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Weather and exercise: A comparative review and the role of geographers

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Abstract

As part of an argument about the value of a geographical approach to the connection between local weather and physical exercise, this paper begins with how that connection features in four areas of scholarship that have been at the forefront of exploring it so far. By comparing how each of them commonly imagines 'the human' and 'the weather' in their studies, we particularly highlight how different bodies of work illuminate different facets of the weather-exercise connection. This, we suggest, represents an opportunity for geographers to explore how these facets combine in context with a view to tackling the complex public health challenges associated with increasing human inactivity and a warming world. Building on that, we end with three promising cross-cutting themes that we think could usefully guide these endeavours: adaptation, decision-making and place.

KEYWORDS
climate change, health promotion, physical activity, public health, weather

1 | INTRODUCTION

There are many reasons for studying how local weather conditions influence the physical activity (PA) of different populations. In many countries, lifestyles are increasingly sedentary, meaning that growing numbers of people do not reach healthy activity levels (Park et al., 2020). Since outdoor exercisers must contend with the weather, understanding how they handle it could help to promote the physical and mental health benefits of exercise more widely (Guthold et al., 2018). Climate change represents another important justification with hotter and more extreme

weather predicted for many world regions. This leads to a different set of public health worries about how outdoor exercise may be encouraged without putting people at risk from the negative effects of these increasingly challenging conditions (Bernard et al., 2021). Linked to this is the final suggestion that future populations might relocate their exercise indoors. This raises additional equity and access issues, as well as concerns about the energy demand associated with providing climatically controlled weather-less environments for exercise (Abu-Omar et al., 2020; Pampel et al., 2010).

Yet how the weather-exercise connection has been studied so far can be characterised by areas of scholarship that have often done so in comparative isolation. As geographers interested in how different perspectives might be productively combined, we start our paper by reviewing how four predominant approaches commonly imagine this connection. Excluding studies of those who exercise outdoors as part of their employment, we discuss researchers who have analysed large datasets to foster population health, those hoping to promote active travel, sports scientists focussed on athletic performance, and how qualitative researchers pay attention to the lived experience. By asking the same two questions of each group of studies - what is 'the human'? and what is 'the weather'?—we foreground how different approaches highlight different facets of the weather-exercise connection and consider how they might be combined. We argue that the contextual sensitivity of geographers could be particularly helpful here and end with three promising cross-cutting themes to help guide their endeavours: adaptation, decision-making and place.

2 | AGGREGATE DATASETS: IDENTIFYING PATTERNS AND DIFFERENTIATING PEOPLE

We start with a set of researchers focussed on how societal PA patterns respond to changing weather and seasons. A well-established area of work, their aim is usually to determine which weather conditions help or hinder the PA of different groups with a view to promoting activity (e.g. Rahman et al., 2019; Turrisi et al., 2021; Witham et al., 2014). Here meteorological data is frequently obtained from the nearest weather station and, although the examined timescales differ (from day-to-day fluctuations to seasonal changes), the most commonly explored parameters include temperature, precipitation, windspeed, visibility, humidity and sunlight (e.g. Harrison et al., 2017; Remmers et al., 2017). These are then compared to activity data commonly captured through movement measuring devices worn by participants such as accelerometers that record activity intensity and total amounts of movement (e.g. Aspvik et al., 2018; Harrison et al., 2017) and pedometers that record the number of steps they take (e.g. Alahmari et al., 2015; Chan et al., 2006). Armed with these data, this group then explores the effect of specific group characteristics including age, gender, body mass index and socio-economic status (Gracia-Marco et al., 2013; Remmers et al., 2017; Turrisi et al., 2021). Cepeda et al. (2017), for example, included 1166 participants in their Rotterdam study of older adults, monitoring activity levels over 5 years to reveal a summer activity peak. Linking activity levels with daily meteorological data also allowed them to identify the most influential weather components and conclude that ambient temperature and sunshine hours most influenced this pattern (Cepeda et al., 2017). These older Dutch exercisers were therefore revealed as both gradually shifting to a summer exercise mode and responding to daily weather fluctuations.

Particular interest groups for these researchers have included children (e.g. Cooper et al., 2010; Harrison et al., 2017), adolescents (e.g. Beghin et al., 2020; Gracia-Marco et al., 2013), older people (e.g. Aspvik et al., 2018; Brandon et al., 2009; Witham et al., 2014) and those with health conditions such as Chronic Obstructive Pulmonary Disease (COPD) (Alahmari et al., 2015; Balish et al., 2017) or osteoarthritis (Feinglass et al., 2011; Robbins et al., 2013). In the case of COPD, for example, Alahmari et al. (2015) asked patients to record when their symptoms worsened, the time they spent outside, and their breathing ability, before comparing these recordings to pedometry and weather data. Finding inactivity highest on cold, wet and overcast days, they suggest that rehabilitation programmes should focus on helping exercise to weather these conditions (Alahmari et al., 2015). This work also draws attention to indirect impacts. For example, Jones et al. (2017) found that snow accumulation led to less activity amongst older

Canadians, which, in line with other studies, they suggest could relate to fear of falling (Bruce et al., 2002; Chan et al., 2006; Jones et al., 2017).

In the first of our four approaches, the (potentially) exercising human is seen, at times, as highly weather responsive as heatwaves or snow are shown to produce abrupt PA declines for certain groups (Chan et al., 2006; Remmers et al., 2017; Tucker & Gilliland, 2007). However, there are limitations associated with movement measurement devices which say little about activity type, whether it actually happens outdoors, and for what purpose (Böcker et al., 2013; Remmers et al., 2017; Turrisi et al., 2021). So, whilst these studies tell us a great deal about how much different groups of participants move, they leave significant gaps in our understanding of how exactly people react to weather. Nonetheless, our first human is clearly differentiated, partly because these researchers are in a position to notice and explore how identified social groups respond to identified conditions.

Turning to how this group of researchers handles the weather, analysing the effects of identified components enables them to map fluctuations in activity and highlight how specific conditions disrupt exercise routines. In that way, weather features in this first body of work as specific recorded parameters, not a complex of interacting elements. Given the health promotion agenda of this work, the result of this focus is often recommendations about helping activity to persist through periods of particular levels of cold or volumes of rain or about providing indoor spaces to minimise observed weather disruptions (Aibar et al., 2015; Beghin et al., 2020; Tucker & Gilliland, 2007).

In summary, this work provides a valuable appreciation of, and sensitivity to, diversity in terms of both exerciser demographics and specific weather components and changes. By putting the spotlight on how different social groups, each with different presumed capabilities, respond to specific conditions, it also pushes us to acknowledge indirect weather impacts. Less, however, is known here about how the lives of the exercisers themselves shape the practices that collectively create the exercise peaks and troughs in which these researchers commonly trade. This approach provides many insights about patterns. But we can only guess at the lived experiences involved.

3 | ACTIVE TRAVEL: EVERYDAY DECISIONS AND ADDRESSING ROUTINE

Our second body of work aims to promote less energy consumptive transport systems and healthier populations by encouraging everyday practices of getting around that involve exercise—what has become known as 'active travel' (Ahmed et al., 2013; Böcker et al., 2013; Miranda-Moreno & Nosal, 2011). The researchers involved are most commonly interested in how weather disrupts or supports travel routines in cities by understanding how it enters the consciousness of, and is accommodated by, the commuters they hope will choose to walk, run or cycle to work (Böcker et al., 2013).

Various approaches are employed by these researchers, including discussion-based studies to learn of how everyday travellers interact with weather (e.g. Galway et al., 2021; Larsen, 2018; Mullan, 2013; Spencer et al., 2013) and combining objective measurements (e.g. weather station data, journey counts) to model the relationship between journeys and weather parameters (e.g. An et al., 2019; Goldmann & Wessel, 2020; Thomas et al., 2013). Others bring together mixed methods (surveys, diaries, interviews, questionnaires) and weather data (e.g. Brandenburg et al., 2007; Chapman & Larsson, 2021; Meng et al., 2016). Larsen's (2018) interviews, for example, highlight wind's significance for commuter cyclists in Copenhagen, shaping their experiences in terms of speed, workload and comfort. Finding even the thought of a cold headwind enough to put off an active commute, he shows how past weather experiences shape the decision to cycle to work (Larsen, 2018). A key focus now is on the choice to travel in certain ways, which can mean looking beyond conditions at the time. Zhao et al. (2019), for example, found rainfall affected cycle trail use in Seattle both before and after rain indicating that commuters may wait for wet and dirty surfaces to dry. Collectively these approaches demonstrate the sensitivity of journeys to different forms of weather and the complex amalgam of practicalities, experiences, and perceptions behind that.

The interest of this group in commuters who, unlike leisure exercisers, must get to work 'whatever the weather', encourages a focus on practical adaptations. Using questionnaires, Bergström and Magnusson (2003) segmented

their Swedish commuters to reveal 'summer-only' cyclists as more sensitive to certain weathers in deciding to cycle than those who valued the exercise element so much that winters were endured. They also found road conditions less important to 'winter cyclists' because they had equipped themselves for it for example, switching to studded tyres. These cyclists had learnt to handle adverse conditions through practical amendments. This is further demonstrated in discussion-based approaches where Spencer et al. (2013), for example, found that commuter cyclists in Vermont had developed a sense of the temperature thresholds and road conditions that would trigger change in their transport mode, while Mullan's (2013) Belfast cyclists discussed weather in the context of everyday safety. Indirect weather effects are therefore also explored here.

This second human most often appears as an informed decision-maker who negotiates the weather alongside other road users, transport infrastructure, and the broader pressures of everyday life. Commonly an urbanite on a regular journey to work, this focus leads researchers to consider how infrastructures enable active commuters to weather themselves. They reflect on the value of more accurate weather forecasts and warnings, but also better surfaces such as tracks and trails (Meng et al., 2016; Zhao et al., 2019). Importantly, the contrasting and combining of approaches means the active traveller is here seen as a person who manages weather effects on their routines, sometimes changing their transport mode, but also sometimes making subtle changes in response to day-to-day weather. We certainly have much more detail here on how perceived conditions inform the behaviours of the often actively thinking active traveller, partly because they are now more often spoken with.

Drawing on both traveller perceptions and objective measurements, weather is now understood in terms of safety, comfort, and tolerance, and as a challenge to sustaining active travel routines. Extremes of temperature and precipitation, for example, are all found to hinder active travel, as revealed in drops in cycle journeys or how they are discussed as problematic (Galway et al., 2021; Miranda-Moreno & Nosal, 2011). Focussing on weather's influence on decision-making also highlights the importance of looking beyond prevailing conditions to consider the wider context for travel decisions, including how weather is planned for or considered in advance in terms of comfort and safety whilst commuting. These are not passive individuals swept up in the trends and patterns revealed in the aggregate datasets we've discussed above. Rather we see them actively drawing on various information sources to reflect on what different weathers mean for their journeys.

This research highlights how multiple weather-related factors inform everyday travel decisions. However, it does this with reference to a person who may be differently motivated to those who exercise for leisure (Cools et al., 2010). The commuter participants in Chapman and Larsson's (2021) study, for example, wanted to become better winter cyclists by adapting their equipment for cold conditions. It is difficult to know whether others would respond in comparable ways, especially when this group is aspiring to possess the resilience needed to sustain a personally valued active commuting routine. Nevertheless, attending to the ways in which weather can challenge potentially active travel usefully suggests looking beyond the responsiveness of aggregate activity levels by turning to particular transport mode choices. And that means considering how people actively respond to weather effects before, during and after their potential cycle, walk or run to work.

4 | ATHLETIC PERFORMANCE: HEAT EXCHANGES AND BODILY ADAPTATION

Less focussed on broader public health, a third sizeable relevant body of work has developed in the sports and medical sciences. This work seeks to understand how sporting bodies respond to different weather conditions and what that means for both safety and success at sporting events (e.g. Gosling et al., 2008; Helou et al., 2012). The starting position now is that, by understanding the effects of these conditions, strategies can be devised to ensure optimum athletic performance (Ely & Ely, 2020; Gibson et al., 2020). And that means attending to how bodies and weather interact.

The achievement focus leads these researchers to develop models comparing weather data with specific performance indicators. For example, due to the wealth of data often produced by them, several studies have examined

what weather does to marathon completion times and how this varies according to running 'ability' (e.g. Ely et al., 2008; Knechtle et al., 2019; Vihma, 2010). Some also incorporate biometeorological indices (e.g. the Wet Bulb Globe Temperature) which translate meteorological data into more refined appreciations of how heat is exchanged between human bodies and their immediate surroundings and the ways in which heat stresses different bodily functions (Havenith & Fiala, 2015). The results of these models are then compared with other physiological responses including heart rate and sweat rate alongside performance indicators for example, finishing times or goals scored (Konefał et al., 2021; Sabou et al., 2020; Zhang et al., 1992). Others explore how weather transforms environments - a drier surface, for example, means higher knee injury risk for Australian football players (Ahamed et al., 2018; Orchard et al., 2001).

While precipitation, wind and humidity are all shown to impact performance, especially in marathons (Knechtle et al., 2019; Trapasso & Cooper, 1989; Vihma, 2010), there is a particular interest in hot weather here (e.g. Brotherhood, 2008; Gosling et al., 2008; Pryor et al., 2019). Higher temperatures are revealed as problematic for many outdoor sports including football, tennis, cycling and running, and not just for performance, but also health, increasing the risk of exertional heat illness (EHI) (Bergeron, 2003; Ely & Ely, 2020; Konefał et al., 2021; Racinais et al., 2015). This leads these researchers to identify strategies to reduce these risks such as including a heat adaptation period during which, for example, a fortnight of acclimatisation training enables cyclists to perform as they would in more familiar lower temperatures (Racinais et al., 2015; Tyler et al., 2016). Monitoring how athletes perform (often pushing themselves to their limits) in the controlled indoor conditions of a 'climatic chamber' is also popular. This uncovers the immediate physical impacts of acclimation, different clothing levels and types, and exercise intensity, drawing out the implications of each for EHI and performance (e.g. Armstrong et al., 2010; Lorenzo et al., 2010; Mora-Rodriguez et al., 2008). Weather also presents athletic opportunities such as how hot weather or altitude training can help athletes to better previous performances or prepare for specific 'race conditions' (Saunders et al., 2019). Overall, this work valuably alerts us to the complex ways in which the physiological workings of the exercising body respond to their surrounding atmospheric conditions.

This body-environment focus allows exercisers and trainers to know when the body is put under strain by the elements and to plan accordingly (Brocherie et al., 2015; Brotherhood, 2008). Our third human is therefore imagined as generally (often very) fit and fully focussed on achieving top performance. However, in line with the implied picture of the human as a host for physiological processes, many biometeorological indicators are often based on a simplified, modelled version. This means they are less able to account for the variety of factors (physiological, morphological, psychological, and activity-based) which determine an individual's weather tolerance (Brocherie et al., 2015; Hermand et al., 2019). Less is also known in this work about how the athletes themselves perceive real world weather conditions, partly because they are assumed to want to stick closely to the advice in pursuit of top performance rather than necessarily enjoy the experience.

Similarly, weather is not now understood as shaping the overall decision to exercise as in the case of commuters, or a triggering effect on activity patterns as in the aggregate data. Rather it is studied as an influence on the body's functioning. Issues of injury and illness are now particularly foregrounded with weather overall being framed an uncontrollable aspect of practice, but one that can be managed with the right strategy (Ely & Ely, 2020). The focus on material exchanges between body and atmosphere also means that, in many studies, weather is now studied as heat owing to heat's dangerous physiological effects for those pushing to their limits in sometimes extreme conditions (Brocherie et al., 2015; Gibson et al., 2020). This draws attention to the point of interaction with the body itself as weather has become something to be mastered by fully understanding its impacts.

Examining how bodies in motion respond to weather, and how athletes and coaches strategise around this, puts the spotlight on bodily adaptation. The well-prepared athlete is one whose body has come to handle the weather without damaging performance, intentionally developing strategies to manage conditions and mitigate risk. Major events such as the Doha 2019 World Athletics Championships brought this into sharp focus where concerns about heat, humidity and dust emphasised the importance of meteorological risk assessment and mitigation (Bermon & Adami, 2019). However, comparatively little is revealed here about how exercisers themselves, athlete or otherwise,

understand and manage their own perceived physical weather responses. We learn a lot here about bodily limits and how this knowledge should be acted on by those who seek optimum athletic performance. Much less has been said about how comparatively casual exercisers evaluate physical heat risks and other physiological weather impacts in their everyday lives.

5 | QUALITATIVE STUDIES: ONGOING INTERACTIONS AND PERSONAL ATTUNEMENT

Our final body of work focuses on the detail of lived experience for outdoor exercisers (Allen-Collinson & Leledaki, 2015). Although less established than the other three, this work has already started to provide fresh insights into how weather is negotiated and felt as exercisers develop a range of weather-related skills (Allen-Collinson, Jennings, et al., 2019). Unlike many of the preceding researchers, this group does not seek to quantify weather effects. Rather, by spending time with identified exerciser collectives, and sometimes even participating in their activities, they unpick how exactly different exercising groups manage a mix of weather elements within their practices.

This work often begins with the idea that exercising outdoors involves an intimate relationship with atmospheric conditions (Simpson, 2019), frequently drawing on Ingold's notion of 'weather worlds' (2011, p. 96) in which people are considered to be fully immersed in, and responsive to, the fluxes and flows of weather. These scholars have examined a range of exercise practices that include mountaineering (Allen-Collinson, Crust, & Swann, 2019), fell running (Nettleton, 2015), marathon training (Larsen & Jensen, 2020) and triathlon (Allen-Collinson, Jennings, et al., 2019), commonly drawing on ethnographic and autoethnographic techniques that help them attend to the detail of this ongoing immersion. This strategy means they can explore how weather is both reacted to unthinkingly in the moment and subject to ongoing interpretation such as the triathlete learning to sense their body temperature in relation to surrounding water or the urban runner made suddenly aware of pollution when suddenly confronted by certain bodies of air (Allen-Collinson, Jennings, et al., 2019; Hodgson & Hitchings, 2018). Emphasis is placed on handling the full diversity of weather elements here, sometimes with a view to encouraging health promoters to see the subtleties of how different exercising groups encounter their environments (Bamberg et al., 2018; Hitchings & Latham, 2017a).

A key finding of this work is that exercisers become weather acquainted in ways that depend on both the activity and the capabilities of those who do it. Weather skills are slowly acquired here through varied physical engagements. The experienced, high-altitude mountaineers in Allen-Collinson et al.'s (2019b) study, for example, use learnt embodied feelings for snow to evaluate risk. Here weather is central, needing to be managed as it is refracted through combinations of terrain, climate, and physical stress. In contrast, the everyday exercisers in Maller et al.'s (2016) project were yet to develop the skills needed to exercise in all weathers leading them to change their exercise practices seasonally. There are many factors at play here including acclimatisation and motivation. Feelings of pleasure or pain are now also considered. A focus on weather immersion furthermore highlights the complexity behind what might superficially be deemed 'bad' or 'good' weather for exercise. Indeed, a positive reappraisal of 'bad' weather is revealed in practices such as fell running, mountaineering and endurance events because of how it represents an enjoyable challenge for those who undertake them (Allen-Collinson, Crust, & Swann, 2019; Kazimierczak et al., 2020; Nettleton, 2015). This work clearly highlights the value of qualitative methods in revealing the very many ways in which weather is experienced during the in-the-moment encounters of specific exercising groups.

The human seen in these studies is most commonly imagined to be both interested in, and connected to, their environment. But this is in a rather different way to those who are managing physiological responses in pursuit of optimum performance. This set of exercisers is reacting and reflecting on the elements as they go, using their acquired attitudes and skills so that they both endure, and often enjoy, the variable nature of their effects (Allen-Collinson, 2018; Vannini et al., 2012). Largely focussed on the enthusiast, likely partly owing to the ease of setting up studies with organised groups, these exercisers are more inclined to keep going whatever the weather and may be especially keen to discuss how they handle (rather than determinedly ignore) different weathers. Still, whilst we should be careful

about extrapolating from these studies to exercisers who identify less with the activity (Hitchings & Latham, 2017b), we are now particularly alive to how exercisers feel and respond to the weather and how they relate to it in ways we could not know in advance.

By taking a qualitative approach that encourages researchers to linger over the experiential detail, weather now features as enveloping, immediate and a combination of many interacting elements. These are either experienced by the researcher or explored in their interviews or ethnographies, from uphill running on warm days to the chill of snow (Allen-Collinson & Owton, 2015; Larsen & Jensen, 2020). Importantly, weather is now seen as ever present and changeable during the activity itself since a particular interest here is in the personally transformative experiences that can result from handling this variability during the exercising event. Less is known of the specific parameters of these conditions, so we don't yet know what exactly is felt to be hot, cold, pleasant, or painful.

Weather is now more than a barrier or facilitator. It is negotiated in the moment. Though this work would seem to have much to add in supporting outdoor exercise, particularly regarding learning, skills and the evident enjoyments of weather experience, its explorative aims so far mean it often stops short of recommendations beyond calls for further study (Hitchings & Latham, 2017b; Phoenix & Orr, 2014). Simpson (2019) gets close in his focus on cycling infrastructure, highlighting the relevance of elemental encounters to planners who might expand their view of positive cycling 'settings'. Foregrounding elemental experiences with enthusiasts also often positions weather as something to be celebrated. Yet it is quite possible that many, including indoor exercisers, may especially value how unchanging environments help them to stick with less weather responsive routines (Hitchings & Latham, 2016). Still, this work does suggest that attending closely to the immediate weather attunements of exercising groups could add much to the public health debate.

6 | DISCUSSION

In the above account, we have seen both the exerciser and the weather morph through various characterisations that we have summarised in Table 1. This is to be expected. Different approaches and objectives naturally highlight particular facets of the issue. What is more useful about this table is how it allows us to identify opportunities for the cross-pollination of ideas between these valuable bodies of work, to notice strategies for addressing some of the blind spots that inevitably result from seeing the weather-exercise connection in certain ways, and to work towards a stronger sense of how this developing connection might be influenced in particular contexts. Though we do not want to suggest there have not been studies that already crosscut these approaches, the ways in which research on this topic has tended to coalesce into different clusters of activity does mean that we are now in a position to reflect on how future studies might usefully straddle them.

What new global exercise patterns will emerge in response to hotter and more variable weather? Faced with harsher conditions will some exercising groups retreat indoors? Perhaps others will give up in ways that exacerbate the problems already associated with widespread sedentarism? Yet others may stick with routines that put them at

TABLE 1 High-level approaches to the human exerciser and the surrounding weather.

	Aggregate datasets	Active travel	Athletic performance	Qualitative studies
Human	Demographically diverse and sensitive to specific conditions	Decision-maker who is working to establish active commuting routines	Manager of a physiological system focussed on achievement	Enthusiast who feels and responds to weather in the moment
Weather	Identified parameters that shape overall activity levels	Conditions that commonly act to disrupt valued travel routines	Specific parameters that have a measurable impact on athletic success	Mix of interacting elements that often enhance the experience

increasing risk as environments warm around them? Faced with the interconnected challenges of a changing climate and increasing human inactivity levels, encouraging safe and sustainable outdoor exercise is a complex public health goal.

Our contention now is that geographers are well placed to work across the above approaches in ways that help tackle these challenges by drawing on their reputation for contextual sensitivity and their readiness to combine various data sources and framings in applying that. Whilst some of the above studies have been done by geographers, we think there remains significant scope for them to find inventive ways of bridging the exciting insights and approaches provided by the above bodies of work in order to know, and then positively influence, how weather-exercise cultures are changing around the world. We end with three cross-cutting themes that we think could help with that.

6.1 | Adaptation

Weather adaptation is at once physical and social. It's about how we learn what weather does to us and how our bodies learn to handle it too. The athletic performance work has much to say about how bodies adapt physiologically to weather. The active traveller is also learning to weather themselves in a different kind of determined adaptation. However, in both cases we don't yet know whether these ideas and strategies have filtered into the practices of groups of less focussed exerciser. Do different recreational runners, for example, 'season' themselves in comparable ways that may level out the activity fluctuations discerned by our first body of work? Is it the same for tennis or football players? Qualitative researchers have much to add here but, in developing an interest in elemental immersion, more remains to be said about how weather is considered beyond the immediate experience. So, what would leisure exercisers say about how they plan for handling weather elements and when they put them off? Connecting elements of the above four ways of looking at the issue, geographers could, for example, consider personal experience alongside physiological thresholds to better understand how non athletes adapt to heat through clothing selection, seeking out shelter and shade, and other cooling and hydration strategies. Understanding these adaptations will surely become more and more important as the slow creep of climate change inevitably makes many currently popular ways of exercising outdoors increasingly dangerous.

6.2 | Decision-making

Our review has shown that weather-related exercise decision-making happens at multiple points and in many ways. The aggregate datasets reveal population level decisions as new weather triggers changes in collective activity. The commuter too is making decisions about what to take and whether to go based on varied sources of information and past experiences. The athlete is deciding how best to achieve optimum performance based on the physiological knowledge that sports science provides them, though none are about whether to keep exercising. Finally, the enthusiasts often appear to be continually making subtle adjustments to their practice as part of an ongoing conversation with the weather. Testing out how these different implied visions combine for different exercising groups will provide a fuller sense of their weather-related decision-making. How often is the active traveller immersed and thoroughly weather engaged in ways that add to the experience? Is the enthusiast always in conversation with atmospheric conditions and when, and with what implications for putting themselves at risk in a hotter world, do these aspects fade out of their consciousness? What would the groups of concern to the aggregate data analysts (children, older adults, those with particular ailments) say to us about what they do with the weather in ways that finesse the picture currently provided by qualitative studies with those who are particularly keen on certain activities? Understanding how decisions (of all these types) are made by creatively sampled groups of (potential) exercisers, along with what prompts them (from official warnings about heat risk to personal feelings of discomfort or pleasure), will, we would imagine, be key in crafting practice and group specific advice and interventions in pursuit of healthy future

exercise. As part of this, we should also stay alive to how both exercisers and policymakers may sometimes want active decision-making to effectively disappear as exercise becomes weatherproofed by valued exercise routines.

6.3 | Place

Given our argument, it is perhaps unsurprising to see us end with place. Nonetheless it is true that place features in interestingly different ways in the above review (see also Böcker et al., 2013). At a high level, aggregate work tells us how groups of exercisers in specific places collectively respond to local climates. The active traveller research particularly reminds us that local features like roads, shading and surfaces all mediate the weather experience in ways that shape exercise levels. Equally, while athletes may travel to certain climates to prepare for predicted competition conditions and improve performance, less is known about how their knowledge regarding the benefits and risks of exercising in particular weathers has filtered through to shape how the less committed manage the local weathers they encounter. The qualitative work emphasises how weather, bodies and landscapes all interact to colour the experience, though more could be said here about variation between contexts and across groups (Galway et al., 2021; Nettleton, 2013). Place-specific beliefs about 'good weather' for exercise could, for example, be putting some people in danger by encouraging them to exercise in especially hot conditions just as how local beliefs about where certain activities should rightly happen might (Ergler et al., 2016). So, how do local norms of stoically coping with weather or recoiling from the suggestion of encountering the outdoors during exercise become established and evolve? Mixing aggregate and in-depth datasets will provide the fullest picture of how locally specific weather-exercise cultures develop as those in some parts of the world retreat seasonally into gyms or indoor courts or start to seek out particular exercise places that benefit from the cooling effects of shade or vegetation. Finally, we note how the growth in global migration furthermore means that we'll likely need to combine insights from all four of our approaches to understand how different exercise cultures are mutating as they move around a warming world—another task to which we imagine geographers are particularly suited.

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