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Cornerstone review

Physical activity and planetary health: A scoping review

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A B S T R A C T

Objectives: The behaviors and attitudes associated with event attendance and engagement in physical and sporting activities exert a significant impact on planetary health. This scoping review aims to scrutinize existing literature, elucidate concepts, investigate methodologies, and identify knowledge gaps pertaining to physical activity behavior within the context of planetary health.

Design & Methods: A systematic search across PsycINFO (Psychological Information), Web of Science, and Scopus, guided by Preferred Reporting Items for Systematic Reviews and Meta-Analysis Guidelines for Scoping Reviews (PRISMA-ScR) guidelines, yielded 62 relevant studies. These studies substantiate the designation of this research domain as "Planetary Health Physical Activity" and/or "Planetary Health Sport".

Results: Results delineate four primary investigation areas: i) individuals' attitudes toward the environment and nature, ii) promotion of active lifestyles, including active commuting, iii) event organization, and iv) direct consequences of physical activity and sports on the natural world. Findings indicate that adopting an active lifestyle contributes to reducing air pollution, but engaging in physical activity and sports in natural settings may have adverse effects on ecosystems.

Conclusions: Results underscore the urgency for more experimental designs to establish causal relationships between physical activity and its ecological consequences on planetary health. This research contributes valuable insights to the emerging field of "Planetary Health Physical Activity", shedding light on the intricate interplay between human activities and the health of the planet.

1. Introduction

The prevalence of sedentary behavior has raised significant concerns within society[1,2] due to its detrimental effects on health, including an elevated risk of cardiovascular disorders, diabetes, cancer, and all-cause mortality.[3–6] To mitigate these risks, various governmental, health, and sports organizations advocate for regular physical activity. Notably, in 2020, the World Health Organization updated its guidelines, recommending that adults engage in 150–300 min of moderate-intensity or 75–150 min of vigorous-intensity physical activity per week, while children and adolescents should aim for 60 min of moderate to vigorous intensity aerobic physical activity per day.[7] Regular physical activity has been substantiated as an effective preventive measure against chronic conditions and mortality,[8,9] and it complements strategies for managing mood disorders.[10,11] Furthermore, exercise enhances well-being and health-related quality of life.[12–14]

In recent years, the concept of "green exercise," denoting physical activity in natural environments, has emerged as a means to augment the health benefits of physical activity.[15] Engaging in physical activities in parks, woodlands, or other natural settings has been shown to have positive effects on mood, affect, and well-being.[15–19] Exposure to green spaces and natural environments has also been linked to enhanced general and mental health.[20] A parallel concept, "blue spaces," encompasses activities near rivers, lakes, or the sea, and similarly promotes positive effects on mental health and well-being.[21,22] However, research in this field faces challenges arising from study design heterogeneity, variability in exposure metrics, and outcome measures, which collectively hinder the ability to draw robust conclusions regarding the benefits of green and blue spaces.[17,21,22]

In a reverse sense, people's behaviors can affect the environment. For example, transport related to sport practices is a source of greenhouse gas emissions and some sports practices can contribute to a negative carbon footprint[23] or can harm biodiversity. Thus, what if we reverse our perspective and investigate how physical activity and sports influence the natural environment? This is a relatively unexplored area that encompasses a wide range of objectives, methodologies, and experimental protocols. We term this inquiry "Physical Activity and Planetary Health". It is inspired by the holistic definition of "planetary health" from the Rockefeller Foundation–Lancet Commission as "the health of

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human civilization and the state of the natural systems on which it depends", which integrates human health and environmental sustainability.[24] The term is also inspired by that of "planetary health diet"[25] and the close interconnection between diet and physical activity as lifestyle behaviors.

McCullough et al.[26] authored a publication on the concept of "Sport Ecology", a complementary framework for the "Physical Activity and Planetary Health" concept. The theoretical foundation of "Sport Ecology" acknowledges the bidirectional relationship between sports and the natural environment, emphasizing that sport and physical activity are influenced by and impact the natural world. The authors define "Sport Ecology" as the examination of the interplay between sports and the natural environment, underscoring seven key concepts: environmentalism, sustainability, green practices, environmental justice, vulnerability, climate capacity, and adaptation. This approach focuses on how sports organizations and management (e.g., marketing, communication, or economics) can enhance this bidirectional relationship, from promoting sustainable practices to adapting to climate change (e.g., winter sports).[27]

Another related concept is the association between environmental behaviors, sustainability and ecological awareness with "green exercise",[28] as well as the need of aligning the physical activity promotion with climate action commitments.[29] A recent perspective publication advocates for systematical investigation of the environmental impacts of all types of physical activity and sports.[30] The authors support a physical activity that promotes health while being respectful of the environment. They propose a two axis model (HEPA model) where both individual and planetary (environmental) health should be benefited by physical activity. There are other concepts such as "one health"[31] or "eco-health"[32] that emphasize the health of people and ecosystems with that of the environment, but they do not place a special emphasis on how people's PA behavior can affect the health of the planet. Alternative views of physical activity such as "slow sport",[33] understood as a practice focused on pleasure, have been proposed more as a strategy to cope with climate change than as a behavior with a two-way relationship with the planetary health. Perhaps a concept closely related to that of "Physical Activity and Planetary Health" is that of "sustainable physical activity", but it is more limited as it includes only those activities that are conducted with sufficient duration, intensity and frequency for promoting health, yet without excessive expenditure of energy for food, transportation, training facilities or equipment.[34] Thus, the authors only consider people's actions that are unsustainable for the planet, without considering a bidirectional relationship.

However, the impact of physical activity and sport extends beyond "sport ecology", "sustainable physical activity", "HEPA-model", "one health", and "eco-health", and in none of these concepts has the importance of people's attitudes toward the environment been addressed in a broad and systematic way. An inspiring systematic review which examines the bidirectional association between physical activities and climate change[23] found that pollution, extreme temperatures and natural disasters reduce the levels of physical activity. In addition, the authors found that physical activity can play a resilience role following natural disasters. Traveling to practice physical activity increases however the greenhouse gas emissions, but it could be reduced by active transport (like cycling). The work by Bernard et al.[23] focuses on the bidirectional relationship between climate change and psychical activity; however, it does not explore broadly the direct effects of physical activity and sport on planetary health like waste, biodiversity, noise pollution and other environmental parameters beyond carbon footprint. Another interesting review[35] aims to identify potential bi-directional associations between climate change impacts and health-related behaviors. The results are addressed to the behavioral medicine community and show that all behaviors which accelerate climate change should be considered unhealthy behaviors. Thus, a revision of the definition of health behaviors is proposed: "*health-related behaviors can be defined as actions and patterns of actions within a context that enable human choices that result in reduced or net-zero carbon, energy, water, and ecological footprint and (in)directly result in equitable improvement, restoration, and maintenance of health for every humans and other living beings' health for current and future generations*".[35]

The concept of "Physical Activity and Planetary Health" encompasses the entire spectrum of how physical activity and sports influence the sustainability of the planet, with a particular focus on individual and societal behavior. This includes both spontaneous activities, such as hiking in a national park, and organized events, such as trail running races, as well as government policies promoting sustainable modes of transportation, like cycling in urban areas. The overarching goal of "Physical Activity and Planetary Health" is to encourage research that evaluates the impact of physical activity on the environment, with the aim of not only identifying harmful behaviors but also promoting those that benefit both human health and the environment. As a society, we should aspire to discover ways to harmonize physical activity and nature to enhance the well-being of both individuals and the environment.

An illustration of the concept of "Physical Activity and Planetary Health" is evident in the promotion of active commuting (or active transport) within urban areas, such as cycling to work. This practice contributes to the reduction of air pollution, the mitigation of the climate crisis, and the enhancement of citizens' health.[36] Furthermore, the increase in active commuting serves as an incentive for policymakers, urban planners, and landscape architects to develop additional bike lanes, pedestrian-friendly streets, and more parks, fostering sports activities, physical activity, and active commuting among the populace.[37–39] Notably, the provision of public bicycle services has been shown to boost the likelihood of active commuting.[40] Additionally, commuting through natural environments has been found to heighten the likelihood of active commuting.[41] These instances serve as compelling examples of how engaging in physical activity can contribute to the improvement of the environment's quality and the reduction of the transportation sector's impact on climate change.

Conversely, physical activity, whether through amateur or professional sporting events, can have detrimental effects on the environment and lead to increased air pollution. For instance, hiking off established trails has been associated with soil erosion and alterations in vegetation,[42] while rock climbing has been linked to a decline in cliff biodiversity.[43] Moreover, the travel associated with both amateur and professional sporting events has been shown to result in elevated levels of air pollution.[44,45] These cases underscore the significance of the concept of "Physical Activity and Planetary Health," which aims to minimize the adverse impact of physical activity on the natural environment and air quality.

Hence, we consider it necessary to comprehensively evaluate the existing literature, elucidate associated concepts, scrutinize research methodologies, and identify knowledge gaps within the domain of "Physical Activity and Planetary Health". A scoping review is the type of systematized review (i.e., systematic, transparent and replicable) most appropriate to address this type of objectives.[46] This proposed scoping review specifically delves into the potential ramifications of physical activity on planetary health and sustainable development. It is distinctive from the existing body of research on sport management, facilities, infrastructure, and the environmental aspects of physical activity, including "green exercise" and "blue space." Our review does not overlap with other reviews as it focuses both on behaviors and attitudes related to the practice of physical activity that also affect multiple aspects of the planetary health, not only climate change, such as biodiversity. In particular, our objectives are as follows: 1) to differentiate between physical activity behaviors that are environmentally sustainable and those that are not, 2) to identify the attributes characterizing sustainable physical activity behaviors, and 3) to synthesize the principal positive and negative impacts of physical activity behaviors on planetary health.

2. Methods

2.1. Review approach

The protocol of this review[47] was prospectively registered. In order to ensure the highest quality in our review process, we will adhere to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis Guidelines (PRISMA) with an extension specifically designed for Scoping Reviews (PRISMA-ScR), as outlined by Tricco et al.[48]

2.2. Search strategy

We conducted a systematic electronic search across several reputable databases, including PsycINFO, Psychological Information, by ProQuest; WoS (Web of Science CORE collection) by Thomson Reuters; and Scopus by Elsevier. Our search strategy comprises an initial filter incorporating these general search terms: ("Planetary Health") AND ("Physical Activity" OR "Exercise" OR "Sport"). We will also employ an additional set of terms preceded by the Boolean operator "NOT" to enhance the specificity of our search strategy. These filters will be customized to suit each database's requirements. To ensure full transparency and reproducibility of our search strategy, we will adhere to the Preferred Reporting Items for Reporting Literature Searches in Systematic Reviews (PRISMA-L), as recommended by Rethlefsen et al.[49] The searches were completed in July 2021. The detailed search terms for the PsycINFO database are provided in Table 1. We applied the same strategy for WoS and Scopus.

2.3. Eligibility criteria

Empirical studies with experimental, quasi-experimental, observational, or qualitative research designs, and that were published in English or Spanish, were considered eligible for inclusion. Additionally, these studies had to provide empirical or measurement information on one or more of the following aspects:

- Negative or positive effects of physical activity, sport, or exercise on planetary health.
- The role and contributions of physical activity, exercise, or sport to enhancing "planetary health."
- Approaches for creating or designing more sustainable physical activity, exercise, or sport.

Articles were excluded if they were theoretical studies or if they addressed:

- The benefits of green or blue spaces in relation to physical activity, exercise, or sport.
- The influence of the environment on promoting or enhancing physical activity, exercise, or sport.
- Sustainability from a social, economic, political, or other non-planetary health perspective.
- Studies related to urban planning, architecture, or smart cities.

Review studies were not included in the systematic search; however, relevant review studies identified during the search and data extraction processes are referenced in the Introduction and Discussion and conclusions of this work.

Table 1
Search strategy for PsycINFO database.

#	Search strings	Results (PsycINFO)
1	DE "Physical Activity" OR "physical activity" OR DE "Exercise" OR "exercise" OR "sport$" OR "physical inactivity" OR "walking" OR "physical outdoor activity" OR "nature hikes" OR "Bicycling" OR "active transport" OR "outdoor activ*" OR "Olympic"	143,601
2	"planetary health" OR DE "Nature (Environment)" OR "natural environment" OR "pro-environmental behavio$r" OR "ecological environment" OR "ecological impact" OR "environmental impact" OR "environmental concern" OR "environmental health" OR "sport ecology" OR "landscape damage" OR DE "Climate Change" OR "climate change" OR "carbon footprint"	16,074
3	#1 AND #2	848
4	DE "Treatment" OR Therapy OR cancer OR DE "HIV" OR HIV OR ebola OR DE "COVID-19" OR covid OR DE "Diavetes" OR Diabetes OR disease OR DE "Disorders" OR disorder OR DE "Obesity" OR obesity OR DE "Physiology" OR physiology OR physiological OR DE "Mental Health" OR "mental health" OR DE "Injuries" OR injuries OR DE "Rehabilitation" OR rehabilitation OR cardiovascular OR DE "Body Weight" OR "body weight" OR DE "Stress" OR stress OR DE "Anxiety" OR anxiety OR DE "Physical Health" OR "physical health" OR DE "Health Promotion" OR "health promotion" OR "general health"	2,604,941
5	DE "Diets" OR "Diet" OR "Dash" OR DE "Metabolism" OR metabolism OR DE "Nutrition" OR nutrition	99,024
6	"Informatic*" OR DE "Robotics" OR "Robot*" OR "Learning Algorithm" OR "sensors" OR "neuro*" OR DE "Engineering" OR "Engineer*" OR DE "Immune System" OR "immune system" OR gaming OR DE "Biomechanics" OR Biomechanics OR DE "Infectious Disorders" OR "infection" OR "seed" OR "fisheries" OR "Exoskeleton" OR "geodesic flow" OR "wireless"	1,430,273
7	"green exercise" OR "blue space" OR "green-exercise" OR "blue-space" OR "green-space"	303
8	(#1 AND #2) NOT (#3 OR #4 OR #5 OR #6 OR #7)	**182**

2.4. Data extraction

The references identified through our search strategy were entered into the Mendeley bibliographic software, and any duplicate entries were removed. The screening process involved the independent review of titles and abstracts by two reviewers in accordance with the eligibility criteria. The full paper was retrieved for further evaluation when determinations could not be made based solely on title and abstract information. The full-text inclusion criteria were similarly assessed by two reviewers independently, and any discrepancies were addressed through discussion, with the involvement of a third reviewer where necessary. The level of agreement between reviewers during the study selection process was assessed using Cohen's kappa statistic.[50]

The information extracted from each selected study included general details (such as author, year, country of origin, and publication details), methodological particulars, information about the target population, the type of physical activity involved, and characteristics of the study sample. If necessary, authors of eligible studies were contacted to obtain any missing or additional data. Data extraction was conducted independently by two reviewers and any discrepancies were resolved by discussion, with the involvement of a third reviewer where necessary. Agreement during the information extraction process was assessed using Cohen's kappa.[50]

2.5. Summarizing and analysis

Data summaries were presented through figures and tables, with a narrative synthesis approach adopted. The synthesized results were organized based on key aspects, including study design, general bibliographic data (author, year, country), year of data collection, methodological details, the target population, type of physical activity, sample characteristics, and a geographical overview of countries' practices. The synthesis addressed limitations and strengths and provided recommendations for further research and practices.

The primary outcomes of the included studies were categorized into three main topics during data extraction:

(1) Study type, including design and research goals.
(2) Type of physical activity, including sport or exercise, the study sample and its characteristics, and the geographical and environmental context.
(3) Outcomes related to planetary health, encompassing response variables, types of assessments, instruments or tools employed,

validation of these instruments, main findings, and a summary of the principal results concerning the impact of physical activity on planetary health.

3. Results

3.1. Screening process

A total of 7245 articles were initially considered for inclusion in the scoping review. After eliminating duplicates, 5690 articles remained for further consideration. Subsequently, 5467 articles were excluded from the review for various reasons based on title and abstract. Specifically, 5217 articles did not adhere to the predefined eligibility criteria, while 250 articles did not conform to the required format. Therefore, a total of 223 articles underwent selection based on the full text and 161 were excluded for reasons related to the eligibility criteria (see Fig. 1). In the end, 62 studies met the eligibility criteria and were included in this scoping review. The level of agreement between reviewers during the initial round of study selection was 85.8 % (Kappa = 0.73; CI 95 %: 0.63 to 0.83), and

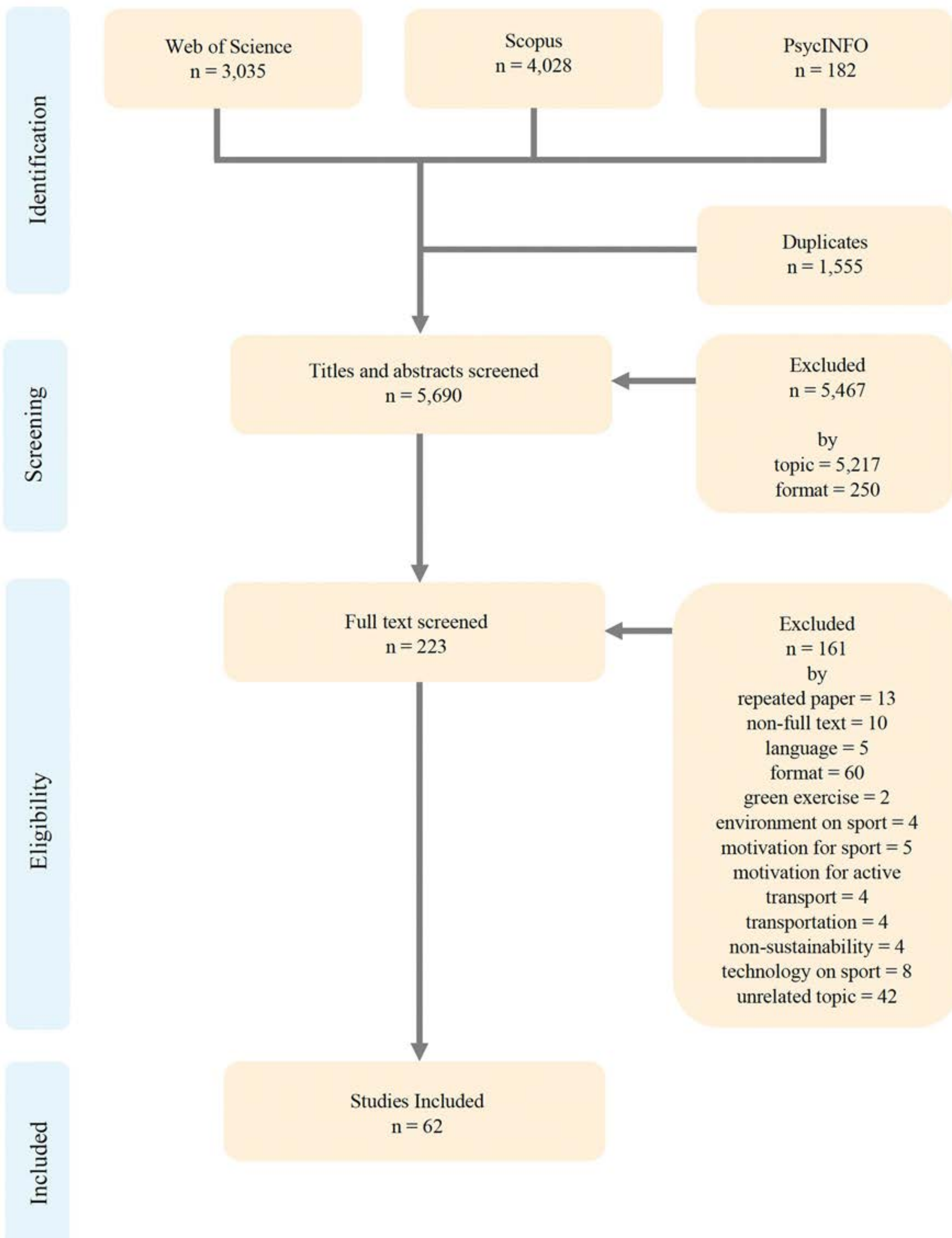

Fig. 1. PRISMA flow chart, explaining the articles inclusion/exclusion process in this scoping review.

during the data extraction phase, it was 83.3 % (Kappa = 0.66; CI 95 %: 0.54 to 0.79).

3.2. Type and characteristics of included studies

The general characteristics of the included articles are summarized in Supplementary Table 1. These studies were conducted on six different continents, with the following distribution: 33 studies in Europe, 10 in North America, 8 in Oceania, 4 in South America, 4 in Asia, 3 in Africa, and 0 in Antarctica. In terms of country distribution, Fig. 2 illustrates that the 62 studies included in the review were conducted in 29 different countries. The most frequently represented countries were the United Kingdom, with 10 studies, followed by Spain with 7 studies, and Australia, Germany, Switzerland, and the United States, each with 6 studies. It must be considered that in some studies the sample comes from different countries.

Supplementary Table 1 presents the authors and publication years of each included study, along with their general characteristics. These characteristics encompass the environmental context of the study (urban, mountain, or coast), the demographics of the analyzed samples (including gender, age, and role), and the type and level of sports analyzed.

3.3. Characteristics of the samples included in the studies

As derived from Supplementary Table 1, in 23 studies (37.1 % of the total), the studied samples consisted of individuals. Among these, 18 studies (78.3 %) provided information regarding the gender of the participants, with an approximate gender balance, as gender was reported to be around 50 %. Regarding the age of the samples, 19 studies (82.6 % of the total) reported this information. Out of these, only 4 studies specified the age in detail, with mean values ranging from 28 to 34 years and standard deviations between 10 and 15.[51–54] In 7 studies (30.4 %), age was reported as "all ages," and in 2 studies (8.7 %) as "over 18". It is noteworthy that these 9 studies where an unspecific age of "all ages" and "over 18" is indicated collectively encompass approximately 50 % of the total sample of individuals studied. In the remaining 6 studies where age was reported, different age ranges were indicated, varying between 15 and 78 years.

In contrast, in 39 studies (62.9 % of the total), the samples analyzed directly were not individuals. Out of these, 15 studies (24.2 % of the total studies) examined "terrain samplings", which typically involved counting the number of plant or animal species by dividing the land into sectors (e.g., plots of trail, grid sections, or quadrats of land). Another 7 studies (17.9 %) assessed the quality of "natural areas" overall (4 studies) or areas surrounding the stadium (3 studies). Additionally, there were 19 (48.7 %) simulation studies: 15 in urban contexts and 4 in mountain and/or coast.

3.4. Environmental context and type of physical activity

Fig. 3 presents the percentage of studies according to the environmental context of the analyzed samples (refer to Supplementary Table 1). Most studies examined samples in mountain (47 %) and urban (43 %) contexts.

Considering that there are 19 studies (30.6 % of the total) that analyze more than one type of physical activity (PA), exercise, or sport, Fig. 4 shows that 14 studies (22.6 %) focus on team, Olympic, or university sports, all of which were conducted in urban settings. Eighteen studies (29 %) investigate activities related to cycling, with 12 in urban settings and 6 in mountain areas. Eight studies (12.9 %) scrutinize walking activities, 4 in urban zones, 2 in mountain areas, and 2 in coastal settings. Thirteen studies (19.2 %) explore hiking activities in mountain regions. Another thirteen studies (19.2 %) concentrate on "running" in a mountain context. Four studies (6.5 %) delve into "skiing" in mountain settings. Three studies (4.8 %) assess "swimming", 2 conducted in coastal regions and one in an urban area. Additionally, 5 studies investigate other outdoor activities, all within mountain settings.

3.5. Methodological characteristics according to the type of study

Supplementary Table 1 also details the methodological characteristics of the included articles, including the type of study and its design. Fig. 5 illustrates the percentages by the type of study. Based on this

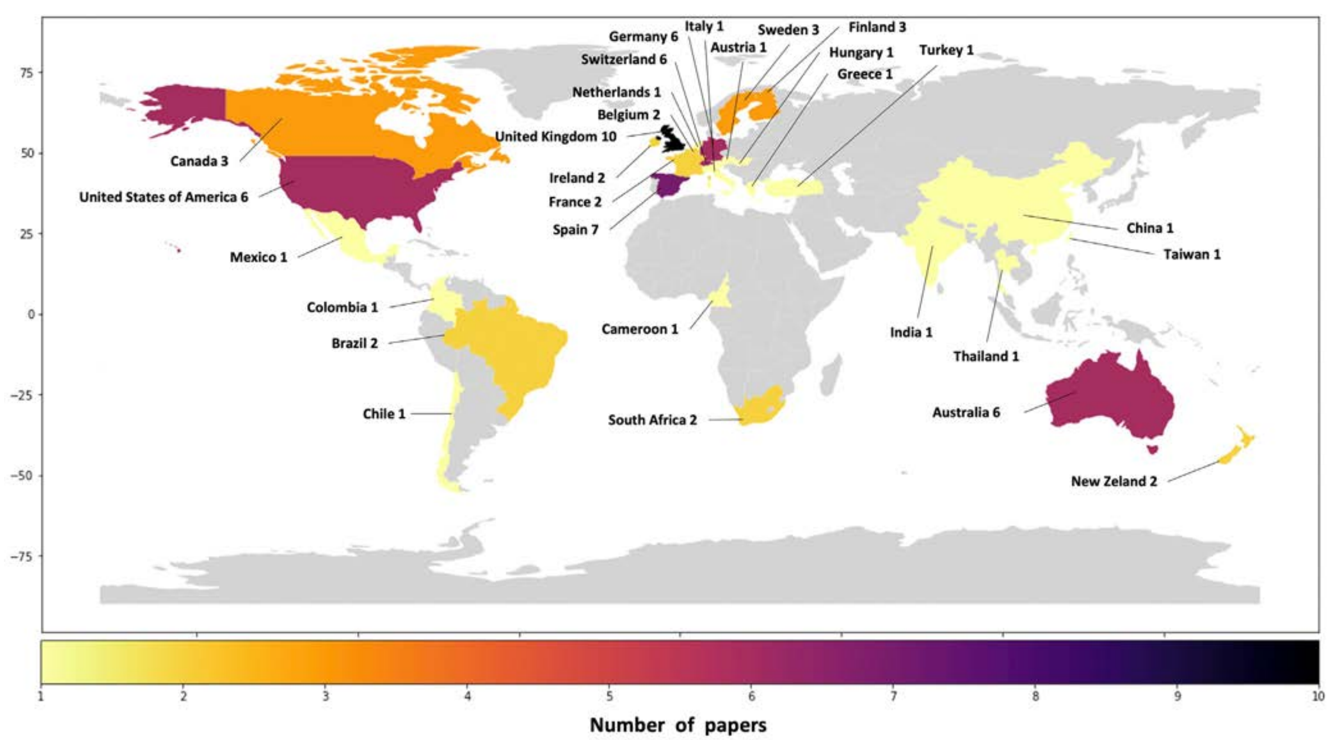

Fig. 2. Location of reviewed studies by continent and country,

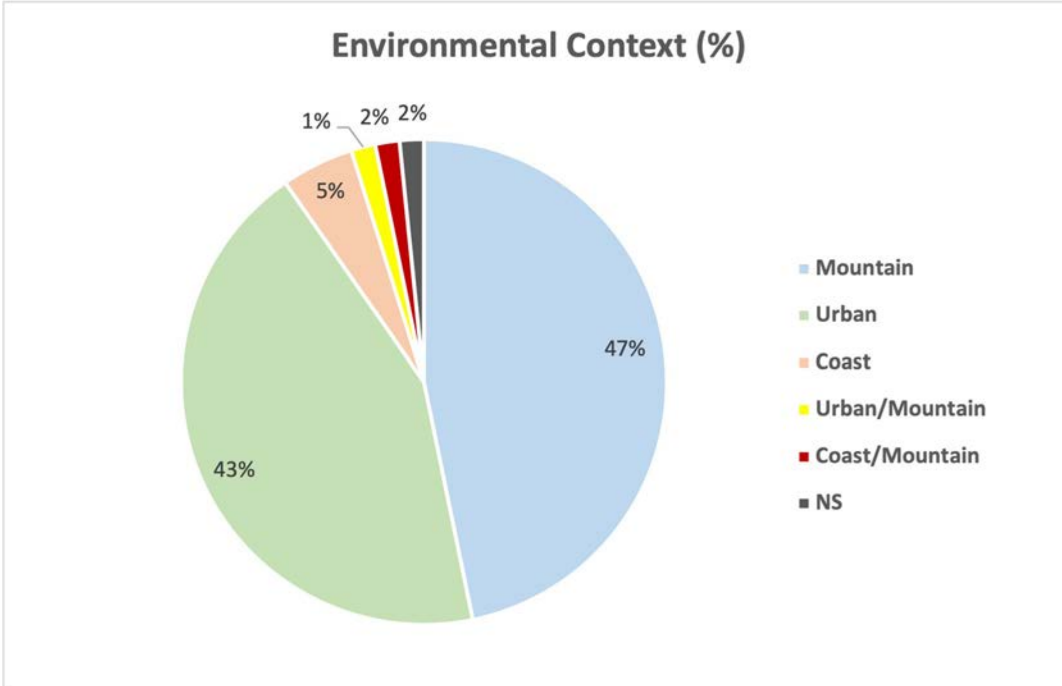

Fig. 3. Percentage of studies by environmental context.

methodological classification, the 62 reviewed studies can be categorized as follows: a) “Observational”, when data collection relies on item counts through direct observation, typically involving terrain samplings; b) “survey”, when results are based on people's opinions collected through surveys; c) “simulation”, when results are analyzed using simulation models; and d) “intervention”, when the effects of an intervention are experimentally analyzed.

3.5.1. Observational studies

There are 23 observational studies (37.1 %), comprising 9 longitudinal studies and 14 cross-sectional studies (Supplementary Table 1). Of these observational studies, 19 (82.6 %) analyze terrain samplings or terrain areas. Among the remaining 4 studies, 3 focus on samples of people (mainly spectators),[45,51,55] and one examines a sample of butterflies.[56]

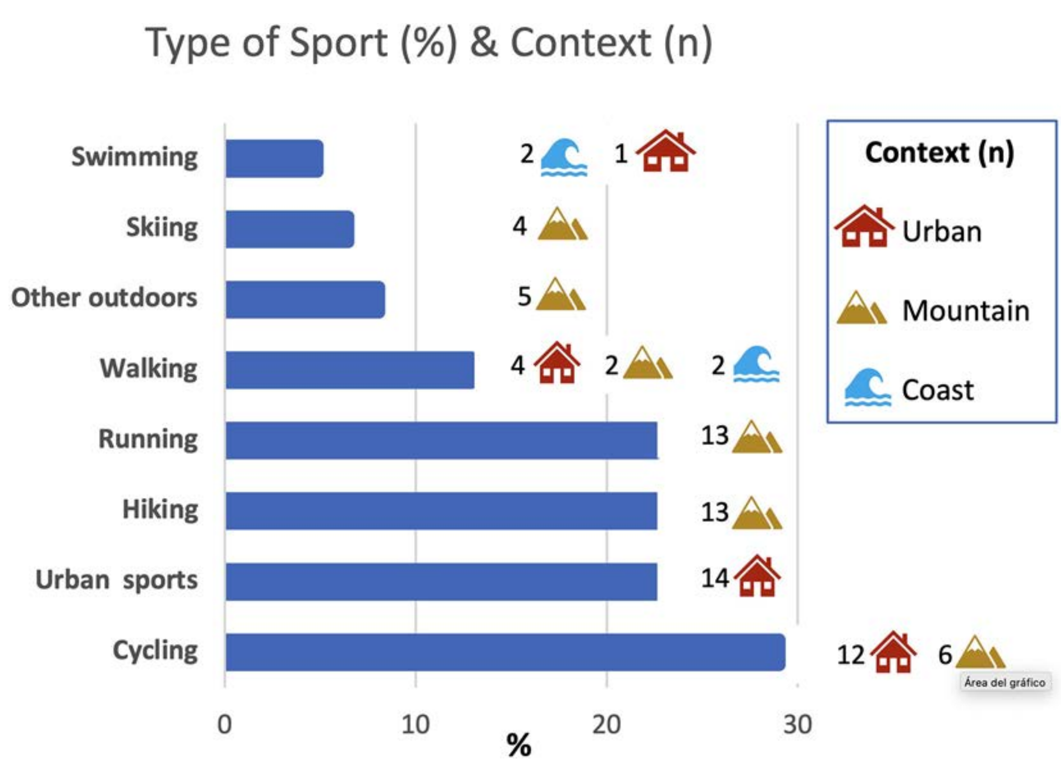

Fig. 4. Type of sports (in percentage) and environmental context (n, number of studies) of the reviewed studies.

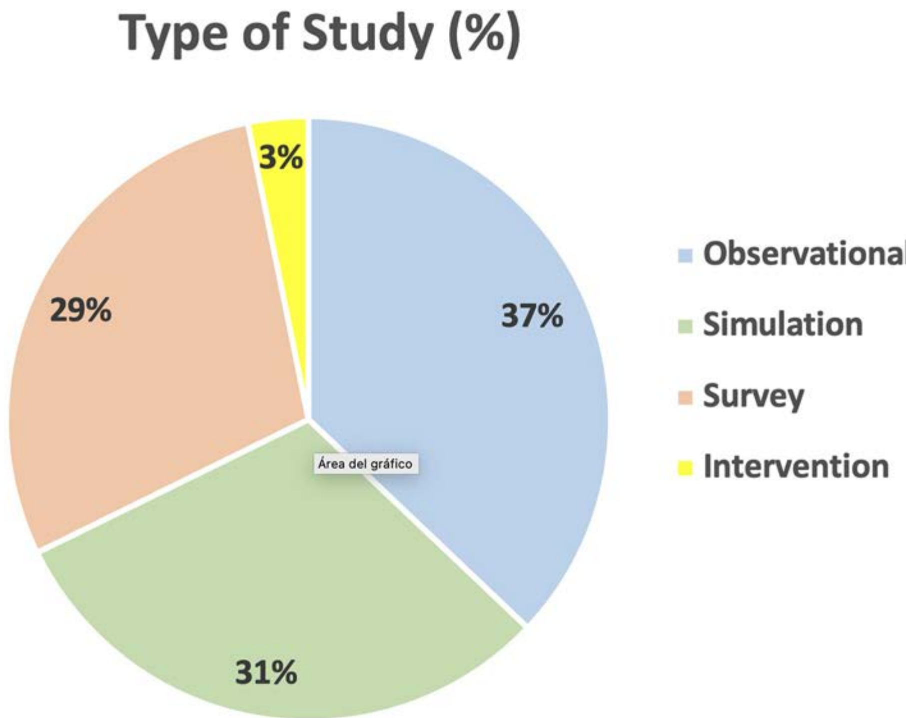

Fig. 5. Percentage of studies by type of study.

For observational studies, methodologies vary, even when considering the same type of sport. The subject of most of these studies was plants, with a minority focusing on animals. For example, Bennett et al.[56] observed the behavior and movement patterns of Karner blue butterflies to differentiate natural behaviors from responses to practitioners, while Bötsch et al.[57] and Huhta & Sulkava[58] assessed the avian community using fixed radius point counts. Additionally, Schmera et al.[43] and Baur et al.[59] examined species richness and relative abundance of land snails. In Müller et al.,[60] the impact of sportive fishing was studied, measuring species abundances semi-quantitatively by comparing the actual occurrences of each species to the full set of faunistic data for that species across the entire area. Regular transects were utilized as a sampling method in several studies to assess area conditions,[42,61–63] but the sample sizes and methods for their establishment varied. Different methods were used to identify and classify plants, such as following the Flora of Eastern Andalusia.[62]

The diversity of observational strategies is evident in climbing-related studies, where the complexity of the rock surface was assessed based on the number of fissures, ledges, and pockets, as specified in Schmera et al.[43] and Baur et al.[59] The choice of control plots used in these articles, which were used for comparison with affected areas, varied. For example, McMillan & Larson[63] distinguished between "documented" and "undocumented routes", while Müller et al.[64] employed specific criteria for selection. Different methods were employed to count the number of plant species, such as photoplots[62] and direct observation.[63,64]

Another set of observational strategies involved analyzing the environmental impact of sporting events, including football matches, Olympic Games, or World Rally. These articles estimated the carbon footprint, but the methods varied. For instance, in Loewen & Wicker,[51] carbon footprint calculation was based on travel distance and mode of transportation to the stadium, followed by a 3-step empirical analysis involving the number of home and away matches visited during the first division of the Bundesliga in the 2018/19 season. Similarly, Triantafyllidis et al.[65] calculated CO_2 emissions based on the football stadium location, transportation mode, and distance traveled. In Shen et al.[66] and De La Cruz et al.,[67] during the Olympic Games, the subject of the studies was air pollutants, but data collection before, during, and after the Olympic Games and Paralympic Games differed between the two. The study in Dal & Akdağ[68] focused on noise pollution caused by the football stadium.

3.5.2. Survey studies

There are 18 survey-based studies (29 %), 7 in urban contexts, 9 in mountain, 1 in coast, and 2 in both urban and mountain contexts. All of these studies involved human participants, with gender specified in 14 of them, and age indicated in 13.

Overall, surveys aimed to gather information on: a) Environmental behavior (16 studies), which inquired about behaviors such as recycling/reusing materials, energy conservation, the impact of transportation choices for commuting, and travel-related environmental impact; b) environmental impact (11 studies), assessing the impact of events in which the surveyed individuals participated, encompassing positive and negative environmental impacts; and c) sociodemographic variables (to be described further with appropriate references).

The format of these survey studies varies, with no standardized set of questions. For instance, some surveys included open-ended questions regarding different aspects of users' environmental behavior,[36,69–73] while others were structured questionnaires.[74–78] The survey studies were diverse in the range and format of questions, aiming to explore a variety of aspects related to environmental behavior, impact, and awareness.

3.5.3. Simulation studies

Nineteen simulation studies (30.6 %) were identified, of which 17 utilized a simulation-model design, and two studies by the same author employed a cross-sectional design[54,79] (Supplementary Table 1). Most of the 17 simulation-model studies (15 studies) were conducted in an urban context.

Nine of these simulation studies were based on a surveyed sample, involving a total of 42,709 individuals surveyed. Among these 9 studies, there are three studies where 24,572 individuals were surveyed, and where collectively they undertook a total of 103,159 trips to sporting events.[36,80,81] In 10 simulation studies the sample consisted of "commuters" who used physical activity as a means of transportation, such as cycling, without it being considered a sporting activity.

3.5.4. Intervention studies

There were only two intervention studies (3.3 %), both employing an experimental design, conducted in a mountain context. These studies used terrain samplings as their sample, aligning with hiking as the type of sport, with a level of amateur participation[82,83] (Supplementary Table 1).

3.6. Impact of physical activity (PA) on planetary health according to the general objectives of the studies

Supplementary Table 2 provides an overview of the general objectives of the reviewed studies, classified into four categories: attitudes, active lifestyle, event, and sport in nature. Twelve studies (19.4 %) focus on attitudes, centering on the attitude, perception, knowledge, or consciousness of participants, spectators, or event organizers regarding the ecological impact of sports. Another 13 studies (21 %) concentrate on active lifestyles, examining the impact of physical activity on planetary health, such as cycling for commuting. Additionally, 16 studies (25.8 %) target events, exploring the effect of sports events themselves on planetary health. Finally, the remaining 21 studies (33.9 %) emphasize sports in natural settings, investigating the direct ecological footprint of engaging in sports in natural environments (see Fig. 6).

3.6.1. Attitudes

Among the 12 studies (19.4 %) that focus on attitudes, three indicate negative environmental effects,[75,77,84] one finds no impact,[76] and eight report positive environmental effects.[52,53,71,73,74,85–87] Of those eight studies demonstrating positive effects, two propose increasing the willingness to pay as a pro-environmental action to compensate for the carbon footprint of a sports event.[53,87] Other studies highlight environmental responsibility, awareness, or concern as positive effects. For example, one study on outdoor leisure activities concludes that participation in physical activity is positively associated with the belief that climate change personally affects individuals.[71] Another study involving participants in various sports shows that environmental consciousness predisposes individuals to pro-environmental actions and improves the carbon footprint.[52] Additionally, a study suggests that mountain bikers view recreational activities as having a significant impact on forest conditions.[73] Another study finds positive environmental attitudes in national golf players.[86] The remaining two studies with positive environmental effects focus on sports events predisposing individuals to pro-environmental behaviors. One of these studies indicates that event attendees at football games were likely to be more environmentally friendly during the event than at home,[74] while the other study finds that adventure race participants exhibit pro-environmental attitudes, with respect increasing as age advances.[85]

In terms of studies reporting negative effects, Bartoletti et al.[84] conclude that more targeted environmental education and dialog with racers and race organizers in adventure races are needed. Similarly, Priskin[77] also suggests the need for improved visitor education and interpretation facilities in outdoor sports such as sandboarding, 4 × 4 driving, and horse riding. The only study that found no environmental impact[76] suggests that perceived environmental impacts (both positive and negative) are not related to overall attitudes toward the Olympic Games.

3.6.2. Active lifestyle

Among the 13 studies (21 %) examining active lifestyles, nine indicate positive environmental effects,[36,80,81,88–93] two report negative effects,[54,79] and two studies indicate both positive and negative effects.[94,95] Of those nine studies reporting positive effects, all of them (11 studies, 17.7 % of the 62 reviewed articles) consider cycling as an active lifestyle behavior with the primary effect of reducing air pollution. Out of these, two studies also consider the negative health effects resulting from personal exposure to air pollution.[94,95] Eleven of these studies (17.7 % of the 62 reviewed articles) advocate for cycling as a positive lifestyle behavior for active commuting,[36,80,81,88–95] and four studies also consider walking as a positive lifestyle behavior for active commuting, in addition to cycling.[36,81,90,92] The two studies that only consider negative environmental effects emphasize air pollution resulting from motorized travel for winter sports[54] and other sports such as hiking, cycling, running, paddling, swimming, and 4 × 4 driving in natural areas.[79]

Looking more closely at the findings, several studies conclude that cycling contributes to the reduction of the environmental impact of motorized transportation, leading to reduced fuel consumption, air pollution, CO_2 emissions, and noise.[80,81,88,91] Some of these studies directly compare active commuting by walking and cycling versus motorized transport, indicating that more cycling or walking results in decreased mobility-related life cycle CO_2 emissions.[36] Another study highlights that transport by car and sports utility vehicles (SUV) is the most carbon-intensive mode of commuting.[93] Replacing motorized transport with bicycles reduces waiting time, and students choose bicycles because they are faster than walking or taking the bus.[90] E-bikes (electric bikes) have a lower environmental impact than cars, including lower greenhouse gas emissions, although E-bikes are worse than cars in terms of the production and disposal of lithium-ion batteries.[89] Additionally, bicycle mobility offers economic savings and saves public

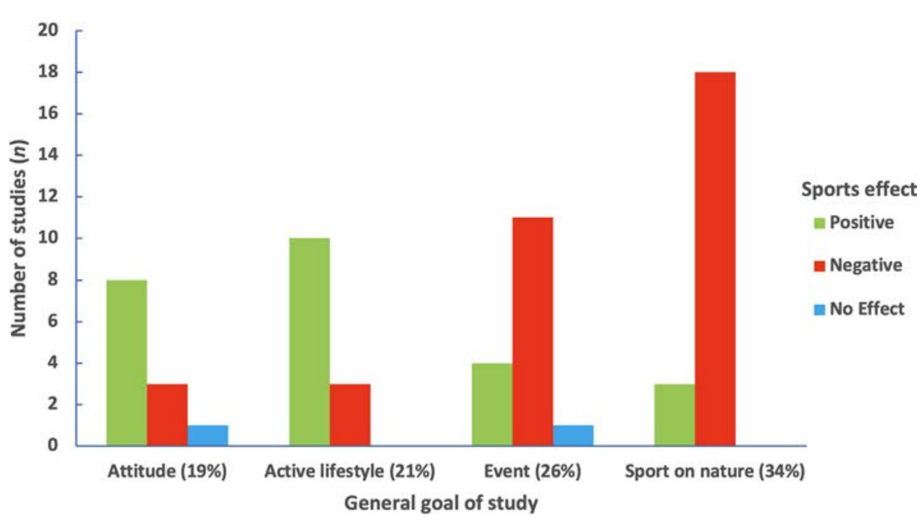

Fig. 6. Sports effects on the general goal of the study.

funds.[80] Therefore, promoting and investing in active travel, such as cycling and walking, should be a cornerstone of sustainability strategies, policies, and planning.[36]

3.6.3. Event

In the context of the 16 studies (25.8 %) focusing on the direct impact of sports events on planetary health, 11 of them report negative environmental effects,[44,51,55,65,68–70,72,96–98] while four studies indicate positive environmental effects.[66,67,99,100] There is one study that finds no significant impact.[101]

Among the 11 studies highlighting negative effects, eight studies identify sports events as having an adverse ecological impact. For instance, trail running competitions have been associated with ecological disturbances.[75,100] Athletics events, particularly concerning accommodation and overnight stays in hotels, contribute to an ecological footprint.[96] Increased CO_2 emissions linked to tourism accompanying cycling events have been observed,[97] as well as elevated noise pollution levels and emissions from spectators in football stadiums.[51,68] Moreover, rallies are shown to generate high CO_2 emissions and have negative impacts on the environment.[55,99]

Another factor considered negative is the environmental impact caused by travel to sports events, especially related to the pollution from international flights of sports teams and spectators.[72,96] It also includes the carbon footprint of automobile emissions resulting from the travel of spectators or athletes.[44,51,65,69,70,98]

In contrast, certain studies highlight positive impacts of sports events. These include the extensive recycling of waste at athletics events,[96] a balance between personal goals and responsibility for environmental protection among trail runners,[75] and the potential for sports events, such as relay races, to enhance the local environment, infrastructures, and environmental education programs specially the younger and more educated spectators.[99] Positive effects have also been noted in relation to the Olympic Games, such as reduced air pollution during the Olympic period in China compared to the previous period[66] and decreasing pollutant concentrations during the Olympic Games in Brazil compared to post-Games.[67]

Concerning the category of sports events, some studies propose actions to evaluate or reduce the environmental impact. For instance, it has been suggested to use the World Tourism Organization (WTO)'s indicator as an effective tool for assessing the sustainability of sports events, based on four indicators (education, literacy, political agendas, economic development[100]). Collins et al.[97] suggest tools for monitoring and evaluating post-event outcomes, including information related to different travel modes to identify the global impacts of additional visitor consumption. Chard & Mallen[70] have proposed engaging in coordinated carpooling efforts to reduce the environmental impacts (neutralize carbon impacts) of minor hockey team members and individual hockey participants (parents). Dolf & Teehan[72] propose opportunities for reducing the environmental footprint for spectators and teams, including the reduction of long-distance air travel, increasing vehicle occupancy rates, and promoting low-emission travel mode choices. Bunds et al.[69] suggest a solution to mitigate the negative impact is for those living in close proximity to a facility to participate in carpooling.

3.6.4. Sport in natural settings

Among the remaining 21 studies (33.9 %), which focus on the direct ecological footprint of engaging in sports in natural environments, 18 of them identify negative environmental effects,[42,43,56–64,78,82,83,102–105] while three papers indicate some positive environmental effects[106–108] (see Fig. 6).

Of the 18 studies noting negative effects, five studies conclude that climbing has these negative impacts, significantly reducing biodiversity and the abundance of plant species and gastropods living in the climbing area.[43,59,62–64] Another four studies emphasize the negative impact of recreational activities at high altitudes, such as the effect of cross-country ski tracks on plant species on the track[108] or a similar effect on horse trails.[104] There have been observations of increased waste after human activity[103] and drastic changes brought about by the urbanization of natural areas, altering bird communities.[58]

On the other hand, six other studies highlight vegetation damage as a negative consequence of hiking,[42,61,78,82,83,102] and the remaining studies demonstrate negative effects of climbing, walking or running in natural environments in terms of disturbances to specific species of coral life, snails, butterflies and birds.[43,56,57,59,105]

For the three papers identifying positive environmental effects, they indicate the potential for a reduction in global warming related to cross-country ski tracks (strongly),[108] an increased awareness among hikers to avoid vegetation damage,[107] or an enhanced awareness of the potential impacts of mountain biking on forests, particularly in comparison to hiking.[106]

4. Discussion and conclusions

We carried out a scoping review to comprehensively evaluate the existing literature and identify knowledge gaps within the domain of "Physical Activity and Planetary Health", which explores how physical activity and sports influence the natural environment. With this review, we provide an in-depth analysis of the physical activity behaviors that are environmentally sustainable and those that are not, we identify the attributes characterizing sustainable physical activity behaviors, and we synthesize the principal positive and negative impacts of physical activity behaviors on planetary health, relating the review results to the existing literature. Our scoping review supports the identification of this applied and research area as "Planetary Health Physical Activity" and/or "Planetary Health Sport".

The results of the 62 studies included in this scoping review reveal a diverse array of research studies examining the impact of physical activity on planetary health. The included studies cover a wide range of environmental contexts, such as mountain, urban, and coastal areas, and investigate a wide range of sports and activities. The methodologies employed in these studies encompass observational, survey-based, simulation, and intervention approaches. Each methodology offers a unique perspective on the relationship between physical activity and its ecological consequences.

4.1. Attitudes toward environmental impact

Among the studies focusing on attitudes, a notable finding is the existence of a gap between self-reported pro-environmental attitudes and the actual ecological impact of physical activity and sports. Most of these studies highlight positive attitudes, centering on the attitude, perception, knowledge, or consciousness of participants, spectators, or event organizers regarding the ecological impact of sports. Examples are the environmental responsibility, awareness or concern and the willingness to pay as a pro-environmental action. While these studies report positive attitudes among participants and event attendees, they also highlight negative ecological consequences, such as increased air pollution and waste generation (see the "Attitudes" subsection in the Results section for specific citations). This dissonance between attitudes and actions is an essential area for future research, as it could significantly impact efforts to mitigate the negative environmental effects of physical activity.

4.2. Promoting active lifestyles

The scoping review emphasizes the role of active commuting (or active transport), particularly cycling, in reducing air pollution and promoting sustainable transportation options. Many studies indicate that replacing motorized transportation with cycling and walking offers substantial environmental benefits, including reduced fuel consumption, greenhouse gas emissions, and noise pollution. Promoting active travel in urban areas, such as cycling to work, emerges as a vital strategy for improving both individual health and the environment (see the "Active lifestyle" subsection in the Results section for specific citations).

4.3. Environmental impact of sports events

Sports events are shown to have a significant impact on planetary health, with both positive and negative effects. While some studies highlight the ecological disturbances caused by events like trail running competitions and athletics events, others underscore the potential for events to promote sustainability.

On the one hand, most studies report negative environmental effects, like now increased CO_2 emissions linked to tourism accompanying events, elevated noise pollution levels and emissions from spectators or the ecological footprint concerning to accommodation and overnight stays in hotels. On the other hand, initiatives such as recycling waste and enhanced infrastructure development suggest that sports events can contribute positively to the environment. However, it's crucial to address the negative ecological impacts of these events, such as increased CO_2 emissions from travel and noise pollution, through sustainable event planning and management (see the "Event" subsection in the Results section for specific citations). In this sense, we have missed studies, that meet the inclusion criteria in our review, that dare to assess major sporting events at the global level, such as motor racing (for example, Formula 1 or motorcycle GP races), or the global environmental impact of the professional football league or sports world championships.

4.4. Sports in natural settings

Engaging in physical activities in natural environments, such as hiking, climbing, and walking, has a mixed impact on the environment. Several studies emphasize the negative consequences of these activities, including reduced biodiversity, vegetation damage, and disturbances to specific species. These findings underscore the importance of responsible outdoor recreation to minimize ecological harm. However, a few studies suggest that raising awareness and altering behaviors can lead to positive environmental effects, such as reduced global warming potential in cross-country ski tracks, increased awareness among hikers to avoid vegetation damage, or an enhanced awareness of the potential impacts of mountain biking on forests (see the "Sport in natural settings" subsection in the Results section for specific citations).

4.5. Methodological considerations

The study identified a wide range of methodological approaches used in the literature, including observational, survey-based, simulation, and intervention studies. These methods each provide valuable insights into the relationship between physical activity and planetary health, but they also highlight the need for more standardized and experimental designs to establish causal relationships between physical activity and its ecological consequences. Researchers should strive for methodological consistency to ensure meaningful comparisons across studies and facilitate a more comprehensive understanding of this complex subject.

An important consideration is the need to unify the analysis methodology for observational studies, when data collection relies on item counts through direct observation, typically involving terrain samplings or terrain area forests (see the "Observational studies" subsection in the Results section for specific citations). We recommend standardizing sample sizes and methods for plant and animal classification in specific geographic areas, for example counting the number of plant species (or animals) in an area of 1 m^2 (or proportional quadrant) through direct observation or, better, a photograph at the time of observation. We also recommend unifying the method to estimate the carbon footprint as observational strategies analyzing the environmental impact of sporting events: calculate CO_2 emissions based on the sport event location, transportation mode, and distance traveled.

About survey studies, we propose to unify a same survey design and standardize the set of questions and possible answers. The design would be a structured questionnaire with only ended questions regarding aspects related to environmental behavior, impact, and awareness. It could be a two-factor questionnaire with items to answer in two situations, "at home" and "during the event", including 10 items for each factor, every item rated on a 11-point scale, 0 to 10 with the value labels: "0 = never, 5 = sometimes, 10 = always". We propose the same strategy for simulation studies given that most are based on surveyed samples.

It should be noted that we only considered two intervention studies that met the criteria to be included in our scoping review. It is probably due to the difficulty of implementing and following an experimental design that allows analyzing the effects of a behavioral intervention on the environmental impact. In any case, to analyze this impact we propose to follow the strategies discussed for observational and survey studies (standard and valid measures, and use of technology to increase objectivity). We encourage researchers to propose and carry out these types of studies because they are the ones that can more objectively demonstrate the importance of a behavioral change related to physical-sports activity in the sustainability of the planet.

4.6. Final statement

This scoping review of the literature on "Physical Activity and Planetary Health" reveals a rich and diverse body of research, showing the multifaceted relationship between physical activity, sports, and the natural environment. There is sufficient evidence to identify this applied research area as "Planetary Health Physical Activity" and/or "Planetary Health Sport". The findings emphasize the intricate relationship between attitudes, active lifestyles, sports events, and activities in natural settings and their impact on planetary health. While many positive outcomes are associated with engaging in sustainable physical activities, there is also a need for increased awareness and responsible behaviors to mitigate the negative ecological consequences. Climate change represents an enormous threat for our planet in terms of biodiversity, society, and economy. Although global warming seems to be mainly caused by human-related activities, governmental policies are not enough to achieve the agreements established in specific meetings between countries. From the automobile industry to nutrition field, all economic sectors are implementing policies to reduce its environmental impact. However, in the field of sports and physical activity there is no consensus regarding its impact on the environment.

Moving forward, researchers should focus on bridging the gap between pro-environmental attitudes and actual behaviors, promoting active commuting, and implementing sustainable event management practices. Additionally, responsible outdoor recreation and sustainable practices in natural settings should be encouraged to minimize the negative impact of physical activities on the environment.

The concept of "Physical Activity and Planetary Health" encompasses a broad spectrum of topics, methodologies, and both favorable and adverse impacts of physical activity behaviors on sustainability. Our research has identified four main areas of investigation: i) individuals' attitudes toward the environment and nature, ii) the promotion of active lifestyles such as active commuting, iii) event organization, and iv) the direct consequences of physical activity and sports activities on the natural world. While adopting an active lifestyle can contribute to the reduction of air pollution, event organization may lead to increased air pollution, and engaging in physical activity and sports in natural settings can have detrimental effects on ecosystems, flora, and fauna. Intriguingly, there appears to be a tendency for individuals to overstate their pro-environmental attitudes in contrast to the actual effects of their physical activity and sports behaviors on the natural environment. It is imperative for future studies to delve deeper into this dissonance, as it may play a pivotal role in mitigating the negative impact of physical activity on planetary health. Most of the existing studies have predominantly employed opinion-based or simulation designs; however, there is a pressing need for more experimental designs to establish causal relationships between physical activity and its ecological consequences on planetary health.

The field of study in "Physical Activity and Planetary Health" offers a promising framework for enhancing both individual well-being and environmental sustainability. This holistic approach considers the relationship between physical activity and the natural world and provides a foundation for future research and practical initiatives aimed at harmonizing physical activity and nature for the benefit of both individuals and the environment. As society continues to address the challenges of physical-sports practice behavior and environmental sustainability, this research area holds great promise for improving planetary health and the well-being of future generations.

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Confirmation of ethical compliance

Our paper is a literature review and not an experimental study. However, it is included in the protocol approved by the Local Ethics Commission for Human Experimentation from Autonomous University of Barcelona (protocol code CEEAH-5745). All the procedures were performed according to the tenets of the Declaration of Helsinki.

CRediT authorship contribution statement

Lluis Capdevila: Conceptualization, Supervision, Funding acquisition, Writing – original draft, Writing – review & editing. **Josep-Maria Losilla:** Methodology, Data curation, Supervision, Writing – review & editing. **Carla Alfonso:** Writing – original draft, Data curation, Investigation. **Tony Estrella:** Writing – original draft, Data curation, Investigation. **Jaume F. Lalanza:** Conceptualization, Supervision, Writing – original draft, Writing – review & editing.

Data availability statement

The detailed search terms for all databases are available on request.

Declaration of interest statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jsams.2024.07.012.

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