding the average physical load, high intensity actions and recovery times between the groups, though comparison may be limited by different tracking type and the definitions of match activities. Beside the apparent difference regarding dribbling, feigning, passing and playing the ball limited to soccer players, a further crucial distinguishing feature of match officials that is mostly neglected in the scientific reviews is the non-competitive and non-contact character of their performance that significantly reduces the physical demand and injury risk when compared to active players who are challenged to physically assert themselves in tackling, heading etc. [56]. By comparison, soccer refereeing on the international top-level requires constant, competent and faultless decision-making ability irrespective of the physical strain, the game speed or the match time. While recent surveys provide data about the impact of extra-time and 120 minutes simulated match duration on the

activity profile and neuromuscular fatigue of soccer players [57, 58], similar analyses of match officials' performance during extra-time are missing.

According to the reported differences regarding the body composition, the diverse training practice, and the specific requirement profiles the standardized maximal cardiopulmonary exercise test in occasion of the pre-competition medical assessment for the FIFA World Cup 2014 revealed a maximal aerobic capacity (VO_{2max}) of on average 51.9±4.2 and 50.8±4.1 ml/kg/min in male field and assistant referees respectively, while for elite soccer players generally values exceeding 60-62 ml/min/kg are reported and required [22, 59, 60].

According to the presented characteristics of elite soccer referees, FIFA implemented specific performance tests and standards for training and injury prevention (FIFA 11+ Referee). The incidence and distribution pattern of injuries and musculoskeletal complaints in match officials was studied during the FIFA World Cups 2006 and 2007 [8, 43]. The injury rate was reported as 20.8 and 34.7 injuries/1000 match hours for male and female referees respectively, while in comparison a rate of 50.8 injuries/ 1000 match hours was reported for players participating in the FIFA World Cup 2014 [61]. Considering that almost two-thirds of the injuries (64.4 %) in elite soccer players are caused by contact [61], the mainly non-contact injury rate in match officials may seem surprisingly high. Differences in age and the individual injuries history, fitness level and recovery times between match engagement, body composition and muscle imbalances as well as the role- and gender-specific activity profiles are reported to impact the incidence of non-contact muscle strains and complaints in soccer [56, 62]. Further, nutrition is known to play a decisive role in prevention of fatigue and injuries. Specific nutritional guidelines for soccer referees are still lacking, and mostly referees are instructed to adopt soccer players' nutritional guidelines, whose up-to-dateness in turn has been questioned recently [63].

Nutritional requirements of elite match officials

Energy needs

The effective daily energy expenditure, composed by the basal metabolic rate (BMR) and the energy cost of physical activity may vary widely depending on physical characteristics, training loads and occupational activities in non- or semi-professional referees. The estimation of the basal metabolic rate (BMR) based on a modified Harris-Benedict formula [64] resulted in 1,718±129 kcal/day and 1,390±69 kcal/day for male and female match officials selected for the FIFA World Cup 2014 and the FIFA Women World Cup 2015, respectively (Table 1). The energy consumed in training depends on its content as well as on the individual physique and may amount to 350-500 kcal/ training hour. Data about energy expenditure (EE) of match officiating vary mainly depending on the analysis method. EE of FR during match officiating estimated by video activity analysis resulted in 734.7±11.9 kcal [65] whereas estimation using direct oxygen consumption measurement (indirect calorimetry) and global positioning system (GPS) receivers indicated about 1,200 kcal for the regular match duration [41].

Generally, the approach to simply meet a fair balance between daily energy expenditure and caloric intake may not be appropriate in athletes. The concept of energy availability (EA) instead defines the amount of metabolic fuel available for physiological processes of the individual fat free mass (FFM) when energy consumed during physical activity and sports is covered separately. EA between 35 and 40 kcal /kg FFM complemented by the energy expenditure during sports and physical activity results in the individual daily energy requirement to maintain body weight, to guarantee health, training progress and performance capacity. So, it becomes comprehensible that the daily energy intake must change as function of muscle mass and the

daily activity level: while recently daily EE in professional soccer players was reported on average 3566±585 kcal/ day [66], the energy requirements of most soccer referees according to the presented data regarding physical characteristics and training load may rarely exceed 2600 kcal on training days and 3000 kcal on match days. In this context, different studies reported the inability of soccer referees to adapt the energy intake and macronutrient distribution to the physical demands between rest, training and match days [13]. The >60 different nationalities of male and female FIFA referees participating in the 2012/13 selections in view of the FIFA World Cup 2014 and the FIFA Women World Cup 2015 further highlight the importance of considering cultural, social and religious habits and conventions for nutrition, particularly in the organization of international referee courses and soccer tournaments. For example, it was reported that during Ramadan, where soccer players refrained from eating and drinking from dawn to sunset, non-contact and overuse injuries were more frequent [67]. Authors linked the higher injury rate to dehydration and muscle glycogen depletion in the course of physical activity [67]. Even though not yet investigated, such findings might also apply for referees, and outline the importance of adequate nutrition for optimal performance and injury prevention.

Macronutrients

Covering the daily energy demand is just one challenge of an adequate nutrition, meeting the right balance between the macronutrients carbohydrates, proteins and fat and providing the organism with all necessary or essential micronutrients is another issue. The prevalence of one can provoke a deficiency of the other component, and differences regarding energy density, palatability, and satiation influence the feeding behavior [68]. In sports nutrition, advice regarding daily energy and nutrient intake is generally given as target range in g/kg body mass (BM) [69]. With respect to carbohydrates (CHO) a daily amount of 7-10 g CHO/kg BM is generally

recommended for elite outfield players to replenish muscle glycogen stores in preparation for or during recovery from match play and very intense or multiple training sessions, while CHO intake should be limited to 5-7 g CHO/kg BM during periods of a less demanding training and competition schedule [70]. The adoption of this advice even by professional field and assistant referees would hardly be adequate when considering the population specific characteristics regarding body composition and training. For match officials a daily CHO consumption in the range of 4-6 g CHO/kg BM may be adequate, with higher CHO intakes during periods of intensified physical training (i.e., during pre-season or tournaments), during preparation for and during recovery from match days [70]. Specifically, it was reported and thus might be recommended that ingestion of carbohydrates three hours before (fueling by consumption of up to 2.0 g CHO/kg BM) and during breaks (CHO solutions) supports physical and cognitive performance [71], while within the first hour after intensive training sessions and competition an amount of 1.0-1.2 g CHO/kg BM was established to optimize immediate recovery [69]. The awareness of elite soccer referees for the importance of an increased CHO consumption on match days was reported recently [72]. Generally, high glycemic index carbohydrates are digested and absorbed more quickly and thus are preferable for pre-exercise loading, during performance and for recovery.

In summary, the timing, amount and quality of dietary CHO have the potential to sustain the consistency of the physical and cognitive performance of match officials, may help to prevent fatigue and injury and support the recovery from intermittent exercise.

The appropriateness of protein ingestion seems easier to reach because a regular diet of adequate energy content is generally considered sufficient in covering the daily needs of 1.2-1.7 g/kg BM in different sports of all levels [73]. Still, supplementation use of animal (whey, casein, etc.) or

plant protein (soy, pea, etc.) or essential amino acid shakes is a widespread practice to support muscle protein synthesis and recovery after strenuous exercise [74]. A mixture of carbohydrate and protein was proven to be most effective in blocking muscle protein breakdown and to stimulate muscle protein synthesis after physical exercise. 20 g protein were found to elicit a maximal effect on muscle buildup with protein consumed in excess serving as substrate for energy metabolism [75]. In case of injury up to 2.5 g/kg BM are required to support muscle mass maintenance during disuse [76]. Among animal and vegetarian nutrients, whey seems a preferable protein source in sports nutrition regarding absorption time (soy and casein are slowly absorbed) and the content of branched chained and essential amino acids (leucine, cysteine, etc.) [77].

Beside its importance as macro-nutrient and energy storage with a caloric content of 9 kcal/g, fat is considered an important source of micronutrients, such as fat soluble vitamins (A, D, E and K) and essential fatty acids that are integrative components of the cell membrane and serve as signaling molecules and as starting substrate for steroid hormones. Generally, fat intake is recommended to range from 20 to 30 % of total energy intake [73]. However, this generally reasonable rule should be implemented with respect to specific needs and individual factors. If for example total, LDL cholesterol and triglyceride levels are elevated, low saturated-fat, trans-fat free, omega-3 fatty acid rich, low-cholesterol foods such as unsaturated vegetable oils (linseed or olive oil), nuts, lean meats and fish should be preferred [78].

Micronutrients

In general, supplementation of vitamins and minerals is not necessary if an athlete is consuming a diet characterized by a variety of foods and adequate energy content [73]. However, some populations are known to be at particular risk for a specific micronutrient deficiency. Examinations performed during the FIFA's World Cup referees' selection 2012/2013, showed

that special attention should be given on mainly two micronutrients, namely iron and vitamin D (unpublished data).

In accordance with the high prevalence of iron deficiency in young premenopausal women, at the pre-competition medical assessment (PCMA) almost half of the FIFA female referees were found to have low ferritin levels ≤25 mcg/l (FIFA's World Cup referees' selection, 2013, unpublished data). Given the demonstrated roles of iron in supporting aerobic capacity, endurance and energetic efficiency, decrements in work capacity and athletic performance may be expected in association with storage iron depletion, independent of hemoglobin levels [79]. Therefore, it is advisable to pay attention on coverage of the daily allowance for nutritional iron of 8 mg and 18 mg in male and female adults respectively [80], to control for proper iron stores by periodical blood analysis, and to make use of iron fortified foods or supplements to prevent or treat iron deficiency, especially in case of vegetarian or plant-based nutritional habits (vegan) that exclude sources of heme iron characterized by high bioavailability.

In accordance with the pandemic prevalence of vitamin D insufficiency worldwide [81], 66 % of the female referees participating in the PCMA 2013 were found with 25(OH) vitamin D values in the insufficient range <75 nmol/l [82] (FIFA Women World Cup referees' selection, 2013, unpublished data). An optimal vitamin D status seems essential to numerous fundamental body functions, among others: bone health, immune function, protein metabolism [83] and muscle function [84]. Consequently, obtaining optimal 25(OH) vitamin D levels should be a goal for all athletes. Beside nutritional intake by consumption of salmon, fatty fish, egg yolks and fortified products (milk, cereal and orange juice), sun exposure is an important source of vitamin D. The current recommended dietary allowance for vitamin D is 600 IU/ day [85]. Recent studies claim a statistical error in estimation of the daily vitamin D needs, highlight the large variability in

response to vitamin D intake [86], and recommend 1885 IU/ day for normal weight people to minimize the risk for both low and high serum 25(OH)D concentrations [87].

Finally, it is decisive to state that sports and population specific recommendations for adequate nutrition are useful and important, but may not guarantee a proper implementation. With regard to existing cultural factors, specific needs and individual preferences, the potential and importance of sports nutritional counseling in this regard is emphasized.

Hydration and body fluid balance

Fluid intake and body fluid balance are known to be important for health and physical performance [88-90]. Body fluid loss by sweat depends on body surface and gender, intensity of physical activity, fluid intake, and environmental factors and is reported to vary widely between individuals. Total body water loss in field and assistant referees was reported to be 1.60 ± 0.13 l and 0.79±0.19 l respectively during a match in warm conditions [91]. However, field referees may be at higher risk for dehydration because fluid intake is generally limited to the half-time break, while players and assistant referees may be provided with drinks at the sidelines. Accordingly, Silva et al. reported moderate dehydration with loss of 1.97±0.18 % of body mass despite ad libitum water intake before the match and during the break [92]. Rates of mild to moderate dehydration characterized by approximately 2 % of body mass loss were found to compromise not only the physical but also cognitive performance in tasks that require attention, psychomotor and immediate memory skills [93, 94]. Consumption of standardized volumes (equal to 1 % of body mass) of carbohydrate electrolyte solution before the match and during the break was found to decrease the time spent in low-intensity activities [92]. To recover rapidly from excessive dehydration, an intake of 450-675 ml of fluid for every 0.5 kg body mass loss during exercise is

recommended [73]. It should be noted that the estimation of the level of dehydration by measurement of changes in body mass is predicated on the assumption of regular fluid balance at baseline. Actually, in course of the body fluid balance and composition monitoring program of FIFA field and assistant referees, the bioimpedance measurements performed in the morning frequently indicated a negative fluid balance by hydration index (optimal range 72.7-74.3) and biavector [95-97].

In case of high temperatures, at least in international matches, the FR in cooperation with the match coordinator and the medical officer, can allow additional drink-breaks (usually two breaks, after 30 and 75 minutes of the match respectively) for players and officials to avoid health detrimental effects of severe dehydration. This happened, for the first time at highest level, during the men's final of 2008 Beijing Olympic Games played at 12:00 local time and under full sun exposure, and more frequently during the FIFA World Cup 2014 in Brazil when the wet bulb globe temperature reached 32°C [98].

Supplements and ergogenic aids

Despite large similarities in preparation and performance of elite soccer referees and athletes, the need and value of ergogenic aids may be limited because referees do not run for records and championships. Generally, meeting an adequate energy availability and respecting a fair macronutrient distribution according to the physical load may be of particular importance. However, considering the proven effects of low to moderate doses of caffeine (3-6 mg/kg BM) on cognitive and physical performance [99], it may be classified a reasonable and helpful aid to delay upcoming fatigue also in refereeing [100].

For many other potentially effective nutritional aids and strategies, such as sodium phosphate loading [101], a high nitrate diet, creatine monohydrate integration [102], the scientific evidence is inconsistent and the specificity regarding soccer refereeing is lacking.

Nutritional recommendations for high-class soccer referees

Table 2 summarizes the key points of this review and tries to establish basic rules and recommendations that need to be adopted in accordance to the mentioned inter-individual characteristics. Merit and potential of sports nutritional counseling is pointed out as integral part of a multidisciplinary assistance in competitive and professional sports.

Conclusion

Soccer refereeing combines a non-competitive, non-contact, highly intermittent running activity with the perceptual-cognitive performance of match officiating and decision-making. The intensity and physical load differ between male and female, field and assistant referees, and depending on the soccer league level. An adequate aerobic capacity just as a proper intermittent exercise ability allow referees to follow the match closely, to recover quickly and to avoid fatigue that may influence the quality of decision-making. Furthermore, specific adaptation of nutritional habits and hydration strategies may contribute to maintain the physical and cognitive performance during match progression, thus avoiding neuromuscular fatigue and injury susceptibility.

Perspectives

The scientific interest in soccer refereeing has come along with the effort of national, continental and international football associations to provide educational courses and professional support for match officials. According to physical demands and cognitive requirements of refereeing, specific programs and standards concerning training, testing and injury prevention were elaborated. With regard to nutrition however, elite match officials were recommended to adopt strategies of professional soccer players neglecting the apparent differences regarding age, activity profile, body composition, work capacity and training load that are presented in the present work. According to the population specific characteristics, basic nutritional rules and recommendations are defined. Adequate implementation requires general education in sports nutrition and professional mentoring about the adaption to individual characteristics and special needs.

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Table 1

Anthropometrical profile of FIFA referees (FIFA's World Cup referees' selection, 2012/13, unpublished data)

	Male field referees (n = 52)	**Male assistant referees (n = 104)**	**Female field referees (n = 42)**
	mean±SD (range)		
Age (years)	37.7±3.3 (30–43)	37.3±4.0 (28–43)	33.7±3.5 (26–42)
Body weight (kg)	76.9±6.8 (64.5–94.0)	72.1±7.4 (53.9–92.0)	61.0±6.0 (45.1–75.5)
Body height (cm)	181.1±5.6 (169.0–192.2)	176.9±7.5 (163.5–196.8)	169.2±5.3 (153.7–180.6)
Body mass index (kg/m^2)	23.4±1.7 (19.2–27.8)	23.0±1.6 (19.1±25.7)	21.3±1.5 (18.7–24.7)
Abdominal girth (cm)	85.3±5.0 (70.0-94.0)	83.4±5.4 (67.0–95.0)	77.0±5.3 (68.0–89.0)
Fat free mass (kg)	61.1±5.1 (50.4–75.7)	58.1±5.5 (47.6–73.3)	45.7±3.8 (36.3–55.8)
Fat mass (kg)	15.8±3.5 (7.9–24.5)	14.0±3.4 (6.3–23.2)	15.3±3.4 (8.8–21.7)
Fat mass (% of body weight)	20.4±3.6 (12.1–27.8)	19.2±3.6 (11.6–25.8)	24.9±4.0 (17.0–33.3)
Basal metabolic rate (kcal/day)	1,718±129 (1,397–2,037)		1,390±69 (1,215–1,553)

Table 2

Summary and nutritional recommendations for high-class soccer referees

- Elite soccer referees differ explicitly from elite soccer players regarding age, height, body composition, requirement profile, and professional assistance for physical preparation. Furthermore, most elite referees are non-professionals engaged in different occupations.
- An athletic physique is an important pre-requisite to cope with physical demands of match officiating at international level, but it may further be advantageous from a psychological viewpoint with concern to the referee's authority on the field.
- Elite soccer referees have lower energy needs relative to top-class soccer players resulting from differences regarding body composition and training habits. Dietary caloric intake should be adapted to the individual training load and only be increased on match days and during periods of intense training or when engaged in occupations with a high-energy demand.
- The individual energy availability (EA) is calculated by subtracting the energy expended during physical exercise and sports from the nutritional caloric intake and must amount to 35-40 x kg fat free mass (FFM) if the objective is to maintain body weight.
- The intermittent activity profile of soccer refereeing taxes both, aerobic capacity and anaerobic power. Dietary practice should provide 4-6 g/kg body mass CHO according to rest, training and match days to support a constant performance level in physical and mental terms and rapid recovery between training days and after match officiating.
- The protein needs of soccer referees may not differ from other athletes and are generally covered by an energy-balanced and varied diet.

- To maintain adequate hydration is a special task in soccer refereeing considering that fluid intake is mainly restricted to the half-time break. Body mass reduction >2 % of body mass should be avoided because of its potentially negative impact on physical and cognitive performance and increased risk of injury. Consequently, consumption of carbohydrate electrolyte solutions prior to the match (6-8 ml/kg during 2 h before start), during the break (equal to 0.5 % of body mass) and after the match (450-675 ml for every 0.5 kg of body mass loss) should be planned.
- Referees are requested to pay attention to adequate fluid consumption during travel, to inform about nutritional habits and potential under-supply of nutritional components abroad, and to adhere to basic hygiene rules to prevent infections by contaminated food.
- Female referees are advised to respect the high incidence of iron deficiency in pre-menopausal women that is associated with a decline of physical performance capacity. Nutritional strategies to prevent iron deficiency include increased consumption of meat, fish and iron supplementation.
- Vitamin D insufficiency is a frequent phenomenon. Considering the emerging evidence on its importance for the musculoskeletal system and health, dietary supplementation, in the case of deficiencies, is recommended also for referees.
- Caffeine doses of 200 mg were found to prevent physical and cognitive fatigue and may thus be a helpful aid also for referees in special conditions, such as jet lag and strenuous match-play (e.g. overtime).
- Soccer referees should be assisted by a sports nutritionist in the implementation of these recommendations to ensure individual adaptation.