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Etiology and Pathophysiology

Characterizing the obesogenic environment: the state of the evidence with directions for future research

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Summary

Despite the explosion of obesogenic environment research within the last decade, consensus on what constitutes the very environment we are trying to measure has not yet been reached. This presents a major challenge towards our understanding of environmental research for obesity, and the development of a desperately needed contextualized evidence base to support action and policies for curbing this epidemic. Specifically, we lack the application of a cohesive definition or framework, which creates the potential for confusion regarding the role of the environment, misinterpretation of research findings and missed opportunities with respect to possible avenues for environmentally based interventions. This scoping review identified primary studies and relevant reviews examining factors related to body mass index, diet and/or physical activity with respect to the obesogenic environment. Using a comprehensive framework for conceptualizing the obesogenic environment, the Analysis Grid for Environments Linked to Obesity (ANGELO), we identified 146 primary studies, published between January 1985 and January 2008, that could be characterized according to the dimensions of ANGELO. Gaps in the literature were clearly identified at the level of the macro-environment, and the political and economic micro-environments, highlighting key areas where further research is warranted if we are to more fully understand the role of the obesogenic environment.

Keywords: ANGELO framework, obesogenic environment, policy, scoping review.

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Introduction

Overweight and obesity rates are increasing globally, with approximately 300 million people around the world classed as obese (body mass index [BMI] greater than 30) (1). This threat to global public health is linked to chronic diseases such as type 2 diabetes, hypertension, various cancers, coronary artery disease and stroke (2). The rise in obesity prevalence rates has been so dramatic that the health consequences threaten to overwhelm health systems and the health and well-being of the global community (3).

Although genetics may explain differences between individuals, it cannot explain the temporal upward trend at the population level (4). As a result, research efforts have been extended from primarily considering the individual to a broader understanding of environmental factors associated with the development of obesity; this is critical for a better understanding of the necessary components for intervention and prevention efforts. This relatively new approach requires a comprehensive framework to understand and characterize what has been described as the 'obesogenic environment', which is currently defined differently, depending on the context of the research. Lack of application of a cohesive definition or framework creates potential for confusion over the role of the environment, misinterpretation of research findings and missed opportunities with respect to possible avenues for environmental interventions. Given that this is an emerging area of study, and

given the complexity of the obesogenic environment, the purpose of this review was to map areas of environmental research relevant to obesity. However, providing a critique of these areas is beyond the scope of this review (see *Methods* section for description). Hence, our objectives were to:

1. Discuss how best to characterize the environment as it relates to obesity;

2. Characterize primary environmental studies and relevant reviews that examine factors related to weight, diet and/or physical activity with respect to the obesogenic environment;

3. Highlight gaps in the literature and directions for further research.

The impalpable obesogenic environment

Despite the explosion of obesogenic environment research within the last decade, consensus on what constitutes the very environment we are trying to measure has not yet been reached. This presents a major challenge towards our understanding of environmental research for obesity, and the development of a desperately needed contextualized evidence base to support action and policies for curbing this epidemic. Defining the obesogenic environment is in itself a complex endeavour as the factors that influence individual weight are many and varied. The environment is a nebulous concept, being complex, dynamic and multilevel. This creates difficulty in identifying opportunities for action, and at what level, to create supportive environments for obesity prevention.

Research on the environmental determinants of overweight and obesity is not new. Indeed, a proposed definition and framework appeared in 1999 when Swinburn *et al.* described the 'obesogenic environment' as 'the sum of influences that the surroundings, opportunities, or conditions of life have on promoting obesity in individuals or populations' (5), or simply put, any characteristic that acts as a barrier to maintaining a healthy weight. Accompanying this definition was a comprehensive framework for conceptualizing the obesogenic environment and prioritizing potential areas for intervention, called the Analysis Grid for Environments Linked to Obesity (ANGELO). This framework dissects the environment on two dimensions: size (micro or macro) and type (physical, economic, political and socio-cultural), for measures related to obesity (e.g. dietary behaviour, physical activity or weight) (see Table 1). Micro-environmental settings are those where groups gather and that relate to food, physical activity or weight. These settings are usually geographically distinct, relatively small and influenced by individuals. As the most frequently researched environment 'size', the concept of the micro-environment allows us to investigate factors related to individuals or groups in a clearly defined setting such as schools, workplaces, homes and neighbourhoods. Macro-environmental sectors are groups of industries, services or supporting infrastructure that may influence diet, physical activity or weight. These are usually geographically diffuse, large and influenced by private and public sectors. Each environmental size consists of four possible dimensions. The physical dimension (e.g. what is available) is the most commonly studied and has also been defined as the summation of urban design, land use and transportation systems (6). In contrast, the natural environment, comprising all characteristics that are not man-made, is less extensively researched; this might include barriers to health behaviours such as steep geographical terrain, climate or the quality of air in urban centres. The economic dimension includes factors such as food insecurity, income and education. The political dimension comprises factors that shape regulations for any age group at the micro- or macro-level (e.g. rules or policies). Lastly, the socio-cultural dimension explores context and includes factors such as neighbourhood crime or social support from family and/or friends for healthy behaviours. The strength of using ANGELO is that all environmental elements are considered, while providing a relatively simple characterization of an immeasurably complex entity.

Conceptualizing the evidence from existing systematic reviews using ANGELO

ANGELO has been used as a framework for conceptualizing research in three separate systematic reviews. These reviews covered children, adolescents and adults for diet

Table 1 The matrix illustrating the ANGELO framework as used in this review

Size	Type			
	Physical	Economic	Political	Socio-cultural
Micro	Physical activity Diet weight/BMI	Physical activity Diet weight/BMI	Physical activity Diet weight/BMI	Physical activity Diet weight/BMI
Macro	Physical activity Diet weight/BMI	Physical activity Diet weight/BMI	Physical activity Diet weight/BMI	Physical activity Diet weight/BMI

ANGELO, Analysis Grid for Environments Linked to Obesity; BMI, body mass index.

Table 2 Summary of the results from three systematic reviews looking at environmental correlates related to physical activity and dietary behaviours in children, adolescents and adults

			Type			
			Physical	Economic	Political	Socio-cultural
Size	Micro (setting)	House	PA (c): 0 PA (a): 0 PA (ad): availability, convenience, accessibility, connectivity, environmental aesthetics DB (c): Availability, accessibility DB (a): 0 DB (ad): ?	PA (c): 0 PA (a): mother's educational level, family (per capita) income PA (ad): 0 DB (c): parents' educational level (high) DB (a): parental education (fruit/vegetables) DB (ad): ?	PA (c): time spent outdoors PA (a): 0 DB (c): NR PA (ad): NR DB (a): NR DB (ad): ?	PA (c): 0 PA (a): 0 PA (ad): social support, having a companion to do PA with, seeing people exercise DB (c): energy-parenting practices, parental fat intake, fruit/vegetables modelling, parental fruit/vegetables intake, parental fast food intake DB (a): parental/sibling fat/energy intake, parenting style (fruit/vegetables), family connectedness (fruit/vegetables) DB (ad): ?
		Education/ workplace	PA (c): 0 PA (a): 0 PA (ad): ? DB (c): 0 DB (a): 0 DB (ad): ?	PA (c): 0 PA (a): 0 PA (ad): DB (c): NR DB (a): NR DB (ad): ?	PA (c): PA-related policies PA (a): school type (high school vs. vocational/alternative) PA (ad): NR DB (c): NR DB (a): NR DB (ad): ?	PA (c): 0 PA (a): 0 PA (ad): DB (c): 0 DB (a): 0 DB (ad): ?
		Neighbourhood	PA (c): 0 PA (a): 0 PA(ad): environmental aesthetics DB (c): NR DB (a): 0 DB (ad): ?	PA (c): 0 PA (a): 0 PA (ad): 0 DB (c): 0 DB (a): NR DB (ad): ?	PA (c): NR PA (a): NR PA (ad): NR DB (c): NR DB (a): NR DB (ad): ?	PA (c): 0 PA (a): crime incidence PA (ad): 0 DB (c): NR DB (a): NR DB (ad): ?
	Macro (sector)	City, etc.	PA (c): 0 PA (a): 0 PA (ad): NR DB (c): 0 DB (a): 0 DB (ad): ?	PA (c): NR PA (a): NR PA (ad): NR DB (c): NR DB (a): NR DB (ad): ?	PA (c): NR PA (a): NR PA (ad): NR DB (c): NR DB (a): NR DB (ad): ?	PA (c): NR PA (a): 0 PA (ad): NR DB (c): NR DB (a): NR DB (ad): ?

Correlates are categorized using the Analysis Grid for Environments Linked to Obesity (ANGELO) framework and show the environments that hold the most correlates and those where research is lacking.
Summary of consistent correlates: 0, no consistent correlate found; ?, no systematic review available; a, adolescent; ad, adult; c, child; DB, dietary behaviour; NR, no research; PA, physical activity.

and physical activity, but at the time of writing, there were no systematic reviews for any age groups for BMI as an outcome using ANGELO as the organizing framework. We combined the results from each systematic review to allow us to identify sections of the obesogenic environment that hold the most correlates, and those where no research has been undertaken (see Table 2). This approach enabled us to immediately see the overall lack of consistent findings, and populations that were not yet systematically reviewed (e.g. dietary behaviour for adults). Given the 255 articles considered for all three systematic reviews and the countless correlates examined, only 27 consistent correlates were found for all age groups across all environment sizes and types for both physical activity and diet. Ten correlates were found for adolescent physical activity and diet, six correlates for child physical activity and diet, and a single

consistent correlate for adult physical activity. These findings suggest that the evidence for a link between the obesogenic environment and obesity is rather weak (7–9), although the lack of convincing evidence regarding the role of the environment in obesity development may be more a reflection of the quality of studies and the lack of consensus around appropriate measures, rather than the absence of a true relationship (10,11). Thus, despite some limitations of research to date, there are many advocates for immediate action towards preventing obesity through environmental change (12).

While systematic reviews are excellent tools for collating and evaluating evidence, they have limitations associated with their strict inclusion and exclusion criteria. This can lead to the exclusion of studies that may be of value to researchers and decision-makers with respect to the design of intervention and prevention efforts. Hence, given the complexity of the obesogenic environment and the recent proliferation of research within this new and emerging field, we sought to expand these findings with a more inclusive review methodology, the scoping review (13). Equally important was to apply the ANGELO framework to conceptualize the research in a consistent way.

Conceptualizing the evidence from non-systematic reviews and primary studies using ANGELO

Method

Our objective was to characterize the extent and nature of available literature from primary studies and relevant non-systematic reviews, beyond those described in Table 2, using a scoping review methodology (described below). These studies were then categorized, and various research area themes emerged. Because of the wide range of study areas and multidisciplinary nature of obesogenic environment research it is not possible to claim exhaustive coverage. Instead, our intent was to 'map' relevant literature and highlight research 'themes' according to the dimensions of ANGELO, not to answer a specific research question or assess the quality of the included studies.

Our scoping review approach followed the recommendations of Arksey and O'Malley (13). This method can be used to address broad, often complex, topics where many different study designs, measures and outcomes are employed. It is important to emphasize that the intent of a scoping review is neither to answer a specific research question nor to assess the quality of the included studies, but to 'map' relevant literature, in this case, across the dimensions of ANGELO. Relevant studies were identified through electronic databases, reference lists and hand searches in key journals (see Appendix S1 for details of the search strategy).

Inclusion criteria were broad: any primary study or relevant non-systematic review involving children (aged 2–12 years), adolescents (aged 13–18 years) or adults (over 18 years) examining the influence of an environmental factor on *some measure* of BMI, diet and/or physical activity. Intervention studies were excluded as preliminary reports of literature reviews have suggested they provide more positive effects than other research; therefore we believe a separate review focused on intervention research is needed (14). After full-text retrieval, two researchers (TP and TM) independently classified manuscripts on the different dimensions of ANGELO, resulting in 146 primary studies for inclusion in the review. Consensus was reached for disagreements, and the included studies were tabulated by two researchers (SK and TP) according to the stated outcome measures and the area of study (see Table S1). This process was iterative rather than linear to ensure that the resulting articles covered the obesogenic environment as broadly as possible. When studies comprised a measure of physical activity, diet or BMI combined, they were classified with BMI as the main outcome to avoid duplication in the table and to emphasize the main outcome of interest, i.e. obesity. Throughout this process, 'themes' of research emerged within each dimension of ANGELO (as mentioned above). The next section presents a summary of the most relevant primary study articles within each theme of the ANGELO framework. An exhaustive summary was not possible because of the large number of articles retrieved; hence the remaining articles not described in the next section are also listed in Table S1 for reference (see *Supporting Information*).

Research at the level of the physical micro-environment

The micro-environment is the most extensively studied of all the components of ANGELO. Primary studies focusing on the impact of the physical micro-environment on BMI comprised the largest body of evidence (54 papers), closely followed by physical activity (47 papers), while studies using a measure of diet comprised just 12 papers. This could reflect the difficulties that are often inherent with studying dietary intake – the lack of inexpensive, objective and reliable measures of diet, particularly for use in population-based studies, and the reliance on self-reported measures of diet that may not be representative of habitual intakes (15). By contrast, physical activity levels and BMI can be measured more objectively. Despite the current emphasis on the built environment in addressing youth obesity, Sallis and Glanz in 2006 (16) argued that no conclusive evidence exists to suggest that the built environment promotes obesity, nor any evidence to suggest that changes to the built environment would reduce rates of obesity directly. However, study of the physical environment in its

broadest sense is still relatively new, and there are many methodological challenges that need to be addressed. According to the ecological model for understanding obesity, the role of diet and physical activity in the development and maintenance of obesity is a mediating effect (17), yet there are often mixed results regarding the indirect impact of the environment on obesity through these mediators. For example, studies have found relationships between environmental variables and physical activity, but have failed to report a significant association with BMI (18). It is therefore important in obesogenic environment research to also include a direct measure of overweight or obesity because changes in physical activity and diet do not necessarily lead to significant changes in weight.

For the studies using BMI as a measure, we identified research within six broad themes – neighbourhood attributes, accessibility and availability (perceived and observed), accessibility (perceived and observed), neighbourhood walkability, sedentary activities, exposure to food advertisements and automotive use. We identified corresponding themes using physical activity as an outcome; these were neighbourhood attributes, accessibility, availability, and neighbourhood walkability, as well as the school environment and television viewing at home. For diet, there were three broad themes of neighbourhood attributes, accessibility and availability (perceived and objectively measured), television viewing at home and exposure to food advertisements. The studies identified were conducted across the lifespan and in some cases comprised both perceived and objectively measured characteristics of the micro-environment.

Conflicting findings were common across the three different measures of interest (BMI, diet and physical activity) and could be attributed to difficulties with measurement. For example, a study that examined observed (street-scale environmental audits) vs. perceived (cross-sectional telephone surveys) neighbourhood characteristics found significant correlates of BMI with perceived neighbourhood characteristics of no nearby non-residential destinations, absence of sidewalks, unpleasant community and lack of interesting sites and observed indicators of poor sidewalk quality, physical disorder and presence of garbage (19). Another study exploring the perceived (i.e. self-reported) and observed (i.e. directly measured) built environment and the relationship to physical activity found poor agreement between perceived and observed characteristics, highlighting the importance of measuring both perceived and observed environments (20).

Differences in outcomes were also apparent across gender. For example the relationship between outdoor physical activity (OPA) away from school and distance to nearest open play space and density of violent crime within a 0.5 mile of home was explored in a study of adolescents (21). Among boys, OPA was inversely related to distance to nearest open play space, while among girls, OPA was inversely related to density of violent crime within 0.5 mile of home. Girls' perception that their neighbourhood was safe was associated with higher OPA levels, but boys' assessment of safety in the neighbourhood was not related to OPA. In a study of preschool children, obesity levels of girls were lower if they lived in walkable neighbourhoods with more intersections, while similar associations were not found with boys (22). This highlights the importance of considering how environments may differ across genders and in relation to other characteristics such as age.

In terms of objective neighbourhood attributes, the literature points to evidence that physical activity levels are associated with a number of built environment factors that are modifiable. In a review of transportation, urban design and planning literature, communities with a higher housing density, greater connectivity and more land use mix report higher rates of walking and cycling for utilitarian purposes than communities with the opposite (23). In a study of children, physical activity was significantly associated with residential density, the proportion of green space and the general impression of activity-friendliness of the neighbourhood (24). Children's physical activity was also associated with sports fields, dog waste, water, safe walking and cycling conditions and the frequency of certain types of residences in the neighbourhood (24).

An innovative avenue of exploration that has recently been reported is the relationship between commute time, or vehicle miles of travel (VMT; an indicator of transportation) and obesity and physical inactivity (25). Using data from three large-scale surveys, highest rank of VMT was associated with the highest mean rank obesity. Similar rank patterns were also found between commute time, obesity and physical inactivity. However, the relationship between physical inactivity and VMT did not reach statistical significance. In another cross-sectional survey, individuals who reported high levels of auto use (particularly for trips to the grocery store and work/school commute) had higher BMI scores (26).

Studies exploring the relationship between sedentary behaviours and obesity have been increasingly prevalent in the literature in recent years. This area holds the same challenges in definitions and measurement as other areas of environmental study. A review of the literature on correlates of television viewing among youth was conducted by Gorely *et al.* in 2004 (27). Based on findings from 68 primary studies, television/video viewing was not found to have clearly consistent correlates. For example, many correlates were found including body weight and between meal snacking. However, they found television/video viewing to be unrelated to body fatness (a different measure to body weight), physical activity and other diet variables. The shift in correlates based on the measure of obesity (i.e. body weight vs. body fatness) is of concern. In terms of the

food environment, recent research is pointing to an association between obesity and exposure to food advertisements. Recognition of food adverts was related to BMI in a group of 5–7-year-old children, replicating the findings of previous studies, which suggest that exposure to food adverts significantly increases food intake in children (28). Studies measuring dietary behaviours but with no direct measure of BMI have also reported higher television use being associated with higher reported junk food consumption (29). Another study found that children of parents, who bought food products that had been advertised on television and seen by their children, ate more snacks and fat (30).

Research at the level of the economic micro-environment

The economic micro-environment is not as extensively researched as the physical environment. However, there is evidence to suggest that economic factors, including neighbourhood socioeconomic status (SES), deprivation measures, parental income levels (in the case of children) and food insecurity, have an important role to play in levels of physical activity, dietary behaviours and especially BMI. We found just one paper relating to physical activity and neighbourhood deprivation in adults (31), and two papers relating to diet and neighbourhood deprivation, again in adults (32,33). For BMI, we found 14 papers, relating to three broad themes of neighbourhood and family deprivation, neighbourhood and family SES and food insecurity.

Area deprivation is a measure of neighbourhood level SES, created by using several related variables such as income and education. In a study to examine the relationship between disparity in access to recreational facilities and additional impact on physical activity and overweight in US adolescents, lower-SES city block groups had reduced access to facilities, which in turn was associated with decreased physical activity and increased overweight (31). The challenge of using certain geographical boundaries is also evident in studies that examine BMI. In a study using several merged databases to examine the spatial relationship between SES and obesity outcomes in children, low SES at the census tract level correlated with both overweight and obesity outcomes (34). In a study to determine if neighbourhood SES was systematically related to the prevalence of overweight children and youth in Canada, neighbourhood socioeconomic data were obtained from the Statistics Canada 2001 Dissemination Area databases, and SES quartiles were constructed using a composite of socioeconomic variables. A gradient of increasing overweight prevalence by decreasing neighbourhood SES quartiles was observed (24% high SES, 30% mid-high SES, 33% mid-low SES, 35% low SES). Controlling for individual age, gender, family income and education, hierarchical analysis found that the odds of a child being overweight increased if living in a low vs. a high SES neighbourhood (35). Also at the community level, a study examined the contributions of both individual SES and community disadvantage in explaining the higher BMI of black adults in the USA. Findings showed that living in communities with higher socioeconomic disadvantage was associated with higher BMI, independent of age, race, individual SES, smoking, physical activity, stress and social support. Community income inequality also had an independent positive association with BMI (36). In relation to dietary behaviour, defined by access to the most popular fast food restaurants, higher density of restaurants were found in areas of higher deprivation (32). The authors described a 'concentration' effect, whereby health-damaging environmental risk factors for obesity appeared to be 'concentrated' in more deprived areas of England and Scotland. Another study examined the association between neighbourhood deprivation and accessibility to fast food outlets and supermarkets and found that the travel distances to both types of food stores were shorter in more deprived areas; therefore both types of food sources were more accessible in those deprived areas (37). However, this work used census block as a basis for defining a neighbourhood, which may not accurately represent what is considered by residents to represent their neighbourhood. In a similar retrospective cross-sectional study, weight problems in children were related to deprivation according to electoral ward stratified by gender, where prevalence of overweight and obesity was not related to deprivation and varied between wards only for girls. The authors concluded that using administrative areas may not be useful for targeting interventions and that more attention should be paid to the physical environment (38). These studies illustrate the importance of including both a measure of fast food and grocery stores as surrogates for access to healthy and unhealthy food, and the difficulty in ensuring that objective environmental boundaries (i.e. census boundaries) hold meaning to the individuals who live in those areas. They also highlight issues of confounding inherent in many observational studies, which environmental researchers should consider in designing and interpreting ecological studies of this type.

Research at the level of the political micro-environment

While we can see that the physical and economic micro-environments have been characterized to some extent, minimal primary research is being conducted within the political micro-environment. This environment can include any 'rule' that is imposed on individuals, from workplace policies regarding break times or cafeteria menus, to household rules for children regarding TV time, and therefore it

incorporates a diverse array of research. We found just one study focusing on physical activity and one focusing on BMI. A study examining the effect of preschool policies on physical activity found that, as might be expected, schools defined as high quality by the researchers and with more resources held more policies related to physical activity. They also participated in more activities such as field trips, employed more college-educated teachers and had children with higher levels of physical activity (39). With respect to television viewing and BMI, children who lived in a family with tight rules governing TV viewing time, or who never watched TV during dinner, had only one TV in the household or had no TV in their bedroom, watched significantly less TV than their counterparts (40).

Research at the level of the socio-cultural micro-environment

The social and cultural context in which individuals make decisions is a critical consideration for those looking for intervention or prevention opportunities. However, research at the level of the socio-cultural micro-environment was limited. We found 21 papers relating to BMI, and four papers relating to physical activity and diet respectively. The themes that emerged for this section of the ANGELO framework comprised parental attributes and perceptions for children and adolescents and social support for all three measures of interest, with BMI also comprising an additional theme of family attributes. A consistent finding across the socio-cultural environment literature was the contribution of parental, and especially maternal, weight status to child weight status. For example, one study found a significant relationship between childhood obesity and maternal BMI (41). Another study examined whether and to what extent the relationship between television viewing and children's weight status differed according to parental weight status. Results showed that when parental obesity is taken into account, television viewing hours do not significantly relate to increased odds of childhood overweight, with parental BMI moderating the relationship between television viewing and child weight status among adolescents (42). For adults, the most common finding was the existence of social support. For instance, in a study of the biological, psychological, social and physical environmental correlates of young women, self-reported height and weight was used to assess relationships with BMI. Key correlates included family support and friends' support/sabotage of physical activity/healthy eating. The authors concluded that intervention strategies aimed at reducing weight gain and obesity need to focus on social and physical environments, as well as psychological factors (43). Research at this level of ANGELO, more specifically within the family environment, also intersects with research at the level of the individual, including the role of genetics in obesity development, making it difficult to determine causation and highlighting another area for research.

Research at the level of the macro-environment

The macro-environment is an area of critical importance because of the ability to effect change at the population level. It includes a wide range of sectors such as the media, food production and manufacturing, food marketing, urban/rural development, transportation and the health system (i.e. Ministry of Health, medical and health professional schools and professional associations). These sectors have the ability to impact many people, yet this level of environment is grossly understudied. We found only one primary study beyond those examined in the systematic reviews discussed previously, which was a study of environmental and policy correlates conducted in 2006. This cross-national study found statistically significant associations with obesity prevalence within the included European countries for economics (real domestic product), food (available fat and fruit and vegetables), urbanization (urban population), transport (passenger cars, price of gasoline, motorways), socio-cultural factors (single mother households) and policy (governance indicators) (44). This study was exploratory in nature; nevertheless, it has helped to bring attention to the role of macro-level environmental factors and their impact on national obesity prevalence. The main recommendation of the authors was to follow up the impact of policy and governance on obesity. Additionally, a review focusing on the 'eating environment' examined macro-environment level approaches, including food and agriculture policies, economics and pricing and food marketing and media influences on obesity (45). Important issues from this review included the disparities in food access for low-income and minority groups, as well as the many surveillance and measurement issues facing the evaluation of nutrition at the macro-level. The authors highlighted the need for action and better regulation regarding food and agriculture policies, food pricing, marketing and media influence to ensure that health is as high a priority as economics.

Discussion and conclusion

The purpose of this review was to better understand the research being conducted regarding the obesogenic environment. This understanding can help us to identify gaps in the literature and avenues for further research, which is becoming increasingly important as society struggles to address the epidemic of obesity that we face. In recognition of the complexity of the environment as it relates to obesity, we began with a brief discussion of how best to characterize the obesogenic environment and found the ANGELO framework to be a most useful tool for characterizing the

environment across multiple levels of influence. However, this useful framework is not widely applied in the literature; in our initial search we discovered only three systematic reviews that used this framework to organize their results, although these did not include BMI as an outcome, only diet and physical activity. When the findings from these three systematic reviews were combined, we were able to clearly identify the gaps in the available literature, primarily at the level of the macro-environment, which is an important step forward in conceptualizing these two key mediators of the obesogenic environment. The strict inclusion and exclusion criteria of systematic reviews greatly limited the amount of research included, and the lack of data on BMI as an outcome further highlighted a key gap in our understanding of the impact of the environment on obesity; hence a broader review methodology was employed.

The addition of primary studies into ANGELO clearly identified the existence of similar gaps at the macro-level, and at the level of the political and economic micro-environments, in contrast to the proliferation of studies at the level of the physical micro-environment. This scoping review is therefore a positive first step in mapping the extent of research of relevance to the obesogenic environment, beyond systematic reviews, while clearly identifying the need for future research efforts at the macro-environment level and the political and economic micro-environment level. It also provides a justification for using a framework such as ANGELO to ensure that all elements of the obesogenic environment are considered. Scoping reviews have limitations, as previously stated, in that they are not designed to answer specific research questions or assess the quality of included studies. Next steps would include identifying areas for a more in-depth and critical evaluation to support recommendations for policy change.

The complexity of the obesogenic environment is apparent from the variety of studies we found. Not only is it an elusive concept that is difficult to define and conceptualize, but attempting to consider every possible environmental contribution to energy balance can quickly become overwhelming. While we did not appraise the quality of the studies we found, the variable evidence available raises an important point with respect to obesogenic environment research. Often the stated purpose of the research we reviewed was to address the obesity epidemic. However, the studies did not always include a direct measure of weight or BMI, but indirect measures of physical activity, and to a much lesser extent, diet. The lack of studies using diet as a measure is a concern, given that 'energy in' is one side of the energy balance equation. This imbalance should be addressed in future research, as should the need to include a direct measure of weight or BMI alongside indirect measures. Researchers should therefore aim to ensure that appropriate direct measures are incorporated into their study designs and address issues relating to confounding. The environment may play a critical role in obesity development, prevention and management, but we have yet to determine the best method for measuring that effect accurately and consistently, or develop an appropriate theory to encompass this very complex and dynamic system. There is clearly more to be done to better understand our obesogenic environment, both in terms of measurement *and* in terms of outcomes.

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Conflict of Interest Statement

No conflict of interest was declared.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1 Primary studies characterized according to the Analysis Grid for Environments Linked to Obesity (ANGELO) framework
Appendix S1 Scoping review search strategy

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