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Sustainable lifestyle and nutrition in the adult population, including physically active people and athletes: the NUTRI_ACTIVE study

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Part 1:

1. Background and rationale

1.1 The role of diet in determining health status and prevention of lifestyle-related diseases

Diet represents one of the most influential and modifiable determinants of health status throughout the human lifespan [1]. Beyond its fundamental role in providing energy and essential nutrients, diet profoundly affects metabolic regulation, immune function, inflammation, and the maintenance of physiological homeostasis. The increasing global prevalence of noncommunicable diseases (NCDs), including cardiovascular diseases, type 2 diabetes, obesity, and certain cancers, has highlighted the importance of addressing modifiable lifestyle factors such as dietary habits, physical activity, and overall behavioral patterns. According to the World Health Organization (WHO), NCDs are responsible for at least 43 million deaths annually, accounting for 75% of all deaths not related to pandemics globally [2].

In this context, the role of diet extends beyond individual nutrients or food items. The concept of dietary patterns has emerged as a more comprehensive and meaningful approach to evaluating diet-disease relationships. Unlike reductionist models focused on single nutrients, the dietary pattern approach considers the interactions among foods and their cumulative effects on metabolism, inflammation, and long-term health outcomes. Numerous epidemiological and clinical studies have consistently shown that diets rich in plant-based foods, unsaturated fats, and complex carbohydrates are associated with reduced incidence of major NCDs, improved longevity, and better quality of life [3,4].

Among these, the Mediterranean Diet (MedDiet) represents one of the most scientifically validated and culturally rooted dietary models [5,6]. A large body of evidence supports MedDiet protective effects against cardiovascular and metabolic disorders, as well as its contribution to overall longevity and wellbeing [7,8]. Importantly, dietary habits should be viewed as an integral component of lifestyle medicine, interacting closely with other behavioral factors such as physical activity, sleep, stress management, and social relationships [9]. This holistic approach recognizes that the benefits of a healthy diet are amplified when combined with regular exercise and other positive lifestyle behaviors. For this reason, dietary assessment and lifestyle evaluation should be considered together when developing health promotion and disease prevention strategies.

At the population level, improving diet quality and adherence to healthy dietary models is a cornerstone of public health policies across Europe and globally. The WHO's Global Action Plan for the Prevention and Control of NCDs 2023-2030 emphasizes the promotion of balanced diets and regular physical activity as key measures to reduce premature mortality and enhance population health [10]. Similarly, the Italian Piano Nazionale della Prevenzione identifies healthy eating as a strategic model for achieving sustainable health outcomes, both for the general and the physically active population [11].

2. The Mediterranean Diet

2.1 Definition and principles

Among the most studied dietary patterns, the MedDiet is widely recognized for its beneficial effects on cardiovascular and metabolic health, primarily due to its balanced composition and richness in essential nutrients [12]. This nutritional model was developed to reflect the typical dietary habits followed during the early 1960s by populations living around the Mediterranean basin, mainly in Crete, much of the rest of Greece and Southern Italy [13]. This dietary pattern was first described by the American physiologist Ancel Keys through the *Seven Country Study*, which demonstrated a lower incidence of coronary heart disease among Mediterranean populations [14].

The MedDiet is characterized by a high intake of plant-based foods, including fruits, vegetables, legumes, whole grains, nuts, and habitual consumption of extra-virgin olive oil, combined with moderate consumption of fish, dairy products, and red wine (within culturally appropriate contexts). A limited intake of red meat and processed foods is also recommended [15]. Beyond its nutritional aspects, the MD represents a cultural and social model that promotes conviviality, seasonality of foods, environmental sustainability, and regular physical activity [15]. These features were formally recognized by UNESCO in 2013, when the MedDiet was included in the list of *Intangible Cultural Heritage of Humanity*, emphasizing its value as a comprehensive lifestyle [16].

A new version of the *Mediterranean Food Pyramid* has been recently published by the Italian Society of Human Nutrition (Società Italiana di Nutrizione Umana, SINU) with the aim of supporting both primary prevention strategies and population-level dietary education (**Figure 1**) [17]. This update was motivated by two main drivers: 1. emerging scientific evidence linking traditional MedDiet with reduced risk of NCDs; 2. growing need to align dietary recommendations with sustainability goals as emphasized by the Food and Agriculture Organization (FAO) - WHO document and the EAT-Lancet Commission report [18,19].

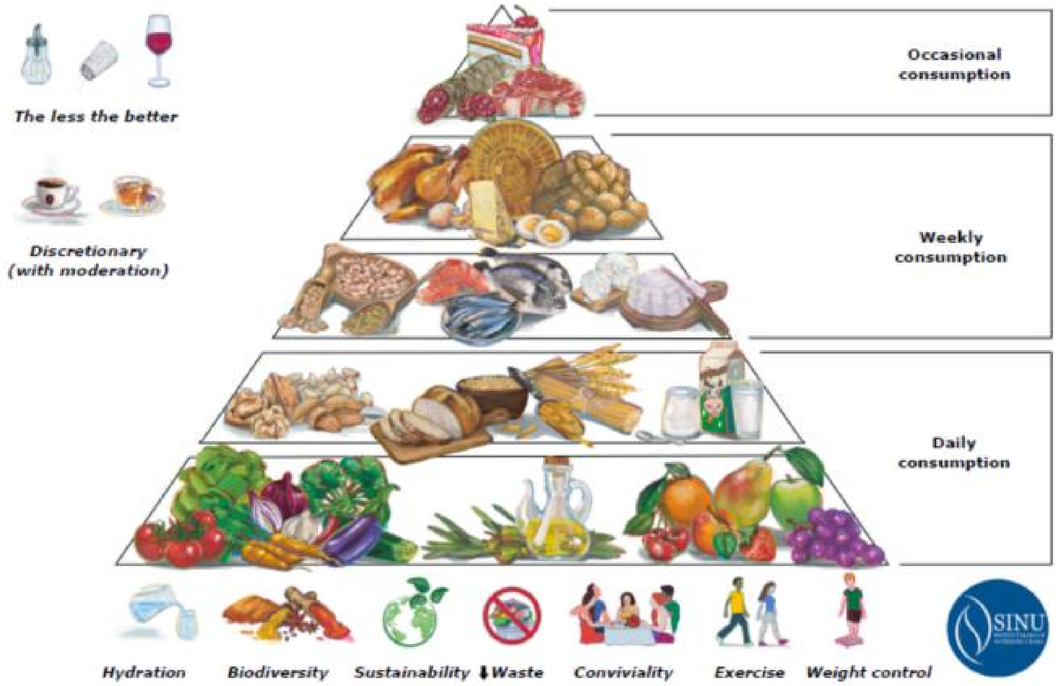


Figure 1. The updated Mediterranean Food Pyramid proposed by the Italian Society of Human Nutrition. The model illustrates the centrality of plant-based foods as the foundation of the MedDiet. Moderate consumption of fish, dairy products, and eggs is recommended, while red and processed meats, added sugars, salt, and ultra-processed foods should be limited. The updated version also reinforced water as the primary beverage, daily physical activity, conviviality, and environmental sustainability [17].

The key features of updated pyramid are reported below:

1. The base of the pyramid emphasized daily consumption of fruit, vegetables, extra-virgin olive oil (EVOO), wholegrain cereals, nuts, and milk and yogurt;
2. The central part of the pyramid included foods that are sources of plant or animal protein. In particular, the two major recommended protein sources, legumes and fish, are positioned in the lower section together with fresh dairy products, highlighting the need to favour them against other animal-based sources. The upper section of the central part included hard cheeses, other animal protein sources (white meats and eggs), and an alternative source of carbohydrates (potatoes);
3. Products with large amounts of added sugars, and red/processed meat were positioned at the top of the pyramid; this more cautious approach is consistent with modern public-health guidance and the principle "the less, the better";

4. Some important aspects of a healthy and sustainable Mediterranean lifestyle are graphically reported in the space below the pyramid. In particular, people are encouraged to prefer seasonal local foods and reduce food waste. Moreover, the pyramid's foundation reinforced the role of water as the primary beverage and includes icons promoting daily physical activity and importance of conviviality.

2.2 The Mediterranean Diet as a model for health and sustainability

The MedDiet has been extensively investigated for its beneficial effects on health and longevity. A substantial body of evidence supports its role in the primary and secondary prevention of cardiovascular disease (CVD), diabetes, obesity, metabolic syndrome, and certain types of cancer [20–22]. These effects arise from the synergistic action of its food components and the overall dietary pattern rather than individual nutrients. One of the most robust demonstrations comes from the PREDIMED trial, a landmark randomized controlled study involving over 7,400 participants at high cardiovascular risk [4]. This study linked adherence to a Mediterranean-style diet supplemented with extra-virgin olive oil or nuts led to approximately a 30% reduction in the risk of major cardiovascular events compared with a low-fat control diet [4].

The health benefits of the MedDiet have been attributed to multiple, interrelated biological processes, despite the exact mechanisms remaining to be fully elucidated [21]. According to the framework proposed by Tosti and colleagues, five major mechanisms are thought to play a central role, involving lipid metabolism, inflammatory and oxidative balance, hormonal regulation, nutrient-sensing pathways, and gut microbiota composition [21] (**Figure 2**).

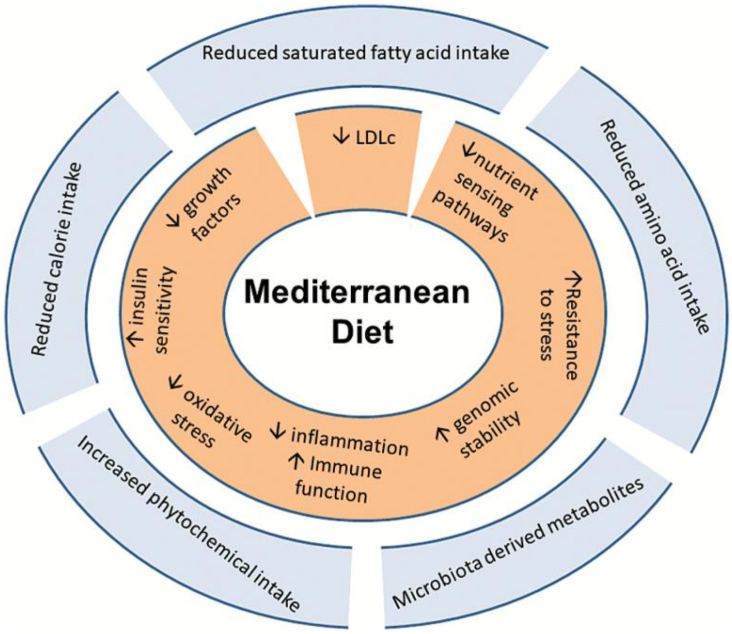


Figure 2. Possible effectors of MedDiet [21].

Specifically, Mediterranean dietary patterns improve plasma lipid profiles through abundant monounsaturated and polyunsaturated fats from extra-virgin olive oil, nuts and fish, determining reductions in low-density lipoproteins and triglycerides and beneficial changes in high-density lipoproteins [23]. The MedDiet pattern is also rich in polyphenols, carotenoids, vitamins and omega-3 fatty acids that exert antioxidant and anti-inflammatory effects, downregulating pro-inflammatory cytokines, and improving endothelial function [24–26]. Additionally, high fibre and polyphenol intake favourably modulates the gut microbiota, increasing short-chain fatty acid producers and metabolites, that reinforce gut barrier integrity and systemic metabolic health [27–29]. The MedDiet is also associated with improved insulin sensitivity and lower circulating growth-factor signalling (e.g., insulin, Insulin-like Growth Factor 1), which may contribute to reduced cancer risk and metabolic disease [21]. Finally, components of the MedDiet can influence nutrient-sensing pathways (e.g., mTOR, AMPK, sirtuins) and amino-acid-related signalling, mechanisms implicated in metabolic flexibility and longevity [30]. Together, these interconnected processes provide a rationale for the consistent epidemiological and trial-based evidence linking MedDiet adherence with lower incidence of CVD, type 2 diabetes, and certain cancers.

In addition to clinical outcomes, recent evidence indicates that the benefits of the MedDiet also extend to health-related quality of life (HRQoL) [7]. HRQoL is a multidimensional construct that encompasses physical, mental, and social wellbeing as influenced by health status and healthcare experiences. A recent systematic review in adults found that higher adherence to the MedDiet was significantly associated with better HRQoL, with the strongest and most consistent associations observed in the physical wellbeing domains [7].

Beyond its health-promoting properties, the MedDiet is recognized as a sustainable dietary model that contributes to both individual well-being and environmental protection [19,31]. The environmental advantage of the Mediterranean pattern derives from its theoretical high consumption of plant-based food compared to animal products.

Indeed, Lorca-Camara and colleagues conducted a systematic review of the literature with the aim to analyze whether the MedDiet is a sustainable and healthy dietary pattern accounting for its carbon footprint, water footprint, land use, and/or energy use [32]. The authors included 35 studies and found that 91% of studies considered MedDiet to be a sustainable dietary pattern. Another systematic review showed that dietary patterns modeled on Mediterranean principles tend to have lower greenhouse gas (GHG) emissions, reduced land use and, in many contexts, lower overall water footprints compared with typical Western diets rich in animal-source foods [33]. These analyses, however, also emphasized heterogeneity across settings and methodological approaches such as the use of different indicators on different populations. Moreover, comparisons among environmental indicators cannot be made, as they are derived from different system boundaries, such as production, distribution, or consumption [33]. Importantly, this heterogeneity highlights that sustainability outcomes may vary substantially depending on population characteristics, dietary choices, and contextual factors, limiting the direct transferability of findings across settings.

Another important consideration emerged in a study evaluating the environmental impact of the EAT-IT dietary pattern, derived from the Planetary Health Diet and contextualized to the Italian-Mediterranean setting, a lower carbon footprint was observed compared with the Italian Dietary Guidelines pattern, whereas water footprint was not reduced [34]. These findings reinforce the notion that optimizing a single environmental indicator does not automatically translate into improvements across all dimensions of sustainability. Importantly, the authors highlighted that individual food choices within the same dietary framework can substantially influence overall environmental outcomes, suggesting that simply reducing animal-based foods may be insufficient to achieve a low-impact diet. This evidence underscores the need to consider dietary sustainability in relation to food selection behaviors and cultural-contextual factors [34].

Intervention studies support the potential for dietary shifts toward MedDiet to reduce environmental impact in real-world conditions. For example, a one-year community intervention promoting Mediterranean eating reported substantial decreases in several environmental indicators, including GHG emissions (GHG: -361 g/CO_2-eq), land (-2,2 m^2) and energy (-842,7 kJ) use associated with diet [35]. These findings illustrate that measurable environmental gains are achievable through feasible changes in food choices at the population level.

Importantly, the MedDiet's sustainability profile is not only environmental but also related to socio-cultural aspects [36]. Evidence shows that key non-nutritional components, such as the preference for fresh, local, and seasonal foods, a high degree of biodiversity in plant-based ingredients, traditional culinary practices, and the conviviality associated with shared meals, promote healthier eating behaviours, enhance dietary variety, and support psychological well-being [36]. In this broader perspective, adherence to the MedDiet reflects not only specific food choices but also a holistic lifestyle that integrates cultural heritage, environmental responsibility, and regular physical activity. This multidimensional framework is considered a key determinant of the beneficial health outcomes traditionally attributed to the Mediterranean dietary pattern.

2.3 Adherence to the Mediterranean Diet in general, physically active population and athletes

Despite its well-established health benefits, several studies documented a progressive decline in MedDiet adherence across Mediterranean countries, including Italy. Data from the Moli-sani study showed this trend in a population-based cohort study composed by 21001 southern Italian citizens (mean age: 54.4 ± 11.4) [37]. The authors reported that the adherence to the traditional MedDiet (evaluated with the Italian Mediterranean Index) significantly declined across all age and socioeconomic groups. In particular, prevalence of high adherence dropped markedly from 31.3% in 2005-2006 to 18% in 2007 ($P < 0.0001$), indicating a substantial population-wide shift away from Mediterranean dietary habits [37]. Similarly, Leone et al., analysed the adherence to MedDiet between 2010 and 2016 among 8584 subjects living in Northern Italy using a 14-item questionnaire (MedScore ≥ 9 points indicated a dietary pattern in line with MedDiet principles) [38]. The authors reported that only 14% of participants adhered to a dietary pattern consistent with the MedDiet, and this proportion remained stable during the six years. Again, the Adherence to the Mediterranean Diet in Italy (ARIANNA) cross-sectional survey aimed to assess the adherence to MedDiet, using the Mediterranean Diet Serving Score (MDSS) in the Italian population [39]. In this large representative sample (n = 3732), only 4.8% of participants exhibited high adherence to the MedDiet, while the majority of the sample had a medium adherence to MedDiet. Younger age, female sex, higher educational attainment, and vegetarianism and veganism were factors positively associated with higher adherence [39]. Looking beyond Italy to Mediterranean countries as a whole, a systematic review published in 2022 summarized current levels of adherence to the MedDiet [40]. The review included 50 studies published between 2010 and 2021. Overall, the majority of studies reported low or moderate adherence to the MedDiet. This was seen both in the average adherence scores and in the fact that low or moderate adherence categories were usually the most common [40].

Taken together, these findings indicate that adherence to the MedDiet in the general population is often suboptimal, despite the well-documented benefits of this dietary pattern. For this reason, it is useful to examine whether similar patterns are seen among physically active individuals and athletes.

Recent scientific contributions have highlighted the potential of the MedDiet not only as a cardioprotective model but also as an optimal nutritional strategy to sustain the high metabolic demands of athletes [41]. Compared with other dietary regimens frequently adopted in sports settings, the MedDiet is distinguished by its ability to modulate inflammation, support immune function, and help maintain hormonal balance-factors that are particularly critical during periods of intense training load. Furthermore, higher adherence to the MedDiet has been associated with improved exercise economy and greater tolerance to effort in endurance contexts, suggesting advantages that extend beyond nutrient provision to functional performance outcomes [41].

Beyond performance-related aspects, the MedDiet offers a sustainable and easily adaptable dietary model for athletes, who often require flexibility, variety, and practicality in their eating habits. This model can be effectively integrated with sport-specific nutritional strategies, such as nutrient timing, in accordance with current international recommendations [42].

These features position the MedDiet as one of the most versatile and sustainable dietary approaches for contemporary athletes.

During physical activity, especially high-intensity exercise or training with substantial volume, there is a significant increase in the production of reactive oxygen species (ROS). When not adequately neutralized, these species can damage cells and muscle tissue, ultimately impairing muscular performance [43]. The MedDiet, rich in natural antioxidants such as polyphenols, vitamins C and E, carotenoids, and lycopene, represents an effective nutritional strategy to counteract post-exercise oxidative stress and promote faster recovery. A 2021 narrative review reported that the Mediterranean dietary pattern reduces ROS levels through the activation of endogenous antioxidant systems (including superoxide dismutase and catalase) and the neutralization of free radicals, without interfering with the adaptive processes induced by training [41].

In addition, a meta-analysis on the MedDiet confirmed its association with significant reductions in inflammatory biomarkers such as C-reactive protein (CRP), interleukin-6 (IL-6), and tumor necrosis factor alpha (TNF-α), even in athletic populations [44]. This evidence reinforces the hypothesis that the MedDiet supports both recovery capacity and athletic performance by promoting a favorable metabolic environment and reducing the risk of overtraining or chronic low-grade inflammation.

With regard to body composition, the high content of fiber and low energy density foods, combined with high nutrient density, supports weight control and reduction of visceral adiposity without compromising the energy availability required for athletic performance. At the same time, the regular consumption of high-quality protein sources and the appropriate distribution of macronutrients throughout the day are conducive to maintaining muscle mass and supporting post-exercise protein turnover. Athletes with higher adherence to the MedDiet have been shown to display greater VO_2max values, lower perceived exertion, better running economy, and enhanced muscular endurance, indicating a positive impact on both physiological and functional domains [45].

Finally, the palatability of foods, the emphasis on seasonality, and the focus on simple yet nutrient-rich culinary preparations contribute to improved long-term adherence, an aspect often overlooked in highly specialized dietary protocols for athletes, which may be overly restrictive or difficult to sustain. In this sense, the MedDiet not only meets the energy and nutritional requirements of athletes but also supports psychological and social well-being, which are essential components of a genuinely holistic approach to health and sports performance [46].

However, despite the growing interest in the MedDiet within sport nutrition, several aspects related to actual adherence to the MedDiet among athletes remain unclear. As highlighted in a recent systematic review [47], there is currently no standardized method to evaluate MedDiet adherence in sports settings, and substantial uncertainty persists regarding how adherence should be measured, applied, and interpreted within physically active populations.

3. Physical activity and nutrition

3.1 Health benefits of physical activity

The WHO, the United Nations agency responsible for global public health, has long emphasized the importance of physical activity and the reduction of sedentary behaviours as fundamental strategies to support physical and psychological well-being across the lifespan, from childhood to old age [48]. Within this framework, *physical activity* refers to any bodily movement produced by skeletal muscles that results in energy expenditure above resting levels, whereas *exercise* is a structured, planned, and repetitive form of physical activity performed with the purpose of improving or maintaining health, physical performance, or both [48]. International guidelines recommended that adults (18-64 years) engage in at least 150-300 minutes of moderate-intensity aerobic physical activity per week, or 75-150 minutes of vigorous-intensity activity, complemented by muscle-strengthening exercises on two or more days per week. Children and adolescents are advised to perform at least 60 minutes per day of moderate-to-vigorous activity. These recommendations also apply to older adults and individuals living with chronic conditions, with appropriate individualization [48,49]. Based on intensity, physical activity is commonly classified as moderate or vigorous using metabolic equivalent of task (METs) and perceived exertion scales. Moderate-intensity activity typically corresponds to 3-6 METs and a perceived exertion of about 5-6 on a 0-10 scale, while vigorous-intensity activity exceeds 6 METs and is associated with higher perceived exertion (7-8). These classifications provide a standardized framework for comparing activity levels across individuals and studies [50].

Together with a healthy diet, regular physical activity is a cornerstone of health promotion, and its beneficial effects are widely documented across the lifespan and for individuals with diverse health conditions [51,52] (**Figure 3**). Current scientific evidence shows that regular physical activity induces a wide range of beneficial metabolic adaptations: improvements in glucose uptake, lipid metabolism, vascular function, and overall body composition [53–55]. These adaptations collectively contribute to improved cardiometabolic regulation and reduced disease risk [56].

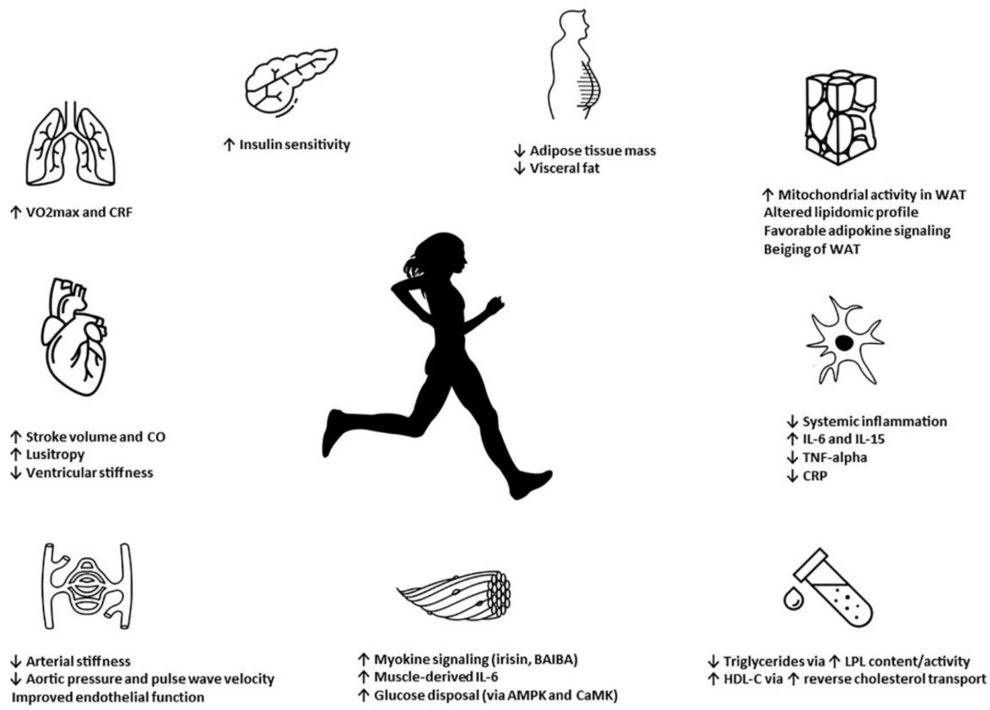


Figure 3. Summary of the cardiometabolic health benefits of exercise/physical activity [52].
Abbreviations: CO, cardiac output; CRF, cardiorespiratory fitness; LPL, lipoprotein lipase; WAT, white adipose tissue

A substantial body of scientific evidence confirms that physical activity plays a central role in preventing weight gain and excessive fat accumulation, thereby reducing the risk of developing adiposity-related pathological conditions. Higher levels of moderate-to-vigorous physical activity are associated with a smaller increase in body weight over time, particularly when activity exceeds 150 minutes per week [56,57]. These findings are consistent with earlier statements from the American College of Sports Medicine (ACSM) in 2009, which emphasized the effectiveness of regular physical activity in counteracting progressive weight gain over time [58].

In recent years, growing scientific attention has also focused on the effects of physical activity on mental health [59]. Exercise is now widely recognized not only as a determinant of physical well-being but also as a key factor in maintaining psychological health and cognitive function across the lifespan. higher physical activity levels are consistently associated with lower risk of anxiety and depression with high versus low activity levels linked to reduced odds of incident anxiety (adjusted odds ratio = 0.81; 95% CI: 0.69-0.95) [60] and depression (adjusted odds ratio = 0.78; 95% C: 0.70-0.87) [61]. Greater participation in moderate to vigorous intensity physical activity has been linked to improvements in several cognitive domains, including processing speed, memory, and executive function, as well as to beneficial changes in brain structure and function [56]. Higher activity levels are also associated with a reduced risk of cognitive decline and neurodegenerative conditions (e.g. Alzheimer's disease, Parkinson's disease, multiple sclerosis) [62,63]. In addition, both acute bouts and regular engagement in physical activity contribute to improvements in sleep quality and broader health-related quality of life outcomes [64].

In addition to the well-established benefits of general physical activity, growing evidence shows that participation in specific sport disciplines can confer distinct and clinically relevant health advantages. A recent systematic review and meta-analysis, which synthesized 136 reports from 76 studies and involved more than 2.6 million participants, demonstrated that several commonly practiced sports are linked to substantial reductions in morbidity and mortality [65]. Sport participation can contribute meaningfully to long-term physiological wellbeing, supporting its relevance in public health [65].

Despite the well-documented health advantages of exercise and sport participation, global surveillance data show that a substantial proportion of the population remain inactive. A large pooled analysis of 507 population-based surveys including 5.7 million adults found that in 2022 31.3% of the global adult population did not meet the recommended physical activity levels [66] (**Figure 4**). This corresponds to approximately 1.8 billion adults, representing a notable increase compared with 2000, when the prevalence was 23.4% (around 900 million individuals). The study also reported that insufficient activity has risen in about half of all countries and in two-thirds of world regions, indicating that most areas are moving further away from the 2030 global target of a 15% relative reduction from 2010 levels. Women consistently exhibited higher rates of insufficient activity than men, although the magnitude of this sex gap varied across regions. Insufficient physical activity increased among adults aged 60 years and older across all regions and in both sexes, whereas age-related patterns varied among individuals younger than 60 years. These trends highlight the urgent need for integrated lifestyle interventions, combining adequate physical activity with health-promoting dietary patterns [66].

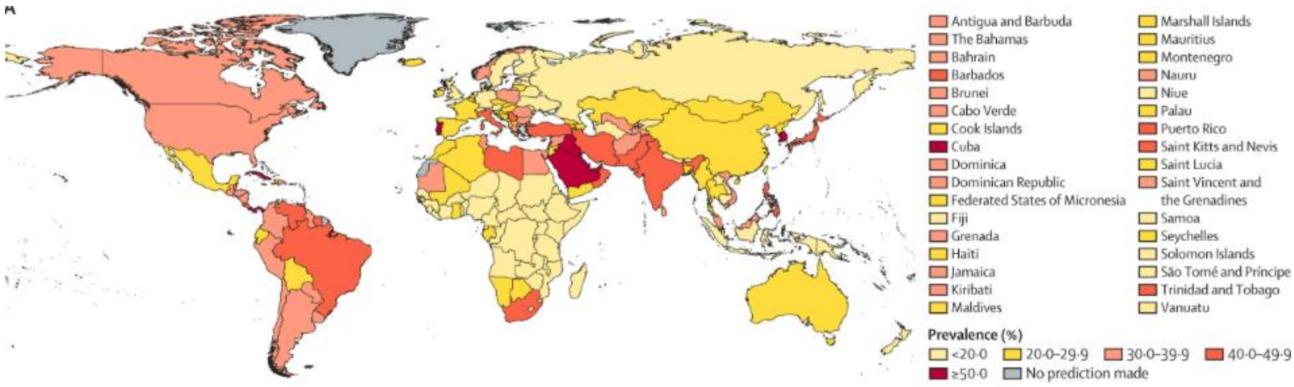


Figure 4. Map showing the age-standardized prevalence of insufficient physical activity among adults (> 18 years) in 2022 [66].

In Italy, recent data from the PASSI (*Progressi delle Aziende Sanitarie per la Salute in Italia*) surveillance system showed that in 2023-2024, approximately 27% of adults were classified as inactive with higher prevalence among women, older individuals, and those with lower socio-economic status [67]. Geographic differences were also evident, with higher inactivity rates in southern regions (38%). Although recent trends suggest modest improvements, subjective overestimation of physical activity levels remains common, highlighting limitations in self-reported assessments [67].

"Athletes" classification methods

To complement prevalence data and better describe patterns of physical activity in populations, it is crucial to employ standardized methods for quantifying and classifying activity levels. Such frameworks are particularly relevant in sport nutrition research, where training load, competition level and sport type strongly influenced nutritional requirements..

Mitchell et al. proposed a model that classifies sports based on dynamic and static components to estimate sport-specific energy expenditure [68]. Activities are categorized into low, moderate, and high static and dynamic demands based on oxygen consumption and muscular load. In particular, the intensity of the sport disciplines was quantified using METs values. METs provide a standardized estimate of the energy cost of physical activities, where 1 MET corresponds to an oxygen consumption of approximately 3.5 mL O_2/kg/min, equivalent to 1 kcal/kg/hour, representing the resting metabolic rate. This unit allows the energetic demand of different activities to be expressed as multiples of resting energy expenditure. Energy expenditure associated with each activity was calculated by multiplying the MET value of the activity by the participant's body mass (kg) and the duration of the activity (hours). This approach also enables the computation of weekly MET-hours, which reflect the total volume of activity while accounting for differences in exercise intensity. To assign MET values to each sport or activity, the Ainsworth Compendium of Physical Activities was used, as it provides standardized estimates for a wide range of disciplines [69]. Based on the resulting intensity estimates, individuals could be classified into three categories: (1) Low intensity: < 3 METs; (2) Moderate intensity: 3.1-6 METs; (3) High intensity: > 6 METs. This framework should be interpreted as a continuum rather than a rigid structure, as athletes participating in the same sport may differ in physiological demands depending on role, training style, or competition context [70].

More recently, the Participant Classification Framework proposed by McKay and colleagues provides a structured, six-tier system ranging from inactive individuals (Tier 0) to world-class athletes (Tier 5) [71]. Classification is based on objective criteria such as average exercise volume (number of training days per week/training hours, quantification of completed tasks), competitive level, recent competition history, participation in major competition and sport-specific experience. This framework addresses a critical methodological gap in sport science by standardizing the description of training background and competitive level, thereby improving the interpretability and external validity of research findings [71].

According to McKay and colleagues, athletes and exercisers can also be classified based on dominant physiological demands, tactical characteristics, and skill requirements of each discipline [71]. Their framework identifies seven major sport categories, each defined by distinct performance determinants:

- ***Team sports*** → e.g., association football, basketball, baseball, cricket, field hockey, handball, ice hockey, netball, rugby, goalball, volleyball, and water polo;
- ***Endurance/long-distance sports*** → including long-distance track events (>5000 m), biathlon, cross-country skiing, road cycling, open-water swimming, pool swimming events of ≥800 m, triathlon, racewalking, marathon, and ultramarathon events;

- ***Middle-distance/power sports*** → such as canoeing, kayaking, rowing, BMX racing, mountain biking, pool swimming events ≤400 m, track events between 800-1500 m, and track cycling;
- ***Speed/strength sports*** → comprising sprinting, track events ≤400 m, alpine skiing, ski jumping, speed skating, field athletics, and weightlifting;
- ***Precision/skill-dependent sports*** → including archery, artistic swimming, curling, diving, equestrian disciplines, figure skating, freestyle skiing, golf, gymnastics, sailing, shooting, snowboarding, surfing, skateboarding, and trampoline gymnastics;
- ***Racquet sports*** → badminton, table tennis, squash, and tennis;
- ***Combat and weight-making sports*** → such as boxing, fencing, judo, karate, taekwondo, and wrestling.

This categorization supports more accurate interpretation of training loads, nutritional needs, and performance profiles by acknowledging the heterogeneous physiological stresses across different sport types.

3.2 Nutritional needs of active individuals and athletes

Nutrition is a fundamental determinant of exercise adaptation, exerting direct effects on performance, recovery, and injury risk by supporting metabolic, neuromuscular, and immune functions, and sustaining homeostasis and long-term health in physically active individuals and athletes [72] [73].

Within this complex framework, nutrition plays a pivotal role across all phases of training. It contributes to effective preparation before exercise, supports the restoration of substrates and tissues during recovery, reduces susceptibility to injury, and enhances the development of training-induced adaptations. By modulating these processes, dietary strategies become an integral component of both performance optimization and athlete health management [72].

A general premise underpinning the recommendations discussed in the following sections is that specific nutritional strategies are warranted primarily when athletic training is sufficiently intense, structured, and frequent. In individuals engaging in recreational or moderate physical activity (≤ 2-3 sessions/week or ≤ 4-6 hours/week), general dietary guidelines for the active population are usually sufficient [74].

Energy requirements

Energy requirements in adults are shaped by a wide range of physiological, behavioral, and environmental determinants [74]. Among these determinants, physical activity represents the most dynamic and individually modifiable component of total energy expenditure [75]. In athletes, whose training routines follow structured, goal-oriented programs, the primary distinguishing feature of their dietary needs is the increased demand for energy directly resulting from elevated metabolic costs of exercise. The energetic cost of exercise varies substantially according to multiple factors. The external characteristics of training, such as its duration, frequency, and intensity, interact with intrinsic factors including sex, age, genetic background, nutritional status (e.g. body mass, body composition) to determine the actual metabolic demand of physical activity [76].

The intermittent and highly heterogeneous nature of team-sport activity patterns makes the precise quantification of energy expenditure in these populations particularly challenging [77].

Moreover, the energy demands of athletic populations fluctuate considerably within the same athlete over time [78]. Modern training theory organizes workloads into annual cycles comprising macrocycles, mesocycles, and microcycles, each with distinct performance goals and varying training volumes [79].

Accurately assessing energy needs is therefore a crucial component of sports nutrition practice. While predictive equations that incorporate fat-free mass (e.g., the Cunningham equation) are commonly used to estimate resting energy expenditure [80], they may underestimate requirements when exercise energy expenditure fluctuates substantially. Direct measurement methods, such as indirect calorimetry for resting metabolism [81] and doubly labeled water for total energy expenditure [82], remain the gold standard in research, though their use is often limited by feasibility constraints. In applied settings, ongoing monitoring of training load, body composition, recovery markers, and dietary intake is essential for ensuring sufficient energy availability throughout the training cycle.

Energy availability

Energy Availability (EA) is defined as the amount of dietary energy remaining for physiological functions after subtracting the energy cost of exercise. It represents a central concept in sports nutrition and has received increasing scientific attention due to its causal role in a broad spectrum of physiological and metabolic dysfunctions [83]. The concept emerged from early investigations into physiological disturbances observed in physically active women, most notably exercise-associated menstrual dysfunction(s), where researchers began to recognize that inadequate dietary intake relative to energy expenditure, rather than exercise stress alone, was the primary driver of these alterations. These observations laid the foundation for the understanding of EA as a key regulator of endocrine, metabolic and reproductive function in athletes [83]. This line of research contributed to the development of the *Female Athlete Triad*, a clinical condition initially characterized by the coexistence of disordered eating, menstrual dysfunction, and impaired bone mineral density in female athletes. Low EA (LEA) was officially recognized as the underlying etiological factor linking the three components of the Triad only in the first decade of the 2000 century [84,85]. Over time, it became clear that the clinical manifestations of LEA were not limited to these three domains. The International Olympic Committee (IOC) therefore introduced the broader term *Relative Energy Deficiency in Sport* (REDs), defining it as a syndrome affecting multiple aspects of physiological function, health, and athletic performance, including metabolic rate, menstrual function, bone health, immunity, protein synthesis, cardiovascular and psychological well-being [86].

The most widely accepted formula for calculating EA, endorsed by the IOC, is:

$$EA = [Energy\ Intake\ (kcal) - Exercise\ Energy\ Expenditure\ (kcal)]/Fat\ Free\ Mass\ (kg)]$$

where Energy Intake (EI) refers to total dietary energy; Exercise Energy Expenditure (EEE) represents the additional cost of exercise after subtracting resting metabolic rate and non-exercise activity; and Fat-Free Mass (FFM) corresponds to lean body mass [86]. Based on available evidence, the IOC has identified general reference thresholds for EA:

- **45 kcal/kg FFM/day** is considered **optimal** for maintaining physiological function, whereas higher values typically lead to positive energy balance and weight gain;
- **30-45 kcal/kg FFM/day** is associated with losses in fat mass and, in some cases, lean mass;
- **≤30 kcal/kg FFM/day** in women is generally considered **indicative of LEA** and associated with adverse outcomes such as menstrual dysfunction and impaired bone health;

In men, no universally accepted cut-off exists, but negative physiological outcomes have been reported for lower range (9 to 25 kcal/kg FFM/day) [87,88].
These thresholds should not be interpreted as fixed cut-offs, given the substantial inter-individual variability in physiological responses [89].

It is important to distinguish between adaptive and problematic LEA. Adaptive LEA represents a normal physiological response aimed at preserving essential functions during periods of transient energy shortage. Problematic LEA, on the other hand, arises when the energy deficit is too severe or too prolonged, resulting in measurable physiological impairments and long-term consequences for both health and performance [86].

Sociological, psychological, and physiological influences may all contribute to the development of inadequate EA. These include sport-specific cultural pressures related to body image or leanness, behavioral tendencies promoting intentional or unintentional dietary restriction, and physiological responses to high training loads that can suppress appetite or increase energy needs. These interacting factors create a multifactorial environment in which LEA can emerge, providing the contextual foundation for the more detailed mechanisms and consequences described in the next section [90].
For example, unintentional underconsumption is common in athletes, particularly when higher training loads are not matched by proportional increases in dietary intake. Contributors include poor nutritional knowledge, limited food access, dietary restrictions due to allergies or intolerances, cultural practices, constrained eating windows, or mismanagement of nutrition during injury rehabilitation. Intentional restriction is another frequent cause of LEA, often adopted to modify body composition, especially in sports emphasizing leanness, weight categories, or aesthetics. Additionally, disordered eating and eating disorders can drive chronic energy deficits through pathological weight-control behaviors. LEA may also be linked to an escalation of training volume that is not accompanied by adequate energy intake, or to compulsive exercise behaviors, often associated with disordered eating, in which physical activity is used as a tool for weight control [91].
While LEA represents the exposure, REDs is the outcome, a multifactorial syndrome that does not occur in every athlete experiencing LEA [92]. Importantly, there is no universal EA threshold below which REDs inevitably develop. Although <30 kcal/kg FFM/day in women is

often cited as a risk indicator, this value cannot serve as a diagnostic criterion. Susceptibility is influenced by multiple factors, including sex, age, gynecological age, clinical history, dietary patterns, and characteristics of the training regimen. For instance, men generally exhibit a greater tolerance to energy reduction and show fewer hormonal disruptions, whereas women may be more vulnerable to adverse outcomes such as stress fractures [93]. To better conceptualize the condition, the IOC developed the REDs Conceptual Model (**Figure 5**), comprising two complementary frameworks:

- the REDs Health Model, which outlines the physiological impairments resulting from problematic LEA;
- the REDs Performance Model, which describes how these impairments translate into declines in athletic performance [86].

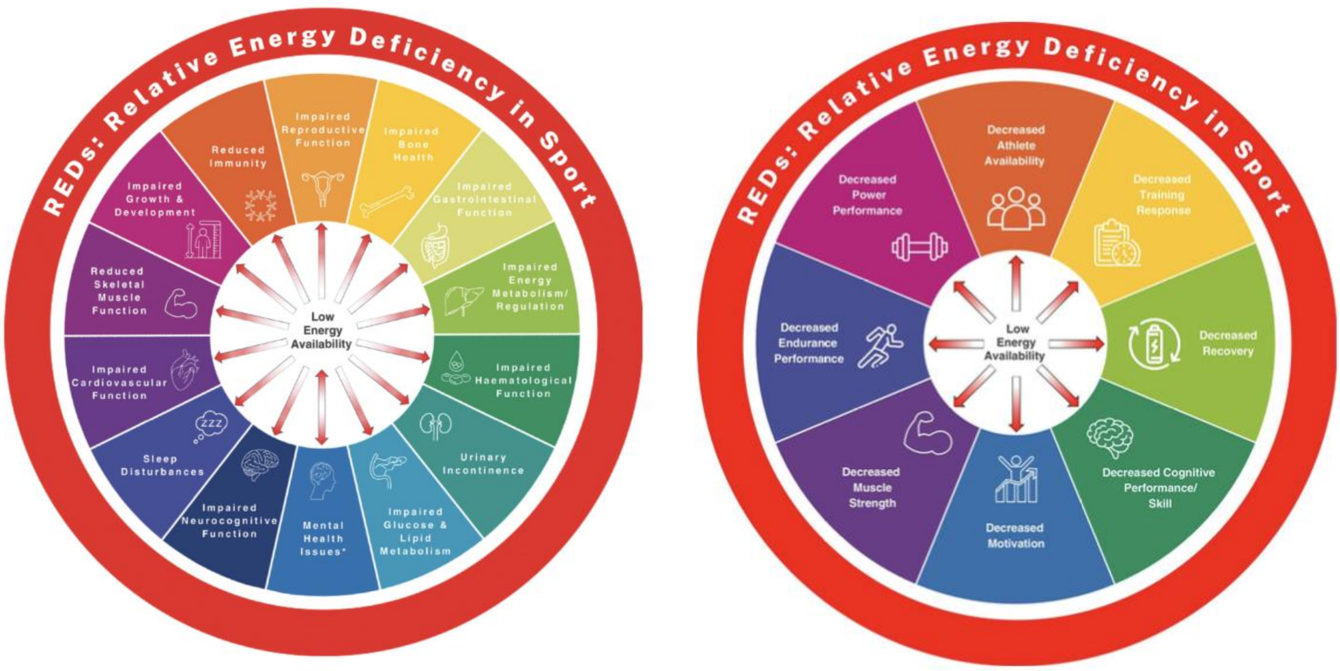


Figure 5.
Left panel: The REDs Health Conceptual Model illustrates how the effects of LEA occur along a continuum. Mild and transient exposure (adaptable LEA) is generally well tolerated (white arrow), whereas prolonged or severe LEA leads to problematic LEA, associated with a range of adverse health outcomes (red arrow). Mental health issues may either precede the development of REDs or emerge as a consequence.
Right panel: The REDs Performance Conceptual Model depicts a similar continuum, where adaptable LEA may not impair performance, while problematic LEA contributes to diverse performance decrements (red arrow). LEA = low energy availability [86].

The REDs Health Model highlights the widespread multisystem consequences, including disruptions to reproductive function, bone health, gastrointestinal function, energy metabolism, glucose and lipid metabolism, hematological status, neurocognitive processes, cardiovascular function, musculoskeletal integrity, growth, and development. Additional concerns include increased susceptibility to infection, sleep disturbances, urinary incontinence, and mental health issues [86]. A more detailed perspective on psychological well-being has been provided in a narrative review conducted by an IOC subgroup, which developed a Psychological Model to illustrate the bidirectional relationship between mental health and REDs [94]. The model highlights how psychological factors, such as perfectionism, anxiety, body image concerns, and maladaptive coping strategies, may predispose athletes to LEA, while the physiological and performance consequences of REDs can, in turn, exacerbate mental health symptoms[94]. The REDs Performance Model emphasizes that compromised health leads to concrete performance decrements, including reduced training availability, impaired adaptation, slower recovery, diminished cognitive and technical performance, lower motivation, and reductions in muscular strength and endurance [86]. The circular structure of the model underscores the systemic nature of REDs, where deficits in one domain can negatively influence others.

Carbohydrates

Carbohydrates represent the primary and most efficient fuel source for moderate-to-high intensity exercise, and their availability is a key determinant of both acute performance and long-term training adaptation [72]. For this reason, carbohydrate intake before, during, and after exercise is considered a cornerstone of sports nutrition guidelines [72,95,96].

Daily carbohydrate requirements vary according to the volume, intensity, and metabolic demands of training. Current recommendations suggest a range of 3-5 g/kg/day for individuals engaging in light or skill-based activity, 5-7 g/kg/day for moderate training loads, and 6-10 g/kg/day during periods of high-volume endurance training. In elite endurance athletes or during intensified training phases (> 4-5 hours/day moderate to high-intensity exercise), carbohydrates intake may reach 10-12 g/kg/day to effectively restore glycogen stores [72].

Carbohydrate availability (CA) influences cellular signaling pathways involved in training adaptation. Low muscle glycogen availability is associated with increased activation of metabolic sensors such as AMP-activated protein kinase (AMPK), leading to enhanced expression and activity of downstream regulators including peroxisome proliferator-activated receptor gamma coactivator 1-alpha (PGC-1α), which are involved in the regulation of mitochondrial biogenesis and oxidative metabolism [97,98]. This mechanistic framework underpins training strategies that deliberately manipulate CA, such as the “train-low” approach, with the aim of potentiating endurance-related adaptations. However, chronic or inappropriate application of such strategies may transiently impair exercise intensity, increase perceived exertion, and negatively interact with immune function[97,98].

Carbohydrate ingestion during exercise is particularly beneficial during prolonged endurance efforts or high-intensity intermittent sports. Exogenous carbohydrate intake helps maintain blood glucose levels, sustain carbohydrate oxidation, and delay fatigue, with optimal intake rates varying according to event duration:

- 30-60 g/hour for exercise lasting 1-2.5 hours;
- up to 90 g/hour for ultra-endurance events when multiple transportable carbohydrates (e.g., glucose + fructose) are consumed to maximize intestinal absorption and oxidation rates [72].

Post-exercise carbohydrate intake is equally crucial for reloading glycogen stores.
Rapid recovery protocols suggest consuming 1.0-1.2 g/kg/hour of carbohydrates during the first hour after exercise, particularly when time between sessions is limited (<8 hours) [72]. Co-ingestion of carbohydrates with protein does not appear to further enhance muscle glycogen resynthesis when carbohydrate intake is sufficient, although an additional benefit may be observed when protein is added without reducing carbohydrate intake, increasing total post-exercise EA. Under these conditions, the higher caloric content of the recovery meal seems to facilitate glycogen restoration [99].

Alongside EA, also CA represents a critical nutritional determinant in physically active individuals and athletes. Low CA (LCA) occurs when carbohydrate intake is insufficient to meet the metabolic demands imposed by training and competition, resulting in limited endogenous glycogen stores and/or inadequate exogenous carbohydrate supply during exercise [86,100]. Under these conditions, the amount of carbohydrate available for oxidation and metabolic regulation is constrained, potentially compromising both acute exercise performance and longer-term physiological adaptations [86]. LCA is frequently observed in athletic populations and often coexists with LEA, as reductions in total energy intake are commonly accompanied by a disproportionate decrease in carbohydrate consumption [101]. However, LCA should be considered a distinct nutritional condition, as it may occur independently of overall energy deficiency [100].

Beyond its well-established role as a primary fuel for moderate-to-high intensity exercise, CA exerts regulatory effects on metabolism, endocrine responses, and immune function. Chronic LCA has been associated with reduced glucose utilization, muscular fatigue, impaired exercise capacity, and altered hormonal responses, including a blunted growth hormone response [101,102].

Emerging evidence suggests that LCA may also exert independent effects on bone health and immune function. Short-term carbohydrate restriction has been shown to alter bone turnover markers, in some cases to a greater extent than low energy availability alone [103,104]. In addition, LCA has been associated with increased illness risk and suboptimal micronutrient intake, particularly iron and calcium, often reflecting reduced dietary variety accompanying carbohydrate restriction [105].

Despite its relevance, CA assessment remains methodologically challenging. No standardized equation or universally accepted biomarker currently exists to quantify carbohydrate availability at the individual level. Consequently, most studies rely on dietary carbohydrate intake expressed relative to body mass (g/kg/day) as a proxy measure [106]. Retrospective analyses suggest that a large proportion of athletes do not achieve recommended carbohydrate intakes. In particular, evidence indicates that approximately 45-98% of female athletes across a range of sports consume insufficient carbohydrates to adequately support the metabolic demands of training [101].

In this context, it is important to distinguish between short-term, intentional manipulation of CA, implemented within specific training strategies to enhance mitochondrial signaling and metabolic flexibility, and chronic LCA, which may undermine health, recovery, and performance when applied without adequate periodization [107]. When prolonged, LCA may exacerbate the physiological demands imposed by high training loads and interact synergistically with LEA, thereby increasing the risk of maladaptation and contributing to the broader clinical picture described within the REDs framework [86].

Proteins

Protein intake represents a central nutritional determinant for supporting training adaptation, muscle remodeling, and recovery in physically active individuals and athletes. According to the International Society of Sports Nutrition (ISSN), dietary protein plays a

fundamental role in stimulating muscle protein synthesis (MPS), attenuating exercise-induced muscle protein breakdown (MPB), and facilitating structural and functional adaptations to both resistance and endurance training [108].
Current evidence indicates that athletes require higher protein intakes than the general population to support the increased metabolic turnover associated with regular training. The ISSN Position Stand recommends a daily protein intake ranging from 1.2 to 2.0 g/kg body weight for most exercising individuals, with intakes at the upper end of this range being particularly relevant during periods of intensified training, injury rehabilitation, or when the primary goal is to increase or preserve lean body mass [108]. Higher protein intakes (2.3-3.1 g/kg body weight) may be required in trained individuals during periods of energy restriction [108].
Protein needs may vary substantially depending on the type of exercise performed. Resistance and strength training predominantly stimulate myofibrillar protein synthesis and muscle hypertrophy, thereby increasing the requirement for essential amino acids, particularly leucine, which is a key activator of the mTOR signaling pathway. In contrast, endurance exercise primarily promotes mitochondrial protein synthesis and structural remodeling of oxidative muscle fibers, processes that also benefit from adequate protein availability, especially during recovery phases [109].
Higher protein intakes may confer additional benefits during periods of energy restriction, such as weight loss phases or sports emphasizing body composition or inactivity (injury/illness) [110].

In addition to total daily intake, the distribution of protein intake across the day is a critical factor in optimizing MPS. Evidence supports the consumption of moderate protein doses (approximately 0.25-0.40 g/kg per meal, equivalent to 20-40 g of high-quality protein) every 3-4 hours to maximize the anabolic response throughout the day [108].
The timing of protein ingestion relative to exercise also influences recovery and adaptation. Protein consumption in the post-exercise period enhances MPS by increasing amino acid availability at a time when skeletal muscle exhibits heightened sensitivity to anabolic stimuli. Post-exercise protein intake remains particularly important for athletes engaging in multiple daily training sessions or when total daily protein intake may otherwise be insufficient [96,108]. Additionally, pre-sleep protein ingestion has emerged as a potent strategy for nocturnal recovery. Consuming 30-40 g of casein protein approximately 30

minutes before sleep has been shown to increase overnight MPS and next-morning metabolic rate without influencing lipolysis [96].
In observational settings, the extent to which athletes translate these timing strategies into habitual practice remains to investigate, highlighting the need for integrated assessment of eating habits.

Fats

Dietary fats are a key macronutrient in the nutrition of physically active individuals and athletes, contributing to energy provision, structural integrity of tissues, and the regulation of multiple physiological processes. During prolonged exercise performed at low-to-moderate intensity, fatty acids represent a major fuel source, supporting total energy expenditure and contributing to glycogen sparing, particularly in endurance-based activities [111]. Beyond their energetic role, lipids are essential for maintaining normal endocrine and metabolic function. They serve as precursors for steroid hormone synthesis and are integral components of cell membranes, where they influence membrane fluidity, receptor activity, and intracellular signaling [112]. Adequate dietary fat intake also facilitates the absorption of fat-soluble vitamins (A, D, E, and K), which are involved in bone health, antioxidant defense, and immune function [112].
The overall dietary fat requirements of physically active individuals and athletes do not substantially differ from those recommended for the general population [74]. Current guidelines suggest that, for most athletes, dietary fats should provide approximately 20-35% of total daily energy intake, with adjustments based on training volume, intensity, metabolic demands, and competitive objectives [72]. Restrictive dietary patterns, often driven by body composition goals, may unintentionally reduce fat intake and contribute to LEA, even in non-elite athletes [93][113].

Dietary fat quality is also relevant in athletic populations. Diets emphasizing unsaturated fatty acids, including monounsaturated and polyunsaturated fats, are associated with favorable lipid profiles and cardiovascular adaptations, even among highly trained individuals [114,115].
Overall, current evidence supports the inclusion of dietary fats as an essential component of nutritional strategies for active individuals and athletes. Rather than minimizing fat intake,

dietary approaches should aim to ensure adequate total EA and a balanced intake of high-quality lipid sources, tailored to training demands and long-term health considerations.

Hydration

Hydration status critically affects performance, thermoregulation, and muscle function. Even a 2% loss in body weight due to dehydration can significantly impair work capacity, elevate perceived exertion, reduce MPS, and negatively affect neuromuscular coordination [116]. During prolonged or hot-environment exercises, timely replacement of fluids and electrolytes, particularly sodium, potassium, and magnesium, is essential to maintain the homeostasis and prevent cramps, hypotension, or arrhythmias [117]. Personalized hydration strategies, guided by individual sweat rates and environmental conditions, are recommended [72].

From a practical perspective, hydration strategies should be conceptualized across three phases: pre-exercise hydration, fluid intake during exercise, and post-exercise rehydration [72]. The primary aim of pre-exercise hydration is to ensure that athletes begin exercise in an euhydrated state [117]. Current guidelines elaborated by the Academy of Nutrition and Dietetics, Dietitians of Canada, and the ACSM, recommend ingesting approximately 5-7 mL/kg of body mass at least four hours before exercise when possible. If this intake does not result in adequate urine output, or if urine remains dark and concentrated in the two hours preceding exercise, an additional 3-5 mL/kg may be consumed. This approach helps optimize hydration status while minimizing gastrointestinal discomfort [72].

During exercise, fluid intake should aim to limit body mass losses to less than 2%, beyond which performance and thermoregulatory function may be impaired. Given the large interindividual variability in sweat rates, hydration plans should be personalized and exploit all available drinking opportunities. For exercise lasting up to 60 minutes under moderate conditions, regular ingestion of water every 15-20 minutes is generally sufficient. In longer or more intense sessions, particularly in hot environments, beverages containing carbohydrates (3-8 g/100 mL) and sodium (approximately 460-1150 mg/L) are recommended to support fluid retention and energy availability. In endurance events, fluid intakes of approximately 1.5-2.0 mL/kg every 15-20 minutes may help attenuate dehydration. Post-exercise hydration aims to fully restore fluid and electrolyte balance in preparation for subsequent training or competition. Due to ongoing fluid losses during recovery, athletes are advised to consume approximately 125-150% of the body mass lost during exercise. The inclusion of sodium, through fluids or foods, facilitates fluid retention and accelerates the return to euhydration, particularly when rapid recovery is required [74].

4. Nutrition knowledge, eating behavior, and body composition

4.1 Nutrition knowledge as a determinant of eating behavior

Nutrition knowledge (NK) is widely recognized as a core component of health literacy and a relevant determinant of dietary behavior across the adult lifespan [118]. It refers to the understanding of fundamental nutrition concepts, dietary recommendations, nutrient functions, food sources, portion sizes, and the relationship between diet, health, and performance.

From a theoretical standpoint, NK is considered a necessary, though not sufficient, condition for behavior change. However, empirical evidence highlights that the relationship between knowledge and behavior is multifactorial and moderated by multiple contextual factors, including socioeconomic status, education level, food environment, cultural norms, and psychosocial determinants [119,120]. Key determinants of athletes' food choices are summarized in Figure 6.

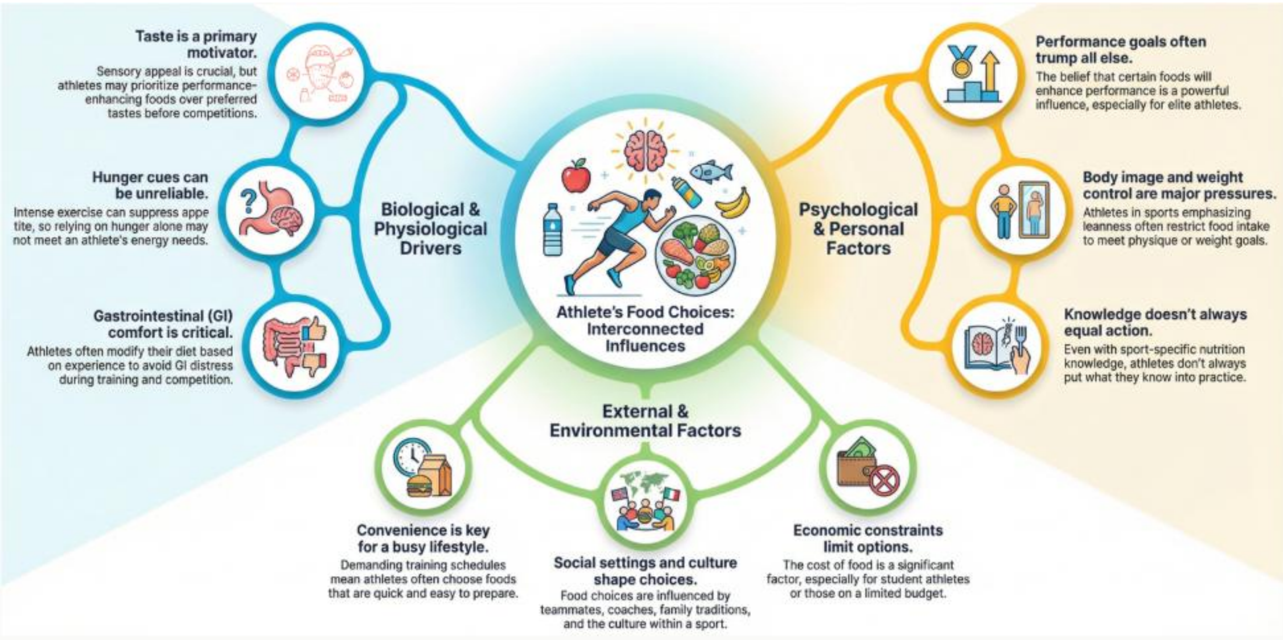


Figure 6. Factors that influence food choice of athletes [based on [120]].
Elaborated with NotebookLM.

Despite the widespread recognition of healthy eating as a cornerstone for health promotion and performance optimization, a substantial body of literature indicates that NK is often inadequate. In physically active individuals and athletes, NK assumes heightened importance due to increased energy expenditure, sport-specific macronutrient requirements, and the role of nutrition in recovery, injury prevention, and performance optimization [121]. Numerous studies have highlighted persistent gaps in athletes' understanding of the key nutrition principles, particularly those related to macronutrient distribution, meal timing, hydration strategies, and nutritional management before, during, and after exercise [122–125]. These gaps represent a critical vulnerability, as they may contribute to suboptimal EA, impaired recovery, and an increased risk of injury, compromising both performance and long-term health [126].

On the other hand, a substantial body of evidence indicates that individuals with higher NK tend to adopt healthier dietary patterns, characterized by greater adherence to dietary guidelines and improved overall diet quality [127,128]. Systematic reviews have shown positive associations between NK and favorable dietary behaviors, including higher consumption of fruits, vegetables, whole grains, and fiber, alongside lower intakes of saturated fat, added sugars, and ultra-processed foods [128,129]. Nevertheless, these associations are not uniform across populations, suggesting that NK interacts with behavioral, environmental and contextual factors.

The integration of structured nutrition education programs within sports organizations is increasingly recognized as essential, starting from youth development pathways. The use of validated assessment tools, the involvement of qualified sports nutrition professionals, and the implementation of targeted educational interventions may substantially improve dietary behaviors and help prevent negative conditions [130,131].

Finally, it is important to acknowledge that NK is not solely an individual attribute but it is strongly shaped by the broader sporting environment. The presence of nutrition-informed coaches, collaboration with sports nutrition professionals, availability of appropriate meals during training camps and competitions, and access to reliable scientific information play a crucial role in fostering informed dietary choices supporting both athletic performance and long-term health [132].

4.2 Assessment of nutrition knowledge in the physically active population and in athletes

The assessment of NK in both general and athletic populations is commonly conducted using validated questionnaires, which allow researchers to objectively quantify levels of awareness, identify knowledge gaps, and explore associations with dietary behaviors. Among the instruments developed for this purpose, the General and Sport Nutrition Knowledge Questionnaire (GeSNK) represents one of the most comprehensive tools available for the Italian population [133]. Specifically developed and validated in adolescents and young adults, the GeSNK consists of 62 items divided into two sections: general (29 items) and sport NK (33 items). Validation studies conducted in mixed samples of Italian adolescents and young adults practicing sports at different levels demonstrated that the GeSNK is a consistent, valid, and reliable instrument over time, capable of identifying strengths and weaknesses in both general and sport-related nutrition knowledge. Its applicability makes it particularly suitable for investigating the relationship between NK and dietary behaviours in Italian physically active populations, as well as for evaluating nutrition education interventions [133].

To address practical limitations related to questionnaire length, particularly in younger populations or in athletes with demanding schedules, a short NK questionnaire comprising 26 items was developed and validated in Italy for adolescents aged 12-14 years [134]. This version was designed to enhance feasibility without compromising psychometric robustness. Validation studies confirmed that this questionnaire maintains adequate reliability and validity for assessing nutrition and sport nutrition knowledge in young individuals, and it has been successfully applied to evaluate the impact of nutrition education programs in this age group [134].

Other widely used tools have been developed and validated primarily in international contexts or for specific adult athletic populations. Among these, the Nutrition for Sport Knowledge Questionnaire (NSKQ) is one of the most extensively used instruments for evaluating athletes' NK. The NSKQ consists of 89 items covering key domains such as macronutrients, micronutrients, hydration, nutrient timing, supplementation, and alcohol intake [135]. An abridged version of this tool, the Abridged Nutrition for Sport Knowledge Questionnaire (A-NSKQ), has been developed. The A-NSKQ is composed of 37 items that assess both general (n = 17) and sports (n = 20) NK and took on average half the time taken to complete the NSKQ [136].

4.3 Body composition as a key indicator of health and performance

Body composition refers to the relative proportions of fat mass (FM) and FFM that together characterize an individual's physical structure [137]. Beyond simple body weight or body mass index (BMI), body composition provides a more accurate and physiologically meaningful indicator of health status, functional capacity, and performance potential [138]. In adult populations, an unfavorable body composition, typically characterized by excess of adiposity and reduced lean mass, is strongly associated with increased cardiometabolic risk, including insulin resistance, dyslipidemia, hypertension, and systemic inflammation, as well as higher all-cause and cardiovascular mortality [139,140].

Skeletal muscle mass plays a central role in metabolic health across the lifespan, contributing to glucose regulation and overall energy metabolism. Emerging evidence suggests that loss of muscle mass impairs metabolic homeostasis and is both a cause and consequence of metabolic dysregulation in aging populations [141]. Furthermore, low muscle mass is associated with increased risk of all-cause mortality in middle-aged and older adults, underscoring its importance as a predictor of long-term health outcomes [142]. Taken together, these findings highlight the relevance of body composition as a key marker linking nutritional and lifestyle factors to health across the adult lifespan.

In physically active individuals and athletes, body composition assumes additional relevance because of its potential influence on sport-specific performance, although performance outcomes cannot be accurately predicted on the basis of body composition alone [72]. In athletic populations, FFM, particularly skeletal muscle mass, has been consistently associated with greater strength, power, and force-generating capacity, which are key determinants of performance in strength- and power-oriented sports [143,144]. Conversely, higher levels of FM represent non-functional load during locomotion and have been linked to reduced movement economy and impaired endurance performance, due to increased energetic cost [145–147]. Optimal body composition varies substantially across sports and disciplines and is influenced by sex, age, training status, competitive level, and phase of the training cycle. As a result, the concept of an ideal body composition must be interpreted within a sport-specific and individual context [148].

Body composition results from a dynamic interplay between energy intake, nutrient quality, training load, recovery, and genetic predisposition [149]. Dietary factors, including total energy intake, macronutrient distribution, protein quality and timing, and micronutrient adequacy, play a critical role in supporting favorable adaptations [149].
However, when body composition goals are pursued primarily through chronic energy restriction, inadequate nutrient intake, or excessive physical activity, adaptive processes may shift toward maladaptive physiological responses [150]. An excessive focus on body fat reduction may have detrimental physiological and psychological consequences. In athletic populations, these effects are encompassed within the broader framework of REDs, which affects both female and male athletes and has significant implications for health, performance, and injury risk [86]. Consequently, body composition management should prioritize health, functionality, and performance rather than aesthetic or weight-based targets [151].

Accurate assessment of body composition is essential in both research and applied sport settings, as it allows monitoring changes over time and evaluating the effects of training and nutritional interventions with greater precision. In athletes methodological rigor and sport-specific considerations are especially important [148,152]. Several techniques are available for the assessment of body composition, each characterized by specific strengths and limitations, and with different applications depending on the research or applied context, the characteristics of the athletic population, and the purpose of the assessment [75]. Accordingly, this doctoral thesis focuses on a selected number of methods, chosen for their scientific validity, feasibility, and relevance to physically active individuals and athletic populations.
Dual-energy X-ray absorptiometry (DXA) remains one of the most widely used reference techniques due to its ability to provide detailed measurements of FM and lean soft tissue mass (LSTM, FFM minus bone mineral content), and bone mineral content (BMC), and it often serves as a criterion method in validation studies [153]. However, its use is constrained by cost, the need for specialized equipment, and exposure to low levels of radiation, which limits its applicability in frequent monitoring or in younger athletes [151].

Bioelectrical impedance analysis (BIA) is a fast, non-invasive and portable technique used for the assessment of water fluid compartments and FFM [152]. BIA estimates body composition based on the differing electrical properties of tissues, reflecting water content and cellular integrity. Lean tissues, rich in water and electrolytes, conduct electrical currents more efficiently than fat tissue, while reactance provides information on cell membrane quality. Predictive equations translate impedance measurements into estimates of FFM and FM. The accuracy depends on device type, measurement configuration, and individual characteristics such as age, sex, hydration, and training status. Consequently, the use of standardized protocols and population-specific equations is essential, particularly in athletic populations where hydration and morphology may vary considerably [154].

An encouraging use of BIA in the sports field is performing bioelectrical impedance vector analysis (BIVA) [148]. By plotting resistance and reactance adjusted for height, BIVA provides qualitative information on hydration status, and cell mass through vector length and phase angle (PhA). Originally developed to detect fluid overload and malnutrition in clinical settings, BIVA offers valuable insights in athletic populations, allowing non-invasive monitoring of hydration, muscle quality, and nutritional status [148,155].

Anthropometric techniques, including skinfold and circumference measurements, remain extensively used due to their accessibility, low cost, and minimal equipment requirements [156]. Skinfold assessment, performed using calipers at multiple anatomical sites, allows estimation of subcutaneous adiposity and, through validated prediction equations, body density and FM. The number of sites measured and the equations applied can vary, making the use of sport-specific and population-validated equations essential to reduce systematic errors [157]. Despite its simplicity and resilience to short-term changes in hydration or recent meals, skinfold assessment is technically demanding: measurement accuracy depends on correct site identification, skin thickness, compressibility, and practitioner experience[158]. When applied carefully by trained personnel using validated protocols, anthropometry offers a practical, cost-effective method to monitor body composition changes over time in athletic populations, complementing more sophisticated techniques such as DXA and BIA/BIVA.

Considering the strengths and limitations of each technique, a multimethod approach is often recommended to maximize accuracy and allow clear interpretation of body composition data in both research and applied sport settings. Longitudinal monitoring under standardized conditions (e.g., hydration, moment of day, pre-assessment training) is critical to distinguish physiological changes from methodological noise [148].

Taken together, current evidence highlights the central role of sustainable dietary patterns, adequate nutrition knowledge, and regular physical activity in supporting health and performance across the adult lifespan, including physically active individuals and athletes. While the MedDiet represents a widely referenced model of healthy and sustainable eating, its practical implementation in sport contexts remains heterogeneous and often influenced by individual NK, environmental factors, and access to professional nutritional guidance. Moreover, despite the growing recognition of *nutrition* as a key determinant of performance and long-term health, discrepancies persist between scientific recommendations and effective dietary behaviors, particularly in athletic populations.

Within this framework, the NUTRI_ACTIVE study was developed to investigate the complex relationships between lifestyle habits, dietary patterns, nutrition knowledge, and body composition in physically active adults and athletes. The second part of this doctoral thesis builds on the theoretical background presented in the introduction and provides an in-depth analysis of the research conducted within the NUTRI_ACTIVE project, including both published and ongoing studies. In addition, it includes a systematic review examining adherence to the MedDiet in athletic populations and applied research focused on the implementation of strategy, such as nutritional counseling, to promote informed, sustainable, and health-oriented dietary behaviors in sport. Together, these contributions aim to bridge the gap between scientific recommendations and applied practice, supporting evidence-based approaches to nutrition and lifestyle interventions in physically active populations.

Accordingly, the specific aims of this part of the thesis were to (i) evaluate the association between adherence to the MedDiet and athletic performance in elite and competitive athletes through a systematic review and meta-analysis; (ii) assess the effectiveness of nutritional counseling in athletes, conceptualized as an interactive process that builds on existing NK to support dietary behavior change; (iii) investigate MedDiet adherence, NK, lifestyle factors, dietary intake, EA, and body composition in physically active adults and athletes; and (iv) examine sex-related differences in dietary habits, eating behaviour, NK, body composition, and EA in physically active Italian adults.

Part 2:

Study 1: Mediterranean Diet and athletic performance in elite and competitive athletes: a systematic review and meta-analysis
Published online at DOI: 10.1016/j.numecd.2025.104165

1.1 Introduction

The term *athlete* generally refers to an individual trained or skilled in physical activity, often participating in organized competition. This definition encompasses a broad spectrum of individuals, ranging from recreational participants to elite professionals, and includes those engaged in both team-based and individual disciplines. However, there is currently no universally accepted terminology to describe the training level or competitive status of an athlete or cohort [159]. Two main classification systems have been proposed to address this issue. The first differentiates athletes according to exercise intent, training volume, and competition level, identifying three main categories: elite, competitive, and recreational athletes [70]. The second framework introduces a six-tier model based on training load and performance metrics, ranging from Tier 0, representing sedentary individuals, to Tier 5, which corresponds to world-class athletes [71]. Regardless of competitive level, athletes strive to reach their optimal performance potential. Achieving peak performance requires the attainment of predefined standards or goals, but this process can be influenced by multiple physiological factors (e.g., endurance, strength, speed, flexibility) as well as psychological aspects (e.g., motivation, concentration, determination) [160,161]. Among the various determinants of performance, nutrition plays a central role in supporting both the achievement and maintenance of optimal athletic function [161].

Adequate and individualized dietary strategies that meet athletes' energy and macro- and micronutrient requirements are fundamental for optimizing training adaptations, enhancing performance, preventing illness and injuries, and supporting the nutritional demands of pre-, during-, and post-training phases [162]. Among the various dietary models associated with positive effects on performance, the MedDiet has gained particular attention. Originating from the traditional eating habits of countries surrounding the Mediterranean basin, the MedDiet is characterized by regular consumption of extra virgin olive oil, abundant intake of fruits, vegetables, whole grains, legumes, and nuts, moderate consumption of fish and dairy products, and limited intake of red and processed meats. A moderate consumption of red wine, preferably during meals, is also traditionally included [13].

The MedDiet is widely recognized as a model of healthy eating due to its contribution to overall health and quality of life. Evidence from numerous studies has demonstrated its beneficial effects, particularly in the prevention of cardiovascular and other chronic degenerative diseases [163,164]. An umbrella review identified the MedDiet as having the strongest and most consistent evidence of beneficial impacts on anthropometric parameters and cardiometabolic risk factors, including reductions in body weight, BMI, total cholesterol, fasting glucose, and blood pressure [8].

In the athletic context, adherence to the MedDiet has been suggested to provide both performance and body composition advantages, primarily due to its nutrient density and anti-inflammatory profile, which supports recovery and adaptation processes [165]. The balanced distribution of lean proteins, complex carbohydrates, and unsaturated fats makes this dietary pattern particularly suitable for meeting the high energy demands of athletes. Griffiths et al. in 2022 proposed several mechanisms through which the MedDiet may enhance athletic performance and promote health in competitive populations, including antioxidant and anti-inflammatory effects, prevention of injury and illness, and improvements in vascular and cognitive function [41]. Furthermore, adherence to the MedDiet has been linked to favorable changes in body composition, a key determinant of performance, especially in endurance and weight-sensitive sports [165].

Thus, given its overall composition, the MedDiet may represent a reference dietary model for athletes. However, its effects on performance, particularly regarding power, strength, and endurance, have not been fully elucidated. To the best of our knowledge, no previously published meta-analyses have provided a comprehensive assessment of the impact of the MedDiet specifically on athletic performance in elite and competitive populations. The present systematic review and meta-analysis was therefore designed to address this gap, focusing on adult athletes across various sports and levels of competition. Specifically, we aimed to determine whether adherence to the MedDiet was associated with measurable changes in athletic performance.

1.2 Materials and methods

This systematic review was conducted according to PRISMA method [166]. The study protocol was previously recorded on PROSPERO (registration number CRD42023459039).

1.2.1 Literature search

The literature search was conducted on October 7, 2024, across four electronic databases: PubMed/MEDLINE, Scopus, Web of Science, and the Cochrane Library. Additional records identified through grey literature were considered when meeting the predefined inclusion criteria. Eligible publication languages included English, Italian, Spanish, and Portuguese. No restrictions were applied regarding the year of publication.

The review included randomized controlled trials, observational studies, case reports, and case series involving competitive or elite athletes. Comparators were defined as any dietary pattern other than the MedDiet.

The search strategy combined both keywords and (Medical Subject Headings) MeSH terms relating to the three primary concepts: (1) adult athletes, (2) MedDiet, and (3) performance. The final search strings applied to each database are presented in **Table 1**, while detailed inclusion and exclusion criteria are summarized in **Table 2**.

Table 1. Search strategy for different databases.

Data base	***Search strategy***	***Number or articles***
Pubmed	(("Adult*" OR "Healthy Adult*" OR "Physical* active adult*" OR "athlete*") AND ("Mediterranean index" OR "Mediterranean diet adherence" OR "Mediterranean score" OR "Mediterranean diet" OR "MedDiet" OR "Mediterranean-style diet" OR "Mediterranean eat*" OR "Mediterranean food" OR "Mediterranean life-style" OR "Mediterranean habit*")) AND ("performance" OR "athletic* performance" OR "fitness" OR "fitness level" OR "physical fitness" OR "physical performance" OR "functional fitness" OR "physical function" OR "muscle strength" OR "muscular power" OR "muscular fitness" OR "muscle endurance" OR "explosive strength" OR "flexibility" OR "musculoskeletal fitness" OR "balance" OR "coordination" OR "agility" OR "speed" OR "motor fitness" OR "aerobic fitness" OR "aerobic capacity" OR "cardiorespiratory fitness" OR "cardiorespiratory endurance" OR "aerobic endurance" OR "body composition" OR "hydration" OR "fatigue" OR "exhaustion" OR "motor skill*")	487
Scopus	(("Adult*" OR "Healthy Adult*" OR "Physical* active adult*" OR "athlete*") AND ("Mediterranean index" OR "Mediterranean diet adherence" OR "Mediterranean score" OR "Mediterranean diet" OR "MedDiet" OR	939

	"Mediterranean-style diet" OR "Mediterranean eat*" OR "Mediterranean food" OR "Mediterranean life-style" OR "Mediterranean habit*")) AND ("performance" OR "athletic* performance" OR "fitness" OR "fitness level" OR "physical fitness" OR "physical performance" OR "functional fitness" OR "physical function" OR "muscle strength" OR "muscular power" OR "muscular fitness" OR "muscle endurance" OR "explosive strength" OR "flexibility" OR "musculoskeletal fitness" OR "balance" OR "coordination" OR "agility" OR "speed" OR "motor fitness" OR "aerobic fitness" OR "aerobic capacity" OR "cardiorespiratory fitness" OR "cardiorespiratory endurance" OR "aerobic endurance" OR "body composition" OR "hydration" OR "fatigue" OR "exhaustion" OR "motor skill*")	
Web of Science	(("Adult*" OR "Healthy Adult*" OR "Physical* active adult*" OR "athlete*") AND ("Mediterranean index" OR "Mediterranean diet adherence" OR "Mediterranean score" OR "Mediterranean diet" OR "MedDiet" OR "Mediterranean-style diet" OR "Mediterranean eat*" OR "Mediterranean food" OR "Mediterranean life-style" OR "Mediterranean habit*")) AND ("performance" OR "athletic* performance" OR "fitness" OR "fitness level" OR "physical fitness" OR "physical performance" OR "functional fitness" OR "physical function" OR "muscle strength" OR "muscular power" OR "muscular fitness" OR "muscle endurance" OR "explosive strength" OR "flexibility" OR "musculoskeletal fitness" OR "balance" OR "coordination" OR "agility" OR "speed" OR "motor fitness" OR "aerobic fitness" OR "aerobic capacity" OR "cardiorespiratory fitness" OR "cardiorespiratory endurance" OR "aerobic endurance" OR "body composition" OR "hydration" OR "fatigue" OR "exhaustion" OR "motor skill*")	832
Cochrane Library	(("Adult*" OR "Healthy Adult*" OR "Physical* active adult*" OR "athlete*") AND ("Mediterranean index" OR "Mediterranean diet adherence" OR "Mediterranean score" OR "Mediterranean diet" OR "MedDiet" OR "Mediterranean-style diet" OR "Mediterranean eat*" OR "Mediterranean food" OR "Mediterranean life-style" OR "Mediterranean habit*")) AND ("performance" OR "athletic* performance" OR "fitness" OR "fitness level" OR "physical fitness" OR "physical performance" OR "functional fitness" OR "physical function" OR "muscle strength" OR "muscular power" OR "muscular fitness" OR "muscle endurance" OR "explosive strength" OR "flexibility" OR "musculoskeletal fitness" OR "balance" OR "coordination" OR "agility" OR "speed" OR "motor fitness" OR "aerobic fitness" OR "aerobic capacity" OR "cardiorespiratory fitness" OR "cardiorespiratory endurance" OR "aerobic endurance" OR "body	442

	composition" OR "hydration" OR "fatigue" OR "exhaustion" OR "motor skill*")	

Table 2. PICOS (*Population, Intervention, Comparison, Outcomes and Study design*) criteria of inclusion and exclusion.

PICOS criteria	***Inclusion criteria***	***Exclusion criteria***
Population	- Healthy adults (≥18 years) classified as competitive or elite athletes, engaging in structured training for ≥6 hours per week; - Absence of any diagnosed medical conditions.	- Children/adolescents; - Sedentary, recreationally active people and exercisers; - Presence of any cardiovascular, metabolic, neurological, pulmonary, or orthopedic disease or disorder.
Intervention	Mediterranean Diet	No mention of dietary pattern
Comparison	Other dietary pattern	No mention of dietary pattern
Outcomes	- performance - fitness (functional, motor, aerobic, musculoskeletal, cardiorespiratory) - muscle strength, muscular power, muscular fitness, muscle endurance - explosive strength - flexibility - balance - coordination - agility - speed - aerobic capacity, endurance - cardiorespiratory endurance - body composition - hydration - fatigue, exhaustion - motor skill	Without performance outcomes
Type of Studies included	Randomised controlled trials; non-randomised controlled trials; uncontrolled observational studies; case reports and case series	Full text not available; reviews, opinion articles, guidelines, letters, editorials, comments, news, conference abstracts, theses, and dissertations; and in vitro or animal studies; grey literature
Research question	*Can the MedDiet be associated with any changes in performance in athletes?*	

1.2.2 Study selection and data extraction

The study selection process was independently conducted by two reviewers (S.F. and M.G.) using Rayyan software [167]. The screening followed two sequential stages: (1) title and abstract screening, and (2) full-text evaluation of potentially eligible studies. The inclusion of articles was guided by the PICOS framework [Population (P): adult athletes; Intervention (I): MedDiet; Comparison (C): other dietary patterns; Outcome (O): any modification in performance; Study design (S): randomised controlled trials, uncontrolled observational studies, case reports, and case series].

Any disagreements between reviewers were resolved by consulting a third author (L.C.L.N.). All retrieved references were managed using Mendeley Reference Manager.

The same reviewers (S.F. and M.G.) performed data extraction independently. Extracted data included sample characteristics, study design, sport type, dietary intervention, adherence to the MedDiet, performance tests, and reported effects of the MedDiet on performance. The extracted information was summarised in **Table 3**.

1.2.3 Quality appraisal

Risk of bias and methodological quality were assessed independently by the same two reviewers (S.F. and M.G.), with discrepancies resolved by a third author (L.C.L.N.).

For randomised controlled trials, the Cochrane Risk of Bias 2.0 (RoB 2.0) tool was applied [168], which evaluates five domains: (1) randomisation process, (2) deviations from intended interventions, (3) missing outcome data, (4) measurement of the outcome, and (5) selection of the reported result.

For non-randomised studies, the ROBINS-I tool was used [169], assessing seven domains across three phases: pre-intervention (bias due to confounding, bias in participant selection), intervention (bias in intervention classification), and post-intervention (bias due to deviations from intended interventions, missing data, measurement of outcomes, and selection of the reported result).The quality of observational studies was evaluated using the Newcastle-Ottawa Scale (NOS), adapted for cross-sectional studies [170]. The NOS employs a star-based scoring system across three domains (Selection, Comparability, and Outcome) with a maximum of 8 points. Studies scoring 7-8 points were considered at low risk of bias, those with 6 points at moderate risk, and those with ≤5 points at high risk [171].

1.2.4 Data synthesis and statistical analysis

All statistical analyses were performed using R Studio [172]. The decision to conduct subgroup meta-analyses was made post hoc, after evaluating the feasibility based on the extracted data.

Performance outcomes were treated as continuous variables and expressed as mean values and standard deviations (SD). When these were not directly reported, the mean and SD were estimated from the median and interquartile range (IQR) using the formulas proposed by Wan et al., 2014 [173].

To standardize different performance measures, effect sizes were expressed as standardized mean difference (SMD) with corresponding 95% confidence intervals (CI). Heterogeneity across studies was assessed using the I^2 statistic, and τ^2 was estimated with the DerSimonian-Laird method. According to Cochrane guidelines, heterogeneity was classified as: not important (I^2<40%), moderate (30-60%), substantial (50-90%), or considerable (75-100%) [174].

A random-effects model was applied for all analyses. Because of the limited number of included studies, publication bias was not assessed, as tests for funnel plot asymmetry are considered reliable only when at least ten studies are available [174].

A sensitivity analysis was conducted by sequentially removing individual studies to test the robustness of the pooled results. A p-value <0.05 was considered statistically significant.

1.3 Results

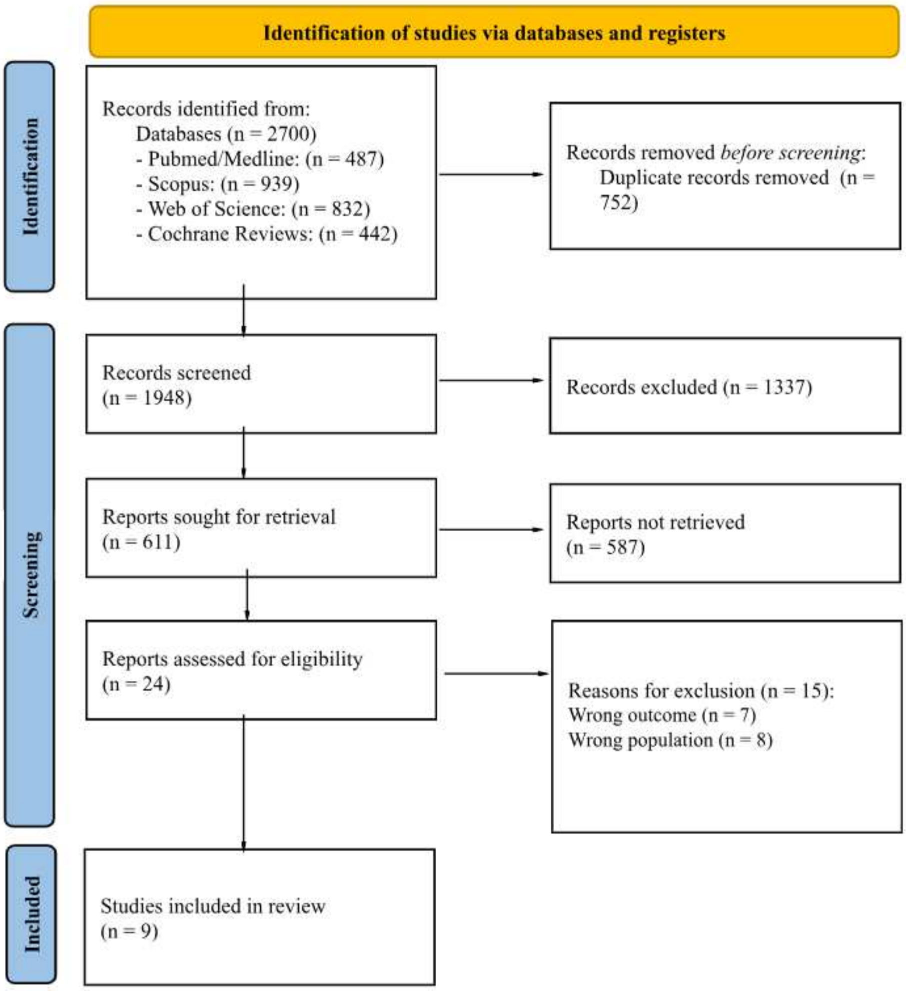
1.3.1 Study characteristics

A total of more than two thousand potentially relevant studies were identified through the selected databases. After removal of duplicates, 1948 records remained for screening. The study selection process is summarized in **Figure 1**.

Following the screening of titles and abstracts, and subsequent full-text evaluation, 14 articles were excluded because the study population or reported outcomes did not meet the predefined inclusion criteria.

Ultimately, nine studies met the eligibility criteria and were included in this systematic review [175–183]. The included studies were published between 2015 and 2023, and all were conducted in Europe, specifically in Spain (n = 5) and Italy (n = 4).

Figure 1. PRISMA 2020 flow diagram for new systematic reviews, which included searches of databases and registers only [From [166]]



A range of study designs was represented: 5 cross-sectional studies [176,178–182], 2 randomized controlled trials [181,183], 1 longitudinal experimental study [177], and 1 longitudinal observational study [175]. Two studies implemented a structured intervention including a control group [177,181], while another two applied a MedDiet intervention without a control group [175,183]. In contrast, two cross-sectional studies assessed the association between MedDiet adherence and performance parameters [176,182], whereas the remaining three studies simply evaluated MedDiet adherence among athletes without any intervention [178–180,182].

The duration of the interventions ranged from 8 weeks [177] to 3 months [183]. Six studies did not report any investigation of supplement use among participants [176,178–180,182,183]. Ficarra et al. excluded athletes using supplements [177], while Miralles-

Amorós et al. stated that most participants did not consume dietary or sports supplements, though some reported occasional use of isotonic drinks during training; however, no quantitative data were provided [181].

Caparello et al. recommended a variety of supplements, including sports drinks, creatine monohydrate, essential amino acids, beta-alanine, recovery beverages containing whey protein and glucose (with optional glutamine), multivitamins, and fish oil (omega-3), but did not specify the type or amount used by each athlete. Moreover, supplement consumption was not analyzed in relation to performance outcomes, potentially influencing the study's results [175]. Detailed study procedures and characteristics are summarized in **Table 3**.

Table 3. Details of included articles: study design, population characteristics, type of sport and diet, adherence to MedDiet, performance test, impact of MediDiet on performance.

STUDY, YEAR, COUNTRY	STUDY DESIGN	POPULATION CHARACTERISTICS (M/F, age, BMI)	SPORT	DIET type (duration)	ADHERENCE TO MedDiet	SUPPLEMENTS USE	PERFORMANCE TESTS	OTHER ASSESSMENTS	MEDITERRANEAN DIET IMPACT ON PERFORMANCE (Y/N)	RESULTS (impact on performance)	OTHER RESULTS
Caparello et al., 2023 Italy [175]	Pilot longitudinal study	n = 11 F (n) = 0 Age, y (Mean ± SD): 27.0 ± 6.0 BMI, kg/m2 (Mean ± SD): 24.2 ± 1.9	Volleyball	MedDiet	Method/tool: MEDAS Adherence rate/score: 9.8 ± 1.1 (baseline); 10 ± 0.2 (pre-season training session); 10.3 ± 0.1 (championship); 10.2 ± 0.1 (play-off)	Yes, recommended (sport drinks, creatine monohydrate, essential amino acids, beta-alanine, balanced recovery drinks with whey protein, glucose and possibly glutamine, multivitamins and fish oil)	Explosive-elastic strength: countermovement jump Alactacid anaerobic power: 15” of continuous jumps Aerobic capacity: Yo-Yo shuttle run test adapted to volleyball Shooting ability: 8 m with standing start Running speed: 15 m running	Electrical bioimpedance: single analyzer pole resistance (Rz), reactance (Xc), phase angle (PhA), total body water (TBW), body cell mass (BCM), free fat mass (FFM), fat mass (FM), body cell mass index (BCMI), fat-free mass/height (FFM/H),	NO	No correlation between MEDAS-14 referring to "Key times" (pre-season, championship, play-off periods)	*Nutritional parameters:* BMI: 24.5 ± 0.3 (pre-season training session); 25.3 ± 0.3*(championship) 25.7 ± 0.6* (play-off) PhA (◦): 6.9 ± 0.5 (pre-season training session); 7.4 ± 0.5* (championship) 7.6 ± 0.5* (play-off) FM (kg): 12.8 ± 0.3 (pre-season training session);

							Acceleration capability: 20 m from standstill Specific ability to break and restart: 6 balls	extracellular mass (ECM), extracellular water (ECW), intracellular water (ICW), lean dry mass (LDM), lean soft tissue (LST), skeletal muscle mass (SMM) Basal metabolic rate (BMR)			13.6 ± 0.4* (championship) 14.2 ± 0.1* (play-off) FFM (kg): 77.6± 0.9 (pre-season training session) 79.7 ± 0.7* (championship) 80.6 ± 0.2* (play-off) BCMI (kg/m2): 11.1 ± 0.1* (pre-season training session) 11.8 ± 0.3* (championship) 12 ± 0.02* (play-off) ECM (kg): 31.4 ± 0.4* (pre-season training session) 30 ± 0.5* (championship)

											29.7 ± 0.4* (play-off) SMM (kg): 37.9 ± 0.5* (pre-season training session) 41.0 ± 0.9* (championship) 41.4 ± 0.1* (play-off) TBW (kg): 53.2 ± 1.3* (pre-season training session) 54.8 ± 0.4* (championship) 55.0 ± 0.1* (play-off) BMR (Kcal): 2338 ± 25.7* (pre-season training session) 2402 ± 22.6* (championship) 2415 ± 5.6 0.008* (play-off)

Citarella et al., 2021 Italy [176]	Cross-sectional study	n = 10 F (n) = 4 Age, y (Mean ± SD): 41. ± 7 BMI, kg/m2 (Mean ± SD): 21.7 ± 1.1	Ultramarathon	MedDiet	Method/tool: MDAS Adherence rate/score: 47.0 ± 12.0*	Not reported	Record in the 100-Km competition (in seconds)	Body weight DXA scans (Total fat mass percentage ,%BF; Trunk fat mass percentage; Appendicular skeletal muscle index, ASMI in Kg/m2)	NO	No correlation between MDAS and record in 100-km competition (r=0,428)	Females had higher dietary adequacy scores compared to their counterpart males (39.9 ± 6.3 vs. 57.5 ± 10.8; p <0.038) MDAS was significantly associated with gender (higher in females) 100 km record was significantly negative associated with age, ASMI and TV/week and positively associated with trunk fat and %BF

Ficarra et al., 2022 Italy [177]	Longitudinal experimental study	n = 22 F (n) = 9 Age, y (Mean ± SD): n.d. 38.03 ± 8.9 (MedD) and 35.6 ± 8.4 (control group) BMI, kg/m2 (Mean ± SD): n.d. 24.2 ± 2.5 (MedD) and 24.0 ± 2.5 (control group)	CrossFit	MedDiet vs control diet (8 weeks)	Method/tool: monitoring and supervision by the dietician Adherence rate/score: n.r.	Not allowed	Explosive strength: Squat Jump Test Explosive-elastic strength: Countermovement Jump Test Muscular endurance: Specific CrossFit Performance Push-Up Test to Exhaustion Chin-Up Test to Exhaustion Maximum anaerobic power: Wingate 30-s Test 30-s Jump Test	Body composition: multi-segmental and multi-frequency instrument fat mass (FM), total body water (TBW) (including intracellular (ICW) and extracellular water (ECW) and dry lean mass (Kg).	YES	In the MedD group: MS increased (T0: 787.3 ± 106.5, T1: 835.4 ± 128.9)* time PP (tPP) reduced (T0: 2851.2 ± 896.8 ms, T1: 1620.7 ± 768.9 ms)* power drop (PD) increased (T0: 20,527.1 ± 7230.3 W, T1: 22,230.4 ± 7854.5 W)* Jump height increased	Fran test improved (T0: 476.3 ± 330.1 s, T1: 365.2 ± 166.7 s)*

										(T0: 27.0 ± 5.6 cm, T1: 29.6 ± 5.6 cm) Jump hang-time during SJ increase (T0: 0.5 ± 0.1, T1: 0.5 ± 0.1)* push-up test to exhaustion improved (T0: 36.1 ± 15.3 repetitions, T1: 38.9 ± 15.5 repetitions)* chin-up test to exhaustion improved (T0: 11.7 ± 5.6, T1: 13.6 ± 6.2)*	

										In the control group: push-up number increased (T0: 31.3 ± 15.4, T1: 34.5 ± 17.2)*	

Marques-Sule et al., 2022 Spain [178]	Cross-sectional study	n = 43 F (n) = 5 Age, y (Mean ± SD): 21.5 ± 6.0 BMI, kg/m2 (Mean ± SD): 23.3 ± 2.6	Canoa polo	None - cross sectional study Evaluation of the association between MedDiet and performance	Method/tool: MEDAS-14 Adherence rate/score: 4.7 ± 1.9	Not reported	Explosive-elastic strength: Countermovement jump test Muscle endurance: Push-up test Sit-to-stand test Joint range of motion: Shoulder rotation range of motion Maximum isometric strength: Handgrip test Maximal strength: 1-Repetition Maximum (estimated) on overall push strength and owing specific push-strength	*Nutritional and dietary variables:* Body composition: fat mass and fat free mass (BIA and skinfold thickness) Healthy Eating Index - Spanish (HEI-S) questionnaire *Psychosocial variables:* Exercise Motivation Index questionnaire	NO	No correlations were found for nutritional variables - MEDAS-14 and 1RM Rowing Strength—Test: z-score -1.2; [-4.5, 2.2] - HEI-S and 1RM Rowing Strength—Test: z-score -0.2; [-3.4, 2.9]	

Martínez-Rodríguez et al., 2021 Spain [179]	Descriptive cross-sectional study	n= 15 senior professional beach handball players F (n) = 15 Age, y (Mean ± SD): 24.8 ± 4.7 BMI, kg/m2 (Mean ± SD): 22.8 ± 2.7	Beach handball	None - cross sectional study Evaluation of the association between MedDiet and performance	Method/tool: KIDMED questionnaire Adherence rate/score: 6.3 ± 2.1 with significant difference in KIDMED score according to the role played	Not reported	Aerobic capacity:Yo-Yo IR level 1 Explosive-elastic strength: Abalakov Jump Test Maximum isometric strength: Handgrip test	Bone quality (bilateral calcanei)	YES	Negative correlation between KIDMED score and Abalakov test (-0,477*)	KIDMED score was positively associated with BMI (0,524*) BMI was positively associated with bone quality (0,661*)
Martínez-Rodríguez et al., 2022 Spain [180]	Descriptive cross-sectional study	n= 18 senior professional beach handball players F (n) = 0 Age, y (Mean ± SD): n.d. 25.0 ± 5.2 (seniors), 16.7 ± 0.5 (juniors) BMI, kg/m2 (Mean ± SD): 24.6 ± 2.7 23.9 ± 2.8 (junior) and	Beach handball	None - cross sectional study Evaluation of the association between MedDiet and performance	Method/tool: KIDMED questionnaire Adherence rate/score: 6.7±2.6	Not reported	Explosive-elastic strength: Countermovement jump test Explosive-elastic strength: Abalakov jump test Aerobic capacity:Yo-Yo IR level 1	Body composition: weight, height, sitting height and wingspan	YES	Positive correlation between KIDMED score Yo-Yo test and VO2 max (0,512* for both tests)	KIDMED score negatively associated with weight (-0,406*) and BMI (-0,418*) Yo-Yo test results (distance travelled and VO2 max) correlate positively with the CMJ (0.523*) and Abalakov test (0.517*)

		25.4 ± 2.5 (senior)					Maximum isometric strength: Handgrip test				
Miralles - Amorós et al., 2023 Spain [181]	Randomised controlled trial	n = 21 professional handball players F (n) = 21 Age, y (Mean ± SD): 22.0 ± 4.0 (FD); 21.0 ± 3.0 (MD); 22.0 ± 4.0 (AD) BMI, kg/m2 (Mean ± SD): n.d. 22.1 ± 1.7 (FD); 24.1 ± 3.2 (MD); 23.5 ± 1.9 (AD)	Handball (elite players)	Mediterranean diet (MD) vs high antioxidant diet (AD) vs free diet (FD) (12 weeks)	Method/tool: weekly verification of adherence by phone Adherence rate/score: n.d.	Absent in most of the participants, a few individuals consumed isotonic drinks during sport practice	Abalakov Jump Explosive-elastic strength: Countermovement jump test Explosive-elastic strength: Abalakov jump test Maximum isometric strength: Handgrip test	*Nutrition assessment* Energy expenditure (indirect calorimetry) energy availability (LEAF-Q) 7-day dietary intake analysis body composition (skinfold thickness and dual indirect bioelectrical impedance) *Health parameters*	YES	Significant differences were found over time for the Abalakov jump test, with jump height improving over time - no differences within groups 13 of the female players were at risk of RED-S (61.9%) - no	

								blood pressure, cholesterol, menstrual function		differences between groups or before/after the intervention Blood pressure, pulse/minute and cholesterol: no differences	
Rubio-Arias et al., 2015 Spain [182]	Observational cross-sectional	n = 12 elite football players F (n) = 12 Age, y (Mean ± SD): 20.3 ± 2.7 BMI, kg/m2 (Mean ± SD): n.d.	Football (elite players)	MedDiet	Method/tool: KIDMED Adherence rate/score: n.d. 7 participants (58.3%) with low adherence, 5 (41.7%) with medium adherence	Not reported	Muscle power: Isokinetic test Explosive-elastic strength: Countermovement Jump Explosive strength: Squat Jump Shooting power: Ball hit Speed:	Body composition (Fat mass and fat free mass)	NO	No significant relationship between MedDiet and performance, nor within the two groups of adherence (low/medium)	

							3x30 meters speed test Anaerobic power/capacity: Repeated Sprint Ability (RSA)				
Soldati et al., 2019 Italy [183]	Randomised controlled trial	n = 40 F (n) = 0 Age, y (Mean ± SD): n.d. Age, y (Median; [IQR]): 33 [18-38] (K) and 36 [28-60] (R) BMI, kg/m2 (Mean ± SD): n.d. BMI, kg/m2 (Median; [IQR]): 22.4 [20.1-28.4] (K) and 23.1 [20.1-24.1] (R)	Kickboxing (K) and running (R)	MedDiet (nutritional counseling) (3 months)	Method/tool: monthly verification of adherence by phone Adherence rate/score: n.r.	Not reported	Maximal aerobic power ($\dot{V}O_2$ max): Bruce Test Maximal strength: 1-Repetition Maximum (estimated using the equation of Brzycki) Explosive strength: Squat jump test Explosive-elastic strength: Counter Movement	Body composition Resting metabolic Rate	YES	Kickboxers receiving Nutritional Counseling (MedDiet) improved: - CMJ test: 32.5 (28.0-34.0) vs 34.0 (31.0-36.3) cm* - squat jump (SJ): 74.5 (59.8-102.5) vs 101.0 (77.0-109.8) cm* - body fat percentage: 13.5% (9.5-17.3) vs 10.5% (4.9-13.3)*	

							Jump test Alactacid anaerobic power: 15” of continuous jumps			Kickboxers not receiving Nutritional Counseling (MedDiet) improved: - CMJ test: 33.0 (31.0-35.5) vs 37.0 (32.0-40.3) cm* - body fat percentage: 7.0% (6.8-11.3) vs 6% (4.8-7.8)* Runners receiving Nutritional counseling (MedDiet) improved: - VO2max: 58.5 (56.5-64.3) vs 61.5 (59.0-70.0) ml/kg/min * - CMJ test: 30.0 (24.8-	

										33.5) vs 31.0 (29.5-37.3) cm* - body fat percentage: 9.0% (6.8-11.0) vs 6.5% (5.0-7.0)* Runners not receiving Nutritional counseling (MedDiet) decreased: - squat jump (SJ): 28.0 (25.8-34.3) vs 25.0 (23.5-30.0) cm* - body fat percentage: 10.5% (9.0-15.8) vs 10% (8.8-12.5)* RMR did not significantly change	

										within the groups or over time	
Abbreviations: BMI, Body Mass Index; BF, Body Fat; FM, Fat Mass; FFM, Fat Free Mass; F, Female; IQR, Interquartile Range; M, Male; MDAS, Mediterranean Dietary Adequacy Score; MEDAS, Mediterranean Diet Adherence Screener; MS, Maximum Speed; N, Number; n.r., Not Reported; RED-S, Relative energy deficiency in sport; SD, Standard Deviation; Y, Years. Statistical significance is denoted by (*).											

1.3.2 Participants characteristics

This systematic review included a total of 192 participants, the majority of whom were male (65.6 %). Sample sizes ranged from 10 to 43 athletes from various sport disciplines: beach handball (n = 2) [179,180], canoa polo (n = 1) [178], crossfit (n = 1) [177], football (n = 1) [182], handball (n = 1) [181], volleyball (n = 1) [175], ultramarathon (n = 1) [176]; one study involved kickboxing and running athletes [183]. All the included studies involved competitive athletes, with six specifically focusing on elite or professional athletes [176,178–182].

1.3.3 Adherence to Mediterranean Diet

Various tools were used to assess adherence to the MedDiet. The assessment instruments included the KIDMED questionnaire [179,180,182], MEDAS-14 [175,178], and MDAS [176], which provided quantifiable measures of adherence. In general, results ranged from low to high adherence to the MedDiet. One study verified adherence through monthly phone calls [183], while another monitored compliance with nutritional advice through weekly phone calls [181]. The study conducted by Ficarra and colleagues ensured participants' adherence through supervision by experienced dietitians throughout the study period [177].

1.3.4 Mediterranean Diet impact on performance

The key findings from each study are summarised in **Table 3**.

Several tests were administered to the participants to assess their physical performance according to the specific sport discipline, as detailed in **Table 4**.

Five studies [177,179–181,183] reported an effect of the MedDiet on athletic performance. Among these, four studies found a positive association between MedDiet adherence and performance outcomes, whereas one study observed a negative correlation between adherence to the MedDiet (assessed by the KIDMED questionnaire) and performance in the Abalakov test [179]. The remaining studies reported no significant effect of this dietary pattern on performance.

In the study by Ficarra et al., a significant improvement was observed in the MedDiet group after eight weeks of intervention in several parameters: maximum speed (T0: 1.0 ± 0.2 m/s; T8: 1.3 ± 0.2 m/s), jump height (T0: 27.0 ± 5.6 cm; T8: 29.6 ± 5.6 cm; $p = 0.035$), chin-up test to exhaustion (T0: 11.7 ± 5.6; T8: 13.6 ± 6.2; $p = 0.008$), and time to complete the Fran test (T0: 476.3 ± 330.1 s; T8: 365.2 ± 166.7 s; $p = 0.002$) [177]. Similarly, Soldati et al. reported that, after three months of a controlled diet based on MedDiet principles combined with training, kickboxers showed significant improvements in the Countermovement Jump (p =

0.0015) and Squat Jump (p = 0.012) tests. In the same study, runners receiving nutritional counseling based on the MedDiet demonstrated increased VO_2max ($p = 0.007$) and better results in the Countermovement Jump test ($p = 0.024$) [183].

Table 4. Type of performance test used in the included studies.

TYPE OF TEST	**PERFORMANCE TEST**	[175]	[176]	[177]	[178]	[179]	[180]	[181]	[182]	[183]
Aerobic capacity	Yo-Yo test	x				x	x			
Anaerobic power	Wingate cycle test			x						
	15 s of continuous jumps	x								
	30-s Jump Test			x						
Maximum anaerobic power	Abalakov Jump test					x	x	x		
Maximal aerobic power	Bruce Test									x
Explosive strength	Squat jump test			x	x				x	x
Explosive-elastic strength	Countermovement Jump Test	x		x			x	x	x	x
Maximum isometric strength	Handgrip strength test				x	x	x	x		
Shooting ability	8 m with standing start	x								
Running speed	15 m running	x								
Acceleration capability	20 m from standstill	x								
Specific ability to break and restart	6 balls	x								
Muscle endurance	Sit-to-stand test				x					
	Push-Up Test				x					
Muscle power	Isokinetic Test								x	
Sport-Specific Tests										

Ultramarathon	Record in the 100-km competition		x							
CrossFit	Push-Up Test to Exhaustion			x						
	Chin-Up Test to Exhaustion			x						
Rowing	Rowing specific Push-strength				x					
Football	Ball hit								x	
Abbreviations: s, seconds; m, meters; km, kilometers										

1.3.5 Study quality

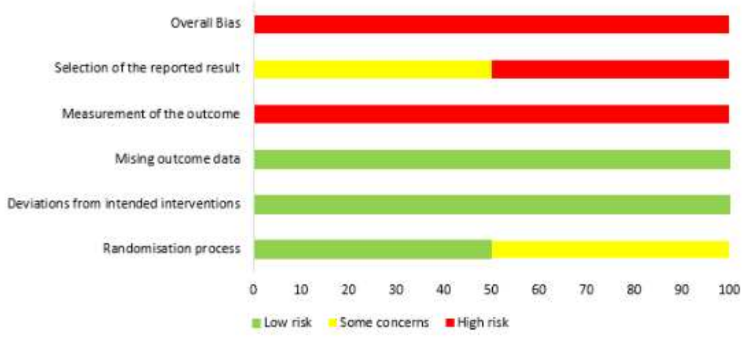
The risk of bias in the two randomized studies was evaluated using the RoB 2.0 Cochrane tool [181,183], with overall results presented in **Figure 2**. Both studies were rated as having a high risk of bias, primarily due to issues in the measurement of outcomes domain. Similarly, concerns were noted in Domain 5 (Selection of the reported result), except for the study by Soldati et al., which was judged as having some concerns. Domains 1, 2, and 3 (Randomization process, Deviations from intended interventions, and Missing outcome data) were generally rated as low-to-moderate risk for all the studies.

For the non-randomized studies, the ROBINS-I tool was applied. The overall risk of bias was considered moderate (**Table 5**), mainly due to moderate risk in the measurement of outcomes domain [175,177] and in the confounding domain [177]. All other domains were rated as low risk.

The quality of observational studies was assessed using the Newcastle-Ottawa Scale (NOS). Three studies scored 5 points [178–180], one study scored 4 points [176], and one study scored 3 points [182].

Figure 2. Results of risk of bias analysis with RoB 2.0 Cochrane tool: (A) Percentage of risk of bias of each domain in all the included studies. (B) Description of each domain of bias according to studies included.

A



B

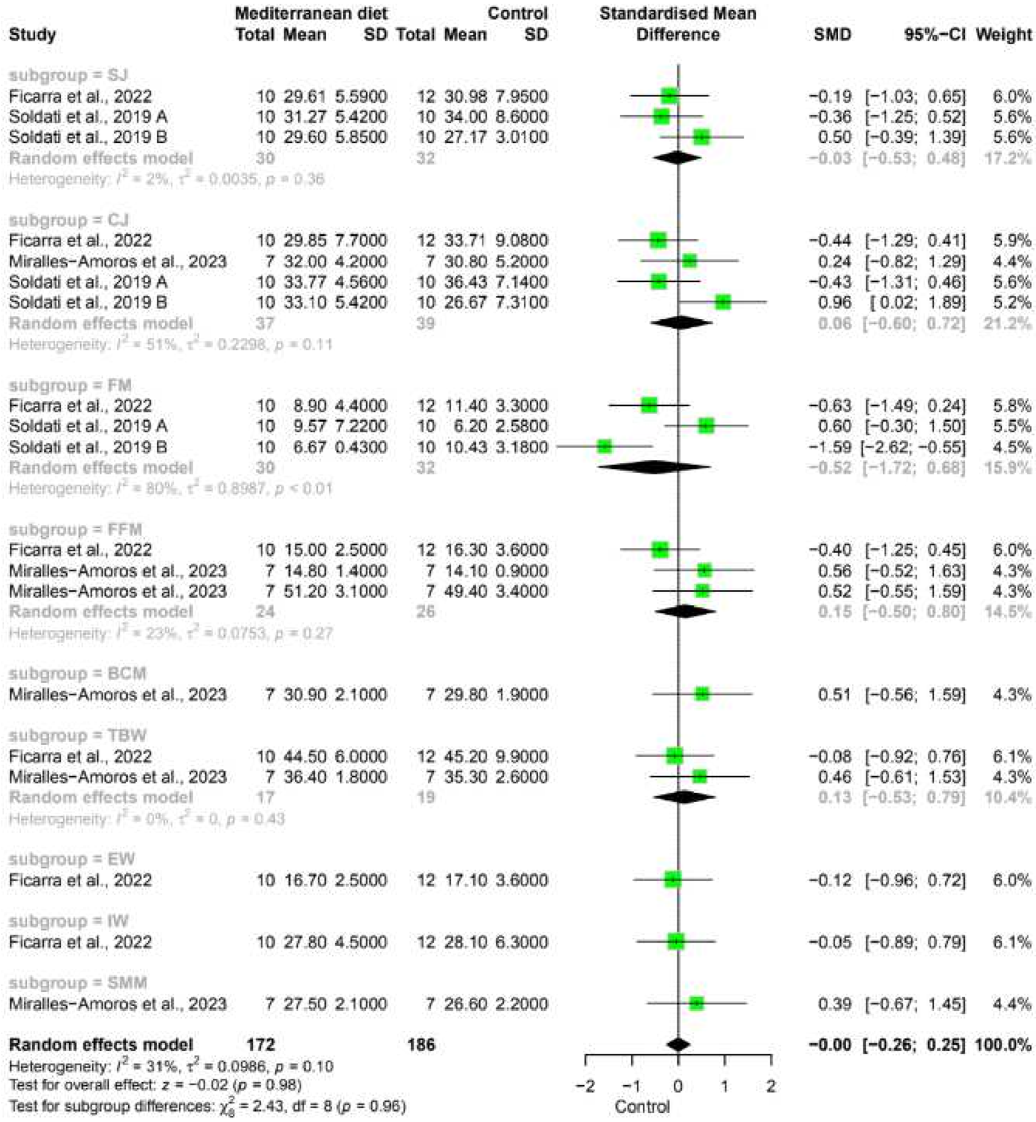
Table 5. Results of risk of bias analysis with Robins-I tool.

	Bias Domain							
Studies	Bias due to confounding	Bias in selection of participants into the study	Bias in classification of interventions	Bias due to deviations from intended interventions	Bias due to missing data	Bias in measurement of outcomes	Bias in selection of reported results	Overall bias
Caparello et al., 2023	Low	Low	Low	Low	Low	Moderate	Low	**Moderate**
Ficarra et al., 2022	Moderate	Low	Low	Low	Low	Moderate	Low	**Moderate**

1.3.6 Data synthesis and statistical analysis

Data from two randomised clinical trials [181,183] and one longitudinal study [177] were pulled and represented in a forest plot (**Figure 3**). The data from the study of Soldati et al. were divided into two data sources: (A) kickboxers and (B) runners [183]. The meta-analysis showed no effect of the MedDiet on the performance outcomes analysed. The overall random-effects model indicated a non-statistical significant SMD 0.00 (CI -0.26; 0.25; p = 0.98). Similarly, when performance outcomes were analyzed separately by subgroup, no significant effect of the MedDiet was observed. Regarding the analysis of some body composition parameters (extracellular water, intracellular water, body cell mass, and skeletal muscle mass) only one study reported data. Substantial heterogeneity was detected for the Countermovement Jump (CJ) tests, and FM (p = 0.11 and p < 0.01, respectively). The sensitivity analysis showed no differences when excluding articles, except for the FM subgroup (Figure 4; Figure 5; Figure 6).

Figure 3. Forest plots displaying the MedDiet effect on the performance of healthy adults (competitive and elite athletes).



SD, standard deviation; SMD, standardized mean difference; CI, confidence interval; SJ, Squat jump test; CJ, Countermovement Jump Test; FM, fat mass; FFM, fat-free mass; BCM, body cell mass; TBW, total body water;

EW, extracellular water; IW, intracellular water, SMM, skeletal muscle mass. Soldati et al. A stands for the kickboxers and B for runners

Figure 4. Sensitivity analysis performed by omitting Soldati et al., 2019 (runners).

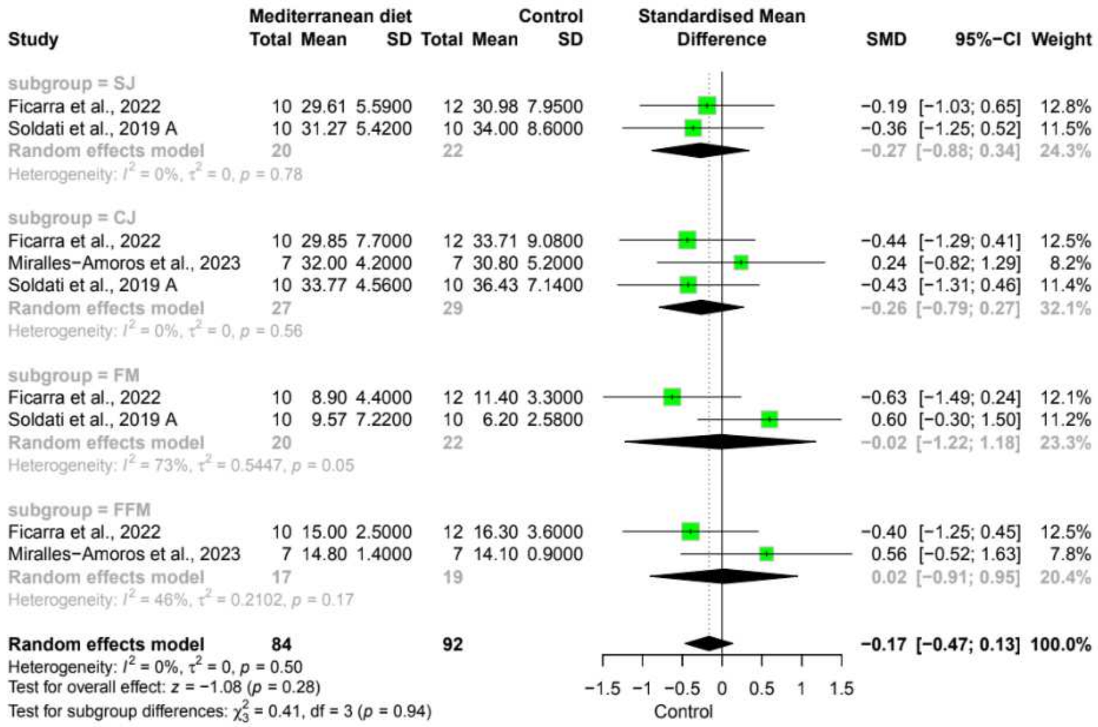


Figure 5. Sensitivity analysis performed by omitting Soldati et al., 2019 (kickboxers).

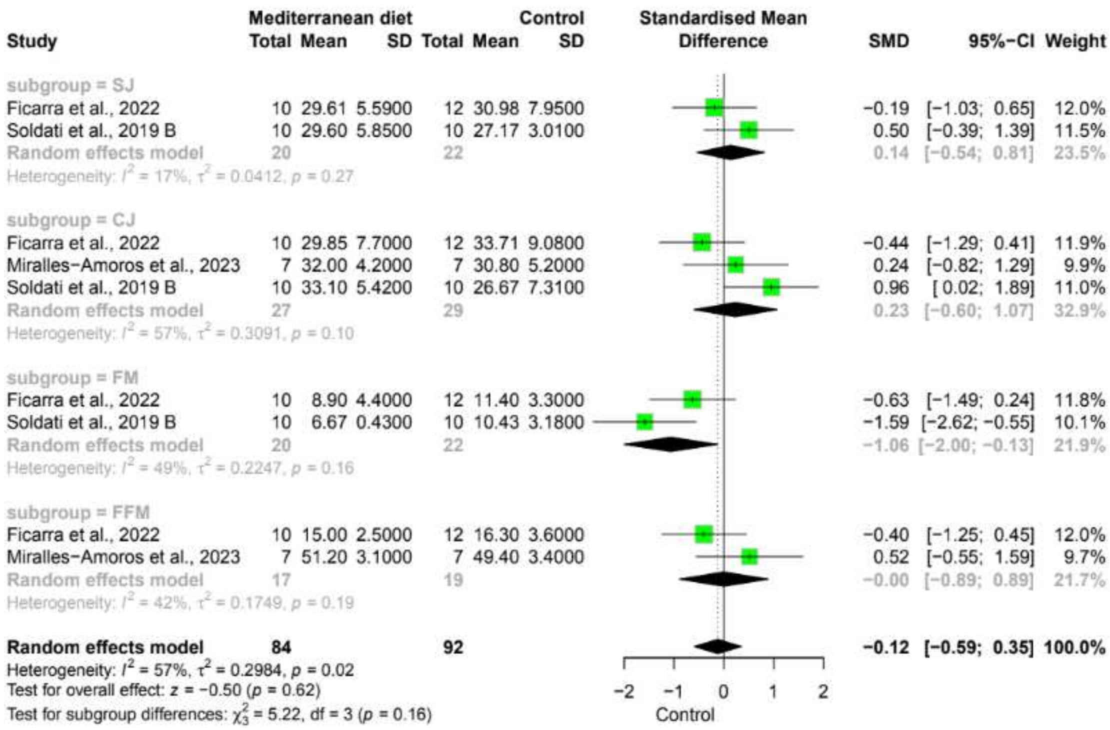
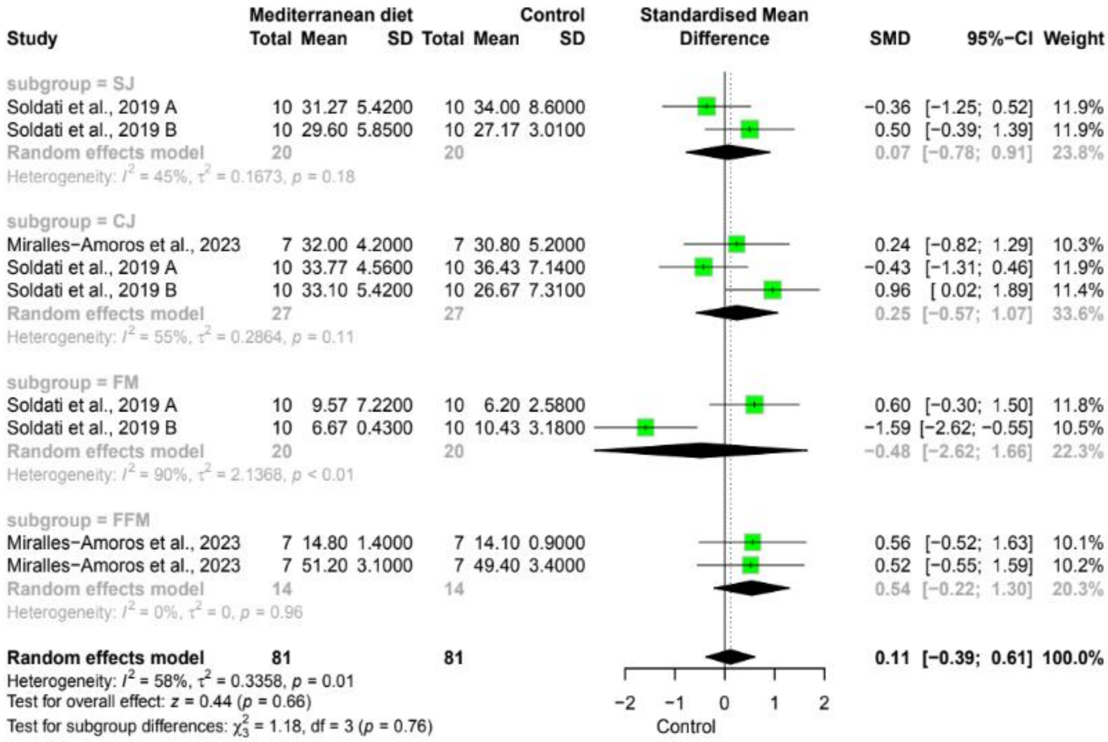


Figure 6. Sensitivity analysis performed by omitting Ficarra et al., 2022.



1.4 Discussion

To the best of our knowledge, this is the first systematic review and meta-analysis specifically investigating the possible impact of the MedDiet on athletic performance in adult athletes across a variety of sports and competition levels. The results from the included studies generally indicated a positive influence of the MedDiet on athletic performance, supporting its role as a health-promoting dietary pattern for athletes. Nevertheless, when data were pooled together in the meta-analysis, no statistical significant overall effect was observed.

Half of the studies included in this review reported improvements in various performance tests following MedDiet interventions. For example, in the study by Ficarra et al. (2022), CrossFit athletes participating in an 8-week MedDiet intervention demonstrated significant improvement in squat jump performance, anaerobic power, muscular endurance, and CrossFit-specific tests compared to the athletes in the control group [177]. Similarly, in the study by Soldati et al. (2019), after three months of adherence to personalized nutritional recommendations based on MedDiet principles, kickboxers from the University of Sports Center Bergamo, Italy, showed statistically significant increases in squat strength and the countermovement jump test [183]. The authors highlighted a significant VO_2max

improvement and a significant reduction of body fat percentage among those runners who received the same advice. In contrast, in a population of elite female futsal athletes, Rubio-Arias et al. found that the MedDiet adherence index did not correlate with either body composition or performance test outcomes [182].

This discrepancy underscores the complexity of the relationships between diet and athletic performance, suggesting that the benefits of the MedDiet may vary depending on sport discipline, specific performance outcomes measured, and individual athletes characteristics. Even among athletes competing in the same sport, individual factors, such as gender, can greatly influence performance results. This variability may help explain the differing outcomes reported in two studies conducted by the same research group [179,180].

Differences in study design, intervention duration, type of dietary intervention, and adherence levels may also contribute to the inconsistent findings.

For example, the duration of dietary intervention in the included studies ranged from a few days to several months, potentially influencing the observed effects. Additionally, the use of different instruments to assess MedDiet adherence complicates the comparability of results across the studies, highlighting the importance of employing validated tools for accurate assessment.

The presence or absence of a well-structured intervention with a control group may further affect outcomes. Some of the intervention studies implemented personalized dietary plans tailored to athletes' nutritional needs [175,177,181,183]. Among these, three studies reported a positive impact [177,181,183], whereas Caparello observed no effect [175]. Conversely, studies, without individualised interventions [176,178,182], reported either no impact or, in one case, a negative impact [179].

This may suggest that improvements in performance could be, to some extent, attributed to overall dietary optimization rather than the MedDiet specifically.

This hypothesis can be, at least partially, counteracted considering the findings of some studies evaluating the effect of MedDiet versus other dietary patterns on sport performance. For instance, a randomised controlled crossover trial investigated the short-term effects of MedDiet versus Western diet on endurance exercise performance and anaerobic exercise in American recreational runners [184]. Adherence to the MedDiet was associated with a significantly faster 5-km run time when compared to the Western diet. This enhancement

occurred without increasing heart rate or perceived effort [184]. This suggests that the nutrient-rich characteristics of the MedDiet may improve endurance performance. However, no significant differences were observed in anaerobic performance tests. Notably, the study presented some limitations including a small sample size (n = 11) and a brief intervention period (4 days).
Further evidence comes from a study in an older population (55-80 years) without previously documented cardiovascular disease, which evaluated the relationship between dietary patterns and physical activity [185]. In that study, a significant negative association was found between adherence to the Western diet and performance in the 30-s Chair Stand Test (repetitions) and 6-min Walking Test (meters). Conversely, the Western dietary pattern showed a significant positive association with the time required to complete the 30-m Gait Speed and 8-foot Timed Up-and-Go tests (seconds), except in men for the latter-reflecting worse performance with higher Western diet adherence. In contrast, among men, the MedDiet was negatively associated with the time of the 30-m Gait Speed test, suggesting a beneficial effect of the MedDiet on physical fitness [185].

Six studies did not evaluate supplement intake [176,178–180,182,183], which limits the possibility of determining its potential effect on performance and complicates the interpretation of the results obtained. Ficarra et al. excluded athletes who reported supplement use, a choice that may have introduced selection bias and reduced the generalizability of their findings [177]. Miralles-Amoros et al. indicated that most participants did not use sports supplements, except for a small number who reported consuming isotonic drinks during training [181]. Caparello et al. suggested the use of some supplements, but did not specify the individual consumption levels or analyse their potential impact on competitive performance [175].

The lack of detailed information introduced a gap in understanding the contribution of supplementation to athletic performance and recovery. When properly managed, some supplements can support athletes in achieving their nutritional needs, improving training adaptations, and sustaining health and injury prevention. Nevertheless, it is well established that supplements play a relatively minor role in sports nutrition, with only a limited number demonstrating a clear ergogenic effect (caffeine, creatine, nitrate, beta-alanine, and sodium bicarbonate) [186]. Notably, the MedDiet has shown to provide adequate protein intake to satisfy the nutritional demands of athletes without additional supplementation [187]. Since distinguishing the specific influence of the MedDiet from that of supplement use is often challenging, future research should consider both the dietary pattern and the type and quantity of supplements consumed, in order to better clarify their respective effects on performance.

It is also worth noting that all the included studies were conducted within the Mediterranean Basin, specifically in Spain and Italy. This geographical bias may have influenced the findings, as participants from these regions are likely to have prior familiarity with Mediterranean dietary habits and a baseline diet already similar to the MedDiet. Such pre-existing factors could have affected the outcomes of the interventions.
Future investigations should therefore extend to populations from non-Mediterranean regions to better assess the generalizability of the results.

The available evidence indicated that the MedDiet may positively affect certain aspects of athletic performance, as previously suggested by Griffith and colleagues in 2022 in a narrative review [41]. More recently, a systematic review examined the impact of the MedDiet on athletic performance, including both professional and non-professional athletes [46]. Their findings suggested that adherence to the MedDiet could enhance muscle endurance, power, and anaerobic performance in CrossFit athletes, and it was also associated with improvements in strength-related outcomes, such as vertical jump height, handgrip strength, and shuttle run performance. However, no meta-analysis was conducted in that review. Our review specifically focused on elite and competitive athletes, offering a more targeted evaluation of this population. Moreover, we conducted a meta-analysis, to provide a quantitative synthesis of the evidence. By including cross-sectional studies as well, our analysis reduces potential bias related to individualised dietary interventions. Importantly, our results align some of the findings reported by Bianchi et al., particularly concerning the beneficial effects of the MedDiet on strength and endurance performance [46].
The preliminary evidence suggested that adherence to the MedDiet could contribute to optimizing various aspects of performance and overall health in competitive athletes, potentially through mechanisms related to inflammation reduction and enhanced recovery.

Diets naturally rich in foods with antioxidant properties have been proposed as a strategy to counteract exercise-induced oxidative stress without impairing physiological adaptation. Regular consumption of fruits, vegetables, whole grains, legumes, and seeds, key components of the MedDiet, may represent an effective approach to meet the antioxidant demands of physically active individuals and athletes [188].

One randomised controlled trial included in our review compared three nutritional approaches on selected performance tests: (1) free diet, (2) MedDiet, and (3) Antioxidant diet. Although the diet groups showed a general trend toward improvement, no statistically significant differences were observed between them, likely due to the small sample size [181]. It is also important to recognise that the effects of antioxidant supplementation can vary depending on several factors such as type, dosage, duration of supplementation, timing in relation to exercise, and individual variability. Furthermore, a limited number of studies has specifically analysed the antioxidant effects of a specific diet on sports performance [189,190]. Further research is needed to clarify the potential influence of such diets on performance and recovery.

Furthemore, the MedDiet may serve as a functional alternative to the use of anti-inflammatory drugs in certain situations. Indeed, some of its components, particularly fish oils rich in n-3 fatty acids and specific fruits, have been shown to reduce the elevated inflammation levels that naturally occur after physical exercise [41].

Although the overall findings are encouraging, this study presents some limitations. These include the small number of eligible studies, the heterogeneity of the sports disciplines examined, the variability in study quality, potential biases linked to self-reported dietary data, and the methodological differences in assessing both adherence to the MedDiet or performance outcomes. After applying the inclusion and exclusion criteria, nine studies evaluating the effects of the MedDiet across various sports were deemed suitable for inclusion. Most of these were conducted in regions within the Mediterranean basin and focused on a range of both anaerobic and aerobic disciplines (e.g., kickboxing, canoe polo, volleyball, and ultramarathon). Moreover, the included studies employed diverse research designs and assessed a variety of outcomes using different measurement methods. This variability considerably limits the generalisability of the findings and influences the overall quality of the evidence. In particular, the main sources of high risk of bias across studies were related to the outcome measurement and the selection of the reported results. Most

studies relied on self-reported dietary information, introducing potential biases in the accuracy of nutritional data. Athletes may have altered their responses due to social desirability, thus affecting data reliability. The heterogeneity in methodologies also prevented direct comparison of the results across studies, making it difficult to establish clear and generalizable recommendations for this specific population.
Consistently, Massart et al. recently highlighted similar methodological shortcomings in their scoping review, noting substantial variability in participant demographics, athletic level, and testing protocols across studies [191].

The heterogeneity of the current findings highlights the need for further research to reach more conclusive evidence. Future investigations should employ standardised and validated dietary assessment tools to overcome existing methodological limitations and strengthen the reliability of results. Moreover, longer intervention durations are required to better elucidate the long-term effects of the MedDiet on athletic performance. Finally, exploring the physiological mechanisms underlying the relationship between diet and performance, particularly the role of specific nutrients and bioactive compounds, could provide deeper insights into how this dietary model influences athletic outcomes.

Study 2: Nutritional counseling in athletes: a systematic review
Published online at DOI: 10.3389/fnut.2023.1250567

2.1 Introduction

Ensuring adequate energy and nutrient intake in athletes is essential to achieve and maintain an optimal nutritional status, which supports peak performance and promotes effective recovery after both training sessions and competitions [72,162]. The nutritional needs of athletes depend on multiple factors such as gender, age, type of sport, training load, competitive season phase, ambient conditions (e.g., temperature, altitude), psychological stress, physical injuries, and, in females, the stage of the menstrual cycle. Therefore, athletes' dietary habits and overall diet composition should be individually tailored according to their specific performance objectives, personal preferences, and training period [72]. This process typically involves guidance from qualified nutrition experts, including Registered Dietitian Nutritionists (RDNs) or accredited sports nutritionists, depending on national regulations.

Several authors have reported that many athletes do not meet their nutritional requirements [192] and fail to achieve adequate intakes of energy [193,194], carbohydrates [195–197], and several micronutrients [194,198]. In contrast, some athletes tend to consume excessive amounts of fat [197,199,200], often exceeding the recommended levels [162], both in relation to general sports nutrition guidelines and the specific demands of their discipline. The extent of these inadequate intakes remains uncertain, partly due to potential underreporting [201–203], and is often associated with limited NK among athletes [128,204,205]). Moreover, athletes may engage in inappropriate or dysfunctional eating behaviors such as fasting, skipping meals, restrictive dieting, binge eating, vomiting, or the use of laxatives and/or diet pills [206]. Insufficient NK and disordered eating (DE) patterns within the training and competition context can lead to a condition known as LEA, defined as a mismatch between energy intake and exercise energy expenditure [207]. LEA may arise unintentionally (due to low awareness of nutritional requirements), intentionally (as an effort to optimize body composition for competition or prevent weight gain during injury or illness), or compulsively (as a result of eating disorders [EDs] or DE behaviors) [90].
One of the major health outcomes associated with LEA is REDs, a syndrome characterized by a wide range of impaired physiological functions affecting multiple systems, including

metabolic rate, menstrual function, bone health, immunity, protein synthesis, cardiovascular and gastrointestinal function, and more [86,208]. Both LEA and REDs negatively impact athletic performance and pose significant risks to an athlete's physical and mental health, making these conditions critical targets for preventive and interventional strategies [89,209].

For all these reasons, the development and application of effective and evidence-based intervention strategies are necessary to support athletes and protect their health. Bentley et al. conducted a systematic review of the main sports nutrition interventions (nutrition education, nutritional counseling, individual and group workshops, consultations), reporting that the current body of evidence is limited in its ability to determine the most effective strategy for athletes [210]. Nevertheless, several studies have shown that nutritional counseling (NC) may represent an important approach to improving athletes' dietary habits and behaviors [211–220], making this a promising area for further investigation.

NC is a structured and supportive process, characterized by a collaborative relationship between the counselor and the client(s) aimed at identifying and establishing food, nutrition, and physical activity priorities, goals, and action plans [221].

It is included in the Nutrition Care Process (NCP) model as a targeted nutrition intervention generally delivered by RDNs [221]. NC may incorporate a variety of models derived from behavior change theories. The most widely used and validated theories include cognitive behavioral theory (CBT), social cognitive theory (SCT), transtheoretical model (TM), health belief model (HBM), systemic therapy (ST), and mindfulness-based approaches. These tools and strategies may be applied independently or in combination (e.g., CBT and TM together) depending on the patients' goals, objectives, and personal skills [221,222]. NC can be delivered to both individuals and groups.

It is important to recognise NC as an intervention that is separate from nutrition education (NE). NE is a formal process designed to teach or guide a client in a skill or to impart knowledge to help them voluntarily manage or adjust food, nutrition, and physical activity choices and behaviors to maintain or improve health [221]. Focused on improving NK, its goal is to support informed food decisions at the community level or within a specific target population [121,223]. In contrast, NC is a dynamic, interactive process that actively engages the client, using their existing NK as a starting point to define and facilitate key behavioral changes. NC typically occurs within an ongoing professional relationship, where the

nutrition counselor works individually with the client over a series of personalized sessions. The role of the sports nutrition counselor is to assist athletes in identifying, adopting, and maintaining a tailored fueling strategy that optimizes training, performance, recovery, and overall well-being, while applying strategies that support nutritionally adequate, balanced eating patterns and address potential obstacles or risk factors for LEA and REDs. Both NE and NC have a place in athlete support, but the most suitable approach is one that is carefully selected by the nutrition professional based on their assessment of the nutritional evaluation, nutrition-related diagnosis, client needs, abilities, and life circumstances [221].
The role of the sports nutrition counselor is to provide guidance to individuals seeking to address various issues that they may encounter, including those related to preparation for athletic performance (e.g., maintaining energy balance according to training duration, type, and intensity), participation in competitions, or enhancing personal image. The counselor offers a new perspective aimed at helping clients overcome perceived or objective difficulties (such as fear of weight gain, inadequate nutrient intake, or injury management) and ultimately optimize athletic performance [224].

To date, no review articles have yet evaluated the application of NC in athletes. Therefore, this paper aims to systematically review the existing evidence on the use of NC among athletes and to identify the specific outcomes examined in order to characterize its overall impact.

2.2 Material and methods

This systematic review was conducted according to the PRISMA guidelines [166]. The literature search was performed across the following electronic databases: PubMed/MEDLINE, Scopus, Web of Science, ScienceDirect, and the Cochrane Library. Articles written in English or Italian were included, in line with the authors' language proficiency. No publication date restrictions were applied.
Eligible study designs encompassed randomized controlled trials, uncontrolled observational studies, case studies, case reports, case series, opinion papers, conference abstracts, theses, and dissertations. The study protocol was previously registered on the PROSPERO platform (registration number CRD42022374502).

2.2.1 Literature search

The literature search was conducted using the subject index terms "nutritional counseling" OR "nutrition counseling" OR "nutritional and eating education" OR "nutritional program" combined with the term "athletes" OR "sports" OR "performance" OR "athletic performance" OR "recreational athletes" OR "elite athletes." Google Scholar was consulted to search gray literature and relevant references cited in review articles were manually included. The populations of interest comprised recreational and elite athletes. No specific comparison conditions were defined, as the aim of this review was to evaluate the application of NC rather than to compare it with other strategies. The complete search strategy is presented in **Table 1**, while the detailed inclusion and exclusion criteria are summarized in **Table 2**.

Table 1. Search strategy for different electronic databases.

Data base	*Search strategy*	*Number or articles*
Pubmed	("Nutritional counseling" [All Fields] OR "Nutritional counselling" [All Fields] OR "Nutrition Program" [All Fields] OR "Nutritional education" [All Fields] OR "EATING education" [All Fields]) AND ("athletes" [MeSH Terms] OR "sports" [MeSH Terms] OR "athletic performance" [MeSH Terms] OR "recreational athletes" [All Fields] OR "elite athletes" [All Fields])	98
Scopus	TITLE-ABS-KEY (("Nutritional counselling" OR "Nutritional counselling" OR "Nutrition Program" OR "Nutritional education" OR "EATING education") AND ("athletes" OR "sports" OR "athletic performance" OR "recreational athletes" OR "elite athletes"))	230
Web of Science	("Nutritional counselling" OR "Nutritional counselling" OR "Nutrition Program" OR "Nutritional education" OR "EATING education") AND ("athletes" OR "sports" OR "athletic performance" OR "recreational athletes" OR "elite athletes")	79
Science Direct	("Nutritional counselling" OR "Nutritional counselling" OR "Nutrition Program" OR "Nutritional education" OR "EATING education") AND ("athlete$" OR "sports")	1948
Cochrane Library	("Nutritional counselling" OR "Nutritional counselling" OR "Nutrition Program" OR "Nutritional education" OR "EATING education") AND ("athletes" OR "sports" OR "athletic performance" OR "recreational athletes" OR "elite athletes") in Title Abstract Keyword	82

Table 2. PICOS criteria of inclusion and exclusion.

PICOS criteria	*Inclusion criteria*	*Exclusion criteria*
Population	- Recreational and elite athletes - All ages - All genders	- General population
Intervention	Nutritional Counseling strategies	No mention of dietary pattern
Comparison	Not applicable	Not applicable
Outcomes	- Adherence - Compliance rates - Nutrition knowledge - Eating disorders - REDs - Athlete triad - Injuries - Performance - Body image - Body dissatisfaction - Low energy availability - Osteopenia - Amenorrhea - Anemia and others	Not applicable
Type of Studies included	Randomized controlled trials; uncontrolled intervention studies; case study, case reports and case series, opinion articles, conference abstracts, theses, and dissertations	Full text not available; without the outcomes of interest; reviews, guidelines, letters, editorials, comments, news, in vitro or animal studies
Research question	*What evidence do we have to deliver nutritional counseling to athletes, and to impact what specific outcomes?*	

2.2.2 Study selection

The research and study selection were conducted by two authors (EP and LCLN) independently, using the Rayyan software [167], and followed a two-step process.

First, the authors screened titles and abstracts, followed by a full-text evaluation of the articles selected in the initial phase. Additionally, other potentially relevant studies identified through the reference lists of included papers were also considered.

The decision to include each article was guided by the PICOS framework: Population (P): athletes; Intervention (I): nutritional counseling; Control (C): placebo; Outcome (O): adherence/compliance rates, nutrition knowledge, eating disorders, REDs, athlete triad, injuries, performance, body image, body dissatisfaction, low energy availability, osteopenia, amenorrhea, anemia, and others; Study type (S): randomized controlled trials, uncontrolled observational studies, case studies, case reports, case series, opinion articles, conference abstracts, theses, and dissertations. When disagreements arose, a third author (SF) reviewed the full-text articles to make the final inclusion decision.

2.2.3 Study quality

The risk of bias was evaluated by two authors independently and in a blinded manner (EP and LCLN), using the RoB 2.0 Cochrane tool [168], which assesses five domains: (1) randomization process, (2) deviations from intended interventions, (3) missing outcome data, (4) measurement of the outcome, and (5) selection of the reported result. When disagreements occurred, a third author (SF) resolved the issue. This tool was applied exclusively to clinical trials, given its specific suitability for this study design and the absence of control groups in the remaining reports.

The overall quality of the evidence was assessed for all included articles using the Mixed Methods Appraisal Tool (MMAT, version 2018) [225]. Two authors (EP and LCLN) conducted the evaluation independently and blinded, and any disagreement was resolved by a third author (SF).

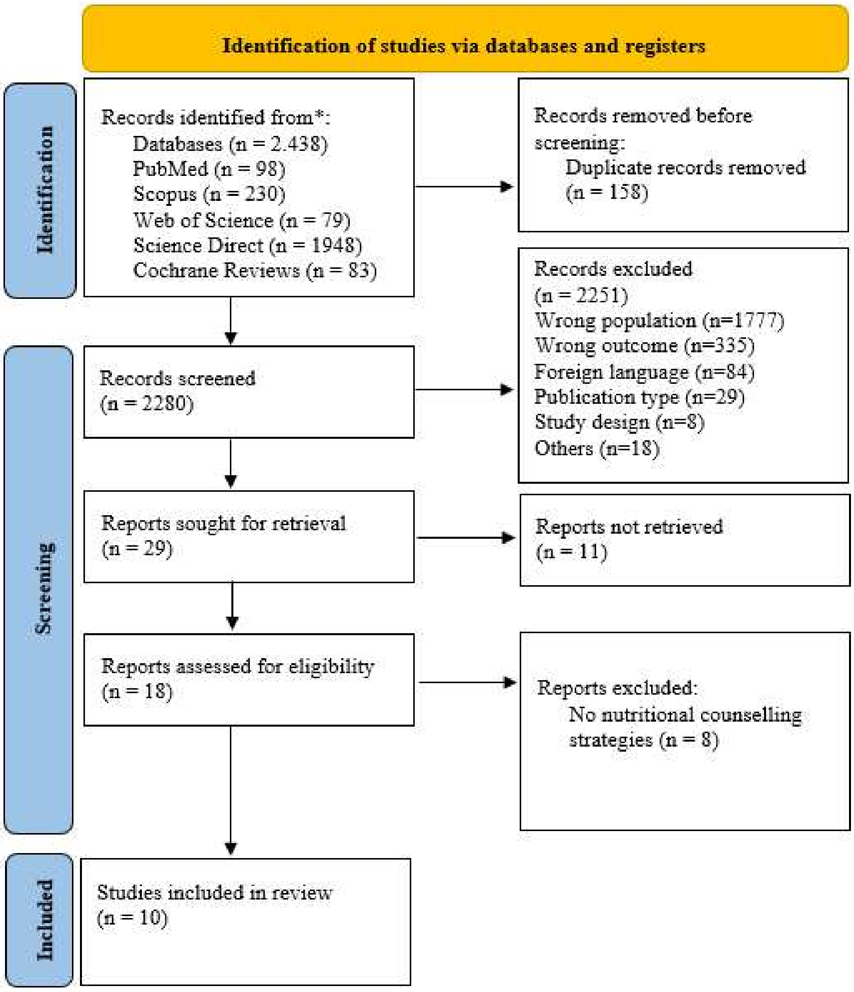
Data extraction tables were developed to summarize the key characteristics and findings of each study.

2.3 Results

A total of 2,438 records were initially identified through database searches. After duplicate removal, 2,280 unique articles remained. Following the first screening of titles and abstracts, 29 records were selected for full-text retrieval. The reasons for excluding 2,251 articles are detailed in **Figure 1**.

Eighteen full-text articles were retrieved and assessed for eligibility. After evaluation, eight articles were excluded because they did not apply nutritional counseling strategies, resulting in a total of ten studies included in this review (**Figure 1**).

Figure 1. PRISMA flow chart.



2.3.1 Study characteristics

The selected studies are summarized in **Table 3**. All were published between 2004 and 2022. Four studies originated from the United States [211,218–220], two from Norway [212,213], one from Poland [214], one from Algeria [217], one from Canada [216], and one from Finland [215].

Table 3. Included studies' details: population characteristics, type of intervention, results and quality of evidence.

Study, year, country	Design	Population characteristic	NC intervention Strategy and duration	Intervention characteristics	Outcomes	Results	Quality (MMAT)
Randomized clinical trials studies							
Abood et	Randomize	N = 30 F,	SCT -	1-h self-	Collected	Interventio	****

al., 2004, United States [211]	d cross over study	equally distributed in soccer team players (intervention group) swim team players (control group) Age, y (Mean ± SD): 19.6 ± 1.0 and 19.4 ± 1.2, respectively BMI, kg/m2 (Mean ± SD): 21.3 ± 2.4 and 21.9 ± 2.6, respectively, type of sport practiced: not specified	group counseling: Social support Problem solving Skill training/demonstration Duration: 8 sessions on weekly basis	efficacy educational sessions Professionals: not mentioned	pre and post nutrition knowledge and self-efficacy questionnaires and a 3-day diet record	n group improved: NK Self-efficacy ($p < 0.05$) Overall number of positive dietary changes ($p < 0.03$)	
Garthe et al., 2011, Norway [212]	Randomized cross over study	N = 21 elite 4F/17M athletes divided in 2 groups: NCG n = 12: 2F/10M, Age: 18.5 ± 1.7 years. ALG n = 9: 2F/7M, Age:19.6 ± 2.7 years. BMI, kg/m2 (Mean ± SD): n.d. Type of sport (%): NCG: Ice hockey (23.8), soccer	Theory-based - Group counseling Self-monitoring Duration: 8-12 week (targeted on BM gain objective)	NCG athletes received NC 1/week for 8-12 week on basic nutrition, sports physiology and possible adjustments in the dietary plan or weight regimen ALG athletes were instructed to eat ad libitum 4 strength	BW DXA Training (h per week) Diet (4-day weighed food record)	In NCG: ↑ Energy intake compared to baseline and ALG ↑ BW ↑ LBM	*****

		(9.5), skating (9.5), volleyball (4.8), taekwondo (4.8) and rowing (4.8) ALG: ice hockey (19), soccer (9.5), skating (9.5), kayaking (4.8)		training sessions/ week were included After the intervention period, all athletes received 1 NC session and 1 exercise counseling session to stabilize their new BM and body composition Professionals: 2 experienced nutritionists, one clinical dietician and one exercise physiologist specialized in sports nutrition			
Garthe et al., 2013, Norway [213]	Randomized cross over study	N = 39 elite 3F/36M athletes divided in 2 groups: NCG n = 21, 2F/19M, Age: 19.2 ± 2.9 years ALG n = 18, 1F/17M, Age: 19.7 ± 2.7 years BMI, kg/m2 (Mean ± SD): n.d. Type of	Theory-based - Group counseling and Individual diet Self-monitoring Duration: 8–12 week (targeted on BM gain objective)	NCG athletes received NC one a week for 8–12 week on basic nutrition, sports physiology and possible adjustments in the dietary plan or weight regimen + personalized diet; ALG	BW DXA Training (h per week) Diet (4-day weighed food record) Strength (1RM, 40 m sprint and CMJ)	NCG ↑ energy intake and BW FM increased more in NCG than ALG	*****

		sport (%): ice hockey (66.7), skating (12.8), rowing (2.6), kayaking (2.6), volleyball (2.6), taekwondo (2.6)		athletes were instructed to eat ad libitum 4 strength training sessions/ w were included Professionals: 2 experienced nutritionists, one clinical dietician and one exercise physiologist specialized in sports nutrition			
Grabia et al., 2022, Poland [214]	Randomized cross over study	N = 46 adolescents (n = 28 NC group; n = 18 non-education group) Gender, not mentioned Age, years (Mean ± SD): n.d. Min-Max: 14–16 years BMI, kg/m2 (Mean ± SD): n.d. Type of sport: soccer	Theory-based - Group education and counseling Problem solving Motivational interviewing Duration: 17 weeks	NC group: 7-part program consisting of sections on motivation, nutritional recommendations for young athletes, peri-exercise nutrition and hydration, supplementation, common nutritional mistakes and improper eating habits Professionals: Not mentioned	Prohealthy-Diet-Index-10 (pHDI-10) Non-Healthy-Diet-Index-14 (nHDI-14) Diet: dietary interviews from 3 days BW Blood sample analysis	In NC group: ↓ Saccharose intake ↑ Digestible carbohydrates, fiber, fluid above 2 L/day Reported by athletes better peri-workout hydration, well-being, faster regeneration	***
Heikkilä et al., 2019,	Randomized	N = 79 endurance	Self-determinat	3 sessions of	Nutrition knowledge	Both groups: ↑	****

Finland [215]	controlled trial	athletes (EDU group n = 37 18F/19M, EDU + APP n = 42 17F/25M) Age, y (Mean ± SD): 18 ± 14 BMI, kg/m2: n.d. Type of sport: cross-country skiing endurance running/race-walking biathlon, orienteering, triathlon	ion theory - Group education and counseling Skill training/demonstration Motivational interviewing Self-monitoring Goal setting Active learning Duration: 3 sessions +17-weeks follow-up	nutritional education (90 min) Professional: Nutritionist	evaluation through a validated questionnaire Diet: 3-day food diary	NK during intervention Use of the mobile app not improve the results further	
Laramée et al., 2017, Canada [216]	Cluster randomized controlled trial	N = 70 adolescent F athletes (intervention group = 37; control group = 33) Age, y (Mean ± SD): 14.1 ± 1.5 and 13.1 ± 1.2, respectively, BMI, kg/m2 (Mean ± SD): n.d. categories (%) Intervention group: underweight (8), normal weight (73), overweight	TPB - Group Counseling Persuasive communication Active learning Observational modeling Duration: 3 weeks +2-3 month follow-up	Both groups had nutrition education during 3 weekly 60-min sessions. In the intervention group a 3 sessions 60-min TPB was added, targeting the specific determinant of intention to use restrictive dietary behaviors for losing weight Professionals:	BW NK evaluation through 37 multiple choice and true/false questions Psychosocial determinants: Intention, attitude, subjective norm and perceived behavioral control.	Intervention group: ↓ intention of using restrictive dietary behaviors for losing weight over time Both groups: ↑ NK score	*****

		(19) Control group: underweight (12), normal weight (73), overweight (12), obese (3) Type of sport (%) Intervention group: synchronized swimming (87), dance (14) Control group: synchronized gymnastic (42), cheerleading (58)		Registered dietitian with formal training in the management of disordered eating and experience in working with adolescents			
Longitudinal and observational studies							
Sahnoune et al., 2020, Algeria [217]	Longitudinal study, pre and post design (no control group)	N = 80 - 39F/41M Age, year (Mean ± SD): 15 ± 1.0 BMI, kg/m2 (Mean ± SD): 20.7 ± 2.8 Type of sport (%): hand-ball (37.5); athletics (33.7); swimming (11.2); judo (8.8); basketball (8.8)	Theory-based - Individual counseling + group intervention Skill training/demonstration Duration: 6 months	6 Nutritional group intervention + face-to-face individual counseling after each workshop Professionals: Nutritionist	BW Adherence MedDiet: KIDMED index Diet: 24 h recall	Athletes increased: MedDiet adherence Energy, fiber, complex carbohydrates and protein intake	***
Stranberg et al., 2020, United	Longitudinal study, pre-post design (no	N = 15 F athletes with eating disorder	CBT, DBT, - Group and individual counseling	Minimum of 18 treatment sessions:	Anthropometric measures Eating	1.5% increase in body weight on	****

States [218]	control group)	diagnoses: OSFED (9), AN (5), BN (1) Age, y (Mean ± SD): 20.9 ± 5.2 BMI, kg/m2 (Mean ± SD): 21.4 ± 2.6 Type of sport (%): distance running (40), ball sports (27), ice hockey (13), body building (13), triathlon (7)	Goal setting Relapse prevention Self-monitoring Motivational interviewing CBT and DBT strategies Duration: Average duration was treatment was 8 weeks	6-week series of group lessons addressing mental health and nutrition for ED recovery Weekly individual sessions with the dietitian and separately with the mental health provider Professionals: Multidisciplinary team of mental health clinicians, RDN, sport psychologists, and exercise science professionals with dual training in eating disorders and sport	disorder behaviors, and compliance with meal plan and exercise prescriptions EDE-Q Satter Eating Competence Inventory (ecSI 2.0) FAST evaluation of eating disorder risk	average Decrease in EDE-Q global score and all subscale scores Increase in eating competence score and all subscores, with 1/3 of patients achieving eating competence by discharge Decrease in FAST score, with 2/3 of athletes in healthy range, 1/3 in subclinical eating disorder range, none in the clinical ED range by discharge Qualitative evidence of impact of treatment that included NC interventions	
Quatromoni, 2008, United States [219]	Case series	N = 68 (n = 25 in the first year) 49F/19M Age, y (Mean ± SD): n.d. BMI, kg/m2	CBT, Individual counseling Problem solving Motivational interviewing	Professionals: Registered dietitian with expertise in sports nutrition	FAST evaluation of eating disorder risk Self-reported height and weight for calculation	>50% of women athletes had FAST scores indicative of subclinical or clinical disordered	***

		(Mean ± SD): from 23.7 to 24.5 on average for all female subgroups, n.d. for men Type of sport: 32% lean sports (swimming, track and cross country), plus crew, basketball, ice hockey, field hockey, lacrosse, golf, soccer, softball, and tennis	Self-monitoring Journaling Goal setting Cognitive restructuring Relapse prevention Assessment of readiness to change Individualized meal plans Eating pattern advice Duration: Up to 2 years (depends on specific case)		of BMI Assessment and monitoring of nutritional adequacy	eating across a range of sports and body sizes	
Quatromoni, 2017, United States [220]	Dual case study	N = 2 athletes with eating disorder diagnoses: n = 1 F with AN n = 1 M with EDNOS Age, y (Mean ± SD): n.d. BMI, kg/m2 (T0): 16.4 (F); 20.8 (M) Type of sport: track and field	CBT and DBT-Individual counseling and education Motivational interviewing Self-monitoring CBT and DBT strategies Duration: 5 years	Female athlete Outpatient nutritional counseling and education + weekly sport psychology sessions provided CBT and DBT Male athlete Outpatient nutritional counseling and education (CBT + DB	Demographics ED onset Clinical and behavioral presentation FAST evaluation of eating disorder risk (female athlete only) Diet: 24-h dietary recalls, food records, and a diet	Both athletes: Restored weight, this allowed them to achieve sport/performance goals Achieved recovery from ED Once recovered, publicly acknowledged their ED and	***

				T) + motivational interviewing Professionals: Multi-disciplinary sports medicine team, including a registered dietitian, sport psychologist, sports medicine and athletic trainers	history interview Anthropometric measures (BW) and body composition assessment (male athlete only) Psycho-social presentation Outpatient ED treatment	how it negatively impacted their sport Maintained recovery, 7 years later Still competing at an elite level	

Abbreviations: BW, body weight; LBM, lean body mass; FM, fat mass; F, female; M, male; RDN, registered dietitian nutritionist; NK, Nutrition Knowledge; FAST, Female Athlete Screening Tool; BMI, Body Mass Index; CBT, Cognitive Behavioral Therapy; SCT, Social Cognitive Theory; NCG, Nutritional Counseling Group; ALG, Ad Libitum Group; TPB, theory of planned behavior; DXA, dual-energy X-ray absorptiometry; 1RM, one repetition maximum; CMJ, countermovement jump; ED, eating disorder; FAST, Female Athlete Screening Tool; EDE-Q, Eating Disorder Examination Questionnaire; OSFED, Other Specified Feeding or Eating Disorder; DBT, dialectical behavioral therapy; EDNOS, eating disorder not otherwise specified; EDU, education session group.

A variety of study designs were represented within the sample. Specifically, there were four randomized cross-over studies [211–214], one randomized controlled trial [215], one cluster randomized controlled trial [216], two longitudinal studies [217,218], one case series [219], and one dual case study [220]. No studies from the grey literature met the inclusion criteria.

2.3.2 Participants characteristics

The studies reported on a cumulative total of 450 participants, predominantly female (60%). One article did not provide the gender of the athletes. Sample sizes showed variation, ranging from a minimum of 2 subjects [220] to a maximum of 80 individuals [217]. Three investigations [218–220] included athletes with clinical EDs. Participants consisted of adolescent athletes, college students, elite athletes (qualified for national teams or members of a recruiting squad), and those competing at the national or international level. The sporting disciplines documented in the samples included: soccer, swimming, track and cross country, crew, basketball, ice hockey, field hockey, lacrosse, tennis, golf, rowing, volleyball, softball, taekwondo, skating, kayaking, synchronized swimming, gymnastics, dance, cheerleading, cross-country skiing, endurance running/race-walking, biathlon, orienteering, triathlon, bodybuilding, athletics, and judo.

2.3.3 Study intervention (exposures) - Nutritional counseling types, strategies and duration

Six studies [211–216] delivered group counseling, one study employed a combination of group and individual counseling [218], and three studies implemented exclusively individual counseling [217,219,220]. The specific theoretical framework of NC was detailed in only 6 articles, with three of them utilising multiple strategies [218–220]. The most commonly used was CBT [218–220], combined with Dialectical Behavioral Therapy in two studies [218,220]. Abood et al. provided NC based on SCT using self-efficacy educational sessions [211]. Laramée et al. centered their intervention on behavior change using the theory of planned behaviour targeting the specific determinant of intention to use restrictive dietary behaviors for losing weight [216]. Grabia et al. dedicated one session of the program to motivation [214]. More specifically, a total of 15 distinct strategies were applied across the interventions, as described in **Table 3**. The most frequently employed strategies included 'motivational interviewing' [214,215,218–220] and "self-monitoring" [212,213,215,218–220], followed by "problem-solving" [211,214,219], "goal setting" [215,218,219] and "skills training" [211,215,217]. Quatromoni's study used a combination of ten different strategies across the sample of athletes [219].

Eight studies reported the topics of intervention, which included caloric intake and energy expenditure, carbohydrates, fats and proteins, fluids, calcium, iron, and zinc (n=6); dietary challenges such as eating on the road (n=4); restrictive dietary behaviors and disordered eating (n=4); supplement use (n=2); Mediterranean Diet pyramid, typical athlete meal, healthy food recipes (n=1); nutritional recommendations for young athletes (n=1); peri-exercise nutrition and hydration (n=2); sports physiology and possible adjustments in the dietary plan for weight management (n=2); fueling for sport and for life, eating competence, body esteem, recovery skills, resilience (n=1). Several topics overlapped across studies, resulting in some themes appearing multiple times in the count.

The duration of the intervention and/or follow-up was highly varied. The shortest intervention period lasted 3 weeks [216], whereas the longest had a duration of 5 years [220]. Only three studies reported each session duration. In the studies by Abood et al. [211] and Laramée et al. [216], the sessions were 60 minutes long, and in the study by Heikkilä et al. [215], workshops duration was 90 minutes. In the reviewed studies, NC was delivered by a

RDN [216,219], a multidisciplinary team in which an RDN was involved [218,220], a nutritionist [215,217], or two experienced nutritionists (one clinical dietitian and one exercise physiologist with expertise in sports nutrition) [212,213]. Two studies did not specify the provider's qualifications or professional background [211,214].

2.3.4 Study results (outcomes)

The possible outcomes were categorized into questionnaire results and Nutritional Counseling efficacy, which was further divided into (1) nutrition knowledge, (2) dietary intake, and (3) remission of eating disorders.

2.3.4.1 Questionnaires

Three studies [211,215,216] administered nutrition knowledge questionnaires to evaluate differences between pre- and post-intervention scores. Three studies [218–220] administered the Female Athlete Screening Tool (FAST), which screens for athlete-specific eating disorder risk [226]. Stranberg et al. [218] also used the Eating Disorder Examination Questionnaire (EDE-Q) designed to assess the frequency and severity of eating disorder behavior [227] and the Satter Eating Competence Inventory (ecSI 2.0) which evaluates eating competence, including the ability to rebuild a healthy relationship with food, develop effective meal-planning skills, maintain consistent self-feeding, and apply informed intuitive eating [228]. Abood et al. [211] used a self-efficacy questionnaire, and Laramée et al. used a questionnaire exploring psychosocial determinants of the intention to use restrictive dietary behaviors for weight loss [216]. Anthropometric data were collected in all 10 studies. Body composition was assessed in three studies [212,213,219].

Seven studies assessed dietary intake and nutritional adequacy, using either a 3-day food record [211,215,216], a 4-day weighed food record [212,213], a 24-h dietary recall [217], a combination of multiple dietary assessment and monitoring tools [219,220], or a questionnaire that was used to compute the ProHealthy-Diet-Index-10 (pHDI-10) and the Non-Healthy-Diet-Index-14 (nHDI-14) [214]. An individualized meal plan was incorporated into the intervention in five studies [212,213,218–220].

2.3.5 Nutritional counseling efficacy

2.3.5.1 Nutrition knowledge

Three studies [211,215,216] reported an improvement in nutrition knowledge among athletes who received NC. Laramée et al. observed an increase in nutrition knowledge in both control and intervention groups, but only the intervention group showed a reduction in the intention to use restrictive dietary behaviors for weight loss [216].

2.3.5.2 Dietary intake

Results from three studies [211,214,217] indicated some measurable changes in dietary intake. Athletes showed higher adherence to the Mediterranean Diet and increased energy, fiber, carbohydrate and protein intake [217], raised their daily fluid intake above 2 liters/day, and reduced sugar consumption [214]. In the study by Abood et al. [211], the NC group significantly improved self-efficacy ($p<0.05$) and reported an overall higher number of positive dietary changes ($p<0.03$) compared to the control, which did not receive any treatment. Two studies [212,213] reported an increase in energy intake and, consequently, in body weight in the Nutritional Counseling Group (NCG), both compared to baseline and to the Ad Libitum Group (ALG), which received no NC intervention. In both studies, athletes in the NCG gained fat mass and lean body mass to a greater extent than those in the ALG.

2.3.5.3 Remission of eating disorder

From a longitudinal observational study of 15 college female athletes who underwent NC in the setting of an intensive outpatient program for the treatment of eating disorders in sport, Stranberg et al. [218] reported a reduction in the FAST score, where two thirds of athletes scored in the healthy range and only one-third scored in the subclinical eating disorder range at discharge. This was in contrast to only 32% in the healthy range, 26% subclinical, and 42% screening positive for a clinical eating disorder on admission. Further evidence of remission from the eating disorder and the achievement of normalized eating patterns was provided by this study, which showed a notable decrease in EDE-Q scores and an increase in eating competence following the intervention. While only 10% of athletes were competent eaters at admission, this proportion rose to 33% at discharge. More than half of athletes gained weight during treatment (58%).

The dual case study that applied NC to athletes with eating disorders in an outpatient setting reported successful weight restoration (evidence of nutritional adequacy) and recovery from the eating disorder, with recovery maintained seven years later following treatment by a multidisciplinary team including a registered dietitian [220].

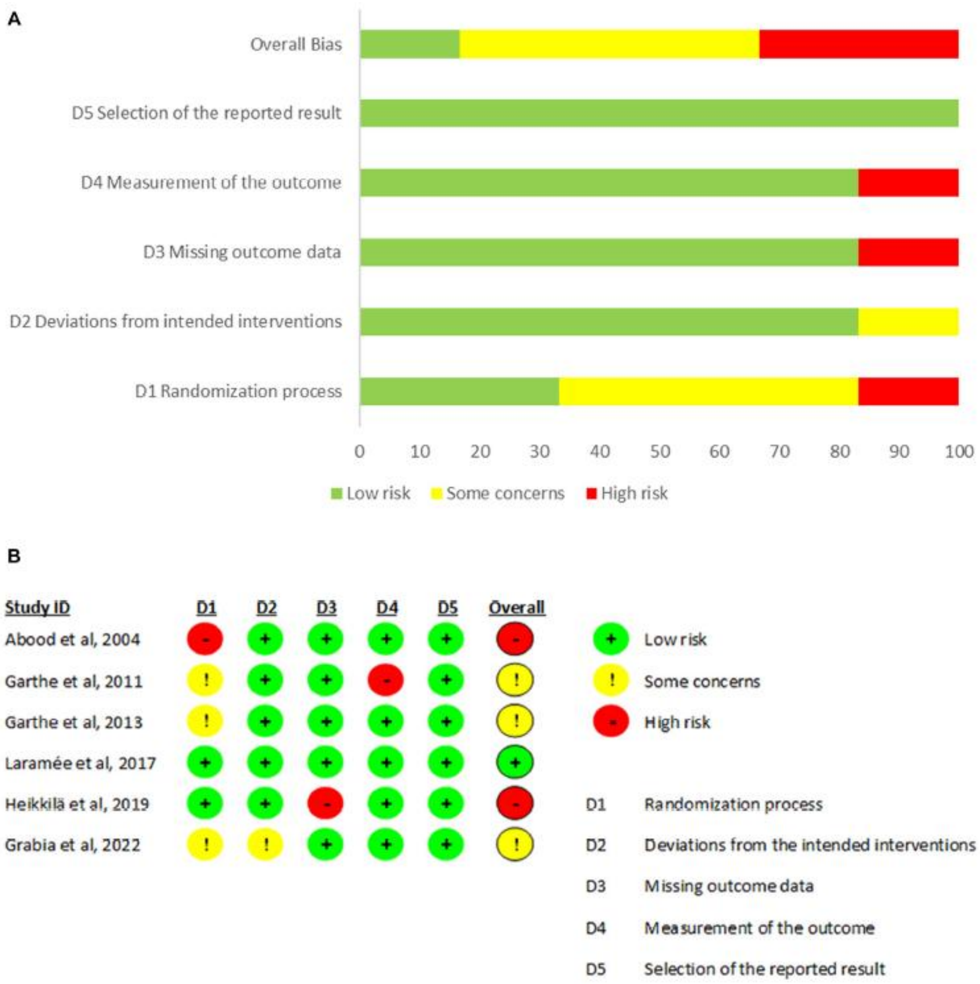
2.3.6 Study quality

The quality of evidence was examined using the MMAT system (version 2018) [225], and the corresponding results are summarised in **Table 3**. Four studies received three stars

[214,217,219,220], three studies [211,215,218] were rated with four stars, and three studies obtained the highest rating of five stars [212,213,216].

The risk of bias was evaluated using the RoB 2.0 Cochrane tool (**Figure 2**) [168] according to the study procedures for six studies [211–216]. Overall, the assessment indicated one study classified as low risk of bias [216], three studies presenting some concerns [212–214], and two studies at high risk of bias [211,215]. The randomization process emerged as the domain with the greater risk of bias. For the studies overall, the domain "selection of the reported results" was judged to be at low risk of bias. Domains 2, 3, and 4 (deviations from the intended intervention, missing outcome data, and measurements of the outcome) received low-to-moderate risk of bias score ratings for all studies, except for Garthe et al. [212] and Heikkila et al. [215] in domains 4 and 3, respectively, where the risk was considered high.

Figure 2. Results of risk of bias analysis: (A) Percentage of risk of bias of each domain in all included studies; (B) Description of each domain of bias according to studies included.



2.4 Discussion

To our knowledge, this is the first systematic review to evaluate the delivery of NC to athletes and summarize its potential effectiveness. All ten studies reviewed reported some beneficial changes in athletes' diets or eating behaviors following NC interventions. The main findings indicated that NC can promote improvements in nutrition knowledge, dietary intake (quality and/or adequacy) with potential implications for athletic performance, and can support recovery from eating disorders. While more research is warranted, these preliminary observations reinforce the importance of including qualified nutrition professionals in sport environments to ensure access to effective NC interventions.

Across the ten studies included, there was substantial heterogeneity in several key areas that influence data interpretation. Authors employed a variety of NC strategies grounded in different behavioral change theories. The duration of the counseling ranged from a few weeks to several years, and in some cases was tailored to individual clinical needs, such as treatment for REDs or ED. Most interventions involved group counseling, some combined group and individual sessions, and others relied solely on individual counseling. The populations studied were also diverse: although female athletes were more frequently represented, some studies included males, and participants varied in age, competitive level and sport type. While this gives some sense of comprehensive diversity and inclusion, it is somewhat challenging to draw definitive conclusions. Despite this heterogeneity, all of the studies reported outcomes that can be interpreted as desirable in terms of athlete nutritional status and well-being. Notably, the case report by Quatromoni et al. provided an in-depth description of outpatient treatment for two collegiate track athletes diagnosed with ED [220]. During the NC sessions, the dietitian integrated CBT, DBT, and MI strategies. Both athletes achieved weight restoration, recovered from anorexia and ED, reached their sport performance goals, and maintained recovery several years after treatment. Stranberg et al. reported similar improvements in a sample of 15 female athletes with eating disorder diagnoses [218]. Importantly, this study is the first to document the low eating competence in athletes undergoing ED treatment and to show that NC interventions targeting personal feeding skills and eating behaviors are relevant, effective, and aligned with ED recovery [218]. Similarly, the study conducted by Laramée et al. demonstrated a reduction in restrictive eating behavior among athletes who received NC [216].

Other studies documented important positive changes in athletes' NKe and dietary intake when NC was delivered by nutrition professionals [212]. It is well established that following a balanced and adequate diet plays a fundamental role in supporting health, enabling athletes to perform at high levels, and recover more efficiently from training and competition stress [72,75]. To apply sports nutrition principles, a basic knowledge of nutrition is necessary; however, knowledge alone does not always lead to behavior change and may not be sufficient for athletes to reach their full potential. The literature on NE is expanding [130,229,230], aiming to promote optimal eating patterns within the general population or specific groups such as athletes. Yet, incorporating NC alongside NE appears crucial. Recent evidence indicates that NE programs alone may be less effective in producing meaningful dietary improvements [128]. In contrast, NC combines information with individualized strategies designed to facilitate behavior change based on personal characteristics, beliefs, and goals, distinguishing it as a valuable intervention on its own.

Moreover, the sports environment frequently influences athletes' eating behaviors in ways that compromise nutritional adequacy and sabotage well-being and performance (pressure to achieve a sport-specific physique, academic demands, team culture, expectations from coaches and family, and social perceptions or norms) [231,232]. Certain sports have been more strongly associated with the onset of disordered eating and ED, such as track, cross-country, cycling, swimming, gymnastics, dance, figure skating, and judo [206]. However, other literature [233,234] indicates that ED in sport is widespread, not confined to any specific sport, gender, or body type, and often remains under-reported, under-diagnosed, and under-treated. Pressure from teammates or training groups may also contribute to the development and persistence of athletes' eating/exercise psychopathology. Both direct comments regarding weight or physique and indirect influences, such as peer modeling or exposure to social media content, appear to play a role [233,234].

For all of these reasons, an effective approach is needed to support athletes' nutritional well-being, given its important interrelationship with physical health, mental health, and sports performance. As shown by the studies included in this review, NC could represent a valuable strategy in this pursuit. From our analysis, it appears that CBT has been the most widely used NC theory. Furthermore, the most commonly adopted strategies were motivational interviewing and self-monitoring, although the importance of integrating multiple strategies also emerged.

There were some limitations in this systematic review. In addition to the heterogeneity of athlete samples and study designs, several studies did not clearly specify the type of NC techniques applied. These factors limit our ability to propose a more detailed hypothesis regarding whether (and which) specific NC theories or strategies might be more suitable or impactful, either generally or for particular subgroups of athletes. Moreover, "nutritional counseling" was not a keyword recognized within MESH terminology, which may have contributed to a possible underestimation of the number of eligible studies if some were not captured for this reason. Some reports included in this review stem from clinical practice observations, while often rich in detail and valuable for informing practice in areas where research is limited, lack the methodological rigor of randomized controlled trials specifically designed to test treatment effects of interventions such as NC. The four studies that were not clinical trials were of moderate quality and naturally carry a greater risk of bias than the RCTs. Although most of the six RCTs presented a low risk of bias across several domains, only one trial achieved an overall low risk of bias.

This review is also supported by some strengths. First, because the scientific literature on NC in athletes is still limited, this article provides the opportunity for critical reflection on this topic and a roadmap for future investigations. Second, this line of research clearly distinguishes NC from NE interventions, highlighting the added value and the unique role that nutrition professionals bring to the sports environment. Indeed, RDNs specialized in sports and human performance nutrition (i.e., sports RDNs) represent the preferred providers of NC interventions due to their extensive and varied training experiences which include clinical nutrition and medical nutrition therapy (MNT), education and behavioral counseling, food service and culinary nutrition, exercise physiology, and evidence-based nutrition guidance for physical performance [235]. Advanced training that allows the RDN to engage in screening, assessment, treatment, and prevention of REDs and eating disorders in sport is also evidenced in this review. Considering the small yet emerging literature on this topic, almost half of the studies reviewed had a minimum quality rating of four stars using the MMAT method.

2.5 Conclusion

NC induces positive, measurable behavioral effects in athletes, improving nutrition knowledge, fostering the adoption of adequate eating patterns, and supporting recovery from REDs and ED in sport. However, there is a lack of consistent research, in terms of study design, population characteristics and methodologies, involving NC provided to athletes which makes it difficult to draw evidence-based conclusions about its efficacy to improve dietary intake, eating behavior, and nutritional risk in this specific population. More studies are required to better understand the importance of NC in athletes, given the unique risks and consequences associated with poor nutrition and nutrition misinformation affecting eating behaviors. Randomized controlled trials of sufficient size and heterogeneity, including all genders and a variety of sports, are needed. In addition, future NC interventions should examine theory-based counseling methods tailored according to factors such as type of sport, level of competition, and age.

Study 3: Mediterranean Diet adherence, nutrition knowledge and lifestyle factors in physically active adults and athletes: the NUTRI_ACTIVE study

3.1 Introduction

Optimal nutrition plays a central role in supporting both physical and mental well-being. Nutritional needs vary according to age, sex, type and intensity of physical activity, health status, and other individual factors. The scientific literature highlights the importance of a varied and well-balanced diet for athletes, whose nutritional requirements are shaped by personal characteristics, food preferences, training load, sport discipline, and competitive goals [72,236]. To sustain optimal physiological function, ensure appropriate macronutrient and micronutrient intake, support body composition goals, and promote adequate recovery, athletes' diets must therefore be tailored to individual needs [72].

Adequate energy intake is fundamental to optimize training adaptations and performance. Beyond energy, appropriate consumption of carbohydrate, protein, and fat is equally essential and must be individualized and adjusted according to the athlete's training program, competitive calendar, and metabolic characteristics. Beyond energy, appropriate consumption of carbohydrate (3-10 g/day, according to the training load), protein (1.3-2.0 g/day), and fat (29-35% of the total energy intake) is equally essential and must be individualized and adjusted according to the athlete's training program, competitive calendar, and metabolic characteristics [72]. Adequate hydration is another key component, with individualized fluid plans reflecting the characteristics of the training session or competitive event [237].

Athletes' energy and nutrient requirements are influenced by numerous factors, including sex, socioeconomic status, exposure to prior nutrition education, nutrition knowledge, sport typology, training intensity and duration, and environmental conditions such as heat, cold, or altitude [122]. More specifically, NK may impact on dietary choices and eating behaviors [120,128]. According to a recent systematic review, athletes with higher NK are more likely to translate that knowledge into healthier dietary behaviors [122], although not necessarily meeting the sport-related recommendations. In fact, despite some studies suggesting that athletes can meet caloric needs through a balanced diet [76], those engaged in high-volume or high-intensity training may struggle to achieve adequate energy intake [162]. This may lead to an increased risk of LEA, a condition determining a wide range of physiological and psychological impairments, including muscle and weight loss, hormonal and menstrual dysfunction, reduced bone health, increased injury and illness risk, impaired recovery, and mental fatigue. These outcomes fall under the International Olympic Committee's framework of REDs, which shows a considerable prevalence across sports, from 23%-79.5% in females and 15%-70% in males [86].

Parallel to performance-focused recommendations, several studies have demonstrated the benefits of the MedDiet for overall health [238,239]. The MedDiet is a predominantly plant-based dietary pattern characterized by high consumption of whole grains, fruits, vegetables, legumes, nuts, herbs, spices, and olive oil, with moderate intake of fish, seafood, eggs, and dairy products, and limited consumption of red meat. Water is the main beverage, with moderate wine intake permitted with meals. This dietary pattern has been associated with reduced risk of cardiovascular disease, certain cancers, and metabolic disorders. Although the underlying mechanisms remain partly unclear, several hypotheses point to lipid-lowering effects, improved oxidative and inflammatory status, modulation of hormones and growth factors, and favorable metabolic signaling [21]. Higher adherence to the MedDiet may therefore benefit athletes by supporting health, recovery, and long-term performance [47].
In the performance context, it is important to evaluate also other non-dietary factors potentially impacting the recovery and overall health in physically active individuals and athletes. For example, adequate sleep duration and quality are essential to support cognitive function, metabolic regulation, immune function, and tissue repair, and to facilitate optimal training adaptations and performance [240,241]. Conversely, poor sleep quality and insufficient sleep have been associated with impaired performance, altered appetite regulation, increased injury risk, and negative effects on mental well-being [242]. Emerging evidence also suggests a bidirectional relationship between diet quality and sleep, with healthier dietary patterns, including higher adherence to the MedDiet [243,244]. However, data on the interaction between dietary patterns and sleep quality in athletic populations remain limited, highlighting the need for further investigation.

Given all these premises, mapping the nutritional status, dietary intake, eating behaviors, and sleep quality of physically active adults and athletes is essential to evaluate the adequacy of current lifestyle practices and to inform the development of targeted interventions. Specifically, the NUTRI_ACTIVE study primarily aims to assess adherence to the MedDiet among physically active adults and athletes. Subsequently, the project deepens into the general and sport-specific nutrition knowledge, examining dietary intake and eating behaviors, and exploring the athletes' sleep quality in relation to nutritional and sport-related characteristics.

3.2 Material and methods

This is a single-centre observational study. Participants were physically active adults and athletes contacted through local sport centres, amateur sports clubs, National Sport Federations, and the Laboratory of Nutrition Education and Sport Nutrition at the University of Pavia, Pavia, Italy, between July 2024 and October 2025. Individuals expressing interest in the project were enrolled after receiving information about the study and signing informed consent. The study was approved by the Territorial Ethics Committee Lombardia 6 - Fondazione IRCCS Policlinico San Matteo (protocol no. 0006999/24, dated 05/02/2024). The Declaration of Helsinki principles were followed when conducting this study.

3.2.1 Participants

Eligible participants were physically active adults and athletes, all genders, aged 18-65 years engaging in regular physical activity, defined as at least 150 minutes of moderate-intensity or 75 minutes of vigorous-intensity aerobic activity per week, or an equivalent combination [48]. Individuals were excluded if affected by health conditions or injuries that could influence nutritional status, metabolism or body composition.

All participants underwent a comprehensive nutrition assessment at the Laboratory of Nutrition Education and Sports Nutrition, Department of Public Health, Experimental and Forensic Medicine, University of Pavia, Pavia, Italy. Participants were screened to verify the inclusion and exclusion criteria and were classified according to the type of sport practiced: team sports, endurance, power, strength, precision, racquet sports, or combat/weight-making. Moreover, participants were categorised using the Classification Framework proposed by McKay et al. [71], which includes several levels based on training volume and performance metrics. In the present study, only Tier 1 to Tier 5 were applicable, ranging from recreationally active individuals (Tier 1) to regularly trained/developmental athletes (Tier 2), highly trained national-level competitors (Tier 3), elite international athletes (Tier 4), and world-class performers (Tier 5). The sedentary level (Tier 0), although part of the original framework, was not relevant given our inclusion criteria. Classification and participant selection were performed by trained professionals from the research team.

During a 20-30 minute interview, general information was collected, including age, gender, educational level, lifestyle and history, any previous or current nutrition interventions, and current use of dietary supplements.

3.2.2 Adherence to Mediterranean Diet

Adherence to the MedDiet was evaluated using the MEDI-LITE score [245,246]. The questionnaire consists of nine multiple-choice items, each evaluating the frequency of consumption of different food groups: (1) fruit; (2) vegetables; (3) legumes; (4) cereals; (5) fish; (6) meat and meat products; (7) dairy products; (8) alcohol and (9) olive oil. For each food group, three response options are presented, differing according to the food group (e.g. <1 portion/day, 1-1.5 portion/day and >2 portion/day for fruit; <1 portion/week, 1-2 portion/week and >2 portion/week for legumes; “occasional use”, “frequent use” and “regular use” for olive oil). For food groups typical of the MedDiet (fruit, vegetables, cereals, legumes, and fish), 2 points were assigned to the highest consumption category, 1 point to the intermediate category, and 0 points to the lowest category. On the contrary, for food groups less typical of the MedDiet (meat and meat products, dairy products), 2 points were assigned to the lowest consumption category, 1 point to the intermediate category, and 0 points to the highest consumption category. The overall MEDI-LITE score, obtained by summing the points of all food groups, ranges from 0 (low adherence) to 18 (high adherence), with an optimal cut-off set at 8.5 [245,246].

3.2.3 Nutrition Knowledge

The General and Sport Nutrition Knowledge Questionnaire (GeSNK) [133] is a validated instrument designed to assess nutrition knowledge across two domains: (1) general NK section comprises 29 items covering basic nutritional concepts, including nutrient composition, the relationship between diet and health, and principles of healthy eating; (2) sport NK section consists of 33 items addressing nutrition strategies before, during and after exercise, hydration and fluid replacement, sport supplements, and nutrition requirements related to physical activity.

Each correct answer is scored as 1 point, whereas incorrect or “I do not know” responses receive 0 points. Total scores range from 0 to 97, with higher values indicating greater nutrition knowledge. Since normative data for adults are not yet available, the classification of knowledge levels followed the scoring procedure proposed in the original validation study [133]. Specifically, we applied the percentile-based cut-offs derived from the adolescent and young adult sample as exploratory reference values: scores below the 33rd percentile were classified as low knowledge, those between the 33rd and 66th percentile as medium knowledge, and those above the 66th percentile as high knowledge. This criterion was applied to both the questionnaire's sections (General NK, Sport Nutrition NK), and the total GeSNK score.

3.2.4. Eating behaviour

In addition to the adherence to MedDiet and NK evaluation, a set of validated questionnaires was administered to assess eating-related attitudes and orthorexic traits.

The Teruel Orthorexia Scale (TOS) is a validated Italian self-report instrument designed to distinguish between two dimensions of orthorexic eating behaviour [247]. The questionnaire consists of 17 items grouped into two subscales: Healthy Orthorexia (9 items), reflecting a non-pathological interest in healthy eating, and Orthorexia Nervosa (8 items), capturing an excessive preoccupation with dietary purity that may interfere with emotional, cognitive, and social functioning. Items are rated on a 4-point Likert scale (0 = completely disagree to 3 = completely agree). Subscale scores are derived by summing the relevant items, with higher values indicating stronger endorsement of each orthorexic dimension. No specific cut-off values have been reported by the authors. The TOS is widely used in both clinical and non-clinical populations to assess maladaptive forms of health-oriented eating.

The Eating Attitudes Test-26 (EAT-26) is one of the most widely used standardized instruments for screening symptoms and concerns related to eating disorders [248]. . It comprises 26 items rated on a six-point scale, generating a total score where higher values indicate greater eating-related psychopathology. A cut-off score ≥ 20 suggests the need for further clinical evaluation. However, low scores do not necessarily exclude disordered eating, as symptom denial may occur. The questionnaire has been extensively applied in both athletic and non-athletic populations.

3.2.5 Dietary habits and intake

Dietary habits were assessed through a structured individual interview conducted by trained investigators. The interview was designed to collect qualitative information on participants' usual eating patterns and behaviors.

Specifically, data were collected on:

- number of daily meals
- breakfast consumption
- meal skipping
- regularity of meal timing
- self-reported eating speed
- frequency of eating out
- current or previous adherence to specific dietary regimens
- use of dietary supplements

Meal frequency was recorded as the average number of eating occasions per day. Breakfast consumption and meal skipping were assessed using dichotomous (yes/no) questions. Meal timing regularity was evaluated by asking participants whether meals were usually consumed at consistent times during the day. Eating speed was self-reported and categorized as slow, medium, or fast.

Eating out frequency was assessed as the number of meals consumed outside the home per week and categorized into predefined frequency classes. Participants were also asked whether they had followed a dietary regimen in the past or were currently following one at the time of the assessment. Dietary supplement use was recorded as a dichotomous variable (yes/no).

All information referred to habitual behaviors over the previous months and was collected prior to dietary intake assessment to avoid influencing participants' responses.

Participants completed a 7-day weighted food diary to obtain a detailed record of actual dietary behaviour. The diary collected information about: (1) all foods and beverages consumed, including snacks and non-caloric items (e.g., water, coffee, tea); (2) quantities in grams/milliliters or standard household measures, specifying whether weights referred to raw or cooked foods; (3) brand and specific product type; (4) timing and place of consumption; (5) added condiments (e.g., oils, cheeses, sugar, sauces); and (6) ingredients and quantities for recipes. Supplement use was also documented. EA was calculated as Energy Intake (EI) minus Exercise Energy Expenditure (EEE), normalized to FFM. EA was expressed as kcal/kg FFM/day. Participants were categorized into EA classes based on current reference thresholds. For female participants, values ≥45 kcal/kg FFM/day were considered indicative of adequate EA, values between 30 and 44.9 kcal/kg FFM/day were classified as suboptimal, and values <30 kcal/kg FFM/day were considered low EA (LEA). Given the absence of sex-specific cut-offs for men, these thresholds were applied descriptively to the whole sample. For male participants different cut-offs were applied: LEA was defined as < 9 kcal/kg FFM/day, sub-optimal EA between 9 and 25 kcal/kg FFM/day, and optimal EA as > 25 kcal/kg FFM/day [86].

Carbohydrate availability was evaluated by comparing individual daily carbohydrate intake, expressed as g/kg body weight, with sport-specific recommendations based on weekly training volume.

Reference carbohydrate requirements were defined according to guidelines for sports nutrition [72], as follows:

- 3-5 g/kg/day for individuals training 3-5 h/week,
- 5-7 g/kg/day for 5-7 h/week,
- 6-10 g/kg/day for 7-21 h/week,
- 8-12 g/kg/day for individuals training ≥4-5 h/day.

Participants whose carbohydrate intake fell below the recommended range for their respective training volume were classified as having low carbohydrate availability (LCA).

3.2.6 Sleep quality

The Pittsburgh Sleep Quality Index (PSQI) is a validated self-report measure evaluating sleep quality over the preceding month [249]. The questionnaire includes seven components: subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbance, sleep medication uses and diurnal dysfunction. These components yield a global score ranging from 0 to 21, with higher scores indicating poorer sleep quality. Specifically, sleep quality was categorised as poor if the PSQI score was ≥ 5 and good if it was < 5.

3.2.7 Physical activity level

International Physical Activity Questionnaires (IPAQ) - long form will also be administered to the participants for physical activity duration and frequency assessment in the last seven days. This questionnaire analyses five domains: 1) job-related activity; 2) transportation; 3) housework, house maintenance, caring for family 4) recreation, sport and leisure time; and 5) time spent sitting [250].

3.2.8 Anthropometric and body composition evaluation

Assessments included body weight, stature, circumferences, skinfold thicknesses, and BIA. Body weight and height were measured using a mechanical scale equipped with an integrated stadiometer. Participants were assessed barefoot and wearing light clothing. Stature was recorded with the participant standing erect, heels, buttocks, and scapulae aligned with the vertical stadiometer bar, and head positioned in the Frankfurt plane to minimize parallax error.

Two anatomical circumferences were measured using a non-elastic tape: (1) waist circumference at the umbilical level; (2) hip circumference at the level of the greater trochanters. From these measurements, the following anthropometric indices were derived: BMI (kg/m^2); Waist-to-Hip Ratio (WHR), an indicator of body fat distribution and cardiometabolic risk (values >0.8 in women and >1.0 in men); Waist-to-Height Ratio (WHtR), considered a sensitive predictor of metabolic risk (values >0.5).

Skinfold thicknesses were measured using a calibrated skinfold caliper. Eight sites (subscapular, suprailiac, biceps, triceps, axillary, pectoral, abdominal, thigh) were assessed in triplicate and the mean value was used for analysis. Body density was estimated using the [251,252]. Body density (BD) was subsequently converted to FM% using Siri's equation (FM% = (495/BD) - 450).

Whole-body composition was evaluated using a BIA 101 BIVA Pro device (Akern), a vector impedance analyzer based on a 50 kHz sinusoidal current. The tetrapolar electrode configuration (hand-foot) was applied on the right side of the body using Ag/AgCl electrodes (Biatrodes, Akern). Measurements were taken in the supine position, with limbs slightly abducted and the body isolated from conductive surfaces. The device records resistance (R) and reactance (Xc), which reflect total body water, fluid distribution, and cellular membrane integrity. Total Body BIA, estimated FFM, FM, and PhA, a marker of cell integrity and metabolic health.

Resting Energy Expenditure (REE) was measured using indirect calorimetry, considered the gold standard for assessing basal metabolic rate under fasting, thermoneutral, and fully rested conditions. The method estimates energy expenditure through oxygen consumption (VO_2) and carbon dioxide production (VCO_2), applying the Weir equation, which does not require urinary nitrogen collection. The respiratory quotient (RQ = VCO_2/VO_2) was also derived to provide qualitative information on substrate oxidation. Measurements were performed using a canopy system (Q-NRG®, COSMED, Italy). Participants fasted for at least 8 hours and were instructed to refrain from any physical activity for the 24 hours prior to the measurement. Measurements were conducted in the morning (at 8 or 9 am), with participants resting in a supine position in a quiet, thermoneutral environment to standardize the assessment. Each assessment lasted approximately 20 minutes, during which expired gases were continuously collected through a transparent canopy.

3.2.5 Statistical analysis

Descriptive statistics were used to summarize baseline characteristics of the study sample. Continuous variables are reported as mean and standard deviation, while categorical variables are presented as counts and percentages. Comparisons between groups were performed using the Student's *t*-test or analysis of variance (ANOVA) for continuous variables instead the comparison for categorical variables were tested using chi-square or Fisher's exact test. A minimum of 181 participants was estimated as necessary to determine the proportion of physically active adults with at least good adherence to the MedDiet: (MEDI-LITE score ≥ 8.5 in ~50% of the sample) with a 99% confidence level and a 10% margin of error. The calculation was based on an estimated population of approximately 40,000 active adults in the Pavia province, accounting for a 10% dropout rate. All statistical tests were two-sided, and a *p*-value < 0.05 was considered statistically significant with Stata® v.19.

3.3 Preliminary results

3.3.1 Participants characteristics

A total of 169 physically active individuals and athletes were included in the analysis. Participants had a mean age of 32.3 ± 11.9 years. The sample was composed of 52.7% females (n = 89). The majority of participants were classified as Tier 1 (n = 96, 56.8%), followed by Tier 2 (n = 42, 24.9%), Tier 3 (n = 26, 15.4%), and Tier 4 (n = 5, 3.0%). Given the sample size and the distribution of participants across multiple Tier categories, with some groups including a limited number of individuals, formal statistical comparisons between Tiers were not performed. The small cell counts would have resulted in limited statistical power and potentially misleading inferences.

Most participants resided in Northern Italy (93.5%), with a smaller proportion from Central (3.0%) and Southern regions (3.6%). Regarding marital status, 74.6% of the sample were single/unmarried while 25.4% were married. The majority of participants did not have children (84.0%).
Educational level was generally high, with 67.4% holding a university degree (bachelor, master or doctorate) and 31.4% a high school diploma. 23.1% of the sample reported a nutritional background.

Lifestyle characteristics indicated that most participants were non-smokers (85.2%), while 14.2% reported current smoking. Alcohol consumption was reported by 67.5% of the sample, with a low average intake (0.1 ± 0.2 alcohol units/day).

When stratified by Tier, sex distribution differed across groups, with a higher proportion of males observed in Tier 2 (54.8%) and Tier 3 (65.4%), while Tier 1 and Tier 4 showed a higher prevalence of females. Mean age was comparable across Tier 1, 2, and 3 (31.2 ± 10.4, 35.2 ± 13.8, and 33.5 ± 13.3 years, respectively), whereas Tier 4 participants were younger (21.7 ± 3.4 years).

Demographic characteristics of the study sample, overall and stratified by Tier, are detailed in **Table 1**.

Table 1. Demographic characteristics of the study population, overall and stratified by Tier.

Participants characteristics					
	Total *(n = 169)*	**Tier 1** *(n = 96)*	**Tier 2** *(n = 42)*	**Tier 3** *(n = 26)*	**Tier 4** *(n = 5)*
Age (years)[a]	32.3 (11.9)	31.2 (10.4)	35.2 (13.8)	33.5 (13.3)	21.7 (3.4)
Female, n (%)	89 (52.7)	58 (60.4)	19 (45.2)	9 (34.6)	3 (60.0)
Area of Residence					
North, n (%)	158 (93.5)	87 (90.6)	41 (97.6)	26 (100.0)	4 (80.0)
Center, n (%)	5 (3.0)	4 (4.2)	0 (0.0)	0 (0.0)	1 (20.0)
South, n (%)	6 (3.6)	5 (5.2)	1 (2.4)	0 (0.0)	0 (0.0)
Marital status					

Unmarried/single, n (%)	126 (74.6)	76 (79.2)	29 (69.1)	16 (61.5)	5 (100.0)
Married/partner, n (%)	43 (25.4)	20 (20.8)	13 (31.0)	10 (38.5)	0 (0.0)
Having children, n (%)	26 (16.0)	12 (13.0)	7 (17.5)	7 (26.9)	0 (0.0)
Education					
High school graduation or lower, n (%)	55 (32.6)	23 (24.0)	12 (28.6)	16 (61.5)	4 (80.0)
University degree, n (%)	106 (62.7)	69 (71.9)	26 (61.9)	10 (38.5)	1 (20.0)
Doctorate, n (%)	8 (4.7)	4 (4.2)	4 (9.5)	0 (0.0)	0 (0.0)
Nutritional background, n (%)	39 (23.1)	25 (26.0)	8 (19.0)	5 (19.2)	1 (20.0)
Smoker, n (%)	24 (14.2)	12 (12.5)	8 (19.0)	4 (15.4)	0 (0.0)
Alcohol consumption, n (%)	114 (67.5)	65 (67.7)	31 (73.8)	16 (61.5)	2 (40.0)

Abbreviations: n = number
[a]*Mean ± standard deviation*

3.3.2 Adherence to Mediterranean Diet

Adherence to the MedDiet, assessed using the MEDI-LITE score, averaged 10.6 ± 2.2 in the total sample. Similar values were observed across Tiers, with scores ranging from 9.9 ± 2.0 in Tier 3 to 10.8 ± 2.3 in Tier 2 and 10.8 ± 2.2 in Tier 4 (**Table 3**).

3.3.3 Mediterranean Diet adherence and associated variables

Associations between the MEDI-LITE score and nutritional, anthropometric, behavioral, and sport-related variables are presented in **Table 2**.

The MEDI-LITE score was significantly and positively associated with NK. Specifically, each one-unit increase in the GeSNK score was associated with a 0.04-point increase in the MEDI-LITE score (β = 0.04, 95% CI 0.02 to 0.07, $p = 0.002$). Similarly, significant positive associations were observed for General NK (β = 0.08, 95% CI 0.04 to 0.12, $p < 0.001$) and Sport NK (β = 0.09, 95% CI 0.02 to 0.16, $p = 0.009$).

No significant associations were observed between the MEDI-LITE score and eating disorder risk, orthorexic tendencies, physical activity levels, or sleep quality.

With regard to body composition, the MEDI-LITE score was positively associated with FM% (β = 0.07, 95% CI 0.02 to 0.12, $p = 0.011$), while a significant inverse association was observed with fat-free mass (FFM, kg) (β = -0.06, 95% CI -0.09 to -0.03, p < 0.001). No significant associations were found between MEDI-LITE and BMI or WHtR.

EA showed a small but statistically significant positive association with the MEDI-LITE score (β = 0.04, 95% CI 0.00 to 0.08, p = 0.045). When EA categories were considered, no significant difference in MEDI-LITE score was observed between participants with adequate EA and those with LEA (β = 0.05, 95% CI -0.78 to 0.88, p = 0.904). In contrast, participants classified as having suboptimal EA exhibited significantly lower MEDI-LITE scores compared with those with LEA (β = -1.80, 95% CI -3.49 to -0.10, p = 0.038).

No other dietary habit variables or previous dieting behaviors were significantly associated with the MEDI-LITE score.

Table 2. Associations between MEDI-LITE score and nutritional, anthropometric, and behavioral variables.

Predictor	β coefficient	95% CI		*p* value
Nutritional knowledge				
GeSNK score	0.04	0.02	0.07	**0.002**
General Nutrition	0.08	0.04	0.12	**<0.001**
Sport Nutrition	0.09	0.02	0.16	**0.009**
Eating behavior and lifestyle				
HeOr	-0.02	-0.09	0.05	0.527
OrNe	0.02	-0.07	0.12	0.632
EAT-26	-0.01	-0.07	0.06	0.847
IPAQ	-0.00	-0.00	0.00	0.697
PSQI	-0.03	-0.18	0.11	0.645
Anthropometry and body composition				
BMI (kg/m²)	-0.02	-0.14	0.09	0.702
Mean FM (%)	0.07	0.02	0.12	**0.011**
FFM (kg)	-0.06	-0.09	-0.03	**<0.001**
WHtR below-threshold vs above-threshold	-0.20	-0.98	0.57	0.608
Eating habits				
Breakfast consumption	-0.92	-2.49	0.65	0.251
Skipping meals	0.21	-0.65	1.06	0.637
Consumption of irregular meals	0.18	-0.56	0.91	0.631
Previous dieting	-0.24	-0.93	0.45	0.491
Currently following a nutrition plan	-0.92	-1.86	0.02	0.056
Energy availability	0.04	0.00	0.08	0.045
Adequate vs inadequate	0.05	-0.78	0.88	0.904
Sub-optimal vs adequate	-1.80	-3.49	-0.10	0.038

Abbreviations: GeSNK = General and Sport Nutrition Knowledge Questionnaire; HeOr = Healthy Orthorexia; OrNe = Orthorexia Nervosa; EAT-26 = Eating Attitude Test-26; PSQI = Pittsburgh Sleep Quality Index; BMI = Body Mass Index ; kg = kilograms; m = meters ; FM = Fat Mass; FFM = Fat Free Mass; WHtR = Waist-to-Height Ratio

3.3.4 Nutrition knowledge

In the overall sample, the mean GeSNK score was 72.8 ± 14.9, with comparable values observed across Tiers, ranging from 70.2 ± 19.1 in Tier 2 to 78.1 ± 8.4 in Tier 3. General NK showed a mean score of 49.4 ± 7.8 in the total sample, with slightly higher values in Tier 3 (51.3 ± 6.9) and lower values in Tier 4 (41.8 ± 6.3). Sport-specific NKe averaged 24.7 ± 4.8 overall and tended to increase across TIERs from 24.1 ± 5.2 in Tier 1 to 26.8 ± 3.0 in Tier 3, while lower values were observed in Tier 4 (23.4 ± 5.5) (**Table 3**).

3.3.5 Eating behavior

Eating behaviors were evaluated using the TOS and EAT-26 questionnaires. In the total sample, mean HeOr score was 14.4 ± 5.0, with higher values observed in Tier 3 (16.4 ± 5.9) compared with the other Tiers. OrNe scores were generally low across the sample, with a mean value of 4.8 ± 3.6, showing minimal variation across Tiers. The EAT-26 score averaged 4.4 ± 5.2 in the total sample, with slightly higher values in Tier 3 (5.1 ± 4.9) and lower values in Tier 4 (2.6 ± 1.7) (**Table 3**). Only 4 participants reported EAT-26 score over the cut-off for increased risk of eating disorder (2.4%).

Table 3. Questionnaires result in the whole sample e and stratified by Tier.

Questionnaires					
	Total *(n = 169)*	**Tier 1** *(n = 96)*	**Tier 2** *(n = 42)*	**Tier 3** *(n = 26)*	**Tier 4** *(n = 5)*
Adherence to the Mediterranean Diet					
MEDI-LITE	10.6 (2.2)	10.7 (2.2)	10.8 (2.3)	9.9 (2.0)	10.8 (2.2)
Nutrition knowledge					
GeSNK	72.8 (14.9)	72.9 (14.2)	70.2 (19.1)	78.1 (8.4)	65.2 (11.6)
General Nutrition	49.4 (7.8)	49.6 (8.1)	48.7 (7.2)	51.3 (6.9)	41.8 (6.3)
Sport Nutrition	24.7 (4.8)	24.1 (5.2)	25.2 (4.2)	26.8 (3.0)	23.4 (5.5)
Eating behaviour					
HeOr	14.4 (5.0)	14.2 (4.4)	13.9 (5.8)	16.4 (5.9)	13.4 (2.9)
OrNe	4.8 (3.6)	5.0 (3.7)	4.6 (3.5)	4.8 (3.4)	3.8 (3.1)
EAT-26	4.4 (5.2)	4.3 (5.3)	4.4 (5.4)	5.1 (4.9)	2.6 (1.7)
Sleep quality					
PSQI	3.8 (2.4)	3.7 (2.3)	4.0 (3.2)	4.1 (1.7)	3.2 (1.1)

Abbreviations: n = number; GeSNK = General and Sport Nutrition Knowledge Questionnaire; HeOr = healthy orthorexia; OrNe = orthorexia nervosa, EAT-26 = Eating Attitudes Test-26; PSQI = Pittsburgh Sleep Quality Index

[a]*Mean ± standard deviation*

3.3.6 Dietary habits

Dietary habits were assessed through a structured individual interview and are summarized for the whole sample and by Tier (**Table 4**).

Overall, participants reported consuming an average of 4.3 ± 0.9 meals per day, with similar values across all Tiers.

The majority of the sample reported regular breakfast consumption (94.7%, n = 160), although 65.7% reported consuming meals at irregular times. 16.6% of the sample reported skipping meals. Eating speed was predominantly reported as medium (36.7%) or fast (47.3%), whereas only 16.0% reported eating slowly.

Eating out frequency varied considerably, with 26.3% of participants reporting eating out twice per week. Higher frequencies (≥3 times/week) were reported by approximately 13.8% of the sample.

Regarding dietary practices, 52.7% of participants reported having followed a diet in the past, while 36.5% were currently following a dietary regimen.

The use of dietary supplements was reported by 55.6% of participants, with a higher prevalence observed in higher Tier groups (100.0% in Tier 4).

Table 4. Dietary habits of the sample population and stratified according to Tier.

Dietary habits					
	Total *(n = 169)*	**Tier 1** *(n = 96)*	**Tier 2** *(n = 42)*	**Tier 3** *(n = 26)*	**Tier 4** *(n = 5)*
Meal pattern					
Number of meals per day[a]	4.3 (0.9)	4.3 (0.9)	4.3 (1.1)	4.4 (0.9)	4.2 (0.4)
Regular breakfast consumption, n (%)	160 (94.7)	90 (93.8)	40 (95.2)	25 (96.2)	5 (100.0)
Skipping meals, n (%)	28 (16.6)	17 (17.7)	6 (14.3)	5 (19.2)	0 (0.0)
Irregular meal timing, n (%)	58 (34.3)	32 (33.3)	15 (35.7)	10 (38.5)	1 (20.0)
Eating speed, n (%)					
Slow	27 (16.0)	12 (12.5)	11 (26.2)	3 (11.5)	1 (20.0)
Moderate	62 (36.7)	42 (43.8)	12 (28.6)	5 (19.2)	3 (60.0)
Fast	80 (47.3)	42 (43.8)	19 (45.2)	18 (69.2)	1 (20.0)
Eating out frequency, n (%)					
≤1 time/week	100 (59.9)	59 (61.5)	23 (56.1)	13 (52.0)	5 (100.0)
2 times/week	44 (26.3)	25 (26.0)	10 (24.4)	9 (36.0)	0 (0.0)
≥3 times/week	23 (13.8)	12 (12.5)	8 (19.5)	3 (12.0)	0 (0.0)
Currently following a nutrition plan, n (%)	31 (36.5)	17 (40.5)	9 (37.5)	2 (13.3)	3 (75.0)

Supplement use, n (%)	94 (55.6)	47 (49.0)	23 (54.8)	19 (73.1)	5 (100.0)
Abbreviations: n = number [a]*Mean ± standard deviation*					

3.3.7 Dietary intake

Dietary information was available only for 141 individuals. Dietary intake was assessed through the 7-day food diary and is detailed in **Table 5**. Most participants followed an omnivorous diet (95.0%), with only a small proportion reporting vegetarian (3.5%) or vegan (1.4%) dietary patterns.

Mean daily energy intake for the whole sample was 2131.7 ± 508.2 kcal/day, with higher values observed in Tier 2 and 3 participants. EA, expressed as kcal/kg FFM/day, averaged 31.3 ± 8.6 kcal/kg FFM/day in the total sample. EA differed across Tier classifications, with lower values observed in participants belonging to higher Tiers (26.1 ± 11.0 kcal/kg FFM/day in Tier 3; 23.4 ± 17.6 kcal/kg FFM/day in Tier 4).

Mean protein intake was 96.3 ± 27.9 g/day, corresponding to 1.4 ± 0.4 g/kg body weight and 18.1 ± 3.9% of total energy intake. Protein intake increased progressively across Tiers, reaching the highest values in Tier 4 participants.

Mean carbohydrate intake was 284.2 ± 79.4 g/day, accounting for 50.2 ± 5.2% of total energy intake and 4.1 ± 1.2 g/kg body weight. Participants in higher Tiers reported higher absolute and relative carbohydrate intakes, consistent with greater training volumes. Mean fat intake was 72.5 ± 19.7 g/day, corresponding to 30.7 ± 4.4% of total energy intake. Saturated fat intake accounted for 9.8 ± 2.3% of energy intake, while polyunsaturated and monounsaturated fatty acids contributed 4.1 ± 0.9% and 14.7 ± 11.5%, respectively.

Mean fiber intake was 27.7 ± 7.6 g/day, while cholesterol intake averaged 223.2 ± 77.5 mg/day.

Mean daily water intake from beverages was 2.2 ± 0.7 L, with higher values observed in higher Tiers.

Mean daily intakes of micronutrients are specified in **Table 5**.

Table 5. Daily energy and nutrient intake assessed by the 7-day food diary (n=141)

Dietary intake (7-day food diary)					
	Total (n = 141)	Tier 1 (n = 83)	Tier 2 (n = 35)	Tier 3 (n = 21)	Tier 4 (n = 2)
Dietary pattern, n (%)					
Omnivorous diet	134 (95.0%)	77 (92.8%)	35 (100.0%)	20 (95.2%)	2 (100.0%)
Vegetarian diet	5 (3.5%)	4 (4.8%)	0 (0.0%)	1 (4.8%)	0 (0.0%)

Vegan diet	2 (1.4%)	2 (2.4%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Total energy intake (kcal/day)[a]	2131.7 (508.2)	2006.3 (408.7)	2290.6 (527.6)	2366.2 (668.5)	2098.7 (785.8)
Energy availability (kcal/kg FFM/day)[a]	31.3 (8.6)	32.8 (8.0)	31.2 (6.5)	26.1 (11.0)	23.4 (17.6)
Low EA, n (%)	25 (17.2)	12 (14.0)	6 (17.1)	6 (27.3)	1 (50.0)
Sub-optimal EA, n (%)	75 (51.7)	52 (60.5)	14 (40.0)	8 (36.4)	1 (50.0)
Adequate EA, n (%)	45 (31.0)	22 (25.6)	15 (42.9)	8 (36.4)	0 (0.0)
Proteins (g/die)[a]	96.3 (27.9)	90.3 (24.7)	100.3 (31.1)	111.2 (29.3)	116.7 (18.8)
Proteins (g/kg)[a]	1.4 (0.4)	1.3 (0.3)	1.4 (0.4)	1.5 (0.5)	1.9 (0.3)
Proteins (%)[a]	18.1 (3.9)	18.0 (3.3)	17.5 (4.4)	19.2 (4.2)	24.3 (12.3)
Carbohydrates (g/die)[a]	284.2 (79.4)	268.8 (61.4)	301.3 (84.7)	316.5 (111.0)	281.7 (172.1)
Carbohydrates (%)[a]	50.2 (5.2)	50.4 (4.3)	50.0 (6.5)	49.6 (5.8)	48.0 (12.7)
Carbohydrates (g/kg)[a]	4.1 (1.2)	3.9 (1.0)	4.3 (1.1)	4.2 (1.5)	4.6 (2.8)
Low CHO availability, n (%)	88 (60.7)	42 (48.8)	25 (71.4)	20 (90.9)	1 (50.0)
Sugar (g/die)[a]	82.3 (26.6)	78.8 (22.8)	87.0 (25.9)	90.0 (35.5)	58.9 (62.8)
Sugar (%)[a]	14.6 (3.7)	14.9 (3.8)	14.4 (3.5)	14.0 (2.9)	9.1 (7.8)
Fats (g/die)[a]	72.5 (19.7)	68.5 (15.7)	78.8 (24.3)	78.6 (22.8)	69.3 (16.7)
Fats (%)[a]	30.7 (4.4)	30.7 (4.1)	31.2 (4.8)	30.1 (5.2)	30.5 (4.2)
SFA (%)[a]	9.8 (2.3)	9.7 (2.2)	10.1 (2.5)	9.4 (2.1)	11.7 (2.6)
PUFA (%)[a]	4.1 (0.9)	4.0 (0.8)	4.4 (1.3)	4.0 (0.7)	4.5 (0.4)
MUFA (%)[a]	14.7 (11.5)	13.9 (2.0)	13.6 (2.7)	19.7 (28.9)	13.1 (1.9)
Fiber (g/die)[a]	27.7 (7.6)	27.8 (7.5)	27.3 (8.0)	28.3 (7.1)	21.7 (14.6)
Cholesterol (mg/die)[a]	223.2 (77.5)	219.2 (67.8)	230.7 (106.7)	226.5 (61.7)	221.5 (48.8)
Vit. A (µg)[a]	737.1 (428.1)	712.5 (411.3)	806.1 (504.7)	733.1 (379.6)	620.5 (266.5)
Vit. B9 (folic acid) (µg)[a]	388.0 (109.4)	390.7 (103.9)	381.0 (126.1)	388.6 (108.3)	391.6 (122.6)
Vit. B12 (cyanocobalamin) (µg)[a]	3.4 (1.3)	3.4 (1.1)	3.5 (1.7)	3.6 (1.3)	4.4 (0.2)
Vit. C (ascorbic acid) (mg)[a]	227.0 (167.1)	213.2 (164.1)	259.8 (170.4)	227.1 (179.7)	257.1 (120.3)
Calcium (mg)[a]	734.7 (201.5)	712.1 (178.4)	765.5 (236.1)	775.4 (217.4)	708.5 (362.7)
Phosphorus (mg)[a]	1480.6 (393.0)	1451.8 (374.7)	1396.8 (379.9)	1714.5 (420.8)	1594.7 (352.6)
Potassium (mg)[a]	3204.5 (659.8)	3119.4 (626.5)	3241.7 (742.8)	3484.7 (618.2)	3087.1 (298.5)

Sodium (mg)[a]	1862.6 (614.3)	1801.7 (546.0)	1863.5 (679.0)	2132.7 (711.6)	1461.5 (606.0)
Iron (mg)[a]	12.8 (3.6)	12.4 (3.0)	12.3 (3.4)	14.8 (5.3)	14.4 (1.6)
Zinc (mg)[a]	10.6 (3.4)	10.1 (3.1)	10.7 (3.7)	12.0 (3.7)	13.2 (6.3)
Copper (mg)[a]	0.9 (0.4)	0.8 (0.4)	0.9 (0.5)	1.0 (0.4)	0.7 (0.6)
Water from beverage (L)[a]	2.2 (0.7)	2.1 (0.7)	2.3 (0.7)	2.2 (0.6)	3.8 (0.8)
Abbreviations: n = number; kcal = kilocalories; kg = kilograms; g = grams; EA = Energy Availability; FFM = Fat Free Mass; SFA = Saturated Fatty Acids; PUFA = Polyunsaturated Fatty Acids; MUFA = Monounsaturated Fatty Acids; L = litres [a]*Mean ± standard deviation*					

3.3.8 Sleep quality

The mean PSQI score in the overall sample was 3.8 ± 2.4. Comparable values were observed across Tier classifications, with scores of 3.7 ± 2.3 in Tier 1, 4.0 ± 3.2 in Tier 2, 4.1 ± 1.7 in Tier 3, and 3.2 ± 1.1 in Tier 4 (**Table 2**).

3.3.9 Physical activity

Physical activity and sport-related characteristics of the study population, overall and stratified by Tier, are reported in **Table 6.** Participants practiced a mean of 2.0 ± 0.9 sports, with 31.4% reporting participation in a single sport, 44.4% in two sports, and 24.2% in three or more sports. Multisport participation increased across Tier classifications, with Tier 3 and Tier 4 showing a higher proportion of individuals engaged in three or more sports compared with Tier 1 and 2.

Regarding sport type, a wide range of disciplines was represented. In the overall sample, strength, endurance, and team-based sports were the most frequently reported primary sport categories, followed by power, racquet, combat, precision, and other sports. The distribution of sport types differed across Tiers, with Tier 1 participants more frequently engaged in recreational and fitness-oriented activities, while Tier 2 and Tier 3 showed a higher prevalence of endurance- and power-based sports.

Training volume increased progressively across Tiers. Mean weekly training volume in the total sample was 7.1 ± 3.7 h/week, ranging from 5.3 ± 2.4 h/week in Tier 1 to 8.5 ± 3.1 h/week in Tier 2, 9.6 ± 3.8 h/week in Tier 3, and 15.4 ± 6.5 h/week in Tier 4. Average daily training time followed a similar trend, with values of 0.8 ± 0.3 h/day in Tier 1, 1.2 ± 0.4 h/day in Tier 2, 1.4 ± 0.5 h/day in Tier 3, and 2.2 ± 0.9 h/day in Tier 4.

Training frequency also differed across Tiers. In the overall sample, participants reported 5.2 ± 2.3 training sessions per week, with mean values increasing from 4.4 ± 1.9 sessions/week in Tier 1 to 9.5 ± 0.6 sessions/week in Tier 4.

Previous sport-related injuries were reported by 40.5% of the total sample. The prevalence of injuries increased across Tier classifications, from 31.6% in Tier 1 to 42.9% in Tier 2, 57.7% in Tier 3, and 100% in Tier 4.

The overall IPAQ score was 8253.4 ± 5470.0 MET·min/week, indicating high levels of physical activity in the study population. When stratified by Tier, IPAQ scores increased progressively from 6767.2 ± 3047.2 MET·min/week in Tier 1 to 9677.0 ± 7878.6 in Tier 2, 10,793.0 ± 6507.4 in Tier 3, and 12,876.2 ± 5102.6 MET·min/week in Tier 4 (**Table 5**).

Table 6. Physical activity profile, overall and stratified by Tier.

Physical activity					
	Total *(n = 169)*	**Tier 1** *(n = 96)*	**Tier 2** *(n = 42)*	**Tier 3** *(n = 26)*	**Tier 4** *(n = 5)*
Mitchell classification, n (%)					
Low intensity	21 (12.4)	20 (20.8)	0 (0.0)	1 (3.8)	0 (0.0)
Moderate intensity	77 (45.6)	50 (52.1)	20 (47.6)	6 (23.1)	1 (20.0)
High intensity	71 (42.0)	26 (27.1)	22 (52.4)	19 (73.1)	4 (80.0)
Number of sport practiced, n (%)					
1	53 (31.4)	40 (41.7)	9 (21.4)	4 (15.4)	0 (0.0)
2	75 (44.4)	47 (49.0)	19 (45.2)	7 (26.9)	2 (40.0)
≥ 3	41 (24.2)	9 (9.3)	14 (33.4)	15 (57.5)	3 (60.0)
Primary sport type, n (%)					
Strength	64 (37.9)	61 (63.5)	2 (4.8)	1 (3.8)	0 (0.0)
Endurance	49 (29.0)	17 (17.7)	16 (38.1)	15 (57.7)	1 (20.0)
Team	20 (11.8)	3 (3.1)	15 (35.7)	2 (7.7)	0 (0.0)
Power	6 (3.6)	1 (1.0)	1 (2.4)	1 (3.8)	3 (60.0)
Racquet	5 (3.0)	4 (4.2)	1 (2.4)	0 (0.0)	0 (0.0)
Combat	4 (2.4)	2 (2.1)	2 (4.8)	0 (0.0)	0 (0.0)
Precision	10 (5.9)	0 (0.0)	5 (11.9)	4 (15.4)	1 (20.0)
Other	11 (6.5)	8 (8.3)	0 (0.0)	3 (11.5)	0 (0.0)
Training volume[a]					
Weekly training volume (h/week)	7.1 (3.7)	5.3 (2.4)	8.5 (3.1)	9.6 (3.8)	15.4 (6.5)
Daily training volume (h/day)	1.0 (0.5)	0.8 (0.3)	1.2 (0.4)	1.4 (0.5)	2.2 (0.9)

Training frequency (times/week)	5.2 (2.3)	4.4 (1.9)	5.9 (2.6)	6.2 (1.8)	9.5 (0.6)
IPAQ (MET-min/week)	8253.4 (5470.0)	6767.2 (3047.2)	9677.0 (7878.6)	10793.0 (6507.4)	12876.2 (5102.6)
Injury history, n (%)					
Previous sport-related injuries	68 (40.5%)	30 (31.6%)	18 (42.9%)	15 (57.7%)	5 (100.0%)
Abbreviations: n = number; h = hours; IPAQ = International Physical Activity Questionnaires; min = minutes [a]*Mean ± standard deviation*					

3.3.10 Anthropometry and body composition

Anthropometric characteristics and body composition parameters of the study population, overall and stratified by Tier, are reported in **Table 7**.

In the overall sample, mean body mass was 70.7 ± 12.4 kg, mean height was 1.7 ± 0.1 m, and mean BMI was 23.7 ± 2.9 kg/m², with comparable values across Tier classifications. Body composition assessment revealed a mean body fat percentage of 18.6 ± 6.6% estimated from skinfold measurements and 22.4 ± 7.3% assessed by bioelectrical impedance analysis. When considering the average value derived from both methods, mean FM percentage was 20.5 ± 6.6%, with progressively lower values observed across increasing Tiers (from 21.8 ± 6.8% in Tier 1 to 18.3 ± 5.2% in Tier 4). Accordingly, FM expressed in kilograms decreased across Tiers, while FFM increased. Women showed a significantly higher FM percentage compared to men (24.3 ± 6.0% vs 16.3 ± 4.2%; $p < 0.001$), while men exhibited greater FFM both in absolute and relative terms ($p < 0.001$).

Indicators of central adiposity showed that most participants were not at cardiometabolic risk, with 79.9%, 82.2%, and 74.0% classified as not at risk according to waist circumference, WHR, and WHtR, respectively. The prevalence of at-risk classifications tended to decrease in higher Tiers.

Bioelectrical parameters indicated a mean phase angle of 6.4 ± 0.7° in the overall sample, with slightly higher values observed in higher Tiers.

Resting metabolic rate measured by indirect assessment averaged 1621.2 ± 315.7 kcal/day, with higher values in participants classified in Tier 3.

Table 7. Anthropometric and body composition characteristics of the study population

Anthropometric and body composition					
	Total *(n = 169)*	**Tier 1** *(n = 96)*	**Tier 2** *(n = 42)*	**Tier 3** *(n = 26)*	**Tier 4** *(n = 5)*
Body mass (kg)[a]	70.7 (12.4)	69.7 (12.5)	70.9 (13.9)	74.5 (9.8)	67.4 (6.6)
Height (m)[a]	1.7 (0.1)	1.7 (0.1)	1.7 (0.1)	1.8 (0.1)	1.7 (0.0)

BMI (kg/m²)[a]	23.7 (2.9)	23.8 (3.2)	23.3 (2.9)	24.1 (2.1)	22.8 (1.7)
BMI distribution, n (%)					
Underweight	4 (2.4)	2 (2.1)	2 (4.8)	0 (0.0)	0 (0.0)
Normal weight	114 (67.5)	63 (65.6)	29 (69.0)	18 (69.2)	4 (80.0)
Overweight	47 (27.8)	27 (28.1)	11 (26.2)	8 (30.8)	1 (20.0)
Obesity	4 (2.4)	4 (4.1)	0 (0.0)	0 (0.0)	0 (0.0)
Body composition					
FM% (skinfold)[a]	18.6 (6.6)	19.6 (6.7)	18.1 (6.6)	16.2 (5.8)	15.9 (5.4)
FM% (BIA)[a]	22.4 (7.3)	23.8 (7.5)	20.8 (6.8)	20.5 (6.7)	20.7 (5.7)
Mean FM%[a]	20.5 (6.6)	21.8 (6.8)	19.4 (6.2)	18.3 (6.0)	18.3 (5.2)
FM (kg)[a]	14.6 (5.8)	15.3 (6.1)	13.8 (5.9)	13.5 (4.5)	12.2 (3.1)
FFM (kg)[a]	56.1 (10.8)	54.5 (10.6)	57.0 (11.6)	61.0 (9.9)	55.2 (7.9)
FFM %[a]	79.5 (6.6)	78.2 (6.8)	80.6 (6.2)	81.7 (6.0)	81.7 (5.2)
Rz[a]	530.5 (69.0)	542.7 (71.1)	524.0 (62.6)	496.6 (61.4)	528.2 (69.1)
Xc[a]	59.9 (7.1)	60.5 (7.7)	60.0 (6.6)	57.0 (4.7)	62.0 (6.6)
PhA°[a]	6.4 (0.7)	6.3 (0.8)	6.5 (0.6)	6.5 (0.7)	6.6 (0.6)
Central adiposity indices					
Waist circumference adobe the cut-off, n (%)	34 (20.1)	23 (24.0)	7 (16.7)	4 (15.4)	0 (0.0)
WHR above the cut-off, n (%)	30 (17.8)	19 (19.8)	8 (19.0)	2 (7.7)	1 (20.0)
WHtR above the cut-off, n (%)	44 (26.0)	27 (28.1)	11 (26.2)	6 (23.1)	0 (0.0)
Resting energy expenditure (kcal/day)[a]	1630.1 (316.8)	1579.8 (308.1)	1674.6 (343.3)	1718.4 (275.7)	1772.2 (354.0)

Abbreviations: n = number; kcal = kilocalories; kg = kilograms; m = meters; BMI = Body Mass Index; FM = Fat Mass; FFM = Fat Free Mass; Rz = Resistance; Xc = Reactance ; WHR = Waist-to-Hip ; WHtR = Waist-to-Height Ratio

[a]*Mean ± standard deviation*

3.4 Discussion

The NUTRI_ACTIVE study provides a comprehensive overview of MedDiet adherence, nutritional status, dietary intake, eating behaviors, and NK in a sample of physically active adults and athletes of different disciplines and training levels. The study population was characterized by a relatively young age, a high educational level, and generally health-oriented lifestyle habits, including low smoking prevalence and low alcohol consumption. These characteristics likely influenced both the overall dietary patterns observed and the low prevalence of dysfunctional eating behaviors in the sample, and should be considered when interpreting the findings.

Overall adherence to the MedDiet was moderate (10.6 ± 2.2) and showed limited variability across participants from different Tiers. Despite marked differences in training volume, physical activity levels, and sport typology, MedDiet adherence did not significantly differ between recreationally active individuals and higher-level athletes. This finding suggests that increasing athletic involvement does not necessarily translate into greater adherence to a high-quality dietary pattern. Similar findings have been reported in previous studies conducted in athletic populations, including those living in Mediterranean countries, where adherence to the MedDiet generally appears to be moderate rather than optimal [161,253–255]. For instance, Costantino and colleagues reported that less than half of physically active individuals adhered to the core principles of the MedDiet [256] , while the systematic review by Calella et al. highlighted that most studies in sport settings describe a medium level of adherence, despite more favorable patterns compared with inactive controls [45]. Athletes frequently prioritize performance-oriented nutritional strategies, such as macronutrient distribution and timing, which may not fully align with traditional dietary patterns [257].

One of the most consistent findings of this study is the positive association between MedDiet adherence and NK, including general, sport-specific, and overall knowledge scores. Although a small increase in the MEDI-LITE score is reported, these results support previous evidence indicating that higher NK is associated with better diet quality and healthier food choices [122,128]. Interestingly, NK scores were relatively high across all Tiers, with only small differences between groups. This may reflect the high educational level of the sample and the widespread availability of nutrition information among physically active individuals. However, the modest strength of these associations suggests that NK alone may not be sufficient to ensure optimal dietary patterns, particularly in athletic populations.

In the present study, the interpretation of EA is better supported by prevalence data rather than by mean values. Given the well-documented sex-specific thresholds for EA, average values calculated in mixed-sex samples may obscure clinically relevant conditions, particularly in populations characterized by heterogeneous training loads and body composition profiles. Further analyses stratified by sex may help to clarify potential differences in the distribution of EA categories and their associations with dietary patterns, an aspect that warrants specific investigation in future studies.

When EA was categorized using sex-specific cut-offs, a substantial proportion of participants were classified as having low or suboptimal EA. This finding is consistent with previous literature reporting a high prevalence of inadequate EA among physically active individuals and athletes, even in the absence of overt signs of disordered eating/eating disorders or low body weight [86,258,259]. This suggests that EA may be influenced not only by food choices but also by dietary timing, portion size, and performance-driven nutritional strategies, which may partially explain the complex relationship observed between EA and adherence to healthy dietary patterns in athletic populations.

In line with this interpretation, the analysis based on EA categories revealed that participants classified as having suboptimal EA exhibited significantly lower MEDI-LITE scores compared with those with LEA, whereas no significant differences were observed between participants with adequate and LEA. This counterintuitive result may reflect compensatory dietary behaviors, whereby individuals with LEA maintain relatively higher diet quality but insufficient overall energy intake. Alternatively, athletes with suboptimal energy availability may adopt more restrictive or performance-focused dietary strategies that reduce adherence to the MedDiet. These findings highlight the complexity of the relationship between diet quality and energy intake in athletic populations and underscore the importance of evaluating both dietary patterns and quantitative intake when assessing nutritional adequacy.

Overall scores for eating disorder risk and orthorexic tendencies were low in the present sample, with slightly higher values observed in participants from intermediate Tiers. These results indicate a generally low prevalence of disordered eating behaviors in this cohort of physically active adults and athletes. This observation aligns with the heterogeneity reported in the literature, where prevalence estimates of eating disorders in athletic populations vary widely according to sex, sport discipline, and competitive level. Available data suggest prevalence ranges from 0% to 19% in male athletes and from 6% to 45% in female athletes, with higher values observed in aesthetic and endurance sports compared with the general population [260]. For instance, a recent cross-sectional study on adult athletes in Italy and Lebanon reported a higher risk of eating disorder, assessed using the EAT-26 questionnaire, equal to 6.1% in Italian athletes (7.8% females, 4.9% males) and 21.3% in Lebanese athletes (27.3% females, 17.0% males) [261].

In the present study, no significant associations were found between MEDI-LITE score and either eating disorder risk or orthorexic tendencies. These findings suggest that adherence to this dietary pattern was not accompanied by any modification in the risk of maladaptive eating behaviors in physically active individuals and athletes. This is consistent with results reported by Muros and colleagues in a large sample of Spanish cyclists and triathletes, where MedDiet adherence did not predict the likelihood of disordered eating, despite other demographic and behavioral factors being significant predictors [262]. In contrast, Martinovic et al. observed a significant negative correlation between MedDiet adherence and ORTO-15 scores in both professional ($r = -0.365$, $p < 0.001$) and recreational ($r = 0.309$, $p < 0.001$) athletes, suggesting that higher adherence to a Mediterranean-style dietary pattern was associated with greater orthorexic tendencies [161]. Conversely, studies conducted in non-athletic populations have suggested a potential protective role of the MedDiet against the incidence of eating disorders, including anorexia and bulimia nervosa [263]. Differences in study populations, assessment tools, and outcome measures likely contribute to these inconsistent findings. In the present study, eating disorder risk and orthorexic tendencies were assessed using self-reported screening questionnaires, which capture risk and behavioral tendencies rather than clinically diagnosed disorders. Moreover, the overall low scores observed across the sample limited the variability required to detect significant associations.

The relatively low scores observed may reflect the recreational or sub-elite nature of most participants, as well as the known limitations of self-reported instruments, which are susceptible to underreporting and social desirability bias [260]. Longitudinal and sport-specific studies are therefore warranted to clarify whether adherence to specific dietary patterns influences the development of eating disorders or orthorexia over time, particularly in high-risk subgroups such as female athletes involved in aesthetic or endurance sports [206].

Sleep quality, assessed using the PSQI, was generally good across all Tiers, with no significant differences observed between groups. The lack of association between dietary pattern quality and sleep quality contrasts with findings from general population studies, where Mediterranean-style diets have been linked to better sleep outcomes [244,264]. In athletic populations, however, sleep quality is influenced by multiple sport-specific factors, such as training schedules, competition stress, and travel demands, which may attenuate potential dietary effects.

Several limitations of the present study should be acknowledged. First, the cross-sectional design does not allow causal inferences to be drawn regarding the relationships between MedDiet adherence, EA, NK, eating behaviors, and sleep quality. Although significant associations were identified, longitudinal or intervention studies are required to clarify the directionality of these relationships. Second, dietary intake and eating habits were assessed using self-reported methods, including a 7-day food diary and structured interviews. While the 7-day diary is commonly used in sports nutrition research and allows detailed assessment of habitual intake, self-reporting is inherently subject to recall bias, misreporting, and social desirability bias, particularly in physically active individuals and athletes who may be more aware of nutritional recommendations. In addition, under-reporting of energy intake may have influenced the estimation of EA, potentially leading to misclassification in EA categories. Third, the assessment of EA itself represents a methodological challenge. Despite the use of indirect calorimetry to assess resting energy expenditure, EA was estimated using indirect measures of energy intake and exercise energy expenditure, which may introduce error. Moreover, although sex-specific cut-offs were applied, EA remains a dynamic construct that can fluctuate substantially across training cycles, competition periods, and recovery phases. A single assessment period may therefore not fully capture chronic exposure to low or suboptimal EA. Fourth, the study population was predominantly composed of young and highly educated individuals residing in Northern Italy, which may limit the generalizability of the findings to other geographic regions, age groups, or populations with different socioeconomic backgrounds. Additionally, although participants were classified across different Tiers, the relatively small number of individuals in the highest Tier reduced statistical power for comparisons involving elite athletes and may have limited the detection of Tier-specific associations. Given the recruitment strategy and sample characteristics, the findings of this study are primarily applicable to physically active adults and athletes engaged in structured sport settings, and may be less generalizable to different sociocultural contexts. Fifth, sleep quality was assessed using the Pittsburgh Sleep Quality Index, a validated and widely used questionnaire. However, subjective measures of sleep may not fully reflect objective sleep parameters such as sleep duration, efficiency, or fragmentation. The generally good sleep quality observed in the sample may have limited the ability to detect meaningful associations with dietary patterns.

Despite its cross-sectional design, the present study offers several strengths that enhance the interpretation and relevance of the findings. A key strength is the comprehensive assessment of nutritional and lifestyle factors within a single cohort of physically active adults and athletes. By evaluating MedDiet adherence, dietary habits and intake, energy and carbohydrate availability, NK, eating behaviors, sleep quality, and sport participation characteristics, the study provides an integrated picture that reflects the complexity of real-world sport nutrition contexts. Another important strength is the inclusion of participants across different competitive Tiers. This approach allows dietary behaviors and nutritional risk factors to be interpreted along a continuum of sport involvement. Finally, the assessment of EA, combined with the evaluation of carbohydrate availability based on sport-specific recommendations, strengthens the clinical and practical relevance of the findings. Collectively, these elements support the robustness of the study and contribute novel insights into the relationship between dietary patterns, nutritional adequacy, and health-related behaviors in physically active populations.

3.5. Conclusions

The findings of the NUTRI_ACTIVE study highlight the importance of addressing both dietary quality and energy adequacy in physically active individuals and athletes. Nutrition interventions should aim to integrate MedDiet principles with sport-specific fueling strategies, rather than treating these approaches as mutually exclusive.

Future studies should adopt longitudinal or interventional designs to evaluate whether targeted nutrition education can improve dietary pattern quality while maintaining adequate EA. Further research exploring sport-specific and sex-specific differences may also contribute to more tailored and effective nutritional recommendations.

Study 4: Sex-related differences in nutritional habits, eating behaviour, lifestyle factors and body composition in physically active Italian adults: insights from the NUTRI_ACTIVE study

4.1 Introduction

Over the past century, women's participation in sport has increased, while sports nutrition research has still focused mostly on male participants. This male-centric approach has led to a limited understanding of the physiological and nutritional needs of female athletes, who have often been treated as an afterthought/reconsideration in scientific studies [265]. Over the last decade, it has also become clearer that sex and gender are often poorly considered in sports nutrition research: a large review of more than 2500 papers showed that many studies did not even report the sex or gender of participants, and that the two terms were frequently confused [265]. Supporting women in achieving optimal performance requires recognising that there are still clear sex and gender gaps in sports nutrition research, largely driven by a historical bias towards male participants, which has limited the understanding of the specific physiological and nutritional needs of female athletes [265]. Many of the nutritional guidelines are still extrapolated from studies conducted primarily in men, with limited consideration of the sex-specific biological differences that may influence performance, recovery and health. Addressing these disparities is crucial in order to ensure that recommendations are appropriate, inclusive, and reflective of the diverse physiological responses observed across sexes. Only when research is designed and interpreted for both women and men nutritional recommendations can truly optimize performance and reduce injury risk for all athletes [265].

There are distinct physiological differences between men and women that go beyond anatomy, affecting how the body manages heat, fatigue, recovery, and energy use. Since female athletes train and compete through every stage of the menstrual cycle, it is important to understand how these hormonal fluctuations impact metabolism and performance, so that nutrition can be tailored more precisely. Estrogen plays a central role regulating body composition and energy metabolism, and its natural variations can directly affect how a woman's body responds to exercise [266]. In addition to these physiological and hormonal aspects, there are also clear differences in body composition: men usually have higher lean body mass and a higher basal metabolic rate compared to women [266].

While much of the existing literature has traditionally centred on male participants, this focus has not always translated into a comprehensive understanding of male-specific health and performance issues. An evident example is the case of the *Female Athlete Triad:* for decades it was conceptualised exclusively as a condition affecting women, with its components, low energy availability, menstrual dysfunction, and impaired bone health, described through a female-specific lens [267]. As a result, the male equivalent of these issues remained largely unexamined. It was only in recent years that the broader concept of REDs was introduced, recognising that low energy availability can affect both women and men, with consequences for metabolic function, endocrine balance, bone health, immunity, and performance [208]. This shows that men have also been under-investigated in critical areas of sports science, highlighting the need for research that considers health risks in both sexes.

Despite the increasing recognition of these disparities, studies comparing nutritional habits, lifestyle behaviours, and body composition across male and female physically active individuals within specific cultural contexts, such as the Italian population, remain limited.
The aim of the present study is to explore sex-related differences among physically active Italian males and females in relation to their nutritional habits, eating behaviour, lifestyle parameters and body composition.

4.2 Material and methods

This single-centre observational study is part of a wider project, named NUTRI-ACTIVE, which involved 169 physically active adults and athletes recruited through local sport centers, amateur sports clubs, National Sport Federations, and the Laboratory of Nutrition Education and Sport Nutrition at the University of Pavia, Pavia, Italy. The recruitment and data collection period took place between July 2024 and October 2025. Eligible individuals expressing interest in the project were enrolled in the study only after receiving information regarding the protocol and signing a written informed consent. The study was approved by the Territorial Ethics Committee Lombardia 6 - Fondazione IRCCS Policlinico San Matteo (protocol no. 0006999/24, dated 05/02/2024) and was conducted in accordance with the principles of the Declaration of Helsinki.

Participants

Participants were considered eligible if they engaged in regular physical activity defined as at least 150 minutes of moderate-intensity or 75 minutes of vigorous-intensity aerobic activity per week, or an equivalent combination thereof. Only individuals from both sexes and aged 18 to 65 years old were included. The only exclusion criterion was the existence of any health conditions or injuries that could affect nutritional status, metabolism, or body composition.

Procedures

At the Laboratory of Nutrition Education and Sport Nutrition (Department of Public Health, Experimental and Forensic Medicine, University of Pavia, Italy) each participant had a nutritional evaluation. Eligible individuals were categorized by sport discipline: team sports, endurance, power, strength, precision, racquet sports, or combat/weight-making after being screened for inclusion and exclusion criteria. Additionally, McKay et al.'s Participant Classification Framework [71] was used to classify the participants. Recreationally active (Tier 1), regularly trained/developmental athletes (Tier 2), highly trained/national level (Tier 3), elite/international level (Tier 4), and world-class (Tier 5) were the five categories used for this study. By design, Tier 0 (sedentary) was not included. Trained research staff carried out the classification and selection processes.

A 20-to-30-minute individual interview was used to gather general information such as sociodemographic information (age, gender, educational level, occupation), lifestyle factors, and specific eating habits (e.g., number of daily meals, frequency of eating out, eating speed, alcohol consumption, and difficulties preparing meals). Weight history, past or present nutritional interventions, were also noted.

Various questionnaires were used to investigate behavioral and lifestyle aspects in addition to MedDiet adherence and NK.

The MEDI-LITE score [245,246] was used to assess adherence to MedDiet. The questionnaire consists of nine multiple-choice items, each evaluating the frequency of consumption of different food groups: (1) fruit; (2) vegetables; (3) legumes; (4) cereals; (5) fish; (6) meat and meat products; (7) dairy products; (8) alcohol and (9) olive oil. The total MEDI-LITE score, which is calculated by adding the points from each food group, has a cut-off point of 8.5 and ranges from 0 (low adherence) to 18 (high adherence).

The General and Sport Nutrition Knowledge Questionnaire (GeSNK), a validated tool developed by Calella et al. [133] was used to assess nutrition knowledge. Two separate domains compose the questionnaire: general NK (29 items) covers fundamental nutritional concepts, whereas sport NK section (33 items) addresses nutrition strategies, hydration and nutritional needs associated with physical activity. In particular, the percentile-based cut-offs was applied derived from the adolescent and young adult sample as exploratory reference values: scores below the 33rd percentile were classified as low knowledge, those between the 33rd and 66th percentile as medium knowledge, and those above the 66th percentile as high knowledge for the general nutrition section, the sport nutrition section, and the total GeSNK score.

The TOS [247], a 17-item questionnaire that distinguishes Healthy Orthorexia (non-pathological interest in healthy eating) and Orthorexia Nervosa (pathological preoccupation), was used to assess orthorexic features. No specific cut-off has been proposed for this questionnaire.

The EAT-26 [248] was used to screen for eating disorder symptoms; a score $\geq$ 20 indicated the need for clinical evaluation.

The PSQI [249] was used to evaluate sleep patterns throughout the previous month. Participants were classified as having poor sleep quality if their global score was $\geq$ 5.

The frequency and duration of physical activity during the previous seven days were measured using the IPAQ - Long Form [250]. The tool examines activity in five areas: work-related, transportation, domestic tasks, leisure, and sitting.

Anthropometric and body composition analysis

Participants wore light clothing and were barefoot when basic anthropometric measurements were taken. A mechanical scale with an integrated stadiometer was used to measure height and weight, making sure the head was in the Frankfurt plane. A non-elastic tape was used to measure the mid-upper arm, waist at umbilical level, and hip. BMI, WHR, and WHtR have all been calculated. Eight sites (subscapular, suprailiac, biceps, triceps, axillary, pectoral, abdominal, thigh) were assessed for skinfold thicknesses using a calibrated skinfold caliper.

The Jackson and Pollock 7-site equation was used to estimate body density and Siri's equation was then used to determine the FM%.

A BIA 101 BIVA Pro device (Akern) with a tetrapolar electrode arrangement and a frequency of 50 kHz was used to measure whole-body composition. In order to determine bodily compartments such as FFM, FM, total body water (TBW), intra and extracellular water (ICW/ECW) and PhA as a measure of cellular integrity, R and Xc were measured.
Resting Energy Expenditure was measured via indirect calorimetry using a canopy system (Q-NRG®, COSMED, Italy) following a strict protocol in order to standardize the assessment: at least 8-hour fasting, 24-hour abstinence from exercise, and 20 minutes of supine rest in a thermoneutral environment. Energy expenditure was calculated using the Weir equation on gas exchange data (VO_2 and VCO_2), and qualitative information on substrate oxidation was obtained by deriving the respiratory quotient (RQ).

Dietary habits and intake assessment

The participants filled out a seven-day weighted food diary. This record keeps track of the precise amounts of all foods, beverages, and supplements, including specific brands, cooking techniques, condiments, recipes, and timing of intake.
EA was calculated as EI minus EEE, normalized to FFM. EA status was classified according to the most recent International Olympic Committee consensus statement on REDs, applying sex-specific thresholds to reflect different physiological tolerance to low energy availability. For female participants, EA was categorized based on established guidelines: LEA for values < 30 kcal/kg FFM/day; sub-optimal EA for values between 30 and 45 kcal/kg FFM/day; and optimal EA for values > 45 kcal/kg FFM/day. For male participants, considering evidence that symptoms of REDs manifest at lower energy levels, different cut-offs were applied: LEA was defined as < 9 kcal/kg FFM/day; sub-optimal EA between 9 and 25 kcal/kg FFM/day; and optimal EA as > 25 kcal/kg FFM/day [86].

Statistical analysis

Comparisons between male and female participants were performed using the Student's *t*-test for continuous variables, instead for categorical variables were compared using the chi-square test or Fisher's exact test. All statistical tests were two-sided, and a *p*-value < 0.05 was considered statistically significant with Stata® v.19.

4.3 Preliminary results

4.3.1 Sample characteristics

A total of 169 physically active adults and athletes were enrolled in the study, including 89 females (52.7%) and 80 males (47.3%). The mean age of the total sample was 32.3 ± 11.9 years. Most participants were single (71.0%), while 25.4% were married or cohabiting, and 84.0% reported having no children. The majority of participants resided in Northern Italy, predominantly in the Lombardy region (74.0%).

The sample was highly educated, with 62.7% holding a university degree and 4.7% a PhD or post-graduate specialization, while 31.4% held a high school diploma. The majority of participants (76.9%) reported no formal education in nutrition-related fields. A significantly higher proportion of women reported a formal academic background in nutrition-related disciplines compared with men ($p = 0.002$).

No statistically significant sex differences were observed for region of residence ($p = 0.32$), educational level ($p = 0.14$), or occupation ($p = 0.27$), indicating a homogeneous cultural and occupational background. Conversely, marital status differed significantly between sexes ($p = 0.031$).

Concerning lifestyle habits, the majority were non-smokers (85.2%). With respect to alcohol consumption, 35.5% of the sample reported abstaining from alcohol, 40.8% reported drinking 1-2 times per week, 15.4% less than once a week, and 6.5% 3-4 times per week. Smoking habits differed significantly between sexes ($p = 0.011$), with a higher prevalence of smoking among men (21.0%) compared to women (8.0%). No significant sex differences were observed in alcohol consumption patterns ($p = 0.18$).

In the female subsample, 31.5% reported experiencing the absence of a menstrual cycle for at least 3 months at least once in their life. The mean age at the onset of this condition was 20.3 ± 6.6 years, with a mean duration of 14.7 ± 14.5 months.

Analysis of sleep patterns using the PSQI revealed a mean global score of 3.8 ± 2.4 for the total sample, suggesting that, on average, the study population reported good sleep quality (score < 5). No significant sex differences were observed in PSQI scores (3.9 ± 2.7 for women vs 3.8 ± 2.1 for men; $p = 0.79$).

4.3.2 Sport practice characteristics

The most frequently practiced activity was gym/fitness training (33.3%), followed by swimming (9.5%), beach volleyball (8.9%), volleyball (7.1%), and running (6.5%). According to the athlete classification framework proposed by McKay et al. [71], most participants were recreationally active (Tier 1: 56.8%), followed by regularly trained/developmental athletes (Tier 2: 24.9%), highly trained/national-level athletes (Tier 3: 15.4%), and a small proportion of elite/international-level athletes (Tier 4: 3.0%).

Overall, 40.8% of participants reported participating in competitions, and 40.5% reported having experienced sport-related injuries. Regarding physical activity volume, the mean energy expenditure reported via the IPAQ questionnaire was 8253.4 ± 5470.0 MET-min/week.

The distribution across athlete classification tiers did not differ significantly between sexes ($p = 0.073$), nor did participation in competitions ($p = 0.12$) or history of sport-related injuries ($p = 0.90$). However, the type of sport practiced differed significantly ($p = 0.002$): women were more frequently engaged in gym/fitness activities (39.0% vs 27.0%) and running (9.0% vs 4.0%), whereas men reported higher participation in beach volleyball (13.0% vs 6.0%), swimming (11.0% vs 8.0%), and cycling (9.0% vs 0.0%).

Regarding physical activity levels assessed by the IPAQ, men reported significantly higher volumes of activity compared to women (10325.6 ± 6608.3 vs 6518.6 ± 3479.4 MET-min/week; $p < 0.001$).

4.3.3 Dietary habits and eating behaviour

The majority followed an omnivorous diet (95.0%), with similar proportions observed between males (96.7%) and females (93.8%). Vegetarian and vegan diets represent a small minority; notably, the vegan diet was present only in the female group (2.5%) and absent in the male group (0.0%).

Regarding weight management, 59.2% reported stable body weight over the previous year, whereas 27.8% reported weight gain and 13.0% weight loss. More than half of the sample (52.7%) reported having followed a diet in the past, most commonly hypocaloric (43.0%), followed by normocaloric regimens (20.3%). Participants reported consuming an average of 4.3 ± 0.9 meals per day. Breakfast consumption was highly prevalent (94.7%), with significantly greater proportions in females. Most participants (81.7%) reported not skipping meals. However, 53.8% of the sample reported experiencing episodes of emotional hunger triggered by anxiety or stress. No significant sex differences were observed regarding having followed diets in the past (p = 0.73) or currently following a specific dietary regimen (p = 0.24). Eating speed differed markedly between sexes (p < 0.001), with 70.0% of men classified as fast eaters compared to 27.0% of women. Conversely, women reported a significantly higher prevalence of emotional hunger related to anxiety or stress compared to men (64.0% vs 43.0%; p = 0.005). Trends of significance were retrieved in skipping meals and supplements use, with males reporting an increased frequency compared to females. Dietary habits for the total sample, as well as for female and male participants, are detailed in **Table 1**.

Table 1. Dietary habits in the total sample and differences between sexes.

Dietary habits				
	Total *(n = 169)*	**Female** *(n = 89)*	**Male** *(n = 80)*	**p-value**
Meal pattern				
Number of meals per day[a]	4.3 (0.9)	4.3 (0.9)	4.3 (1.1)	1.000
Regular breakfast consumption, n (%)	160 (94.7)	88 (98.9)	72 (90.0)	**0.010**
Skipping meals, n (%)	28 (16.6)	10 (11.2)	18 (22.5)	0.073
Irregular meal timing, n (%)	58 (34.3)	29 (32.6)	29 (36.2)	0.620
Eating speed, n (%)				**<0.001**
Slow	27 (16.0)	20 (22.5)	7 (8.8)	
Moderate	62 (36.7)	45 (50.6)	17 (21.2)	
Fast	80 (47.3)	24 (27.0)	56 (70.0)	
Eating out frequency, n (%)				0.470
≤1 time/week	100 (59.2)	53 (59.6)	47 (58.8)	
2 times/week	44 (26.0)	26 (29.2)	18 (22.5)	
≥3 times/week	23 (13.6)	9 (10.1)	14 (17.5)	
Not reported	2 (1.2)	1 (1.1)	1 (1.2)	
Currently following a nutrition plan, n (%)	31 (36.5)	19 (42.2)	12 (30.0)	0.240
Supplement use, n (%)	94 (55.6)	44 (49.4)	50 (62.5)	0.088
Abbreviations: n = number [a]*Mean ± standard deviation* p-values refer to differences between females and males.				

The mean EAT-26 score for the total sample was 4.4 ± 5.2, with no significant difference observed between women (4.7 ± 5.5) and men (4.1 ± 4.7). Regarding the Test for Orthorexia Nervosa (TOS), the mean score for the healthy dimension (*TOS healthy*) was 14.4 ± 5.0 in the total sample, with values of 13.8 ± 4.6 in women and 15.2 ± 5.4 in men. The orthorexia nervosa dimension (*TOS nervosa*) averaged 4.8 ± 3.6 overall, with women scoring 5.3 ± 4.1

and men 4.3 ± 2.8. Adherence to the MedDiet, assessed via the MEDI-LITE questionnaire, showed a mean score of 10.6 ± 2.2 for the whole sample. A significant difference was found between sexes ($p < 0.001$), with women reporting higher adherence scores (11.2 ± 2.2) compared to men (9.9 ± 1.9).

4.3.4 Dietary intake

The dietary intake analysis, assessed via a 7-day food diary, was conducted on the total sample (n=141) and subsequently stratified by gender into females (n=81) and males (n=60) and is detailed in **Table 2**.

As expected, for total energy intake (mean value 2131.7 ± 508.2 kcal/day), a gender difference was reported: men report a significantly higher caloric intake (2483.2 kcal/day) compared to women (1858.3 kcal/day).

Assessment of EA showed that only 31.0% of participants were classified as having optimal EA, while 51.7% were classified as having sub-optimal EA and 17.2% as having LEA. A marked sex-related difference emerged in EA according to the IOC consensus framework ($p < 0.001$). The majority of men (70.3%) were classified as having optimal EA (>25 kcal/kg FFM/day), whereas no women (0.0%) reached the sex-specific threshold for optimal EA (>45 kcal/kg FFM/day). Conversely, 72.8% of women were classified as having sub-optimal EA and 27.2% as having LEA (<30 kcal/kg FFM/day), a condition associated with increased risk of REDs-related health and performance consequences. In contrast, only 4.7% of men were classified as having LEA (<9 kcal/kg FFM/day).

Significant sex-related differences emerged in macronutrient intake. Men reported a significantly higher absolute protein intake compared with women (113.4 ± 26.5 vs. 83.0 ± 21.0 g/day), while protein intake relative to body weight was comparable between sexes (1.4 ± 0.4 vs. 1.3 ± 0.4 g/kg). Similarly, absolute carbohydrate intake was significantly higher in men than in women (330.5 ± 83.6 vs. 248.2 ± 53.6 g/day), whereas carbohydrate intake expressed per kilogram of body weight did not differ between sexes (4.1 ± 1.3 vs. 4.0 ± 1.1 g/kg). Total fat intake was also significantly higher in men than in women (83.0 ± 22.3 vs. 64.4 ± 12.4 g/day); however, fat contribution to total energy intake was similar between sexes (30.3 ± 4.9% in men and 31.1 ± 4.1% in women). Saturated fatty acid intake did not differ between groups, accounting for approximately 10% of total energy intake in both sexes. Sugar intake, expressed as percentage of total energy intake, was significantly higher in women compared with men (15.0 ± 3.4% vs. 14.0 ± 3.9%), whereas fiber intake did not differ between sexes (28.1 ± 7.3 g/day in women and 27.1 ± 8.1 g/day in men). Finally, cholesterol intake was significantly higher in men than in women (254.4 ± 85.3 vs. 198.9 ± 61.1 mg/day). As per micronutrients intake, females reported significantly lower intake of calcium (702.5 ± 190.8 vs. 776.1 ± 208.7 mg/day), phosphorus (1412.7 ± 334.5 vs. 1567.9 ± 445.1 mg/day), potassium (3075.5 ± 640.1 vs. 3370.4 ± 652.5 mg/day), sodium (1699.2 ± 502.9 vs. 2072.5 ± 681.4 mg/day), zinc (9.5 ± 2.5 vs. 11.9 ± 3.9 mg/day), copper (0.8 ± 0.4 vs. 1.0 ± 0.4 mg/day) compared with men.

In addition, daily water intake differed significantly between sexes, with women reporting lower consumption than men (2.1 ± 0.6 vs. 2.4 ± 0.9 litres/day).

Table 2. Daily energy and nutrient intake assessed by the 7-day food diary.

Dietary intake (7-day food diary)				
	Total *(n = 141)*	**Female** *(n = 81)*	**Male** *(n = 60)*	**p-value**
Total energy intake (kcal/day)[a]	2131.7 (508.2)	1858.3 (299.2)	2483.2 (506.8)	**<0.001**
Energy availability (kcal/kg FFM/day)[a]	31.3 (8.6)	33.1 (7.7)	29.0 (9.2)	**0.004**
Energy availability distribution				**<0.001**
Low EA, n (%)	25 (17.2)	22 (27.2)	3 (4.7)	
Sub-optimal EA, n (%)	75 (51.7)	59 (72.8)	16 (25.0)	
Adequate EA, n (%)	45 (31.0)	0 (0.0)	45 (70.3)	
Proteins (g/die)[a]	96.3 (27.9)	83.0 (21.0)	113.4 (26.5)	**<0.001**
Proteins (g/kg)[a]	1.4 (0.4)	1.3 (0.4)	1.4 (0.4)	0.260
Proteins (%)[a]	18.1 (3.9)	17.9 (4.1)	18.4 (3.6)	0.520
Carbohydrates (g/die)[a]	248.2 (79.4)	248.2 (53.6)	330.5 (83.6)	**<0.001**
Carbohydrates (%)[a]	50.2 (5.2)	50.4 (5.2)	49.9 (5.2)	0.550
Carbohydrates (g/kg)[a]	4.1 (1.2)	4.0 (1.1)	4.1 (1.3)	0.600
Low CHO availability, n (%)	88 (60.7)	45 (55.6)	43 (67.2)	0.18
Sugar (g/die)[a]	82.3 (26.6)	73.7 (18.1)	93.2 (31.4)	**<0.001**
Sugar (%)[a]	14.6 (3.7)	15.0 (3.4)	14.0 (3.9)	0.120
Fats (g/die)[a]	72.5 (19.7)	64.4 (12.4)	83.0 (22.3)	**<0.001**
Fats (%)[a]	30.7 (4.4)	31.1 (4.1)	30.3 (4.9)	0.280
SFA (%)[a]	9.8 (2.3)	9.7 (2.1)	9.9 (2.5)	0.630
PUFA (%)[a]	4.1 (0.9)	4.1 (0.9)	4.1 (1.0)	0.870
MUFA (%)[a]	14.7 (11.5)	15.6 (15.1)	13.6 (2.8)	0.310
Fiber (g/die)[a]	27.7 (7.6)	28.1 (7.3)	27.1 (8.1)	0.430
Cholesterol (mg/die)[a]	223.2 (77.5)	198.9 (61.1)	254.4 (85.3)	**<0.001**

Vit. A (μg)[a]	737.1 (428.1)	670.6 (393.7)	822.7 (457.8)	0.034
Vit. B9 (folic acid) (μg)[a]	388.0 (109.4)	381.1 (106.1)	396.9 (113.7)	0.390
Vit. B12 (cyanocobalamin) (μg)[a]	3.4 (1.3)	3.3 (1.2)	3.6 (1.4)	0.110
Vit. C (ascorbic acid) (mg)[a]	227.0 (167.1)	248.7 (188.5)	199.5 (131.6)	0.081
Calcium (mg)[a]	734.7 (201.5)	702.5 (190.8)	776.1 (208.7)	**0.029**
Phosphorus (mg)[a]	1480.6 (393.0)	1412.7 (334.5)	1567.9 (445.1)	**0.018**
Potassium (mg)[a]	3204.5 (659.8)	3075.5 (640.1)	3370.4 (652.5)	**0.007**
Sodium (mg)[a]	1862.6 (614.3)	1699.2 (502.9)	2072.5 (681.4)	**<0.001**
Iron (mg)[a]	12.8 (3.6)	12.5 (3.5)	13.2 (3.7)	0.23
Zinc (mg)[a]	10.6 (3.4)	9.5 (2.5)	11.9 (3.9)	**<0.001**
Copper (mg)[a]	0.9 (0.4)	0.8 (0.4)	1.0 (0.4)	**0.041**
Water from beverage (L)[a]	2.2 (0.7)	2.1 (0.6)	2.4 (0.9)	**0.039**

Abbreviations: n = number; kcal = kilocalories; kg = kilograms; g = grams; EA = Energy Availability; FFM = Fat Free Mass; SFA = Saturated Fatty Acids; PUFA = Polyunsaturated Fatty Acids; MUFA = Monounsaturated Fatty Acids; L = litres

[a]*Mean ± standard deviation*

p-values refer to differences between females and males.

4.3.5 Anthropometry and body composition

The mean body weight of the sample was 70.7 ± 12.4 kg, with a mean BMI of 23.7 ± 2.9 kg/m². Mean fat mass percentage was 20.5 ± 6.6%, calculated as the average value obtained from skinfold caliper assessment and bioimpedance analysis.

As expected, men exhibited significantly higher body weight (79.3 ± 7.8 kg vs 63.0 ± 10.6 kg; $p < 0.001$), height (1.80 ± 0.06 m vs 1.65 ± 0.06 m; $p < 0.001$), and BMI (24.4 ± 2.2 vs 23.1 ± 3.3 kg/m²; $p = 0.002$). Women showed a significantly higher fat mass percentage compared to men (24.3 ± 6.0% vs 16.3 ± 4.2%; $p < 0.001$), while men exhibited greater fat-free mass both in absolute and relative terms ($p < 0.001$).

4.3.6 Nutrition knowledge

Regarding the GeSNK questionnaire, the mean total score was 72.8 ± 14.9, with women scoring 74.8 ± 13.4 and men 70.5 ± 16.3. In particular, women scored significantly higher in the general nutrition subsection (51.1 ± 7.7 vs. 47.5 ± 7.5; $p = 0.004$). However, in the sport and nutrition subsection, the overall mean was 24.7 ± 4.8, with similar values observed between women (24.6 ± 4.4) and men (24.9 ± 5.2).

4.4 Discussion

The present study aimed to explore sex-related differences in nutritional habits, eating behaviour, lifestyle factors and body composition among physically active Italian adults. The

main findings indicate that, despite a relatively homogeneous socio-demographic and sport-related background, males and females exhibit markedly different behavioural and physiological profiles, particularly with respect to eating behaviours and EA. Notably, the most critical result concerns the sex disparity in EA, with no female participants meeting the sex-specific threshold for optimal EA, while the majority of men achieved values considered adequate. While the majority of men achieved values classified as optimal, no women reached the sex-specific threshold for optimal EA, and more than one quarter were classified as having LEA. This finding is consistent with previous evidence, although the sex difference observed in the present study appears more pronounced. Recent work by Armento and colleagues examining adolescent athletes reported a high prevalence of subclinical and LEA in both sexes, with no statistically significant proportional differences between males and females when EA was categorized using clinical cut-offs. Importantly, differences in age, developmental stage, sport type and methodological approaches may partly explain the discrepancy with the present findings [268]. More comparable evidence emerges from sport-specific investigations in adult athletes. In advanced and elite rock climbers, Monedero et al. reported a very high prevalence of sub-optimal EA and LEA in both sexes; however, only female climbers exhibited energy intakes significantly below calculated energy requirements, highlighting a sex-specific mismatch between intake and expenditure [269]. This observation closely aligns with the present results, in which inadequate EA was disproportionately observed among women despite comparable engagement in physical activity.
These findings suggest that while low or sub-optimal EA can affect both sexes, females may be more likely to experience a persistent imbalance between dietary intake and exercise energy expenditure [86]. Differences in physiological sensitivity to energy deficiency, sex-specific EA thresholds, and behavioural factors related to dietary intake may contribute to this pattern, reinforcing the need for sex-specific approaches when assessing and interpreting EA in physically active populations.

As per the dietary habits, although the overall dietary pattern of the sample was characterized by a high prevalence of regular meal consumption, relevant sex-related behavioural differences emerged. In particular, women reported a higher prevalence of breakfast consumption compared with men, whereas men were more frequently classified as fast eaters. Conversely, women reported a significantly higher prevalence of emotional hunger linked to anxiety or stress. These findings are consistent with recent literature indicating that men and women differ in eating behaviours, independently of physical activity level. Population-based studies have shown that men are more likely to engage in behaviours such as meal skipping, faster eating and less structured meal patterns, whereas women tend to display greater dietary restraint and higher susceptibility to emotional or stress-related eating [270–272].

Regarding dietary intake, men reported a significantly higher daily energy intake compared with women, together with greater absolute intakes of protein, carbohydrates and fats. This pattern aligns with recent sport-specific research showing that male athletes tend to consume more total energy and carbohydrate relative to female counterparts in competitive settings [273]. When protein and carbohydrate intake is expressed relative to body weight, the sex differences often attenuate or disappear. Protein intake in both men and women was within ranges commonly recommended for physically active individuals, whereas carbohydrate intake remained within the lower range of recommended values. Similar findings have been reported in recent studies, highlighting that carbohydrate intake is frequently suboptimal in physically active populations, even when total energy intake appears adequate [274–277]. Evidence directly comparing energy intake between men and women remains limited and often sport-specific. For example, in elite rock climbers, Monedero et al. reported that although both sexes exhibited a high prevalence of sub-optimal EA, only women showed energy intakes significantly below estimated requirements, suggesting a sex-specific mismatch between intake and expenditure [269]. While sport-specific factors may influence these findings, they are consistent with the pattern observed in the present study.

As expected, men in the present study exhibited significantly higher body weight, height and BMI compared with women, together with markedly greater fFFM both in absolute and relative terms, whereas women showed a significantly higher FM%. These findings are fully consistent with the well-established differences in body composition, which reflects distinction in hormonal milieu and skeletal structure leading to higher FFM in males and greater essential and subcutaneous fat storage in females [278]. Similar sex-related differences in body composition have been consistently reported in both athletic and recreationally active populations, regardless of sport discipline, with male athletes typically presenting higher FFM and lower relative FM compared with female counterparts [144,266,279,280]. When interpreting the observed sex differences in body composition, it is important to consider that absolute values of FM and FFM are strongly influenced by the assessment technique (e.g. skinfold-based equations, bioelectrical impedance analysis, dual-energy X-ray absorptiometry), the sport discipline and the training phase. For example, seasonal variations in training volume and intensity may further affect body composition, particularly in athletes engaged in periodized training programs, leading to fluctuations in FM/FFM across the competitive calendar [281]. Therefore, while the sex-related differences observed in the present study are physiologically expected and consistent with previous literature, caution is warranted when directly comparing absolute body composition values with those reported in studies involving different sport disciplines, competitive levels or measurement protocols.

In the present study, women demonstrated significantly higher general nutrition knowledge scores and greater adherence to the MedDiet compared with men. This finding is consistent with previous evidence from both general and physically active populations, indicating that women tend to show higher nutrition-related knowledge and greater adherence to healthier dietary patterns, including the MedDiet [121,128,282–284].
However, despite higher nutrition knowledge and adherence to the MedDiet, women in the present sample did not exhibit a higher prevalence of nutritional adequacy, as reflected by the absence of women reaching the sex-specific threshold for optimal EA. This apparent dissociation between diet quality, NK and energy adequacy is supported by existing literature, which suggests that higher nutrition knowledge does not necessarily translate into sufficient total energy intake, particularly among physically active individuals [285,286]. In a systematic review conducted by Janiczak and colleagues, the authors reported weak-to-moderate positive associations between athletes' nutrition knowledge and positive dietary behaviours, suggesting that higher knowledge is generally associated with more appropriate macronutrient choices. However, the same review highlighted that protein intake in athletes often exceeds current recommendations, while carbohydrate intake frequently remains at or below recommended levels [122].

Ultimately, in our sample, men and women differed significantly in the types of sport and physical activities practised, with women engaging more frequently in gym/fitness and running, and men reporting higher participation in beach volleyball, swimming and cycling. This observation aligns with recent cross-sectional evidence showing sex-specific patterns in sport preferences: in a study of over 2000 adults, men were predominantly involved in team sports, whereas women tended to favour strength training and skill-based activities, particularly in early adulthood (30-39 years) [271]. Large population-level analyses in European adults also indicate that men and women differ in their physical activity behaviour, with women more likely to participate in moderate intensity activities and men more likely to engage in high-intensity sport forms [287]. Consistent patterns have been reported internationally: in Australia, men show higher participation in team sport and women in individual and active recreation activities, contributing to persistent gender gaps in overall physical activity levels [288]. Additionally, according to the recent *ALL IN PLUS analytical report promoted by the Council of Europe and the European Union, female participation remains below 25% in the majority of sport disciplines across Europe, with very low representation (≤10%) in traditionally male sports such as football, rugby, ice hockey, boxing, wrestling and fencing, while only few disciplines show female predominance, including equestrian sports and weightlifting* [289]. These participation gaps highlight the presence of some barriers, cultural norms and limited access to certain sport environments which may influence sport selection patterns among recreationally active adults.

Several limitations should be acknowledged when interpreting the present findings. The cross-sectional design does not allow for causal inferences, and the assessment of EA represents a snapshot in time. As a result, it was not possible to distinguish between *adaptable* and *problematic* LEA, which may have different physiological and clinical implications. Longitudinal studies are therefore needed to better capture the temporal dynamics of energy balance in physically active individuals. Dietary intake and physical activity were assessed using self-reported tools, which are subject to recall bias and underreporting. Although standardized questionnaires and validated methods were used, some measurement errors cannot be excluded. The body composition was assessed using field-based techniques, which, while appropriate for large and heterogeneous samples, may yield different absolute values compared with reference methods. In addition, the multisport nature of the sample and the lack of control for training phase or seasonality may have contributed to variability in body composition and energy expenditure estimates. Future research should investigate whether targeted interventions addressing not only nutrition knowledge but also practical fueling behaviours can improve EA, particularly in physically active women.

A major strength of the present study is the comprehensive and multidimensional assessment of physically active adults, including nutritional habits, eating behaviour, lifestyle factors, and body composition with a specific focus on sex-related differences. The inclusion of both recreationally active individuals and athletes across different sport disciplines allows for a broader interpretation beyond elite sport settings. Furthermore, the simultaneous assessment of energy intake, physical activity, body composition, nutrition knowledge and adherence to the MedDiet provides a framework for interpreting EA beyond single behavioural or nutritional variables. Finally, the detailed characterization of the sample with respect to lifestyle factors and eating behaviours contributes to a more holistic understanding of the determinants of low or sub-optimal EA in physically active populations.

4.5 Conclusions

This study highlights marked sex-related differences in eating behaviours, dietary patterns, body composition and EA among physically active Italian adults. Despite a relatively homogeneous socio-demographic and sport-related background, women exhibited a substantially higher prevalence of sub-optimal and LEA, with no female participants reaching the sex-specific threshold for optimal EA.

Importantly, higher NK and greater adherence to the MedDiet observed in women did not translate into adequate EA, underscoring that diet quality and nutrition knowledge alone are not sufficient to ensure appropriate fueling in physically active populations. Instead, these findings point to a complex interaction between behavioural, physiological and sport-related factors that may disproportionately affect women. Collectively, the present results reinforce the need for sex-specific approaches in nutritional assessment and intervention, with particular attention to energy requirements and fuelling strategies in physically active women. Future research should adopt longitudinal designs to better characterize the chronicity of LEA and to evaluate targeted interventions that go beyond nutrition education, addressing practical and contextual determinants of energy balance.

Conclusions and future perspective

This doctoral thesis investigated the role of the MedDiet and lifestyle-related factors in physically active adults and athletes, within different sport contexts. The work provides a comprehensive overview of how diet quality, energy availability, nutrition knowledge, and behavioral aspects interact in shaping nutritional practices in sport settings.
Overall, the findings highlight that adherence to the MedDiet among physically active individuals and athletes is generally moderate and does not substantially differ across levels of sport engagement. While the MedDiet is widely recognized as a healthy dietary pattern, the results of this thesis suggest that higher levels of physical activity or competitive involvement do not necessarily translate into greater adherence. This underscores the complexity of dietary behaviors in sport, where nutritional choices are influenced not only by health-related considerations but also by performance-driven strategies, training demands, and individual beliefs.
A key contribution of this thesis is the integrated evaluation of diet quality alongside energy and carbohydrate availability. The findings indicate that suboptimal EA remains prevalent in physically active populations, particularly when assessed using sex-specific criteria and prevalence-based approaches. Importantly, these results emphasize that adequate diet quality does not automatically ensure sufficient EA, reinforcing the need to assess both qualitative and quantitative aspects of dietary intake in sport nutrition research and practice.
Another relevant aspect emerging from this work is the role of NK. Although higher levels of general and sport-specific NK were associated with better adherence to the MedDiet, the strength of these associations was modest, suggesting that knowledge alone may be insufficient to fully guide dietary behaviors. This observation aligns with the notion that effective nutrition strategies for athletes should go beyond NE alone and incorporate behavioral, contextual, and individualized components.

Future research should prioritize longitudinal and intervention-based designs to better elucidate causal relationships between dietary patterns, EA, and health- and performance-related outcomes in physically active populations. In particular, studies specifically addressing sex differences, training periodization, and changes across competitive seasons

would provide valuable insights. Additionally, the integration of objective performance metrics and biomarkers could further strengthen the evidence base.
Given the characteristics of the NUTRI_ACTIVE sample, which primarily included physically active adults and athletes engaged in structured sport settings, the findings of this thesis are most applicable to populations with similar activity levels and sociocultural contexts. Accordingly, caution is warranted when generalizing these results to athletic populations operating in substantially different organizational or cultural environments. From an applied perspective, the results of this thesis may have implications for screening and counseling contexts, supporting the combined assessment of dietary patterns, NK, and EA as part of integrated approaches aimed at promoting informed and sustainable dietary behaviours in physically active populations. These implications should be interpreted as potential applications rather than prescriptive recommendations, and require further validation within intervention-based frameworks.

In conclusion, this thesis contributes to the growing body of literature on sport nutrition by demonstrating that adherence to the MedDiet while beneficial for overall health, represents only one component of a broader nutritional framework required to support physically active individuals and athletes. A comprehensive, individualized, and context-specific approach remains essential to effectively translate nutritional principles into practice.

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Appendix

Appendix A - MEDI-LITE Questionnaire

Qual è il consumo dei seguenti gruppi alimentari?

Questionario di aderenza alla dieta Mediterranea

FRUTTA *1 porzione: 150 g (esempio: 1 mela, pera, arancia; 3 prugne, mandarini)*	<1 porzione/die ☐	1-2 porzioni/die ☐	>2 porzioni/die ☐
VERDURA *1 porzione: 100 g (esempio: 1 piatto di insalata; 2 pomodori; ½ vaschetta di verdura cotta)*	<1 porzione/die ☐	1-2,5 porzioni/die ☐	>2,5 porzioni/die ☐
LEGUMI *1 porzione: 70 g (esempio: ½ scatoletta di fagioli o ceci o lenticchie o piselli)*	<1 porzione/sett. ☐	1-2 porzioni/sett. ☐	>2 porzioni/sett. ☐
CEREALI (pane, pasta, biscotti etc.) *1 porzione: 130 g (Esempi: 1 porzione pasta: 80 g; 4 biscotti frollini: 50 g)*	<1 porzione/die ☐	1-1,5 porzioni/die ☐	>1,5 porzioni/die ☐
PESCE (eccetto molluschi e crostacei) *1 porzione: 100 g*	<1 porzione/sett. ☐	1-2,5 porzioni/sett. ☐	>2,5 porzioni/sett. ☐
CARNE E SALUMI *1 porzione: 80 g (Esempi: 1 porzione carne: 100 g 1 porzione salumi: 50 g (esempio: ½ vaschetta prosciutto)*	<1 porzione/die ☐	1-1,5 porzioni/die ☐	>1,5 porzioni/die ☐
LATTE E LATTICINI *1 porzione: 180 g (Esempi: 1 tazza di latte: 150 g; 1 yogurt: 125)*	<1 porzione/die ☐	1-1,5 porzioni/die ☐	>1,5 porzioni/die ☐
ALCOL *1 U.A. = 1 bicchiere di vino; 1lattina birra*	<1 U.A./die ☐	1-2 U.A./die ☐	>2 U.A./die ☐
OLIO D'OLIVA	Occasionalmente ☐	Frequentemente ☐	Regolarmente ☐

Totale: ☐

Adattato da Sofi et al., Public Health Nutr 2014

Appendix B - General and Sport Nutrition Knowledge Questionnaire (GeSNK)

GeSNK: QUESTIONARIO SULLE CONOSCENZE NUTRIZIONALI GENERALI E NELLO SPORT

Nome: Cognome:
Genere: Maschio ☐ Femmina ☐
Data di Nascita:
Peso: Altezza:
Attività lavorativa padre/madre.........................

Titolo di studio padre/madre..........................
Pratichi un'attività sportiva? SI ☐ NO ☐
Attività svolta:
Volte a settimana:
Durata media *(minuti al giorno)*:

Le mie conoscenze sulla sana alimentazione derivano: (si può scegliere più di una risposta)

Da programmi di educazione alimentare a scuola	☐	*Da quello che vedo in Tv*	☐
Da programmi di educazione alimentare in altri luoghi	☐	*Da internet*	☐
Da quello che mi dicono i miei insegnanti	☐	*Dai miei amici*	☐
Da quello che mi dicono i miei genitori	☐	*Non ho conoscenze sulla sana alimentazione*	☐
Da quello che mi dicono i miei allenatori	☐	*Altro*..	

PRIMA PARTE: NUTRIZIONE GENERALE

Di seguito sono riportati dei quesiti che si riferiscono alla composizione nutrizionale di alcuni alimenti.
Indicare la risposta giusta con una X.

1. Questi alimenti presentano un contenuto di Carboidrati:

	Alto	Basso o assente	Non So
Prosciutto cotto	☐	☐	☐
Pane bianco	☐	☐	☐
Pomodori	☐	☐	☐
Mela	☐	☐	☐
Ricotta	☐	☐	☐
Cereali da colazione	☐	☐	☐

2. Questi alimenti presentano un contenuto di Proteine:

	Alto	Basso o assente	Non so
Pollo	☐	☐	☐
Fagioli secchi	☐	☐	☐
Pera	☐	☐	☐
Riso	☐	☐	☐
Merluzzo	☐	☐	☐
Parmigiano	☐	☐	☐
Cioccolato	☐	☐	☐

3. Questi alimenti presentano un contenuto di Lipidi:

	Alto	Basso o assente	Non so
Salame	☐	☐	☐
Maionese	☐	☐	☐
Ceci secchi	☐	☐	☐
Pasta	☐	☐	☐
Burro	☐	☐	☐
Marmellata	☐	☐	☐

4. Questi alimenti presentano un contenuto di Fibre:

	Alto	Basso o assente	Non so
Miele	☐	☐	☐
Pane integrale	☐	☐	☐
Petto di pollo	☐	☐	☐
Patate	☐	☐	☐
Pera	☐	☐	☐
Pane bianco	☐	☐	☐

5. Questi alimenti presentano un contenuto di <u>Sale:</u>

	Alto	Basso o assente	Non so
Pane bianco	☐	☐	☐
Zucchine	☐	☐	☐
Piselli in scatola	☐	☐	☐
Tonno in scatola	☐	☐	☐
Piselli surgelati	☐	☐	☐

6. Questi alimenti presentano un contenuto di <u>Calcio:</u>

	Alto	Basso o assente	Non so
Fesa di tacchino	☐	☐	☐
Piselli	☐	☐	☐
Noci	☐	☐	☐
Olio d'oliva	☐	☐	☐
Pane integrale	☐	☐	☐

7. Questi alimenti presentano un contenuto di <u>Ferro:</u>

	Alto	Basso o assente	Non so
Vitello	☐	☐	☐
Mela	☐	☐	☐
Miele	☐	☐	☐
Spigola	☐	☐	☐

8. Questi alimenti presentano un contenuto di <u>Potassio:</u>

	Alto	Basso o assente	Non so
Pasta	☐	☐	☐
Lenticchie secche	☐	☐	☐
Olio d'oliva	☐	☐	☐
Miele	☐	☐	☐

Queste affermazioni sono vere o false? (barrare una sola casella per questione)

9	*L'albume dell'uovo è ricco di colesterolo*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐
10	*Gli alimenti ricchi di grassi sono sempre ricchi di colesterolo*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐
11	*L'olio d'oliva è ricco di grassi monoinsaturi*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐
12	*La frutta secca è una buona fonte di grassi essenziali*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐
13	*I formaggi stagionati contengono più sale dei formaggi freschi*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐
14	*Un alimento calorico è esclusivamente un alimento grasso*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐
15	*Il pane integrale ha un più alto contenuto di fibra rispetto al pane normale*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐
16	*La crusca è la parte esterna dei cereali e contiene molta fibra*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐
17	*I legumi in scatola contengono più sale dei legumi secchi*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐
18	*Omega-3 e Omega-6 sono particolari tipi di grassi*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐
19	*Il corpo può sintetizzare vitamina D con l'esposizione ai raggi solari*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐
20	*Il ferro contenuto nella carne è meglio assorbibile del ferro contenuto nelle verdure*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐

21	*Molti alimenti contengono naturalmente sale*
	VERO ☐ FALSO ☐ NON SO ☐
22	*I formaggi sono una buona fonte di ferro*
	VERO ☐ FALSO ☐ NON SO ☐
23	*La carota è una buona fonte di vitamina A*
	VERO ☐ FALSO ☐ NON SO ☐

24.L'Indice Glicemico di un alimento:(indicare l'unica risposta corretta)

Indica il contenuto di carboidrati di un alimento	☐
Permette di classificare gli alimenti in base all'effetto che hanno sul livello di glucosio nel sangue (glicemia)	☐
Indica la velocità con cui aumenta la glicemia in seguito all'assunzione di un alimento contenente una quantità nota di proteine	☐
Indica la densità calorica di un alimento	☐

Queste affermazioni sono vere o false? (barrare una sola casella per questione)

25	*L'alimentazione non equilibrata rappresenta l'unico fattore di rischio per lo sviluppo di malattie cardiovascolari*
	VERO ☐ FALSO ☐ NON SO ☐
26	*Nell'instaurarsi dell'obesità l'alimentazione gioca un ruolo fondamentale, la mancanza di attività fisica no*
	VERO ☐ FALSO ☐ NON SO ☐
27	*Un'alimentazione povera di calcio e vitamina D nel corso della vita, associata ad una scarsa attività fisica, può facilitare il rischio di fratture*
	VERO ☐ FALSO ☐ NON SO ☐
28	*Le fibre aiutano a ridurre la costipazione*
	VERO ☐ FALSO ☐ NON SO ☐
29	*Per ottenere un dimagrimento sano, i carboidrati non vanno eliminati dalla dieta*
	VERO ☐ FALSO ☐ NON SO ☐

SECONDA PARTE: NUTRIZIONE E SPORT

Queste affermazioni sono vere o false? (barrare una sola casella per questione)

30	*Mangiare Carboidrati non fa bene ad uno sportivo*
	VERO ☐ FALSO ☐ NON SO ☐
31	*Le Vitamine del gruppo B sono utili al metabolismo muscolare*
	VERO ☐ FALSO ☐ NON SO ☐
32	*Uno sportivo deve limitare al minimo l'assunzione di grassi*
	VERO ☐ FALSO ☐ NON SO ☐
33	*Mangiare carboidrati dopo le 5 del pomeriggio migliora la prestazione*
	VERO ☐ FALSO ☐ NON SO ☐
34	*Più si mangiano proteine più aumenta la massa muscolare*
	VERO ☐ FALSO ☐ NON SO ☐
35	*Per una persona che fa sport la dieta non deve contenere più del 15% di grassi*
	VERO ☐ FALSO ☐ NON SO ☐
36	*Uno sportivo può mangiare qualsiasi cosa poiché ha il metabolismo accelerato*
	VERO ☐ FALSO ☐ NON SO ☐
37	*L'esercizio fisico è il principale fattore che induce un aumento della forza muscolare*
	VERO ☐ FALSO ☐ NON SO ☐
38	*Un eccesso di proteine nella dieta induce un sovraccarico a reni e fegato*
	VERO ☐ FALSO ☐ NON SO ☐
39	*Uno sportivo deve mangiare alla fine dell'allenamento*
	VERO ☐ FALSO ☐ NON SO ☐
40	*Bisogna ridurre l'assunzione di pane pasta e patate durante il periodo di allenamento*
	VERO ☐ FALSO ☐ NON SO ☐
41	*Un uomo ed una donna della stessa età, che praticano lo stesso sport non hanno lo stesso fabbisogno di calorie*
	VERO ☐ FALSO ☐ NON SO ☐

42	*Per un atleta è consigliabile consumare un pasto ricco di Carboidrati a basso indice glicemico 1-2 ore prima dell'allenamento*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐
43	*Atleti che praticano allenamenti intensivi hanno un fabbisogno di proteine doppio rispetto a quanto raccomandato alla popolazione generale*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐
44	*I liquidi devono essere ingeriti prima, durante e dopo una gara*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐
45	*Gli allenatori non devono permettere agli atleti di bere durante l'allenamento*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐
46	*Il miglior consiglio che si può dare ad uno sportivo è di bere quando ha sete*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐
47	*L'acqua fredda disseta di più uno sportivo*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐
48	*Durante l'allenamento uno sportivo può tenere in bocca un cubetto di ghiaccio per dissetarsi*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐
49	*Un importante aiuto per la prestazione di un atleta è l'acqua*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐
50	*Bevande per sportivi e bevande energetiche sono la stessa cosa*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐
51	*Le bevande per sportivi contengono sali minerali*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐

52.Qual è la bevanda più appropriata dopo due ore di allenamento?

Bevanda energetica	☐
Bevanda per sportivi	☐
Succo di frutta	☐
Cola	☐
Non so	☐

Queste affermazioni sono vere o false? (barrare una sola casella per questione)

53	*Gli integratori possono essere validi sostituti dei pasti per lo sportivo*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐
54	*Un atleta non potrà mai soddisfare il suo fabbisogno di ferro con l'alimentazione, è necessario un supplemento*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐
55	*Le bevande per sportivi contengono caffeina*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐
56	*Se un atleta non riesce a coprire il proprio fabbisogno di proteine con la sola alimentazione è necessaria un'integrazione di amminoacidi*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐
57	*Gli integratori alimentari sono sempre necessari, sia nello sport agonistico che non agonistico*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐
58	*Poiché gli integratori alimentari sono innocui, non è necessario il consiglio dello specialista*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐
59	*Il supplemento di vitamina C è sempre necessario a chi pratica sport di forza*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐
60	*Mangiare scondito è il miglior modo per fare massa e tonificare per uno sportivo*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐
61	*Carne e albume d'uovo contengono proteine, gli altri alimenti no. Questa è la base dell'alimentazione di uno sportivo*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐
62	*I prodotti light possono essere consumati a piacimento da uno sportivo*		
	VERO ☐	**FALSO** ☐	**NON SO** ☐

Appendix C - Teruel Orthorexia Scale (TOS)

TOS – Teruel Orthorexia Scale

Falgares, G., Costanzo, G., Manna, G., Marchetti, D., Barrada, J. R., Roncero, M., Verrocchio, M. C., & Ingoglia, S.

versione italiana

Le seguenti domande riguardano le Sue idee e i Suoi atteggiamenti sul cibo. In particolare, ci piacerebbe sapere quanto sia importante per Lei seguire una dieta salutare, basata su alimenti privi di grassi, sali, conservanti, additivi prodotti dall'uomo o qualsiasi sostanza che ritiene dannosa o tossica, come erbicidi o pesticidi.

		Per nulla d'accordo	Leggermente d'accordo	Abbastanza d'accordo	Completamente d'accordo
1.	Mi sento bene quando mangio cibo sano	☐	☐	☐	☐
2.	Dedico molto tempo all'acquisto, alla pianificazione e/o alla preparazione di cibo, affinché la mia alimentazione sia più salutare possibile	☐	☐	☐	☐
3.	Credo che il mio modo di mangiare sia più salutare di quello della maggior parte delle persone	☐	☐	☐	☐
4.	Mi sento in colpa quando mangio qualche alimento che considero non sano	☐	☐	☐	☐
5.	Le mie relazioni sociali sono state influenzate negativamente dalla mia preoccupazione per il cibo sano	☐	☐	☐	☐
6.	Il mio interesse per l'alimentazione sana è una parte importante del mio modo di essere e di comprendere il mondo	☐	☐	☐	☐
7.	Preferisco mangiare un alimento sano e poco gustoso, piuttosto che un alimento gustoso e non salutare	☐	☐	☐	☐
8.	Mangio principalmente cibo che considero sano	☐	☐	☐	☐
9.	**La mia preoccupazione per l'alimentazione sana occupa molto del mio tempo***	☐	☐	☐	☐
10.	Mi preoccupa la possibilità di mangiare alimenti poco salutari	☐	☐	☐	☐
11.	Non mi importa di spendere di più per acquistare un alimento, se credo che questo sia più salutare	☐	☐	☐	☐
12.	Mi sento triste o sopraffatto/a se mangio cibo che non considero sano	☐	☐	☐	☐
13.	Preferisco mangiare poco e sano, piuttosto che saziarmi con cibo che potrebbe non essere salutare	☐	☐	☐	☐
14.	Evito di mangiare con persone che non condividono le mie idee sull'alimentazione sana	☐	☐	☐	☐
15.	Provo a convincere le persone che mi circondano a seguire le mie abitudini alimentari sane	☐	☐	☐	☐
16.	Se qualche volta mangio cibo che considero non sano, mi punisco per questo	☐	☐	☐	☐
17.	I pensieri sull'alimentazione sana non mi permettono di concentrarmi su altre attività	☐	☐	☐	☐

Appendix D - Eating Attitudes Test-26 (EAT-26)

EATING ATTITUDES TEST
(EAT-26)

L'Eating Attitudes Scale è un questionario utilizzato per cogliere i tratti psicologici e i sintomi caratteristici dei disturbi dell'alimentazione.
È indispensabile, quando i soggetti realizzano un punteggio superiore o uguale a 20 in questo questionario, somministrare loro un'intervista diagnostica specifica per valutare l'eventuale presenza di un disturbo del comportamento alimentare.
È bene sempre rivolgersi ad professionista psicologo esperto in DCA se si ha il dubbio di soffrire o se si è preoccupati per un familiare o amico che si pensa possa avere un Disturbo Alimentare.
Solo un professionista può fare una diagnosi.

	Sempre	**Normalmente**	**Spesso**	**Avolte**	**Raramente**	**Mai**	*Punti*
1. Sono terrorizzata di essere in sovrappeso	O	O	O	O	O	O	
2. Quando ho fame evito di mangiare	O	O	O	O	O	O	
3. Penso al cibo con preoccupazione	O	O	O	O	O	O	
4. Mi è capitato di mangiare con enorme voracità sentendomi incapace di smettere	O	O	O	O	O	O	
5. Ho l'abitudine di sminuzzare il cibo	O	O	O	O	O	O	
6. Faccio molta attenzione al potere calorico degli alimenti che mangio	O	O	O	O	O	O	
7. Evito in particolare gli alimenti con un alto contenuto di carboidrati (ad esempio, pane, riso, patate, ecc)	O	O	O	O	O	O	
8. Sento gli altri che vorrebbero che mangiassi di più	O	O	O	O	O	O	
9. Vomito dopo aver mangiato	O	O	O	O	O	O	
10. Mi sento molto in colpa dopo aver mangiato	O	O	O	O	O	O	
11. Mi tormenta il desiderio di essere più sottile	O	O	O	O	O	O	
12. Mi sottopongo a esercizi fisici intensi per bruciare calorie	O	O	O	O	O	O	

13. Altri pensano che io sia troppo magra	O	O	O	O	O	O	
14. Mi preoccupa l'idea di avere del grasso sul mio corpo	O	O	O	O	O	O	
15. Impiego più tempo degli altri per mangiare	O	O	O	O	O	O	
16. Evitare cibi dolci	O	O	O	O	O	O	
17. Mangiare cibi dietetici	O	O	O	O	O	O	
18. Sento che il cibo controlli la mia vita	O	O	O	O	O	O	
19. Mi piace mostrare un grande autocontrollo verso il cibo e dominare la fame	O	O	O	O	O	O	
20. Sento che gli altri fanno pressioni su di me perché io mangi	O	O	O	O	O	O	
21. Dedico al cibo troppo tempo e troppi pensieri	O	O	O	O	O	O	
22. Mi dispero se mangio dei dolci	O	O	O	O	O	O	
23. Mi impegno in programmi di dieta	O	O	O	O	O	O	
24. Mi piace che il mio stomaco sia vuoto	O	O	O	O	O	O	
25. Ho l'impulso di vomitare dopo mangiato	O	O	O	O	O	O	
26. Mi piace provare nuovi cibi elaborati	O	O	O	O	O	O	
PUNTEGGIO TOTALE *(vedi pagina seguente istruzioni per calcolo punteggio)*							

EAT-26 David M. Garner & Paul E. Garfinkel (1979), David M. Garner et al., (1982)

Appendix E - International Physical Activity Questionnaires (IPAQ)

NOME E COGNOME DATA

QUESTIONARIO INTERNAZIONALE SULL'ATTIVITÀ FISICA (IPAQ)

Siamo interessati a conoscere quali tipi di attività fisiche le persone svolgono normalmente durante la giornata. Le domande riguarderanno il tempo che hai trascorso svolgendo diverse tipologie di attività fisica **durante gli ultimi 7 giorni**. Sei pregato di rispondere a tutte le domande anche se non ti consideri una persona attiva. Pensa alle attività che ti impegnano sul lavoro, in casa e in giardino, per i trasferimenti da un posto ad un altro e infine durante il tuo tempo libero per il divertimento e lo sport.

Pensa a tutte le attività **vigorose** e **moderate** che hai svolto negli **ultimi 7 giorni**. Per attività **vigorosa** si intende quella attività che richiede un importante sforzo fisico e che ti fa respirare molto più velocemente del normale. Per attività **moderata** si intende una attività che richiede uno sforzo fisico moderato e che ti fa respirare un po' più velocemente rispetto al normale.

PARTE 1: ATTIVITÀ FISICA SVOLTA SUL LAVORO

La prima parte del questionario riguarda l'attività lavorativa. In essa sono incluse le attività lavorative svolte dietro compenso, l'attività agricola, il volontariato, corsi di formazione e ogni altra attività lavorativa svolta senza compenso al di fuori della propria abitazione. Non devi includere quelle attività domestiche e di giardinaggio, di manutenzione e la cura dei propri familiari. Questi aspetti saranno indagati nella terza parte del questionario.

1. Attualmente svolgi una attività lavorativa, remunerata o non, al di fuori dell'abitazione?

   ☐ Sì

   ☐ No ➞ *Passa alla PARTE 2: SPOSTAMENTI*

Le domande successive riguardano l'attività fisica che hai svolto nell'ambito della tua attività lavorativa, retribuita e non, **negli ultimi 7 giorni**. Non includere gli spostamenti per e dal posto di lavoro.

2. **Durante gli ultimi 7 giorni** per quanti giorni ti è capitato **nell'ambito della tua attività lavorativa** di svolgere **attività fisiche vigorose** come trasportare carichi pesanti, scavare, salire le scale? Pensa solo a quelle attività che hai svolto per almeno 10 minuti consecutivi

   _____ **n. giorni**

LONG LAST 7 DAYS SELF-ADMINISTERED version of the IPAQ. Revised October 2002.

☐ Non ho svolto attività fisica vigorosa nell'ambito della mia attività lavorativa → *Passa alla domanda 4*

3. Quanto tempo hai trascorso in uno di questi giorni facendo **attività fisiche vigorose** nell'ambito della tua attività lavorativa?

   _____ **ore al giorno**
   _____ **minuti al giorno**

4. Continua a pensare a quelle attività fisiche che hanno avuto una durata di almeno 10 minuti consecutivi. Durante gli **ultimi 7 giorni nell'ambito della tua attività lavorativa**, per quanti giorni hai svolto **attività fisiche moderate** come trasportare carichi leggeri? Non includere il camminare.

   _____ **n. giorni**

   ☐ Non ho svolto attività fisica moderata nell'ambito della mia attività lavorativa → *Passa alla domanda 6*

5. Quanto tempo hai trascorso in uno di questi giorni facendo **attività fisiche moderate** nell'ambito della tua attività lavorativa?

   _____ **ore al giorno**
   _____ **minuti al giorno**

6. Durante gli **ultimi 7 giorni** e **nell'ambito della tua attività lavorativa**, per quanti giorni hai **camminato** per almeno 10 minuti consecutivi? Non considerare gli spostamenti da e per il posto di lavoro.

   _____ **n. giorni**

   ☐ Non ho camminato nell'ambito della mia attività lavorativa → *Passa alla PARTE 2: SPOSTAMENTI*

7. Quanto tempo hai trascorso in uno di questi giorni **camminando** nell'ambito della tua attività lavorativa?

   _____ **ore al giorno**
   _____ **minuti al giorno**

PARTE 2: SPOSTAMENTI

Le prossime domande riguardano gli spostamenti da un posto ad un altro inclusi il posto di lavoro, i negozi, il cinema e via dicendo.

8. Durante gli **ultimi 7 giorni**, per quanti giorni hai utilizzato **veicoli a motore** come treno, autobus, macchina, tram, motorino?

_____ **n. giorni**

☐ Non ho utilizzato veicoli a motore → *Passa alla domanda 10*

9. Quanto tempo durante uno di questi giorni hai passato **viaggiando** in treno, in autobus, in macchina, in tram o in qualche altro veicolo a motore?

_____ **ore al giorno**
_____ **minuti al giorno**

Ora pensa solamente al tempo che potresti aver passato utilizzando la **bicicletta** o **camminando** allo scopo di andare e tornare dal lavoro, per fare delle commissioni o per spostarti da un posto ad un altro.

10. Durante **gli ultimi 7 giorni**, per quanti giorni hai usato la **bicicletta** per almeno 10 minuti consecutivi per spostarti **da un posto ad un altro**?

_____ **n. giorni**

☐ Non ho usato la bicicletta per spostarmi da un posto ad un altro → *Passa alla domanda 12*

11. Per quanto tempo in uno di questi giorni hai utilizzato la **bicicletta** per andare da un posto ad un altro?

_____ **ore al giorno**
_____ **minuti al giorno**

12. Durante **gli ultimi 7 giorni**, per quanti giorni hai **camminato** per almeno 10 minuti consecutivi per spostarti **da un posto ad un altro**?

_____ **n. giorni**

☐ Non ho camminato per spostarmi da un posto ad un altro → *Passa alla PARTE 3: LAVORI DOMESTICI E CURA DEI FAMILIARI*

13. Per quanto tempo in uno di questi giorni hai **camminato** per andare da un posto ad un altro?

_____ **ore al giorno**
_____ **minuti al giorno**

PARTE 3: LAVORI DOMESTICI E CURA DEI FAMILIARI

Questa sezione riguarda alcuni tipi di attività fisica che potresti aver fatto in casa negli **ultimi 7 giorni** come i lavori domestici, il giardinaggio, lavori di manutenzione e la cura dei tuoi familiari.

14. Pensa a tutte quelle attività fisiche che puoi aver fatto per almeno 10 minuti consecutivi. Durante gli **ultimi 7 giorni**, per quanti giorni hai svolto attività fisiche di tipo **vigoroso in giardino o in cortile** come sollevare carichi pesanti, tagliare la legna, spalare la neve o scavare?

_____ **n. giorni**

☐ Non ho svolto attività vigorose in giardino o cortile → *Passa alla domanda 16*

15. Per quanto tempo in uno di questi giorni hai svolto **attività fisiche di tipo vigoroso** in giardino o cortile?

_____ **ore al giorno**
_____ **minuti al giorno**

16. Ora pensa a quelle attività fisiche che puoi aver fatto per almeno 10 minuti per volta. Durante gli **ultimi 7 giorni**, per quanti giorni hai svolto **attività fisiche di tipo moderato in giardino o in cortile** come trasportare carichi leggeri, spazzare i pavimenti, e rastrellare?

_____ **n. giorni**

☐ Non ho svolto attività moderate giardino o in cortile → *Passa alla domanda 18*

17. Per quanto tempo in uno di questi giorni hai svolto **attività fisiche moderate** in giardino o in cortile?

_____ **ore al giorno**
_____ **minuti al giorno**

18. Ora pensa a quelle attività fisiche che puoi aver fatto per almeno 10 minuti consecutivi. Durante gli **ultimi 7 giorni**, per quanti giorni hai svolto **attività moderate** come trasportare carichi leggeri, lavare i vetri, strofinare e spazzare i pavimenti **all'interno dell'abitazione**?

_____ **n. giorni**

☐ Non ho svolto attività moderate In casa → *Passa alla PARTE 4: PASSATEMPI, SPORT E TEMPO LIBERO*

19. Per quanto tempo in uno di questi giorni hai svolto **attività fisiche moderate** in casa?

_____ **ore al giorno**
_____ **minuti al giorno**

PARTE 4: PASSATEMPI, SPORT E TEMPO LIBERO

Questa sezione riguarda tutte le attività fisiche che hai fatto negli **ultimi 7 giorni** esclusivamente a scopo ricreativo, sportivo, e nel tempo libero. Non includere tutte quelle attività che hai già considerato.

20. Escludendo gli spostamenti a piedi che hai già considerato, durante gli **ultimi 7 giorni**, per quanti giorni hai **camminato** per almeno 10 minuti consecutivi **durante il tuo tempo libero**?

_____ **n. giorni**

☐ Non ho camminato nel tempo libero → *Passa alla domanda 22*

21. Per quanto tempo hai **camminato** in uno di questi giorni durante il tuo tempo libero?

_____ **ore al giorno**
_____ **minuti al giorno**

22. Pensa solo a quelle attività fisiche che puoi aver fatto per almeno 10 minuti consecutivi. Durante gli **ultimi 7 giorni**, per quanti giorni hai svolto **attività fisiche vigorose** come l'aerobica, la corsa, la corsa in bicicletta o il nuoto a ritmo sostenuto durante **il tempo libero?**

_____ **n. giorni**

☐ Non ho svolto attività vigorosa durante Il tempo libero → *Passa alla domanda 24*

23. Quanto tempo hai passato in uno di questi giorni svolgendo **attività fisica vigorosa** nel tuo tempo libero?

_____ **ore al giorno**
_____ **minuti al giorno**

24. Ora pensa a quelle attività fisiche che puoi aver svolto per almeno 10 minuti consecutivi. Durante gli **ultimi 7 giorni**, per quanti giorni hai svolto **attività fisiche moderate** come il pedalare e nuotare a ritmo regolare, o giocare un doppio a tennis durante il tuo **tempo libero**?

_____ **n. giorni**

☐ Non ho svolto attività moderate durante il tempo libero → *Passa alla PARTE 5: TEMPO TRASCORSO SEDUTO*

25. Per quanto tempo in uno di questi giorni hai svolto **attività fisiche moderate** durante il tempo libero?

_____ **ore al giorno**
_____ **minuti al giorno**

PARTE 5: TEMPO TRASCORSO SEDUTO

Le ultime domande riguardano il tempo che hai trascorso stando seduto durante l'attività lavorativa, in casa, e durante il tempo libero (ad esempio durante una visita in casa di amici, durante la lettura, mentre guardi la televisione in poltrona o al letto). Non devi includere il tempo che hai trascorso stando seduto su veicoli a motore.

26. Durante gli **ultimi 7 giorni**, quanto tempo hai trascorso stando **seduto** nei giorni **dal lunedì al venerdì**?

_____ **ore al giorno**
_____ **minuti al giorno**

27. Durante gli **ultimi 7 giorni**, quanto tempo hai trascorso stando **seduto nel fine settimana**?

_____ **ore al giorno**
_____ **minuti al giorno**

Appendix F - Pittsburgh Sleep Quality Index (PSQI)

PITTSBURGH SLEEP QUALITY INDEX (PSQI)

Le seguenti domande servono a valutare come è stato il suo sonno nell'ultimo mese. Per ciascuna domanda scelga la risposta che descrive meglio la maggioranza dei giorni e delle notti dell'ultimo mese. **Le chiediamo, gentilmente, di rispondere a tutte le domande.**

1. Nell'ultimo mese, di solito, a che ora è andata/o a letto la sera?

ORARIO IN CUI SI DISPONE A LETTO _______

2. Nell'ultimo mese, di solito, quanto tempo (in minuti) **ha impiegato ad addormentarsi ogni notte?**

DURATA DELL'ADDORMENTARSI IN MINUTI ______

3. Nell'ultimo mese, di solito, a che ora si è alzata/o al mattino?

ORARIO IN CUI SI ALZA DAL LETTO _______

4. Nell'ultimo mese, quante ore ha dormito effettivamente per notte? (potrebbero essere diverse dal numero di ore passate a letto)

ORE DI SONNO PER NOTTE _______

Per ciascuna delle seguenti domande, segni con una crocetta (X) la risposta più appropriata al suo caso. Anche in questo caso, per favore, faccia attenzione a rispondere a tutte le domande.

5. Nell'ultimo mese, quanto spesso ha avuto problemi di sonno dovuti a:

a. non riuscire ad addormentarsi entro 30 minuti

□ non durante l'ultimo mese □ < 1 volta/settimana □ 1-2 volte/settimana □ 3 o più volte/settimana

b. svegliarsi nel mezzo della notte o al mattino presto senza riaddormentarsi subito

□ non durante l'ultimo mese □ < 1 volta/settimana □ 1-2 volte/settimana □ 3 o più volte/settimana

c. alzarsi nel mezzo della notte per andare in bagno

□ non durante l'ultimo mese □ < 1 volta/settimana □ 1-2 volte/settimana □ 3 o più volte/settimana

d. non riuscire a respirare bene

□ non durante l'ultimo mese □ < 1 volta/settimana □ 1-2 volte/settimana □ 3 o più volte/settimana

e. tossire o russare forte

□ non durante l'ultimo mese □ < 1 volta/settimana □ 1-2 volte/settimana □ 3 o più volte/settimana

f. sentire troppo freddo

□ non durante l'ultimo mese □ < 1 volta/settimana □ 1-2 volte/settimana □ 3 o più volte/settimana

g. sentire troppo caldo

□ non durante l'ultimo mese □ < 1 volta/settimana □ 1-2 volte/settimana □ 3 o più volte/settimana

h. fare brutti sogni

□ non durante l'ultimo mese □ < 1 volta/settimana □ 1-2 volte/settimana □ 3 o più volte/settimana

i. avere dolori

□ non durante l'ultimo mese □ < 1 volta/settimana □ 1-2 volte/settimana □ 3 o più volte/settimana

j. C'è qualche altro problema che può aver disturbato il suo sonno?

□ no □ sì (specificare) ………………..

E quanto spesso ha avuto problemi a dormire per questo motivo?

□ non durante l'ultimo mese □ < 1 volta/settimana □ 1-2 volte/settimana □ 3 o più volte/settimana

6. Nell'ultimo mese, quanto spesso ha preso farmaci (prescritti dal medico o meno) per aiutarsi a dormire?

□ non durante l'ultimo mese □ < 1 volta/settimana □ 1-2 volte/settimana □ 3 o più volte/settimana

7. Nell'ultimo mese, quanto spesso ha avuto difficoltà a rimanere sveglia/o alla guida o nel corso di attività sociali?

□ non durante l'ultimo mese □ < 1 volta/settimana □ 1-2 volte/settimana □ 3 o più volte/settimana

8. Nell'ultimo mese, ha avuto problemi ad avere energie sufficienti per concludere le sue normali attività?

□ per niente □ poco □ abbastanza □ molto

9. Nell'ultimo mese, come valuta complessivamente la qualità del suo sonno?

□ molto buona □ abbastanza buona □ abbastanza cattiva □ molto cattiva