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Sustainable Diets for Athletes

Nanna L Meyer[1] · Alba Reguant-Closa[2] · Thomas Nemecek[3]

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Abstract

Purpose of Review Sustainable production and healthy consumption have been the topic of recent publications. Due to the high environmental impact of the current food system, significant changes in how food is produced, distributed, and consumed are needed in all sectors and groups. While most research in sustainable diets has focused on the general population, limited work has involved athletes. The purpose of this review is to summarize the current knowledge on food and sustainability in athletes.

Recent Findings Meeting but not exceeding protein requirements through flexitarian and plant-based approaches, reducing packaged foods and food waste, and prioritizing seasonal produce were identified as possible mitigation options in athletes.

Summary There is urgency for more research on plant-centric, whole food–based strategies for post-exercise skeletal muscle and training adaptation, the effect of sustainable diets on health and performance, and behaviors to reduce packaging and food waste in athletes.

Keywords Food systems · Plant-based · Flexitarian · Protein · Sports nutrition · Environment · Food literacy

Introduction

Human-induced global warming through greenhouse gas emissions (GhGe) has reached approximately 1 °C above pre-industrial levels in 2017. In 2018, the Intergovernmental Panel on Climate Change (IPCC) released a call to action to reduce current trends to stay below 1.5 °C of warming [1•].

Sustainability was first defined in 1987 by the Brundtland Commission as follows: "Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs" [2]. Recently, the United Nations published 17 sustainable development goals (https://sustainabledevelopment.un.org/sdgs). The purpose of these goals is equally to find synergies among them and promote win-win-win solutions for planetary health, human well-being, equity, and prosperity [3].

As part of sustainable developments, a sustainable diet is a decade-old concept that was first defined by participants of the 2010 International Conference organized by the Food and Agriculture Organization and Biodiversity International. A sustainable diet is "a diet with low environmental impacts which contributes to food and nutrition security and to healthy life for present and future generations" [4]. It has also been recognized that sustainable development can only occur if food system problems are addressed trans-disciplinarily, promoting systems thinking, linking ecological with human health and wellbeing, while ensuring social equity and economic prosperity [5•]. Thus, "a sustainable food system is protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy, while optimizing natural and human resources" [4].

Globally, few countries have integrated sustainability concepts into governmental dietary guidelines [6]. Nevertheless, many non-governmental organizations [1•, 3, 7•], along with an impressive body of scientific literature [5•, 7•, 8–11, 12•,

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✉ Nanna L Meyer
nmeyer2@uccs.edu

Alba Reguant-Closa
albareguantclosa@gmail.com

Thomas Nemecek
thomas.nemecek@agroscope.admin.ch

[1] Johnson E. Beth-El College of Nursing and Health Sciences, Department of Human Physiology and Nutrition, University of Colorado Colorado Springs (UCCS), 1420 Austin Bluffs Parkway, Colorado Springs, CO 80918, USA

[2] International Doctoral School, University of Andorra, AD600 Sant Julià de Lòria, Andorra

[3] Life Cycle Assessment Research Group, Agroscope, Reckenholzstrasse 191, Zürich CH-8046, Switzerland

13], have released calls to action for changes in agricultural production and eating practices to conserve natural resources and promote healthy ecosystem services including a thriving food system that is accessible, healthy, and prosperous for communities.

Recently, the EAT-Lancet Commission called for the "Great Food Transformation," for the developed world, to promote healthy diets from sustainable food systems. Such dietary shifts would address climate change, diet-related illness, and food insecurity by creating solutions for the benefit of people and the planet jointly. The authors suggest more plant-based dietary approaches rich in vegetables, fruits, legumes, whole grains, nuts, and seeds. Substantial shifts away from foods that are harmful to those that are beneficial for human and planetary health would likely reduce diet-related mortality, lower health care costs, and protect planetary resources [7•].

Athletes and active individuals have only recently been included in the discussion of sustainable diets [14, 15, 16••, 17•, 18••, 19•]. For the most part, these publications have diffused the knowledge from sustainable food systems to the diets of athletes with the intent to reduce environmental impacts, while maintaining health and performance in exercising humans.

Athletes have greater energy and nutrient needs than the general population [20–22]. While it is important that athletes meet dietary guidelines to maintain health and improve performance capacity, studies consistently show that athletes exceed protein intakes [23–25], are prone to follow food trends [26, 27], and use a large number of dietary supplements, especially protein powder, often with no clinical reason [28–30]. Thus, some athlete groups might fall into what Garnett [31] called the category of the "healthy and wealthy," consuming foods consistent with dietary trends to gain a performance edge with no or limited knowledge of and no consideration of planetary impacts.

Thus, the purpose of this review is to summarize the current knowledge on food and sustainability with special attention to athletes' diets. Though sustainability encompasses multiple dimensions, this review will focus on the environmental issues with the objective of presenting recommendations toward more environmentally friendly food choices, while maintaining the performance edge of tailored sports nutrition guidance.

The Environmental Impact of Food and Diets

With the development of life cycle assessment (LCA) of agriculture and food and the increasing availability of data for many food products, countries of origin, and production methods, the analysis of complete diets has become more common [32, 33]. LCA is particularly suitable for the analysis of food production and consumption, since it considers a life cycle of a product, and therefore can represent a food supply chain, including manufacturing of the agricultural means of production, farming (including direct emissions), transport, processing and storage of food, and finally, food consumption [34]. In contrast to footprint methods, which consider a single aspect like GhGe, land use, or water use, LCA performs a comprehensive environmental assessment by including all relevant environmental impacts. These include climate change, eutrophication, acidification, photochemical ozone formation, stratospheric ozone depletion, ecotoxicity, abiotic resource use, water scarcity, biodiversity, soil quality, and impacts of particulate matter and toxic substances on human health. Thus, LCA is a method of system analysis, defining clear system boundaries, so that strength and weaknesses of different systems or alternatives can be compared [35]. A typical life cycle of a food product is shown in Fig. 1.

The contribution of life cycle stages to the total environmental impact varies according to the food group [12•] (Fig. 2). The impacts are generally dominated by agricultural production (crop production, livestock production, and land use), which is more important than processing, packaging, and transport. The contribution of land use change is particularly high, whenever deforested areas or former peatland (i.e., rich organic soil) is used (e.g., in the case for soybeans and palm oil). Transport is mainly relevant for fruits and vegetables, where 1 kg of product causes relatively low impacts and, therefore, transport gains relative importance (Fig. 2). Furthermore, air freight strongly increases the environmental impact [36]. Packaging can be important for some food products including liquids [37] and could potentially be more important for athletes, who are often eating on the go. However, if protective packaging is reduced leading to more food waste, the total impact is likely to increase [38]. Figure 2 shows life cycle data of various food groups.

Systematic reviews on the environmental impacts of different diets [39, 40, 41•, 42] show that reducing or avoiding animal-sourced food (ASF), particularly meat, decreases the environmental impacts of the food system. Consequently, vegan diets, followed by vegetarian diets, show lower environmental impacts than omnivorous diets [41•, 43–46]. The effects are higher on climate change (− 40 to 50% for vegan and − 30% for vegetarian) and land use (− 50 to 60% for vegan or vegetarian) than on water use (− 30% for vegetarian) [40]. Vegetarian diets contain more fruits and vegetables, which often stem from irrigated fields. The higher environmental impacts of ASF are mainly caused by the losses during the conversion of feed (e.g., corn, soy, hay) to animal products. Further, additional emissions from animal husbandry, such as methane from enteric fermentation and nitrogen and phosphorus emissions from manure management [12•], contribute significantly to a higher environmental impact of meat. However, it is not necessary to have completely vegetarian or vegan diets to reduce environmental impacts, since it is also

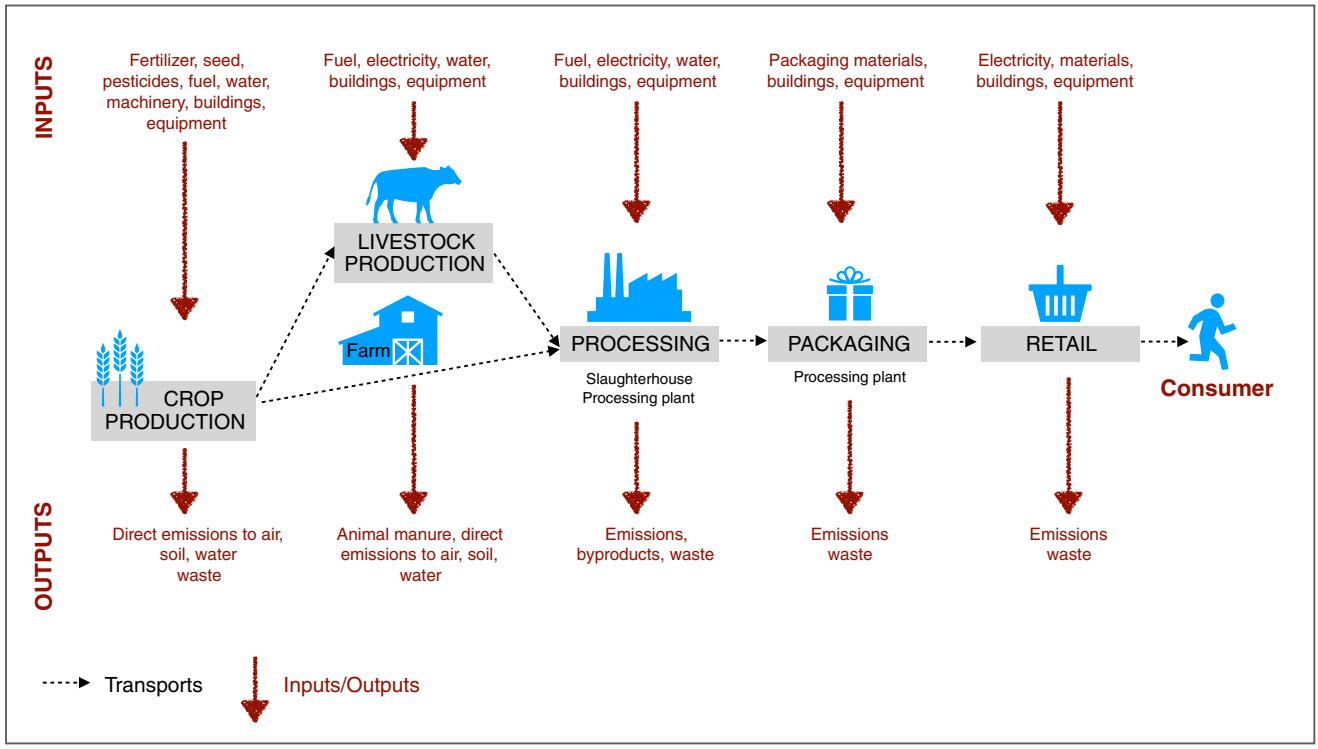

Fig. 1 Typical life cycle of a food product

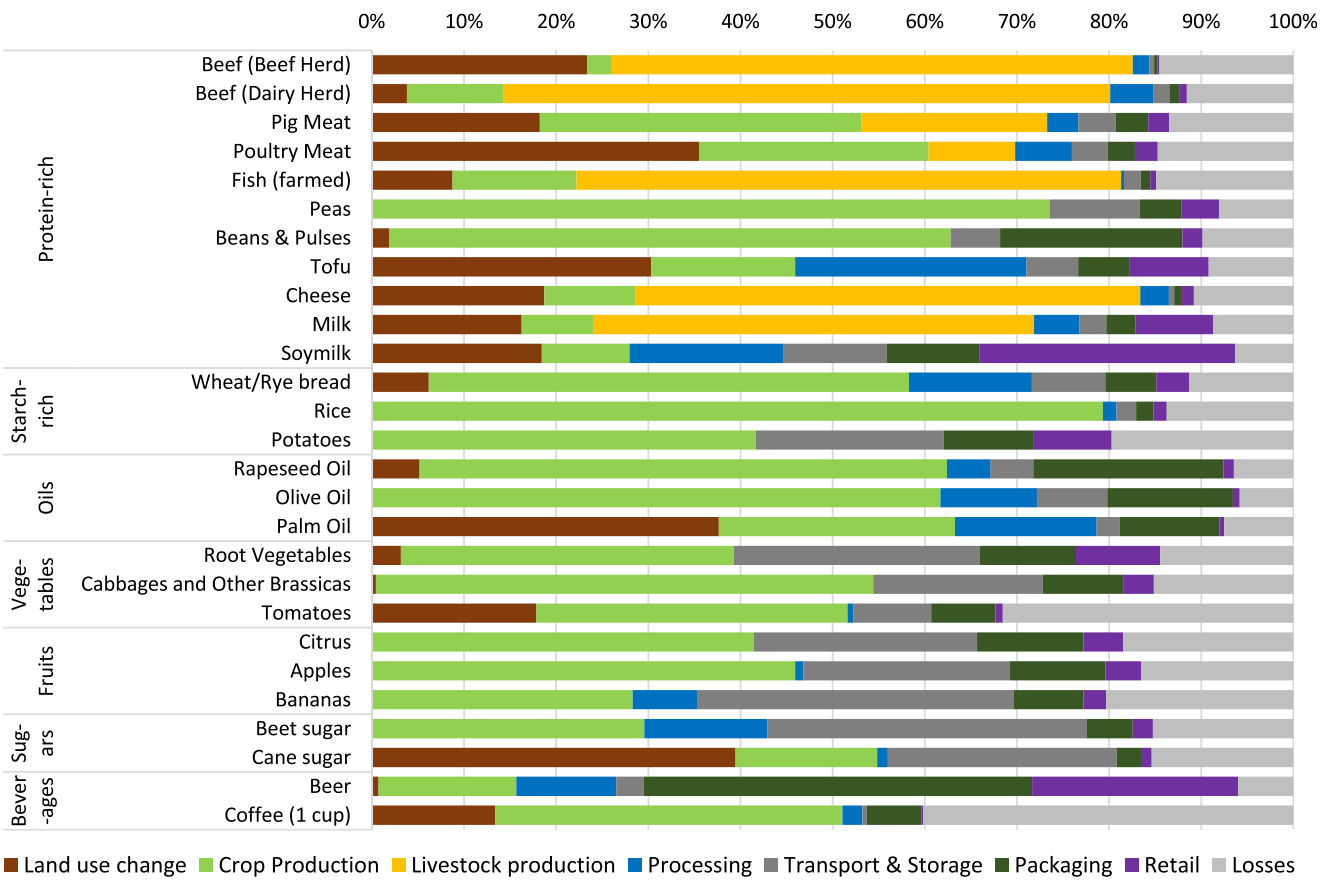

Fig. 2 Contribution of different life cycle stages to the greenhouse gas emissions of selected food groups (based on data from Poore and Nemecek [12•])

possible to define flexitarian diets with less ASF and considerably lower environmental impacts [41•]. This approach could be meaningful in athletes, as it allows for meeting but not exceeding protein requirements.

Following healthy dietary guidelines, as recommended nationally, is generally favorable for the environment [47], but this is not always the case [46], depending on what is used to replace meat [40, 42]. Thus, the impact on the environment depends on the context, with larger effects in high-income countries [48]. Cultural preferences [49] and individual behavior [50, 51] also play an important role for the environmental footprints of food consumption.

When comparing different food products, in particular plant-based and ASF, differences in nutrient composition and nutrient quality of the products matter. Meat has significantly higher environmental impacts than plant-based alternatives [52]. However, if nutritional quality (e.g., amino acid profile of protein, protein digestibility, and micronutrients) in meat is taken into account, the differences are smaller but remain significant [53•, 54, 55, 56••]. It will be critical for the diets of athletes to ensure protein quantity, quality, and distribution relative to exercise when evaluating the environmental impact.

Several studies link the impact of food on the environment to impacts on human health [7•, 43]. Although strong synergies exist between environmental and human health impacts of diets, their association is not always clear [50]. In addition, while healthier diets are characteristic of greater diet quality due to higher fruit and vegetable consumption, these diets are also associated with greater waste of fresh produce, especially on the consumer level [57]. Beretta and Hellweg [58] highlighted the importance of food waste. Avoiding food waste, as shown in a Swiss case study, could reduce environmental impact from food by 30–40%. For athletes, food waste could be significant due to the lack of time and skills in food handling and storage and frequent travel.

Seasonality also plays a dominant role; vegetables or fruits from heated greenhouses cause significantly higher environmental impacts [59]. Therefore, the consumption of seasonal, fresh food is generally more favorable. Considering that athletes often eat in dining halls of institutions or training centers, planning menus for athletes should favor fresh seasonal fruits and vegetables, as packaged, processed, frozen, or canned foods not only elevate the environmental impacts [37, 60–63] but also may compromise flavor and nutrition [64–66]. In a recent study performed at an elite training center, higher environmental impacts were identified from frozen and canned vegetables compared to fresh options (Reguant-Closa et al., under review). While food service and support staff or athletes may not always know when produce is in season or the nutritional, flavor, and environmental ramifications of out-of-season products [64, 66, 67], food literacy approaches can remedy such gaps.

The environmental impacts largely differ also within a food product depending on its origin and the production system [12•], which shows the large mitigation potential in food production. ASFs have higher environmental impacts than plant-based alternatives, but large differences between different ASFs exist. For example, beef from beef herds needs 23× more land and causes 9× more GhGe per 100 g of protein compared to poultry meat [12•]. However, ruminants (and other roughage feeders like horses) can also use feed from grasslands, while monogastric animals (poultry and pigs) directly compete with human nutrition [68]. Often cattle are fed with concentrated feedstuffs, like cereals, corn or soybean meal, or alfalfa. In these cases, a direct competition between livestock production and human nutrition exists [69]. Compared to beef, dairy production uses the resources more efficiently and should therefore be the first choice when using grassland. Therefore, the environmental impacts are lower per unit of protein for milk than for beef [70]. The environmental hotspots of wild-caught fish are the fuel use for the trawlers and the over-exploitation of fish stocks. The latter aspect is not well covered by current LCA. For aquaculture, the production of the fish feed, water pollution, and methane emissions from fish ponds and energy use are the main drivers for environmental impacts [71].

From the literature, we can conclude that diets with less ASF and, in particular, less meat have lower environmental impacts. However, there are large differences among ASFs, since foods such as milk, eggs, and poultry have lower environmental impacts than meat from ruminants. The environmental impact of pork is in between ruminants and poultry. Part of the ruminant feed stems from grassland and is therefore not in direct competition with human nutrition. Diets following governmental nutrition recommendations tend to have lower impacts than current Western diets. A large mitigation potential lies, therefore, in changed human diets, including a reduction in meat and waste and in optimized food production.

Health and Performance Opportunities of Sustainable Diets

Defining a sustainable diet encompasses environmental, agricultural, sociocultural, health, and socioeconomic factors [6]. Athletes have specific nutritional requirements depending on training intensity and volume, performance goals, and health status [22], but considerations of environmental impacts and sustainability remain mostly elusive when tailoring diets for athletes [16••, 18••]. With the growing concerns of climate change and the evidence that consumer choice can effectively reduce environmental impacts [7•, 10, 12•, 47], the integration of sustainability in athletes' diets can no longer be avoided.

While a sustainable athlete's diet can be approached from different angles, the following section focuses on the hotspot of ASF and protein, highlighting the most environmentally impactful solutions, while also acknowledging additional important steps toward environmentally friendly eating.

Meeting But Not Exceeding Protein Requirements

The protein content of an athlete's diet is important to ensure adequate muscle protein synthesis, tissue repair, and training adaptation. Protein requirements for male and female athletes range from 1.2 to 2 g*kg body mass (BM)$^{-1}$*day^{-1} [21, 22, 72]. To support weight loss, aging, or periodized training strategies with low carbohydrate availability in athletes, higher recommendations of 2 to 2.4 g*kg BM^{-1}*day^{-1} have been described to preserve lean mass [73–79]. Unfortunately, there is lingering belief and practice to favor higher protein intakes for active and athletic individuals, with some studies showing excessive intakes as high as 4.3 g kg BM^{-1} day^{-1} [23–25].

Muscle adaptation to training is dependent not only on the amount of protein but also on the timing of ingestion. The distribution of protein through the day of about 0.25–0.31 g kg BM^{-1} meal^{-1} or 20–25 g of protein per meal through 4–5 meals positively improves muscle protein synthesis [80–82, 83•], with older adults benefiting from as much as 0.4 g kg BM^{-1} meal^{-1} [80]. It has also been recommended that 20–25 g of whey protein post exercise [83•, 84, 85] and additional protein before bedtime [86, 87] promote muscle protein synthesis [21, 82], although smaller amounts of intact protein from whole foods may be sufficient [19•, 88••]. Taken together, besides meeting overall protein requirements in athletes, adequately distributing daily portions of protein at meal times, relative to exercise and before bedtime is recommended.

Muscle protein synthesis is also determined by the quality of ingested protein. Protein quality is commonly expressed by the true ileal digestibility of essential (indispensable) amino acid score or Digestible Indispensable Amino Acid Score (DIAAS) [89]. Protein from ASF has a higher DIAAS than that of plant-based origins [89]. In exercise and to meet goals of muscle protein synthesis, the branched chain amino acids, and especially leucine [90, 91], have been identified as critical [21, 75, 80, 92–94], although this appears to be true only for isolated protein sources [95••]. While ASFs are typically more complete in indispensable amino acids with a higher DIAAS value, plant-based options do exist with slightly lower, equal, or slightly higher leucine content compared to ASF [96••]. Nevertheless, due to the less favorable amino acid composition and concomitant lower DIAAS [97] of plant-based options overall, greater quantities [54, 98] or combinations or blends [96••] are likely needed if used as protein isolates as opposed to whole foods [88••, 95••].

In addition to protein's role in muscle, there are further nutritional benefits from the ingestion of ASF, such as iron, zinc, calcium, and vitamin B_{12}, all of which are also important for athletes [22]. According to Moore [83•], even if recommended intakes post exercise increase slightly (from 0.25 to 0.31 g kg BM^{-1}), overall protein recommendations for athletes rarely exceed 2 g kg BM^{-1} day^{-1}, except perhaps for weight loss transiently [77]. Thus, evaluating carefully athletes' overall quantity, quality, and distribution of protein and avoiding excess intake is the first step to an environmentally friendly approach.

High protein intakes from ASFs, and especially red meat, are common in Westernized diets with high socioeconomic status [99] and also in some athletes [100, 101]. If high in red and processed meat, such diets are neither health-promoting [7•, 102] nor performance-enhancing [83•] nor protective for the environment [41•]. While research on whole food diets and the skeletal muscle adaptive response is still limited, preliminary data indicate that less, not more, protein is likely sufficient [75]. Thus, athletes need professional guidance so they learn to adjust protein sources, quantity, and distribution according to the evolving evidence in protein nutrition relative to exercise.

Athletes are also heavy users of dietary supplements, especially protein powders [103, 104]. Protein supplements (such as protein shakes or protein bars) are typically used by athletes to optimize muscular adaptations post exercise [29, 105–108]. While convenient [109], athletes exceed quickly recommended amounts of proteins when using these products. Besides concerns of supplement contamination [110], recent research on the microbiome also raises concerns of such practices. Especially in the absence of adequate fiber, excess protein can result in fermentation in the gastrointestinal tract, which has been associated with inflammation, damage, and dysfunction [111••]. A recent study also evaluated a 10-week supplementation trial using protein powders and their effect on the microbiota. The authors found a decrease in health-related bacteria, suggesting negative impacts from prolonged intakes of protein powders on the gut microbiota [112]. A healthy gut is associated with exercise [113] and athletic performance [114••]. Long-term protein supplementation raises concerns not only for the deterioration of individual health but also for planetary health if it leads to overall excess protein intake. Protein concentrates, such as whey, are typically by-products with high nutritional value yet relatively low environmental impact [56••]. Thus, using whey in small quantities in the post-exercise period can still meet training goals [84, 85]. However, a safe, whole food first approach, high in fiber and nutrients, without an excess of ASF and/or supplements, should be preferred in athletes to ensure optimal health, skeletal muscle support and performance, and environmental protection.

Finally, high protein intake increases satiety and can displace adequate carbohydrate intake [73]. Many athletes have suboptimal intakes of carbohydrates [115, 116], which can be detrimental to training adaptation, health, and performance [75, 117, 118]. Popular eating approaches, such as gluten-free, Paleolithic, and ketogenic diets [27, 119] or training with low carbohydrate availability [73], are also used by athletes. Such diets can be high in protein, and specifically ASF, and high in fat [31]. While these diets may provide a temporary training or a necessary clinical solution, they may also be a nutritional fad. Unfortunately, these approaches are costly in the long term, for the environment and, most likely, also for health [31, 120, 121].

Plant-Forward, Flexitarian Approaches

As ASFs have a higher burden on the environment than plant-based protein sources [12•], replacing some of the animal protein content of the diet with plants might provide sports performance opportunities. A plant-forward diet, also understood as a flexitarian approach with less meat, is generally associated with better health outcomes [43, 102] and lower environmental burden [41•].

Increasing plant-based foods from fruits, vegetables, legumes, and whole grains promotes weight and fat loss [122] due to the lower fat and energy density and higher dietary fiber content [123]. Such modifications are also mostly environmentally friendly. Increasing plant-based foods also boosts vasodilatory, antioxidant, and anti-inflammatory properties of the diet, which can lead to improved blood flow, reduced oxidative stress and inflammation, and thus, enhanced endurance performance, reduced muscle damage, and speedier recovery [124–126].

Because research on plant protein is still scarce in sports [18••], it is generally accepted that animal-derived protein is optimal for recovery, especially post exercise [127, 128]. Studies have mostly focused on isolated, high-quality milk proteins, especially whey and casein but also soy to promote muscle protein synthesis post exercise, with whey protein generally showing greatest results [84, 129–131]. Recently, co-ingestion of carbohydrate with 20 g of protein from milk, whey, or casein showed no differences in myofibrillar and mitochondrial protein synthetic rates in young men post concurrent resistance and endurance-type exercise. Protein and carbohydrate co-ingestion, however, increased myofibrillar protein synthesis compared to carbohydrate alone, which shows that protein and carbohydrate combinations post exercise are an effective nutrition strategy [131]. While plant-based proteins are not well researched, a 3-month resistance training study using whey versus pea protein supplementation compared to placebo showed no difference in muscle gain and strength between the two different proteins [132].

Further, using whole nutrient-dense foods, compared with processed or isolated equivalents, while still understudied in plants and whole meals, has shown greater impacts [133, 134] on post-exercise muscle protein balance, at lower quantity [83•], and independent of leucine content [95••]. In addition, there seems to be individual adaptation to lower protein intakes in some cultures [135] at no compromise to performance, indicated by the recent Kenyan success story in the marathon [136]. Considering climate change and the projected reductions in crop yields [137] and nutrient density, including protein [138], sustainable solutions to protein will be needed, also in athletes. Several countries have already made shifts to low-meat options within traditional food culture contexts [8, 11, 13]. Whether quality-corrected isolated or whole foods rich in protein with the lowest environmental impact [56••], mixed animal and plant blends or complementary plant combinations [139], or other low-impact options (e.g., insects [140]), sports nutrition of the future will require, at the very least, a flexitarian approach.

Flexitarian, plant-forward, or semi-vegetarian diets have become popular alternatives to fully plant-based lifestyles. Data show that flexitarian approaches, with occasional animal protein from meat, dairy, or fish, can still reduce the environmental impact of the diet [40, 141•]. These diets are also becoming more popular among athletes [27] for health, ethical, environmental, or religious/spiritual and aesthetic reasons. The EAT-Lancet Commission proposed a reference diet for human and environmental health with a recommended intake of meat of no more than 300 g (10.5 oz), and less than 100 g (3.5 oz) of red meat, per week [7•]. This is in agreement with Aiking [10], suggesting to reduce overall daily protein intake by 1/3, replace 1/3 by plant-based options, and choose 1/3 from high-quality sources [10]. On the athlete's plate, this suggests a protein flip [142], moving plant-based foods to the center of the plate, while using ASF as a topping [16••].

Plant-Based and Vegetarian Approaches

While vegetarian diets for athletes have been discussed in the past [143, 144], the popularity of such diets among athletes has re-surfaced [18••, 27]. While these approaches have been highlighted positively in the popular press [145], there are still concerns of nutrient deficiencies, suboptimal training adaptation, and performance impacts [27, 146–149]. Due to reduced protein quality of plant-based proteins [89], protein recommendations for vegans/vegetarians are likely greater [150] than for omnivores. Employing the DIAAS in athletes, Ciuris et al. [151] showed significantly lower scores using prospective food records in a cross-sectional sample on omnivorous and vegan/vegetarian endurance athletes with isocaloric diets. These lower scores also related linearly to differences in lean body mass and strength measures. While this study did not examine endurance performance variables, it

seems prudent that athletes on plant-based diets focus on adequate protein quantity and quality, choosing from diverse food sources over the day to ensure complementarity action of amino acids such as lysine and methionine [149]. Though still scarcely studied, most research on performance in vegan/vegetarian athletes neither shows performance gains or losses [18••].

Few studies have investigated the impact of a plant-based diet on athletic performance. The majority of these studies show no difference in endurance capacity [147, 148], endurance performance [148, 152], or performance in strength/power tasks [152]. These studies were summarized by Craddock et al. [148] and Lynch et al. [18••], indicating no performance differences among omnivores, vegetarians, and vegans. Most of the studies have been centered on aerobic capacity and performance. Lynch et al. [152] evaluated the cardiorespiratory capacity, showing significantly higher VO_2 max values in female vegetarian athletes versus omnivorous athletes. But, no significant differences were found in the male athletes [152]. More recently, Nebl et al. [147] analyzed the maximal exercise capacity of recreational runners following an omnivorous, lactovegetarian, and vegan diet with no differences in exercise capacity, adding to the literature that plant-based diets have no negative impact on performance. Fewer studies have focused on the effect of a vegetarian or vegan diet on strength and power. Lynch et al. [152] examined the strength (by peak torque for leg extension) cross-sectionally of vegetarian versus omnivorous athletes with no differences. Some vegetarian athletes may have less lean body mass than omnivorous athletes [151], which could impact performance especially in strength and power sports, but thus far, no studies have shown this and there are many athletes on plant-based diets that seem to succeed in their sports [145, 153].

Plant-based diets may also have health benefits that could boost performance in the long term. It is well documented that plant-based diets reduce the risk of chronic illness such as cardiovascular disease, diabetes, metabolic syndrome, and cancer [154–157] and all-cause mortality [158]. Plant-based diets are associated with lower body mass index [159] and metabolic and inflammatory indices consistent with better health outcomes [160–162]. Recently, a plant-based diet was suggested for endurance athletes because of its cardioprotective effect and possible performance advantage, the latter may be due to the high carbohydrate intake of these diets, among other reasons [163••].

On the opposite spectrum, there has been concern that vegetarian diets could increase the risk of eating disorders. Because plant-based diets are naturally lower in fat and calories [163••], they might help athletes with energy restriction. Thus, it is unclear that plant-based diets per se cause eating disorders [164, 165]. In fact, studies have repeatedly shown no significant differences in the health [166, 167] and immune status [168], or micronutrient intakes [146], between vegetarian and omnivorous athletes. In addition, a diet rich in vegetables, fruits, legumes, and diverse grains is also rich in antioxidants and could provide a broad range of nutrients available in limited amounts in Westernized diets [146, 163••]. Nevertheless, athletes on plant-based diets should be vigilant regarding energy, protein, iron, zinc, vitamin B_{12}, and omega 3 fatty acids, as these nutrients could be reduced, increasing the risk of suboptimal intakes [18••, 169]. Finally, plant-based diets are known to be high in grains, legumes, and beans which can increase antinutritional factors such as phytates [170, 171]. These factors, however, can be reduced through various methods of soaking, sprouting, fermenting (sourdough), and nixtamalizing (for corn-based foods). These processes, some of which are traditional, can increase the bioavailability of nutrients, including amino acids [172].

In conclusion, sustainable sports nutrition strategies must first ensure athletes meet but not exceed protein recommendations. Choosing a variety of protein sources from animals and plants, distributed according to meal patterns, exercise, and sleep will be sufficient to achieve optimal muscle repair, protein synthesis, and training adaptation. The flexitarian approach could be a win-win-win strategy for athletes, since overall protein needs are likely met, protein quality is met, and sustainability guidelines are met. Finally, athletes may also choose to integrate plant-based meals, days, or diets as long as these meet health and performance goals and prevent suboptimal energy and nutrient intakes. Due to athletes' lifestyles, other environmental hotspots, besides ASF, likely include processed, packaged, and wasted foods (Table 1). There is a great need for research in these areas to develop sustainable practices for athletes.

Sustainable Diets for Athletes: The Role Of Sports Dietitians, Teams, And Institutions

Sustainable dietary practices include a broad range of areas. The sports dietitian is the professional to ensure awareness, knowledge, and skills in sustainability practices are promoted in athletes, coaches, the support team, and institutions (e.g., national sporting organizations or universities). There are several concept papers published that can act to support the integration of sustainability into curricula [173•, 174] and nutrition practices of registered dietitians and fitness professionals [15, 16••, 175•].

The Sports Dietitian

Athletes are mainly concerned about performance enhancement through nutrition. However, young people are becoming more aware of the impact the current food system exerts on people and the planet. There are many eye-opening

Table 1 Five steps to sustainable diets in athletes

Area to reduce	Area to rethink and redo
1. Reduce animal-sourced foods (especially red and processed meat)	Increase plant-based foods; consider flexitarian, plant-forward approaches
2. Limit protein supplements	Practice food-first approaches using whole foods whenever possible
3. Reduce processed, frozen, and canned foods	Increase food literacy and prioritize locally grown, seasonal, fresh food
4. Reduce food waste	Teach purchasing, cooking, storage, food safety, and food literacy
5. Avoid unnecessary packaging	Use sustainable options but evaluate solutions in the light of food safety and food waste

experiences for athletes to ignite awareness of their own actions (e.g., conducting a food waste study at home, evaluating reusable packaging, exploring local food sources). To integrate sustainability in sports nutrition practice, sports dietitians will need to provide context, choose the right timing, and create learning opportunities through food literacy. Food literacy is defined variably [176, 177] but focuses on knowledge and skills related to food and nutrition, connecting learners to where food comes from, how and when it is grown, and by whom. Food literacy also includes know-how in purchasing and kitchen work to learn what is in season and available fresh and how to assemble, cook, eat, and fuel as well as safely preserve, store, and prepare food for eating on the go. Providing a visit to a farmer's market and guidance about direct-to-consumer purchasing options when training at home is a great introduction. Food citizenship [174, 178] develops gradually, as young people begin to understand that their food choices either support or threaten a healthy, environmentally protected, and just food system. When athletes travel or are in competition, these place-based approaches will flexibly adjust, although travel also gives rise to cultural exposures depending on the destinations, time availability, and food access logistics. It is the sports dietitian's role to teach sustainable travel practices with packaged foods and vessels (e.g., water bottles) that are permitted at airport and are safe and environmentally friendly.

The sports dietitian is responsible for the athlete's understanding and implementation of relative quantity, quality, and distribution of proteins according to performance goals. Sports dietitians should understand the reasons for and differences in plant-based and plant-forward strategies and help athletes integrate these into their daily and weekly training diets using personalized nutrition and creative cooking techniques using the protein flip [16•, 142]. A recent validation study on the athlete's plate educational tool, conducted with sports dietitians at a national training center, found a higher protein content than recommended (up to 2.9 g kg BM^{-1} day^{-1}), with 70% of total daily protein intake coming from ASF when sports dietitians were asked to make plates according to training load and two weight categories for males and females [17•]. In a follow-up study, LCA showed higher environmental impacts for ASFs compared with other foods on the plate, plates made for hard training days, and those made for male athletes (Reguant-Closa et al., under review). While the athlete's plate model will be revised to integrate sustainable practices, it is also important to adjust protein recommendations as discussed in this article.

The Team

Sustainability practices should be woven through the team's philosophy, which could address travel, waste, and recycling policies. Further, food visions, as part of the team's sustainability plan, ensure environmentally friendly eating practices are not only promoted but also communicated to the local community. A team's food vision could include reduction of excess red meat; incorporation of plant-based meals and days; reduction of food and packaging waste; increase in locally purchased and seasonal products for recovery centers, training tables, and catered meals; and prioritizing food establishments that offer locally sourced and sustainable options. To our knowledge, sports teams have yet to put forward their food visions.

Institutions and Organizations

Sporting organizations, universities, and national training centers can make the biggest impact through changing food procurement processes. The International Olympic Committee (IOC) has developed the Sustainability and Legacy Commission, which aims at increasing awareness and inclusion of sustainability considering the Olympic Movement. Following this goal during 1999, the IOC developed the Olympic Movement's Agenda 21: Sport for sustainable development with the objective to encourage members of the movement to play an active part in the sustainable development of the planet [179]. This document included sections for health and access to healthy food but did not specify concepts related to sustainable diets. During the London 2012 and Rio 2016 Olympic/Paralympic Games, sustainability initiatives

pertaining to food procurement and diet design were instated for the first time [180, 181]. During the 2012 London Olympic Games, food provision and nutrition of the Olympic menu was assessed among sports dietitians at the Games. While sustainability was integrated in the Olympic menu, very few were aware of this [14]. A follow-up paper about the food provision at the Rio 2016 Olympic/Paralympic Games unfortunately did not include food sustainability in the assessment [182]. This highlights the urgency for greater integration in menu assessment and procurement policies/food visions that include sustainable practices.

While institutional procurement regulations vary by contracts, food service managers can emphasize plant-based and plant-forward options [142], reduced ASF serving sizes, sustainable protein options, locally sourced seasonal vegetables and fruit, a minimum of packaged liquids and snacks, and a reduction in food waste.

Institutions and organizations hosting sporting events should also consider initiatives such as the Green Sports Alliance [183] and the Sports for Climate Action [184]. The wastefulness of sporting events has recently been addressed at the London Marathon and Tokyo Olympics, and various sports have integrated sustainable practices as part of their principles (e.g., ski mountaineering) [185–187].

Conclusion

Very few sports nutrition recommendations and guidelines include sustainability and even less integrate the environmental impact of food choices in a quantifiable manner. There is a significant research gap on plant-centric, whole food–based strategies for post-exercise skeletal muscle and training adaptation. More research is needed on the effect of sustainable diets on athletes' health and performance. Finally, research to reduce packaging and food waste in athletes is also needed. Moreover, dietary guidelines and effective educational tools, specifically for active and athletic individuals, need to align with sustainability principles to promote win-win-win solutions for healthy eating, athletic performance, and a sustainable future.

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Compliance with Ethical Standards

Conflict of Interest Nanna L. Meyer, Alba Reguant-Closa, and Thomas Nemecek declare no conflict of interest.

Human and Animal Rights and Informed Consent All cited studies by the authors were approved by institutional review boards of their respective institutions.

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