Mini review

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Obesogenic environments: environmental approaches to obesity prevention

Abstract: Childhood obesity is a major concern for public health. There are multiple factors (e.g., genetic, social, and environmental) that contribute to unhealthy weight gain. Drawing from findings on “obesogenic environments” and core principles of preventive strategies to reduce health inequalities, this paper gives an overview of recent childhood prevention programs that target aspects of the physical environment (“environmental changes”). Out of the ten reviews we screened (including more than 300 studies), we identified very few that addressed aspects of the environment. We focus here on 14 programs that follow different approaches to environmental changes (e.g., access to/quality of playgrounds, changes in school cafeterias). Altering the environment offers opportunities for healthier behaviors and seems to be an effective strategy to prevent childhood obesity. However, the evaluation of those (mostly) multidimensional interventions does not allow drawing firm conclusions about the single effect of environmental changes. We conclude that obesity prevention programs should combine person-based and environmental approaches.

Keywords: childhood obesity; environment design; prevention; review.

Childhood obesity – causes and consequences

Obesity in children is a major concern, not only for the affected individuals but also for public health. Although prevalence rates in many industrialized countries around the world have started stabilizing since 2004 (1), they still remain at a high level. Due to the direct and indirect implications of childhood obesity, effective treatment and prevention interventions are of utmost importance (2). During the last 3 decades, a number of empirical and theoretical works have focused on the development of obesity in children. This paper gives an overview of strategies to prevent childhood obesity. First, we briefly summarize recent findings on different factors associated with childhood obesity. Second, we present core principles of preventive strategies aimed at reducing inequalities in health in general and obesity in particular. Third, we depict selected intervention (prevention) studies that explicitly include “environmental changes” and the role of obesogenic environments in childhood obesity. Finally, we draw conclusions from existing studies and suggest future programs.

Genetics

During the last 2 decades, there has been a shift from a monogenetic approach toward seeing obesity as a multifactorial disease. From a genetic point of view, obesity is currently seen as a “complex, multifactorial condition with high hereditability” (3). Family studies with twin and adopted children indicate a significant influence of genes on an individual’s predisposition to developing obesity, accounting for up to 70% of heritability estimates for BMI (4, 5) [reviewed in (6)], whereas monogenic reasons
for obesity are rare. In search for the actual responsible gene loci, comprehensive search strategies have evolved during the last decade. Starting from a candidate gene approach, where individuals were tested for being carriers of known genetic variants of metabolism, genome-wide linkage studies concentrated on genetic transmission of linked genes on one chromosome within one family, but the identified common variants could only explain a small proportion of the risk for obesity (7).

The most recent change in the search doctrine was the implementation of genome-wide association studies (GWAS), screening for genetic commonalities in hundreds of thousands of subjects (rather than small samples of candidate families) and analyzing such large data without a priori knowledge or a hypothesis. New risk alleles could be identified, but the effect of each of the alterations was rather disappointing, with an effect of approx. 0.17 kg/m² (7, 8). Some of the alleles found seem to play a different role depending on the age of the respective children, indicating that, e.g., intrauterine environment could temper adipogenic effects of some of the genetic variants such as the obesity-related allele FTO (9, 10). Summing up, gene-by-environment interactions are not yet sufficiently understood (7). With this in mind, current studies focus on epigenetic modifications like the methylation status of gene promoters that might be associated with an individual’s obesity in later life (3, 7, 11).

Socioeconomic influences

There is a vast body of research demonstrating associations between parental socio-economic status and obesity in children in industrialized countries (12). In addition to parental occupation and income, educational attainment seems to be the strongest predictor for childhood obesity (12). Social determinants of childhood obesity in a German population are discussed in detail in the works of Lange et al. (13). They reported lower parental educational level, a lower degree of professional education, low income, nationality (German vs. non-German), limited living space per person, and single parenthood as the most relevant predictors for being overweight or obese (13).

Obesogenic environments

Obesogenic environments are “the sum of influences that the surroundings, opportunities, or conditions of life have on promoting obesity in individuals or populations” (14, p. 564). They comprise a resident’s aggregate socioeconomic status (SES) as well as aspects of their social and physical environments. Evidence suggests that children living in low SES areas are more often overweight or obese (12, 15, 16). Aspects of the social environment (social cohesion, collective socialization and trust, in particular) seem to be relevant for unhealthy weight gain in children and adolescents (15).

Regarding the physical environment, Feng et al. (17) summarize three domains that may influence obesity: 1) facilities for physical activity (i.e., parks, playgrounds, sports clubs that promote active play and sports); 2) land use and transportation (i.e., mixed land use, walkability, access to public transport or walking/cycling paths that facilitate active commuting to school/work); and 3) foodscape (availability of healthy or unhealthy food). In this sense it was reported that fewer resources for recreation (e.g., parks, playgrounds), sports or active commuting (street connectivity, land-use-mix) and a high density of fast food outlets are related to overweight and obesity in children and adolescents (15, 18, 19). Recent studies also suggest that air pollution may cause higher mortality among individuals with type 2 diabetes (20, 21), increase the risk for insulin resistance in children (22) and increase the risk for asthma in children, especially in the overweight (23). However, it is possible to show that children living closer to parks and recreational spaces are less likely to experience weight gain (24). Moreover, the availability of food outlets in the neighborhood was not necessarily associated with unhealthy diets but was associated with higher consumption of fruit per day (25).

Summing up, the development of overweight and obesity during childhood is a result of complex mechanisms at different levels of influence (individual, social, environmental) (Figure 1). There are various theoretical
or conceptual frameworks describing this complexity. Socioecological models, for example, point out the influences of intrapersonal, interpersonal, organizational, community, and policy levels as well as their interactions, which are relevant for an individual’s health (26). The “full obesity system map” illustrates its complexity by mapping the clusters of individual and social psychology, individual activity, activity environment, food consumption, food production, individual physiology, and physiology that influences an individual’s energy balance (27).

To choose the most relevant and preventable factors contributing to childhood obesity for future intervention studies, it would be appealing to know which factors contribute most to childhood obesity. This approach is accounted for by the concept of “attributable risk to obesity”. On the basis of four German studies comprising >34,000 individuals, Plachta-Danielzik et al. (28) identified parental obesity, parental smoking, and parental education levels to be the most relevant attributable risk factors for childhood overweight – each of them representing targets for prevention that are hard to change. Consequently, realizing that individual determinants are more important than environmental for explaining the development of childhood obesity (29) does not necessarily mean that environmental approaches should be deemed invalid.

**Preventive strategies**

In general, interventions to reduce health inequalities may operate at different levels, aiming at 1) strengthening individuals (using person-based educational approaches), 2) strengthening communities (by building social cohesion and mutual support), 3) improving living and working conditions (by reducing exposure to health damaging environments and improving conditions), and 4) promoting healthy macro policies (38). Taking into account that obesity is “the result of people responding normally to the obesogenic environments they find themselves in” (39, p. 804), preventing or treating obesity requires multidimensional strategies focusing on individual, familial, institutional, and environmental levels of influence (40, 41).

**Intervention approaches – from individuals to environments**

There is evidence that community-based approaches are the most promising or effective strategies in preventing obesity. Especially for children who have little control over the social and environmental conditions of their lives, comprehensive community-based interventions are appropriate (42). According to Foltz et al., “communities are commonly referred to as networks or groups of individuals who share common beliefs, values, or culture [...] but can also be individuals who reside and work in common geographic locales and share a variety of common institutions [...] and resources [...]” (43, p. 402). Thus, community-based interventions comprise the access to the target group (setting approach) as well as contextual changes in different types of environments such as physical, economic, political, and sociocultural environments (14).

In this work, we put emphasis on intervention studies to prevent childhood obesity that employ changes of the environment with the goal of creating opportunities for healthier choices regarding mostly physical activity and food intake for children and adolescents.
Materials and methods

To obtain an overview of current literature for this work, we screened PubMed/MEDLINE for relevant review articles. Searching for “childhood obesity intervention”, we selected ten review articles focusing on obesity-related prevention studies (not treatment) in children (35, 37, 42, 44–50). Eight of the selected reviews comprised interventions targeting childhood obesity prevention (encompassing 314 studies meeting the respective inclusion criteria of reviewers in total, not corrected for double-listing), two reviews focused on interventions to improve physical activity (37, 50). Moreover, single studies not being currently included in available reviews were retrieved and reference lists of selected articles from the above-mentioned reviews were screened for additional articles. Studies were included if they explicitly contained environmental changes. We use the term “environmental change” [according to the definition of the Centers for Disease Control and Prevention (CDC)] for interventions that focus on the physical environment and create opportunities for healthier choices (e.g., park renovations – physical activity; installation of bike lanes – active transport; healthier options in school cafeteria – healthier diet). We did not include interventions that were solely aimed at improving aspects of the social environment (e.g., social cohesion, trust between neighbors). Moreover, we identified studies focusing on increasing physical activity by environmental modification only, of which we will discuss three. Most of the recent studies employed multidimensional interventions, making it impossible to disentangle the single effect of environmental modifications from the whole effect of more complex interventions on the BMI of participating children.

Result of studies on environmental changes

Effects of built-environment modifications only

Boarnet et al. (52) evaluated California’s “Safe Routes to School” legislation (SR2S), which allocated more than $66 million to improvements on routes to school, like installation of bicycle lanes during Autumn 2003. Results of retrospective questionnaires on commuting behavior completed by parents showed an increased probability to walk or cycle to school after completion of construction works (52).

The effects of providing a safe space to play in afternoons and on weekends were investigated in another project. Directed at students of a school with children from prekindergarten through sixth grade, their school yard was opened for extra hours and monitored by attendants to prevent bullying, vandalism and entering of unrelated adults or older children. Compared to a school in a neighboring district with similar sociodemographic characteristics, it could be observed that the number of children being outdoors and physically active was 84% higher. Moreover, a decline in sedentary behavior among students during the course of the project was also observed (53).

Several groups assessed the effect of public park renovations. These interventions also represent incentives to be more physically active. Tester and Baker were able to show increased frequency of visits to and overall physical activity in a park that underwent physical playfield renovations compared to a park where similar action was desisted (54) (Table 1, section I).

Multidimensional interventions

Searching for studies that examined the effect of environmental changes to create opportunities for health promoting behaviors, we identified predominantly complex multidimensional interventions. Mostly, environmental changes were part of setting-based interventions (i.e., they were conducted in schools, kindergartens, or community centers) that also comprised educational approaches. In none of the studies the effect of single components was analyzed, only the total effectiveness of the entire intervention (Table 1, section II).

In a program targeted at children (activity lessons in school, sessions on healthy nutrition), parents (promotion of physical activity, healthy food, limitation of screen-time), and teachers (support for lessons), the built environment was altered to promote physical activity during breaks or school time with climbing walls, balls, cords, or stilts. Comparison to standard was yielded by cluster randomization. Results showed an increase of approximately 11% for aerobic fitness and a decrease of 5%–10% in body fat for the intervention group, with no effect on participants’ BMIs compared to the BMIs of controls. In reaction to the results, some Cantonal health promotion programs in Switzerland implemented modules of this intervention (55).

A school-based trial in the Netherlands included students aged 12–14 years who underwent a multidimensional health promotion intervention. It consisted of educational components (classes in biology and physical education, a computer-based information program) as well as environmental changes such as specific advice to the school canteen proposing smaller portion sizes, “healthier” products, or restricted access to vending machines. Additionally, posters labeling foodstuff into red, yellow, or green categories were installed. Twelve-month follow-up measurements showed reduced skinfold thicknesses, lower consumption of sugar-containing beverages, and less screen time (only in boys) in the intervention schools (56, 57).
## Table 1: Childhood obesity prevention programs addressing obesogenic environments.

<table>
<thead>
<tr>
<th>Author/project name/country</th>
<th>Sample/target group</th>
<th>Intervention (environmental change part only, where applicable)</th>
<th>Duration/interval</th>
<th>Outcome measures</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Interventions focusing only on environmental changes and physical activity</td>
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<tr>
<td>Boarnet et al. (52)/Safe routes to school (SR2S)/US</td>
<td>Third to fifth grade students; n=1244 respondents to questionnaires Prekindergarten to sixth grade students</td>
<td>Bike lanes, sidewalks, crossings, traffic control Opening schoolyards on afternoons and weekends, vigilance by teachers</td>
<td>2 years</td>
<td>Proportion of children cycling or walking more to school Proportion of children being physically active, watching TV or DVD Visits and overall physical activity (SOPARC)</td>
<td>Greater proportion of increased cycling or walking Proportion of physically active children 71% vs. 38%, reduced screen-time (50% vs. 70%) Increases in visitation and overall physical activity</td>
</tr>
<tr>
<td>Farley et al. (53)/US</td>
<td>Park visitors</td>
<td>Park playfield renovations</td>
<td>1 year</td>
<td>Aerobic fitness, body fat, BMI</td>
<td>Better fitness, reduced body fat, no effect on BMI</td>
</tr>
<tr>
<td>Tester and Baker (54)/US</td>
<td>Park visitors</td>
<td>Fixed and mobile equipment on/in school(yard)</td>
<td>1 year</td>
<td>Body composition (waist circumference, skinfold thickness, BMI), dietary and physical activity behavior</td>
<td>Reduced skinfold thickness, reduction of screen-viewing behavior in boys, sugar sweetened beverages after 12 months BMI z-score improvement in boys only, physical fitness improvements in both genders Higher proportion stayed normal weight (52.1% vs. 40.7%); improvement in math scores in intervention group Lower BMI-increase in intervention; odds ratio 0.41 to become overweight</td>
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<tr>
<td>II. Multidimensional interventions comprising “environmental changes”</td>
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<tr>
<td>Puder et al. (55)/“Ballabeina”//Switzerland</td>
<td>Students/preschoolers in high migrant areas, mean age 5.1 years, n=652//school</td>
<td>Changes in and around school cafeteria</td>
<td>20 months</td>
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<tr>
<td>Singh et al. (56, 57)/“NRG-DoIT”//Netherlands</td>
<td>Teenagers, mean age 12.7 years, n=1108//school</td>
<td>Fixed and mobile equipment on/in school(yard)</td>
<td>1 year</td>
<td>Body composition (waist circumference, skinfold thickness, BMI), dietary and physical activity behavior</td>
<td>Better fitness, reduced body fat, no effect on BMI</td>
</tr>
<tr>
<td>Kain et al. (58)/Chile</td>
<td>Students, first to eighth grade, age average 10.6 years, n=2141 intervention, 945 controls//School</td>
<td>Promote healthier choices in kiosks</td>
<td>6 months</td>
<td>BMI z-score</td>
<td>Reduced skinfold thickness, reduction of screen-viewing behavior in boys, sugar sweetened beverages after 12 months BMI z-score improvement in boys only, physical fitness improvements in both genders Higher proportion stayed normal weight (52.1% vs. 40.7%); improvement in math scores in intervention group Lower BMI-increase in intervention; odds ratio 0.41 to become overweight</td>
</tr>
<tr>
<td>Hollar et al. (59)/HOPS//USA</td>
<td>Students (qualified for free or reduced-price meals), mean age 8 years (4–13); n=1197 (n_{int}=974)//school</td>
<td>Healthier school-meals, school gardens</td>
<td>2 years</td>
<td>BMI-change, academic skills (math, reading)</td>
<td></td>
</tr>
<tr>
<td>Simon et al. (60, 61)/ICAPS//France</td>
<td>First-level students, aged 11.7±0.6 years, n=954//community</td>
<td>Environmental conditions to enable physical activity (contact to policy makers, no actual changes stated)</td>
<td>4 years</td>
<td>BMI-change, fat-mass</td>
<td></td>
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<tr>
<td>Economos et al. (62, 63)/“Shape up Somerville (SUS)”//US</td>
<td>Elementary school children age average 7.92 years (grade 1–3) n=1178, //community</td>
<td>Traffic calming, school food, equipment, approved restaurants, city ordinances on walkability, bikeability</td>
<td>2 years</td>
<td>BMI z-score</td>
<td>Decrease in BMI z-score (~0.1005) after 2 years.</td>
</tr>
<tr>
<td>De Silva-Sangiorski et al. (64)/“Romp &amp; Chomp”//Australia</td>
<td>Preschool children, baseline 2 years and 3.5 years; n=12,000//community, childcare centers</td>
<td>Provision of water, policy changes</td>
<td>4 years</td>
<td>Weight status, BMI z-score</td>
<td>Decrease in BMI z-score in the 3.5 years (~0.04) after 3 years; more children with healthy weight in both age groups</td>
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<tr>
<td>III. Quasi experimental environmental change-intervention in CHILDREN AND ADULTS</td>
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<tr>
<td>Ludwig et al. (65, 66)/“Moving to Opportunity”//US</td>
<td>Recipients of vouchers (adults with children) n=1788//community</td>
<td>Moving to better-off area</td>
<td>10–15 years</td>
<td>BMI, level of HbA1c</td>
<td>Reduced prevalence of extreme obesity and diabetes</td>
</tr>
</tbody>
</table>
The effect of additional weekly physical activity classes and classes on healthy nutrition for parents and students was assessed in another school-based obesity-prevention intervention in Chile. From the “environmental change” perspective, school kiosks were advocated to offer healthier choices to students and were advised how they could remain profitable. Whereas it was possible to decrease BMI z-scores in boys and to improve physical fitness in both genders, the kiosk-intervention did not seem to contribute to this effect as registered proportion of healthy foods sold by kiosks did not change during the intervention period (58).

The school-based Healthier Options for Public School-children (HOPS) intervention combined measures targeting healthy nutrition by school-meal modifications and the implementation of school gardens as well as physical activity through 10–15 min “desk-side physical activity” during regular lessons (involving math and spelling tasks). Moreover, students and parents were taught about good nutrition and physical activity during lessons and via monthly newsletters. After 2 years of intervention, significantly more students in the intervention group stayed within the normal weight (<85th percentile) compared to the control group (52.1% vs. 40.7%). Moreover, students in the intervention group improved their academic performances in math (59).

The effects of multiple interventions on physical activity and BMI were evaluated in another school-based trial. In addition to creating new opportunities for physical activity in and after school time, the promotion of active commuting to school, and the education of teachers and parents, additional measures were undertaken in the “out-of-school environment”. Reduced entry fees to sport areas, public transport to physical activity sites, and improvements of bicycle lanes around schools were implemented. Four years after randomization, students in the intervention group showed a lower increase in BMI than their age- and gender-adjusted controls, the rate of students practicing physical activity was higher, and screen time was lower in the intervention group (60, 61).

The project “Shape up Somerville” (SUS) evaluated a community-based environmental change intervention. The program included the improvement of opportunities for physical activity around the school (traffic calming, information on safe routes to school, walking school bus), within the school (new equipment) as well as community-wide instruments such as approving restaurants to SUS guidelines. Results taken 2 years after 1 year of intervention showed that BMI z-scores of children in the intervention community decreased by 0.06 compared to controls. Prevalence of overweight/obesity decreased in males and females, and remission increased in males and females in the intervention group compared to controls (62, 63).
Although the Australian intervention program “Romp und Chomp” focused mainly on capacity building in the participating communities by increasing the awareness and qualifications for health promotion in local organizations, it also resulted in noteworthy measures of “environmental changes”. In addition to the provision of water in childcare centers, childcare policies regarding healthy eating and physical activity were changed. Moreover, childcare professionals were trained in physical activity and nutrition related skills. After 3 years of intervention, the proportion of children with healthy weights was significantly higher in the intervention group (64).

**Quasi-experimental trial: moving to opportunity**

For individuals, the easiest way to change one’s living environment is to move to a different area. The unique social experiment “moving to opportunity” (65, 66) conducted in the cities of Baltimore, Boston, Chicago, Los Angeles, and New York investigated the health effects of moving from a high-poverty area to a more affluent one. The study group evaluated the development of body weight and the level of glycated haemoglobin (HbA1c) of 1788 randomly selected women and their children who were given vouchers to move. Thus, they were able to instantaneously improve their potentially depriving and health-damaging environment. After 10–15 years, randomization results show a lower prevalence for overweight and obesity (BMI >35, BMI >40) and a lower proportion of elevated levels of glycated haemoglobin (HbA1c) in the intervention group (65). The authors were not able to explain the mechanisms underlying this effect. Nonetheless, this intervention shows the public health potential of modifying environmental factors for health improvement (Table 1, section III).

**Interventions in progress**

A French obesity prevention trial (EPODE – Ensemble Prévenons l’Obésité des Enfants) focused on school- and family-based interventions but was additionally supported by the local councils (67). EPODE has been transferred to more than 500 communities worldwide from its origins on the basis of clear network recommendations (68). The EPODE program clearly contains aspects of environmental changes including “rearrangement of school play-grounds, the installation of multisport courts in neighborhoods, the development of baby gym facilities and activities, and improvements to the ‘walkability’ of the town” (68, p. 306). Unfortunately, although the program is being expanded internationally (69, 70), until now no detailed evaluation has been published.

In 2012, the New York City Obesity Task Force (NYOTF) was launched (71). Together with all relevant departments and agents, strategies aimed at reducing obesity, addressing disparities between communities, reducing preventable health conditions, and lowering health care spending were elaborated. The project explicitly recognizes obesity as an environmental problem (between others) that can be addressed by environmental improvements such as availability of healthier food and water in public places (e.g., water jets and salad bars in schools and universities), making public spaces safer and more attractive for physical activity and active transport, and promoting building design to encourage physical activity (71). It also involves media campaigns as well as educational approaches. Moreover, the city published “Active Design Guidelines”, a collection of strategies to increase opportunities for physical activity in the built environment that is directed to designers, developers, and policy makers. In December 2013, some indicators already showed improvements, with final results expected in 2016 (72) (Table 1, section IV).

**Discussion**

Today, most interventions are multidimensional following the recommendations of the Cochrane Review on obesity prevention in children (47). Regarding the large number of screened community-based obesity prevention studies in total, we could only identify a small number that explicitly focused on “environmental changes” (i.e., modifications of the “obesogenic environment”). The majority of the included studies were school-based, while some addressed the whole community. Drawing back to the above-mentioned intervention strategies, programs focused mostly on person-based educational approaches, whereas the improvement of living conditions (“environmental change”) to offer healthier choices played a minor role. Only a few trials (Romp & Chomp, NY OTF, EPODE) were directed to capacity building (strengthening communities) and macro-policy changes. All of our included studies showed effects on physical activity or weight-related outcomes in children and adolescents in the desired direction. However, we have to take publication biases into account. In addition, this paper does not claim to be an exhaustive systematic review but an overview on interventions targeting aspects of the “obesogenic environment”. Hence, we can neither draw conclusions about the effectiveness of “environmental” interventions.
Nevertheless, offering healthier choices may be insufficient to induce behavioral change as behavior results from combining options with subjective norms and attitudes fueled by (perceived) behavioral control (78). Norms and attitudes are influenced by one's social context. From a psychological perspective, behavioral change models such as the theory of planned behavior (79) or social cognitive theory (80) may have the potential to explain why changing attitudes that lead to unfavorable (unhealthy) behaviors to desired (healthy) behaviors are so difficult to accomplish (81). In any case, one should not expect environmental change programs to work equally for everybody without the modification of inner views. Thus, environmental interventions need to be seen as complementary to individual approaches and not as a substitute (36). Figure 2 illustrates possible decisions before and after the installation of alternatives. First (A), there is only one option and thus one possible decision. After the installation of alternatives, the individual has to decide (according to individual and social characteristics, norms) between B and C. Consequently, no behavior change can occur without a change of choices and attitudes.

Figure 2: There is no behavior change without a change of choices and inner views.

(A) Situation before installation of alternative choice offers only one possible decision. (B, C) After the installation of alternatives, the actual decision will depend on inner variables of the individual.

Regarding the cost-effectiveness of specific environmental interventions, studies are lacking (82). However, some multidimensional school-based studies have been shown to be cost-saving (77). In conclusion, complex interventions aiming at environmental changes and the strengthening of individuals and communities as well as macro-policy changes are promising strategies to reduce obesity in children (and adults) without increasing socioeconomic inequalities. Medical practitioners, educators, and policy makers should be aware of the complex causes of childhood obesity.
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