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Amidst the COVID-19 pandemic childhood obesity is still an epidemic-spotlight on obesity's multifactorial determinants

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ABSTRACT

Purpose: Childhood obesity is a global epidemic and a chronic disease. Multifactorial determinants have long been linked with childhood obesity. These have been challenged with the onset of COVID-19 and the associated mitigation measures. The study aimed to re-highlight these determinants while exploring the effects of the ongoing COVID-19 pandemic on these pre-existing childhood obesity determinants, while providing evidence that may be beneficial for the post-COVID-19 recovery plan.

Methods: A PubMed literature search (2016–2021) using the keywords, "childhood obesity", "gender", "sex", "obesity in youth", "obesity in adolescents", "COVID-19″ and "SARS-CoV2" was performed.

Results: Genetic predisposition, biologically low leptin levels, certain cultural beliefs and socio-economic statuses, as well as exposure to an "obesogenic" environment were found to have a positive association with childhood obesity. Additionally, the onset of COVID-19 further aggravates the childhood obesity epidemic, increasing childrens' susceptibility to obesity and all associated consequential diseases.

Discussion: A possible key to the control and prevention of the burden of childhood obesity, lies in dealing with its precursors and risk factors. Certain factors, including socio-cultural norms, cultural beliefs and geographical factors are amenable. COVID-19 further challenged these and it is evident that the childhood obesity epidemic is still a critical one. Encouraging preventative interventions, such as screening programs, public awareness and policies targeting the environment, amongst others, are recommended.

Introduction

Obesity is a current worldwide epidemic, and has been existent since the dawn of humanity, having origins that "*can be traced back 30,000 years, to our prehistoric ancestors*" [1]. The World Health Organisation recognised obesity as a global epidemic in 1997 [2,3]. Nowadays, obesity is an escalating problem threatening global public health and recently has been declared a disease [4–6]. Across the years, several strategies have been set forward, yet the obesity rates have been on the incline with a threefold increase reported from 1975 to 2021 [7]. Indeed, it is predicted that at least 18% of adults across the world will be obese by 2025 [8]. An increase in obesity rates have also been reported amongst children and adolescents [7,9–11].

There are numerous factors contributing to childhood and adolescent obesity including gender, biology, geographical and socio-economical aspects, amongst others [12–14]. It is paramount that immediate preventive and management plans are instituted to effectively deal with childhood and adolescent obesity that inevitably will have a repercussion on their life course with potential development of adult obesity [15–17]. This narrative review aims to provide a holistic understanding of the various factors contributing to the global childhood and adolescent epidemic while exploring their significance especially now amidst a pandemic to ensure a sustainable global future.

Methods

A literature search was conducted using the PubMed database using the following keywords, "childhood obesity", "gender", "sex", "obesity in youth", "obesity in adolescents", "COVID-19″ and "SARS-CoV2". Studies published between 2016 and 2021 were considered in this search strategy. The reference lists of the selected articles were also considered. Article selection was primarily based on title relevance, as well as compendious nature of the abstract, excluding any articles with non-relevant abstracts or pertaining to adult obesity. In addition to this, in order to retrieve additional records, reference snowballing was applied to certain eligible papers. For all searches, 82,036 articles and reports were retrieved, of which 59 met inclusion criteria. Additionally, international organizations websites of the World Health Organisation (WHO)

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and the World Obesity were also utilized for reports on population statistics and data.

Results/discussion

Several factors have long been acknowledged that contribute to the development of childhood and adolescent obesity. However, in the midst of the ongoing COVID-19 pandemic and its associated mitigation measures, it is important to re-highlight these factors. These unprecedented times have further challenged these obesity factors and it is anticipated that the world will face a higher obesity burden in the future unless urgent action is taken.

Obesity: the early life

The susceptibility for obesity initiates from the pre-conception phase, where maternal or paternal obesity can predispose the phenotype of the foetus [18–20]. Hence, this highlights the importance of screening preconceptionally as well as during pregnancy. This can be portrayed as a prophylactic measure to identify risks of childhood obesity or any of its complications in a timely manner [21]. Additionally, the biological dimorphism that exists between the sexes, possibly gives rise to differences in the predisposition of a child to being obese. Indeed, in-utero the head and abdominal circumference of a female foetus is smaller than that of a same-aged male, recorded from the second trimester onwards [22]. On the other hand, an English study conducted by the Helmholtz Centre for Environmental Research (UFZ) concluded that maternal stress during pregnancy up until the first year post-partum predisposes the child to developing obesity. This was specifically found to affect female infants more than males [23].These results demonstrate how early the onset of the obesity disease really is.

Puberty, adolescence and obesity

Leptin is a hormone secreted by adipose tissue, that acts as an appetite-suppressor and also has a role in energy expenditure. Leptin concentrations increase greatly during the pre-pubertal years. In females, leptin levels are higher after puberty, when compared to pre-pubertal ones. This is not the case in males, due to the suggested inhibitory effect of testosterone on leptin [24].Therefore, adolescent females have a higher leptin concentration in comparison to males, predisposing the males to a higher susceptibility to gaining weight, leading to obesity [25]. During fat patterning, which occurs during early puberty (and possibly even pre-pubertally), males tend to accumulate more visceral abdominal fat when compared to females, further increasing the risk of male obesity [26,27].

Studies have reported a decline in physical activity in both sexes during adolescence, especially in peripubertal girls when compared to boys [28,29]. A study involving a cohort of girls aged 11 to 13 years concluded that girls, especially those who mature earlier than their peers, feel self-conscious and dissatisfied about their body. For them, exercise is less enjoyable and motivation to train decreases, leading to the underachievement of the recommended daily duration of moderate to vigorous activity (MVPA) of 60 min [30,31]. Another study conducted in America focusing on MVPA and childhood obesity identified a bidirectional relationship between MVPA and television viewing, which was associated with increased childhood obesity prevalence [32]. This was also the case for a cohort of European adolescents, which took part in the Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) study. As, part of this study, active adolescents who achieved the recommended daily MVPA duration, were compared to less active ones. It was reported that the active adolescents had a lower abdominal fat percentage, and hence a lower risk in presenting with obesity [33]. Hence, the decline in physical activity amongst pubertal females increases their risks for adolescent obesity, and consequently, predisposes to adult obesity.

The socioeconomic effects on childhood obesity around the globe

On a global level, it has been reported that boys aged five to nine years had a higher obesity prevalence compared to girls, in privileged countries, such as Switzerland and Norway, amongst others [13]. However, different geographical locations may be associated with different obesity trends. Cultural and social aspects also have a contributing effect towards obesity. For instance, in Bosnia and Herzegovina, the parental belief that boys should have a higher calorific intake than girls, might explain the higher obesity prevalence in certain geographical regions [14,34]. While, in China, obesity prevalence depends on one's assigned social status, or *"hukou"*. Individuals of an agricultural *"hukou"* live in a rural area and do not have access to social benefits, including healthcare. This population has a less advanced nutrition transition, ie. limited access to high-calorie foods, a fairly active lifestyle and a diet rich in fibrous plants and protein [35]. Having this type of agricultural (rural) social status is associated with lower risk of obesity in girls aged seven, and vice versa [13,14,36]. Conversely, individuals having a non-agricultural *"hukou"*, living in an urban area, have access to social benefits including healthcare. Boys aged seven in the said area, have a higher risk for presenting with obesity [14,37]. Nonetheless, controversy still exists as to whether obesity, specifically childhood obesity, is primarily a disease of the poor or of the rich, due to conflicting research outcomes. Indeed, "the causal direction of the relationship between socioeconomic status (SES) and obesity is complex" [37].

Another social effect that contributes to the relationship between obesity and sex difference can be seen through a Portuguese study. These authors assessed the weight status outcome following the participation in organised sports amongst a cohort aged six to eleven years. Interestingly, it was observed that girls habitually participate in less sports activities than boys, and were often expected to be socially vulnerable [12]. This could explain the high prevalence of female childhood obesity in this geographical area. Of note, such social imposition may also be evident in other geographical areas. Behavioural attitudes, apart from social norms, may also play a part in the type of sports each sex opts for. Indeed, a systematic review concluded that boys prefer sports involving vigorous physical activity, compared to girls, who give more importance to socializing during break time [38]. However, of interest, it was reported that boys' lack of participation in extracurricular sport did not affect BMI values, which was not the case for girls [14,39].

The environment and obesity

Another childhood obesity determinant is the environment children are exposed to, both at school and the family home environment. Having an "obesogenic" environment at school puts children at a higher risk for presenting with paediatric obesity. This was highlighted in a study conducted in Macaé, Rio de Janeiro, where schools with the most exposure to snack bars and unhealthy food advertisements showed the highest prevalence of obese attendees in schools [40]. The environment around the school is another determining factor to childhood obesity. The presence of doughnut and ice-cream vans right next to schools as well as the frequent presence of fast-food chains and confectionaries within the schools district also have a behavioural impact on these children [41,42], with higher chance of obesity.

Other than the school environment, studies report that several factors can contribute to making the family home environment "obesogenic" [43–45]. For example, children exposed to abuse or violence are at a higher risk of being obese [46,47], in part due to the body's response seeking security through fat patterning [48]. Additionally, the family's socioeconomic background can be a determining risk factor for childhood obesity [49]. Having a low socioeconomic status (SES) in industrialised countries puts a low-income child at a higher risk for being obese [37,50–55]. Indeed, children from low SES families were reported to develop unhealthy dietary habits adopted from their home environment [54,56] due to limited finances, including frequent take-away

food consumption [57–59], high-fat [54,60–62], sugar [63–66] and salt meals [67], oily food [58] and minimal intake of fruit and vegetables [54,56,66,68,69]. These high-energy foods together with large portion sizes result in excess weight gain [70], and therefore the development of obesity. Notably, a study conducted by the 'International Association for the Study of Obesity' concluded that the link between SES and childhood obesity lies in infant feeding practices. Low SES infants were found to be predominantly formula fed as well as exposed to unhealthy feeding practices, such as bottle feeding to sleep, which promote paediatric obesity [53,56,71]. However, this does not exclude those having a high SES, as studies show that having a high SES living in a developing country also puts an individual at a higher risk of being obese [72,73]. Even though their consumption of fruits and vegetables is higher than that of their low SES counterparts [54,56].

Thus, it is of utmost importance to take into consideration the childrens' surroundings as well as to provide adequate social support, while promoting healthy school and family environments as the way forward to reduce childhood obesity. Hence, in addition to targeting the school environment, the family environment, including parental nutritional education and general welfare, is of utmost importance in the multi-faceted action plan for tackling childhood obesity. Reducing obesity will inevitably reduce the risk of the known, non-communicable diseases that are linked with obesity including diabetes and cardiovascular disease. In fact, this is one of the reported WHO goals and action plans to combat this epidemic [40,74].

Consequences of childhood obesity

A state of childhood overweight or obesity is associated with severe health sequelae and poor adult outcomes, presenting both acutely and chronically, like cardiovascular disease (eg hypertension). Newborns of obese mothers were found to be more likely to be resistant to insulin, compared to infants of non-obese mothers [75]. Being obese and insulin-resistant in later years, like the prepubertal years, leads to large amounts of abdominal subcutaneous fat and liver fat content (hepatic steatosis) [76,77]. This can develop into hepatitis (liver inflammation), cirrhosis (scaring), and hepatocellular carcinoma (liver cancer) [78] amongst other complications including premature death. Additionally, metabolic syndrome can develop as a result of the combined insulin-resistant state and the obesity of an individual [17]. Paediatric metabolic syndrome often leads to adult metabolic syndrome [79], which can cause cardiovascular events following childhood. One such obesity-related health problem is hypertension, which persists from childhood to adulthood [80].

Early childhood obesity in females heightens risks of presenting with polycystic ovarian syndrome (PCOS) due to the peripubertal hyperandrogenaemia (high levels of androgens) [81]. Of note, studies concluded that PCOS in youth is also linked to hypertension and increased thickness of tunica intima of the carotid artery (atherosclerosis) [82]. PCOS secondary to obesity increases an individual's risk of endometrial cancer as an adult, amongst other cancers, including breast cancer [17]. PCOS can also lead to even more weight gain, further aggravating the obesity disease [81].

Obesity is also a major risk factor for the development of type 2 diabetes, and it makes the diabetes state more difficult to treat therapeutically [83]. Of note, treatment of type 2 diabetes often leads to exacerbation of the obesity, since therapies like insulin and thiazolidenediones were found to cause weight gain [84]. In addition to this, obese patients with type 2 diabetes have higher mortality rates than non-obese patients with insulin-resistance [85].

Further to this, it has been concluded that childhood obesity is also associated with negative academic, social, emotional and psychological repercussions [86–88]. Paediatric and adolescent obesity increase the likelihood of suffering from mental health conditions, such as depression and anxiety disorders [87,89,90]. These consequences extend into adulthood, just like physical comorbidities [87]. Overweight children are more vulnerable to stigmatisation, prejudice and discrimination by their peers, parents as well as health providers [87,91,92]. Of note, childhood obesity is also associated with negative academic consequences. Studies concluded that an obese child is four times more likely to struggle with low grades at school, when compared to healthy children of the same age [91,93]. Additionally, out of fear of being negatively precepted by those around them, obese children refrain from class participation, leading to a reduced educational outcome [94]. Consequentially, in order to overcome the aforementioned challenges, the affected individuals often resort to comfort foods and sedentary activities, which make weight management even more difficult to achieve [86]. Hence, it is evident that the consequences of childhood obesity, tracking to adult obesity, are far from minimal.

The effect of COVID-19 on childhood and adolescent obesity

With the ever-increasing obesity rates worldwide, it is logical to question whether COVID-19 affects the current obesity situation. It has been reported that the ongoing pandemic aggravates childhood and adolescent obesity rates, making it imperative to keep childhood and adolescent obesity at the core of the action plan for the pandemic recovery [95]. Clinical manifestations of COVID-19 in children and adolescents vary greatly amongst different geographical regions [96,97].

However, obesity is a risk factor for contracting COVID-19 infection and those infected get a severe form of infection [98]. This was even observed amongst children and adolescents with obesity [96]. On the contrary, since the onset of the pandemic, normal weight children were reported to have less susceptibility to contracting Covid-19 and those that do, exhibit mild symptoms [99].

Behavioural and environmental factors linked to childhood obesity have been "challenged" throughout the progression of the pandemic [100]. Periods of social isolation could lead to increased fat accumulation in children [101,102]. School and day-care centre closures led to a decrease in physical activity [103–105], mental health [106] as well as sun exposure [96], and an increase in screen-time, fast food intake, sweetened beverages, stress and sleep disorders, amongst others [105,107]. This puts an individual at an increased risk of obesity due to weight gain and abdominal adiposity [50,96,100], apart from causing a decline in childrens' mental health [106,108] and academic performance [109]. Mental health problems have proven to be factors that contribute to childhood obesity, or else maintain it [88]. Moreover, during pre-Covid-19, it was reported that children and adolescents were more likely to put on more weight during the summer period when on holidays, compared to weight gain during the scholastic year [110]. Hence, it is anticipated that with COVID-19 lockdowns and isolation periods in place, children and adolescents are more susceptible to increase in weight with a risk of developing obesity, as these periods can be considered as an "early onset-summer holiday" [100].

However, the above containment strategies have also reduced the exposure of children and adolescents to COVID-19, relatively "sparing" them, and this is shown in the low infection rates in the paediatric population. This could explain why studies related to COVID-19 in children are lacking too [99].

Low-income families struggled financially during the COVID-19 pandemic, and this predisposed them and their children/adolescents to food insecurity [50]. Food insecurity is the scarcity of safe, nutritive food in a supply that is adequate in order to lead an operative, healthy lifestyle [111]. Food insecurity may be a susceptible variable to developing an overweight or obese status, although this is not clear yet [50].

A summary of all the different determinants predisposing to childhood obesity is shown in Fig. 1.

Strengths and Limitations

TSo our knowledge, this study targeted all factors that can determine childhood obesity. The search terms used were broad, ascertaining con-

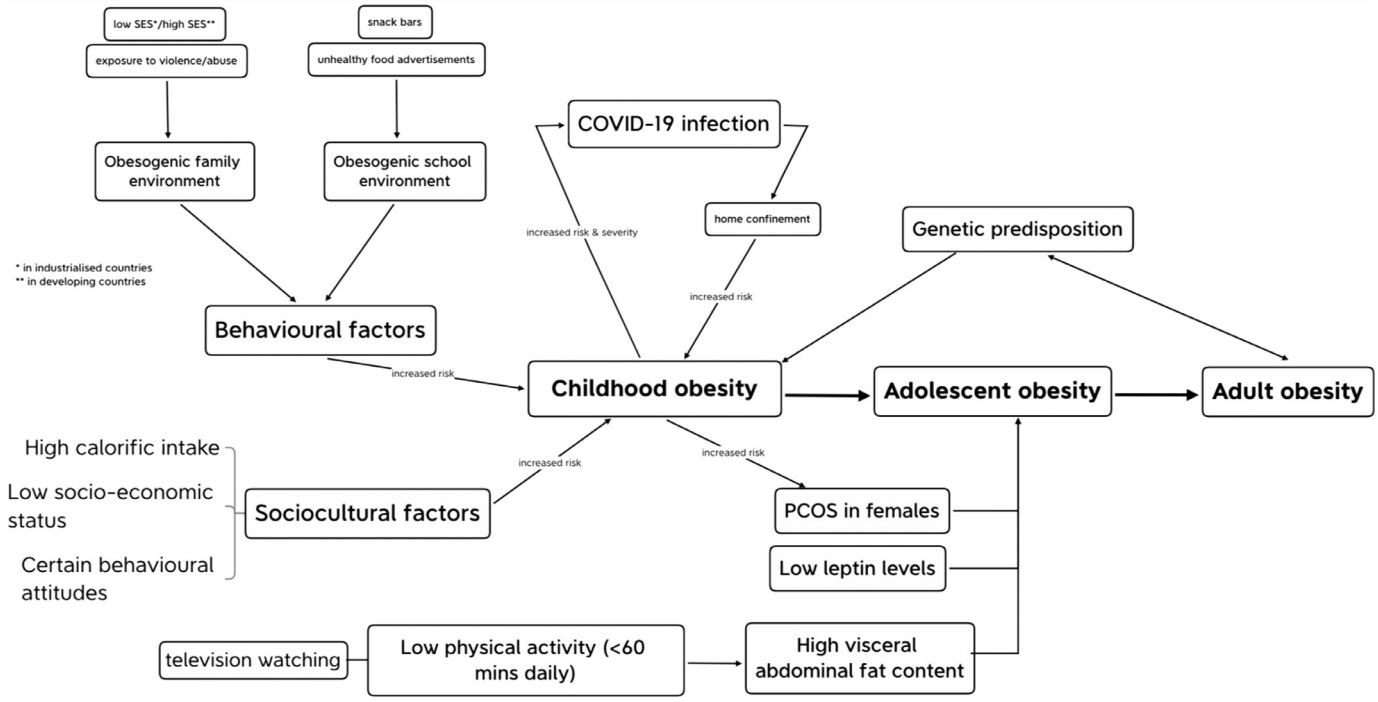

Fig. 1. A summary of all the different determinants predisposing to childhood obesity (created by XMind software).

siderable analysis of the literature and thousands of references to be screened. However, any literature that was not identified using a set of keywords and/or did not meet the inclusion criteria was not considered. Additionally, the literature in the review is sourced from one database, i.e. PubMed. Therefore, any articles not featured in this database were missed, limiting the literature review.Implication for policy.

Preventive measures to reduce the childhood obesity burden needs to start from the pre-conception period and/or during gestational period. Pregnant women should be given advice and encouraged to maintain a healthy weight during pregnancy. Such educational campaigns should be continuous throughout the life course of every individual. However, education on its own will not be enough. Targeted action plans to address other contributing factors need to be in place. Alerting social and cultural habits is not a trivial task,so school based physical activity programmes with equal opportunities of vigorous exercise across the sexes can be of great benefit. Targeting the food environment that children are exposed to, is another recommendation. Indeed, some countries have banned food trucks from setting up in the vicinities of schools [112–116], while others have banned fast-food commercials from airing during children's viewing times on television [114,116–120]. Moreover, the impact of the family environment on childhood behaviour and inevitably obesity needs to be acknowledged. This is a complex socioeconomic trajectory as it involves multiple stakeholders. However, parental education about food availability, convenience, and making wise food choices whilst on a budget is something that could be considered [74]. With the onset of Covid-19 these social determinants have been further challenged with an anticipated deterrent effect on childhood obesity. Therefore, now more than ever, tackling childhood obesity through a multi-faceted action plans should be on everyone's agenda as part of the post-Covid-19 recovery plan.

Conclusion

Obesity is a complex global health crisis, with a multifactorial contributing origin that if not controlled or prevented increases the risk of other health problems. However, knowing which aspects act as the precursors leading to childhood obesity, are a possible key to a healthier future. Although genetic and biological factors may be hard to control, the socio-cultural, and geographical factors that play a crucial role in childhood obesity can be targeted through various action plans.

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Availability of data and material

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Code availability

Not applicable.

Ethics approval

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Consent to participate

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Consent for publication

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Declaration of Competing Interest

Both authors declare no conflict of interests.

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