Factors associated with ultra processed food intake in children: A systematic review of observational studies.

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ABSTRACT

Background

Ultra processed food (UPF) makes a substantial and growing contribution to diets globally. UPF intake is associated with adverse health outcomes. Childhood represents an ideal time for interventions to reduce UPF intake as it is when dietary behaviours are established. Understanding factors associated with UPF intake in children will help inform the design of future interventions. The socioecological model provides a framework in which to conceptualise factors contributing to dietary behaviours, such as UPF intake.

Aim

To synthesise the current body of knowledge on the factors associated with UPF intake in children.

Methods

A comprehensive literature search of three databases was conducted to identify quantitative evidence of factors associated with UPF intake in children. A total of 3,271 articles were identified. After screening, 32 reports from 20 original studies (18 cross-sectional and two prospective cohort) were included. A narrative synthesis of factors across levels of the socioecological model was performed.

Results

The majority of studied factors were at the interpersonal and individual levels of the socioecological model. Few factors had been studied at the community level and none at the policy level. Studies have identified positive associations between screen time, screen use during meals and having a parent who smokes and children's UPF intake, and generally negative associations between breastfeeding duration and UPF intake. Sex, ethnicity, gestational age, birthweight and parents BMI did not tend to be associated with children's UPF intake. There were inconsistent associations for age, physical activity, socioeconomic status, parents age and family size and children's UPF intake. A wide range of other factors had been examined in one or two studies.

Conclusions

Screen use, parental smoking and breastfeeding appear to be related to UPF intake in children, but how these factors influence UPF intake requires further study. There is a paucity of knowledge on how factors at the community and policy levels of the socioecological model influence UPF intake in children. Further research is needed to understand factors associated with UPF intake in children and

which interventions are successful, the findings of this review may be used to inform the design of such studies.

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LIST OF ABBREVIATIONS

BMI	Body mass index
CVD	Cardiovascular disease
DALY	Disability adjusted life years
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-analyses
SES	Socioeconomic status
UPF	Ultra-processed food

CHAPTER 1: INTRODUCTION

1.1 Background

Poor diet is a leading contributor to the global burden of disease, responsible for 22% of deaths and 15% of disability-adjusted life years (DALYs) lost among adults in 2017 [1]. Cardiovascular disease (CVD) is the leading cause of diet-related deaths and DALYs, followed by cancer and type 2 diabetes [1]. Research has, to-date, largely focused on identifying single nutrients, foods and dietary patterns associated with the development of these diseases [1-5]. Only more recently, after the advent of the NOVA classification system which identifies '*ultra*' processed foods, has the impact of food processing on health outcomes come under scrutiny [6, 7].

The NOVA classification system, developed in 2009 and now in widespread use, categorises foods into one of four groups according to the extent and purpose of industrial processing they have undergone [8, 9]. NOVA group one, '*unprocessed and minimally processed foods'*, includes foods such as fruits, vegetables, grains, legumes, milk and meat; group two, '*processed culinary ingredients'*, such as salt, sugar and oil; and group three, '*processed foods'* such as fresh bread, plain yoghurt, cheese and canned fruit. NOVA group four, '*ultra-processed foods'* (UPFs), includes foods such as soft drinks, ready-to-eat meals, reconstituted meat products and some types of breakfast cereals, breads and yoghurts. The production of UPFs involves a series of industrial processes, and they consist of food-derived ingredients, such as high-fructose corn syrup and hydrolysed proteins; cosmetic additives such as colours, flavours and emulsifiers; and little or no whole foods.

Traditional dietary patterns consist of unprocessed or minimally processed foods, prepared with processed culinary ingredients and complemented with processed foods such as cheese, breads and pickled vegetables (i.e. foods from NOVA groups one to three) [8]. It was not until recent advances in food science and processing that UPFs became possible, and with the coinciding emergence of a monolithic global industrial food system, began to dominate the food supply [9, 10]. Of total energy intake, UPFs now contribute more than 50% in high-income countries [11, 12] and up to 30% in middle-income countries [13, 14]. A central feature of the nutrition transition underway in middle-income countries is the replacement of minimally processed foods with UPFs, so the latter figure is likely to rise [15]. As more than two-thirds of the world's population live in these countries, the global consumption of UPFs could increase substantially in the coming years. UPF intake also tends to vary by age, with younger age groups being greater consumers than older age groups [16, 17].

Concerningly, a growing body of research has linked UPF consumption with a range of adverse health outcomes. Meta-analyses published within the last five years have identified associations between UPF intake in adults and CVD [18], type-2 diabetes [19, 20], cancer [21, 22], mental disorders such as depression and anxiety [23], cognitive decline [24] and mortality [25, 26]. Among children, higher UPF consumption has been associated with dental caries [27], altered lipid profiles [28, 29], low-grade inflammation [30], increased body fat [31] and poor sleep [32].

1.2 Justification of the research

The substantial and increasing contribution of UPFs to diets globally and evidence linking them to adverse health outcomes has led to advice for individuals to reduce their UPF intake, and for systematic changes to support them to do so [33-36]. As evidence suggests dietary patterns and taste preferences are developed during childhood [37, 38], this could represent an ideal time for interventions supporting a reduction in UPF consumption. However, in order to inform the development of such interventions, an understanding of the factors which influence UPF intake are needed. For example, systematic reviews of the determinants and correlates of a range of dietary behaviours such as eating rate [39], seafood consumption [40], sugar-sweetened beverage consumption [41], fruit and vegetable consumption [42] and dietary patterns [43], have been performed with the aim of understanding these behaviours and informing intervention design. We are, however, not aware of any previous studies which have systematically reviewed factors associated with UPF intake in children.

As dietary behaviour is complex, UPF intake is likely to be explained by a multitude of factors, from those proximal to individuals to those in the social and physical environments in which they live. The socio-ecological model [44] provides a framework for conceptualising the range of factors underlying complex health behaviours such as dietary choice. The socioecological model could be useful for conceptualising the factors contributing to UPF intake in children, and identifying where gaps in knowledge exist.

We therefore conducted a systematic review of quantitative evidence from observational studies on factors associated with UPF intake in children, with a narrative synthesis informed by the socio-ecological model. The review was limited to primary school aged children (5 to 12 years), as the factors affecting food intake may be different in preschoolers and adolescents. This study will be the first to systemically review factors associated with UPF in children. The findings of this review will inform the development of strategies to reduce UPF consumption and identify knowledge gaps in our understanding of factors influencing UPF intake in children.

1.3 Aim

To synthesise the current body of knowledge on the factors associated with UPF intake in primary school aged children.

1.4 Objectives

- To perform a systematic review of observational studies (prospective cohort and cross-sectional) to identify factors associated with UPF intake in children.
- To perform a narrative synthesis of factors associated with UPF intake by levels in the socio-ecological model.

1.5 Hypothesis

A range of factors operating at each level of socio-ecological model will be associated with UPF intake in children.

1.6 Thesis structure

Chapter 1 provides background to the thesis, justification of the study and the aims and objectives. **Chapter 2** provides a review of the literature. **Chapter 3** is presented as a manuscript and includes an introduction, description of methods, presentation of results, discussion of the results and the conclusions of the study. **Chapter 4** summarises the findings of the study, describes its strengths and limitations and presents final recommendations.

1.7 Research contributions

Sarah McArley	Wrote the review protocol, registered the study, performed the search, screened the studies, performed the data extraction and synthesis, performed the critical appraisal, wrote the thesis
Professor Carol Wham	Provided supervision throughout the research process, provided advice, edited the protocol and thesis

CHAPTER 2: LITERATURE REVIEW

2.1 Ultra processed foods

Nutrition research and dietary advice issued by governments and expert bodies, to-date, has focused on nutrients, foods and food groups. This approach has been reasonable in the past, as human diets have consisted solely or primarily of foods that have undergone minimal or low levels of processing [9]. However, advances in food processing techniques and the emergence of an industrialised global food system in the 1980's has led to a new category of highly processed food that has begun to dominate the global food supply and is now the primary source of food energy in many high-income countries [10]. The rise in highly processed food consumption has been concurrent with the rise in noncommunicable diseases such as type 2 diabetes, CVD and cancer. This has resulted in calls for the effect of food processing on health to be more closely examined [6, 7, 9].

Establishing links between processed foods and disease is complicated by the fact that most food available in the modern food system is processed to some degree. Food processing in and of itself does not result in foods of poor nutritional quality, and has unquestionably aided in human survival and evolution through our ability to reduce food spoilage, extend shelf life and increase palatability and nutrient bioavailability [45]. Humans have always processed food to some degree through techniques such as grinding, curing, cooking and fermenting. Thus, to examine the impacts of modern industrial food processing on health, a way of classifying foods according to their degree of processing was first required. This lead to the development of a classification system known as NOVA (a name, not an acronym), which seeks to identify food products that are *'ultra'* processed [7, 9]. That is, they consist mostly or entirely of substances extracted from foods, or constituents of food, with very little intact food present, and generally include a variety of colours, flavours, preservatives and other additives to enhance their sensory qualities and extend their shelf-life.

The NOVA classification system classifies all foods and drinks into one of four groups depending on their level of processing [7, 9]. Group one, '*unprocessed or minimally foods',* consists of staple foods such as fruits, vegetables, beans and legumes, grains, nuts and seeds, eggs, meat, fish, milk and plain yoghurt that are fresh or have undergone minimal processing such as being dried, ground, chilled, frozen, pasteurised or fermented. Group two, '*processed culinary ingredients*', consists of foods such as sugar, salt, vegetable oil or butter that have been extracted from unprocessed foods (or nature) through processes such as pressing and refining and are used in domestic kitchens to transform group one foods into culinary preparations. Group three, *'processed foods'*, are foods manufactured through the addition of group two foods to group one foods and includes freshly made breads, cheeses, canned vegetables or legumes in brine, canned fish and cured meat. NOVA group four, '*ultra-processed foods'*, includes foods that have undergone industrial processing including hydrolysis, hydrogenation and extruding, and generally contain industrial ingredients not used in domestic kitchens such as maltodextrin, modified starches, hydrogenated oils, flavouring agents and cosmetic additives such as artificial sweeteners, dyes and emulsifiers. Foods in this group include instant noodles, dehydrated soups, packaged bread, chicken nuggets, processed meat (preserved with ingredients other than salt, e.g. nitrites), soft drinks (diet and sugar-sweetened), muesli bars, preprepared pizza, and meal replacement shakes. UPF products tend to be ready-to-consume, hyper-palatable, and low-cost, making them convenient and attractive for consumers, and, as they are made from low-cost ingredients, highly profitable for producers.

Advocates of the NOVA system encourage consumers to reduce their intake of, or avoid entirely, UPF products. While this advice aligns broadly with conventional dietary advice, as UPF tend to be those foods high in sugar, fat and salt, there are exceptions. Foods such as fatty cuts of red meat and fruit juice, which consumers are usually advised to limit, are examples of unprocessed or minimally processed foods. Foods generally considered healthy, such as packaged wholemeal bread, many wholegrain breakfast cereals and fruit-flavoured yoghurt, are categorised as UPF. Indeed, recent studies have suggested the health risks associated with UPF may be due to certain products within the UPF category, while other UPF may be associated with improved health. For example, sugar-sweetened beverages, artificially-sweetened beverages and processed meats have been associated with greater CVD and mortality risk, and breakfast cereals and yoghurt/dairy desserts with lower risk [18, 26]. Furthermore, the effects of food processing on health need to be carefully considered in the context of the challenges in securing a food supply for a growing global population that is safe, affordable, nutritious and sustainable [46]. Nonetheless, the increasing global consumption of UPF and mounting evidence of health risks associated with exposure means this is currently an area of great interest.

2.2 Ultra-processed food consumption trends

UPF consumption is currently greatest in high-income countries, though rising in most areas globally. In an analysis of global trends in UPF purchasing, UPF sales per capita in 2019 ranged from 134 kg in Australasia and North America and 113 kg in Western Europe to 9 kg in South and South East Asia and 12 kg in Africa [15]. All regions, except for Western Europe, demonstrated strong growth in UPF sales between 2006 and 2019 and were projected to rise in 2024. Indeed, the nutrition transition underway in low to middle-income countries is characterised by a shift away from traditional diets based on minimally processed foods to diets with increasingly greater contributions of highly processed foods [47-49]. As more than two-thirds of the world's population lives in these countries, any negative health impacts of UPFs could have a profound effect on global health.

Within high-income countries, the contribution of UPF to dietary energy varies substantially: In nationally representative surveys in Canada, the USA, the UK and the Netherlands UPFs contributed ~50-55% of total energy intake, in Australia 39%, France 31%, and in Italy 18% [50]. Concerningly, UPF intakes tend to be higher in children and adolescents. For example, in the UK, the contribution of UPFs to energy intake was 66% in children and 67% in adolescents, compared with 54% in adults [51]. This pattern of higher consumption among younger age groups is observed in most countries [50]. There is also a relationship between socioeconomic status (SES) and UPF, with lower socioeconomic groups consuming greater amounts of UPF [52, 53]. However, in middle-income countries such as Mexico and Colombia, this relationship is generally reversed, with more affluent groups consuming higher amounts of UPF [54, 55].

Increasing UPF consumption is associated with declines in consumption of less processed foods. Among adults in the US, the contribution of UPF increased from 53.5 to 57.0% kcal from 2001 to 2018, while consumption of minimally processed foods decreased from 32.7% to 27.4% [56]. In surveys of Mexican households, the contribution of UPF increased from 10.5% to 23.1% kcal between 1984 and 2016, while the contribution of minimally processed foods fell from 69.8% to 61.4% kcal and culinary ingredients from 14.0% to 9.0% kcal [55].

2.3 Ultra-processed foods and health

The association between UPF intake and health outcomes has been the subject of many epidemiological studies in the past decade. Meta-analyses of these studies published within the last five years have identified associations between UPF intake and a range of adverse health outcomes among adults including hypertension [57], metabolic syndrome [58] CVD [18], type-2 diabetes [19, 20], Crohn's disease [59], chronic kidney disease [60] non-alcoholic fatty liver disease [61], cancer [21, 22], mental disorders such as depression and anxiety [23], cognitive decline [24] and mortality [25, 26]. A recent umbrella review of such meta-analyses examined the credibility of the evidence of associations between UPF and adverse health outcomes, including 45 unique analyses and 9,888,373 participants [62]. Convincing evidence was identified of a relationship between UPF and higher risks of CVD mortality, type-2 diabetes, prevalent anxiety outcomes and combined mental disorder outcome; and suggestive evidence of a relationship between UPF exposure and higher risks of all-cause mortality, heart-disease related mortality, type-2 diabetes, depressive outcomes, adverse sleep outcomes, wheezing and obesity.

In children, UPF exposure is associated with dental caries [27], altered lipid profiles [28, 29], low-grade inflammation [30], increased body fat [31] and poor sleep [32], setting children on a trajectory to developing chronic diseases in adulthood.

2.4 Mechanisms by which ultra-processed foods affect health

How UPFs negatively impact health is not fully understood, but there are a number of plausible mechanisms [63]. UPFs tend to have a lower nutritional quality than other foods, with higher sugar, fat, sodium and energy density and lower fibre, vitamins and minerals [64, 65], which could explain their adverse effects. A meta-analysis of studies that had examined UPF intake in relation to the nutritional profile of the diet found that UPF intake was positively correlated with intake of free sugars, total fats, and saturated fats and negatively correlated with intakes of fibre, protein, potassium, zinc, magnesium, and vitamins A, C, D, E, B12, and niacin [66]. UPF intakes are also inversely associated with intakes of phytochemicals such as flavonoids [67] and phytoestrogens [68]. However, many observational studies relating UPF intake to negative health outcomes have adjusted for aspects of the nutritional profiles of diets and the link between UPF and disease has been maintained, suggesting this only partly explains the relationship [63].

Although research in this area is currently limited, aspects related to food processing itself may underlie the negative effects of UPFs. Changes in the food matrix during processing may promote higher energy intakes through reduced satiety [69] or by increasing the bioavailability of ingested nutrients. UPFs may promote overeating through ‘hyper-palatable’ combinations of ingredients and food textures. Evidence that UPF promote overeating (that is not explained by their greater energy density or sugar and fat content), was provided in a cross-over trial of 20 adults provided with ultra-processed or unprocessed diets for two weeks matched in energy, energy density, macronutrients, sugar, sodium and fibre [70]. Participants were instructed to eat as much as they like and were found to consume 500 kcal more per day when receiving the ultra-processed diet compared with the unprocessed diet, and to gain 0.9kg while on the ultra-processed diet and lose -0.9kg on the unprocessed diet.

UPF may also adversely affect health through the presence of potentially harmful substances formed during processing, transferred to food from packaging, or purposefully added to food. Food processing techniques can result in the formation of toxic compounds such as furans, acrylamide, heterocyclic amines, advanced glycation end products and trans-fatty acids. Contaminants such as phthalates, bisphenols and microplastics may migrate from packaging in contact with the food into the food itself, especially with the long shelf life of UPFs. Indeed, in a nationally representative sample of people aged >6y in the US, UPF intake was positively correlated with urinary phthalates and bisphenol [71]. Many of these substances have been shown to be carcinogenic and/or to increase cardiovascular risk or insulin resistance [72-75]. UPFs also contain a range of approved additives such as artificial sweeteners, food colourants, emulsifiers and nanoparticles (i.e. titanium dioxide). Recent studies have linked additives used in the vast majority UPF products with adverse effects on health, which appear to be mediated through their effects on the intestinal microbiota [76]. The artificial sweetener erythritol was shown to increase cardiovascular event risk, which appeared to be mediated through its effects on platelet activity and thrombus formation [77].

2.5 Characteristics of ultra-processed foods

Taste, cost, convenience and nutrition are understood to be the main influences of peoples food choice and consumption [78, 79]. These factors can explain the desirability and popularity of UPFs, which are highly palatable, low-cost and convenient. Furthermore, despite being generally poorer in nutritional quality than less processed foods [80], most UPFs feature messaging about being nutritious or good for health. As UPF dominate the food advertising landscape [81-84], these desirable aspects of UPFs (among others, such as novelty) are communicated widely and consistently to populations. These messages may be particularly targeted at low-income groups [81, 85] and children [86, 87].

Food price is known to be a primary determinant of food consumption patterns [88] and is even more influential for low-income consumers [89]. The cost of UPF per 100 kcal is substantially lower than that for minimally processed foods [80, 90, 91], and diets with a greater caloric share from UPF are cheaper than those with a greater share from minimally processed food [90]. In middle-income countries like Brazil the cost of UPF still tends to be higher than that of minimally processed foods, but trends in pricing suggest UPF will be cheaper than minimally processed foods by 2026 [92]. Food pricing is complex and related to a range of factors, but those which explain the lower prices of UPFs may be their inclusion of low-cost ingredients and additives, longer shelf life, easy transportation and storage, mass production and economies of scale.

The taste of UPFs will be another factor driving their consumption. UPFs contain a range of ingredients and additives designed to enhance their sensory qualities and exploit our neurobiology and behavioural predisposition to consume palatable foods [93]. Sugar and fat are nutrients with high palatability. While foods containing both sugar and fat do not occur naturally, many processed foods contain high amounts of both, resulting in artificially high palatability [94]. The flavour umami, which describes 'savoury deliciousness', increases the palatability of foods and may stimulate appetite [95]. It is present in high-protein foods that have been cooked or aged, as well as certain vegetables like mushrooms and tomatoes. However, umami flavour can also be added to UPFs with no protein or vegetable content through the addition of monosodium glutamate (MSG) and other flavour enhancers [96]. Artificial sweeteners are added to UPF products with no-caloric value to enhance their palatability. The texture of a food also determines its palatability [97], and with modern food technology, UPF can be engineered to provide a texture appealing to their targeted population.

The convenience of food is a multifaceted concept and refers to not just minimising the time associated with meal planning, preparation and clean-up, but also the physical and mental effort associated with these tasks [98]. Although not all foods that are convenient are ultra-processed (e.g. prepared bagged salad), all UPFs are convenient due to their 'ready-to-consume' or 'ready-to-heat' nature. The convenience of UPFs may also be imbued by factors such as their widespread availability in stores [65], long-shelf life (i.e. they can be purchased in bulk at one time and stored, as opposed to fresh foods which must be purchased regularly), and easy transportation (i.e. they may be less easily damaged and lighter than many unprocessed foods).

Consumer's ability to consider nutrition when making food choices may be undermined by the sophisticated product packaging of UPFs featuring confusing messaging about the product's actual nutritional quality. A survey of UPF products in Australia found that 56% had nutrition claims and 25% had health claims on their packaging despite a high prevalence of added sugars and moderate health rating [87]. In Brazil, a survey of 2,200 products found that 60% featured promotional strategies, and that the most common promotional strategies were nutrition claims and health claims [99]. In a survey of UPF foods in Uruguay, 67% were shown to feature at least one health related cue, which included pictures of culinary ingredients, natural and minimally processed foods, references to 'naturalness', and claims related to critical nutrients [100]. The presence of health-related cues on the packaging was not related to the nutritional composition of the product.

2.6 Factors associated with ultra-processed food consumption

As reviewed thus far, the global consumption of UPFs is increasing, they have been associated with a range of adverse health outcomes, there are plausible mechanisms through which they may exert negative effects on health and UPFs have several characteristics which make them highly appealing to consumers. This has resulted in advice for individuals to reduce their intake of UPF, and for systematic change to support them to do so [33-36]. However, to understand how reductions in UPF intake may be achieved, an understanding of the factors which contribute to an individual's intake of UPF is needed. For example, advising people to decrease UPF intake will not be successful if there are financial and physical barriers to accessing unprocessed foods; nor if they lack the cooking skills or time to prepare meals from scratch.

Childhood represents an ideal time for interventions aimed at reducing UPF consumption. Childhood is the time when dietary preferences develop [101] and significant growth and development is occurring; yet children currently have the highest intakes of UPF [50] and detrimental health effects are already occurring [29, 30]. Moreover, dietary behaviours in childhood have been shown to track into adulthood and predict risk of diseases [102, 103]. Understanding the factors associated with UPF intake in children will inform the development of evidence-based interventions. The following section will review the socioecological model, which provides a broad framework in which to conceptualise the factors contributing to health behaviours, such as UPF intake.

2.7 The socioecological model

Human health behaviour is highly complex and related to a multitude of factors interacting with one another. The socioecological model is based on the recognition that individuals and their behaviour cannot be separated from the larger social units and environments in which they live. The model builds on a theory proposed by psychologist Urie Bronfenbrenner in the late 1970's, which described human psychological development as a series of interactions between the growing human and its environment [104]. In this theory, child development is embedded in multiple spheres of influence that range from those proximal to the child, such as their family, to those with more distal influence, such as public policy. This theory was later redefined by McLeroy et al in the 1980's as a framework for health promotion campaigns [105]. Critics of health promotion at the time argued that lifestyle interventions had a victim-blaming ideology, ignoring the importance of environmental and social influences on health and disease. McLeroy *et al* [105] proposed a variation on Bronfenbrenner's model consisting of five levels that could be targeted in health promotion: i) intrapersonal factors (characteristics of the individual such as knowledge and behaviour); ii) interpersonal factors (social networks and support systems, including the family, work and friendship groups); iii) institutional factors (social institutions with organisational characteristics and rules and regulations for operation, such as work places and schools); iv) community factors (the face-to-face groups in which the individual interacts, the relationships between groups and organisations in a local area or a population defined by political and geographical boundaries); and v) public policy (local and national laws and regulations).

The Centres for Disease Control and Prevention have adapted a socioecological model to inform their health promotion campaigns [106]. In this model the first level represents the individual, and includes biological factors, age and education; the second level represents relationships, and includes family, partners and friends; the third level represents community, and explores the settings in which people have social relationships such as schools and workplaces; and the fourth level, societal factors that influence health such as cultural and social norms, and policies related to health, the education and the economy.

The socioecological model emphasises the interaction between, and interdependence of, factors within and across all levels in explaining health behaviours. It has been used to conceptualise the factors contributing to a wide range of health behaviours including immunisation uptake [107, 108], alcohol use [109] and physical activity [110, 111]. This model has also been applied to dietary behaviours such as intake of sugar-sweetened beverages [112, 113] and fruit and vegetables [114]. It has been suggested as being useful for understanding the multiple factors that may contribute to UPF in children [115]. The following section summarises the factors known or thought to be related to dietary behaviour in children across levels of the socioecological model. In order to simplify the model for use in children, the institutional and community levels have been combined (as community) in this thesis. Reference will be made as to how factors within each level (individual, interpersonal, community and policy) may influence UPF intake.

2.7.1 Individual factors

Children's individual taste and food preferences are likely to influence their dietary behaviours. Variations in genes related to sensitivity to bitter tastes were associated with a greater preference for sweetened carbonated beverages (a UPF) and lower preference for milk [116]. Taste-preferences and food intake may also be programmed by the intra-uterine environment. Low birth weight has been associated with a greater acceptance of salty and sweet tastes [117, 118]; and high birthweight with higher intake of sucrose in children [119]. Thus, low and high birthweights, which can both reflect exposure to an adverse intrauterine environment, may drive consumption of sugary and salty foods such as UPFs. The age at which a child is born may also influence their future dietary preferences. Being born preterm is associated with increased pickiness in childhood [120], possibility due to early issues with feeding and delayed oral motor development.

Sex may influence UPF intake. In a survey of British schoolchildren girls reported liking fruit and vegetables more than boys; while boys reported liking fatty and sugary foods and processed meats more than girls [121]. Another study in British children found that girls had higher intakes of fruit and vegetables than boys, while boys had higher intakes of breakfast cereals and sugary foods.[122]. Sex differences in food intake in childhood have been reported in a number of other studies, which have tended to report higher intakes of "healthy" foods among females, and "unhealthy foods" among males [123]. These patterns would suggest that UPF intake may be higher in boys.

Children's diets have been shown to change as they get older and move into the period of adolescence. Fruit and milk intake tend to decrease, while soft drink consumption substantially increases [124-126]. These changes may be due to increased autonomy over food choices as children get older [127]. As children have an elevated preference for sweet and salty flavours [128] and as marketing for UPFs is targeted at children [86, 87], this greater autonomy could result in increased UPF consumption in older children.

Factors such as how much time children sleep and how physically active they are have been associated with the healthfulness of their diets. In a meta-analysis of 10 studies, shorter sleep was associated with unhealthy eating habits and increased snack consumption and soda intake [129]. Sleep deprived individuals have been shown to have higher desire for snacks with high sugar and saturated fat [130], suggesting insufficient sleep could promote UPF consumption. More physically active children have been found to have healthier dietary habits, such as higher intakes of fruit and vegetables, than less physically active children [131, 132]; while sedentary activities were associated with intakes of potato chips and sweetened drinks in a study of French 12-year olds [133]. Whether this reflects greater health consciousness among physical active children (or their parents) or that physical activity itself influences the types of foods children choose to consume is unclear.

2.7.2 Interpersonal factors

Parents (or caregivers) are central to shaping children's dietary behaviours because children, for the most part, do not interact autonomously with the food environment. Interpersonal factors which may influence a child's UPF intake are described here within the domains of parent-child interactions; parent's own health, behaviour and psychosocial factors; and family demographics.

2.7.2.1 Parent-child interactions

The influence of parents over dietary behaviour in childhood starts at birth. Breastfeeding has been positively associated with children's future intakes of fruit, vegetables and water, and inversely associated with their intake of sugar-sweetened beverages [134-136]. This association may be at least in part related to reduced pickiness in breastfed children [137] due to exposure to different flavours in breast milk [136, 137]. The timing of solids introduction, and the type of food they are introduced to, may also influence later dietary behaviour. For example, children who were not introduced to lumpy solids until after 9 months of age had lower intakes of fruit and vegetables, and more feeding problems, when they were 7 years old [138]. Introducing children to vegetables as a first food, and providing them regularly, increases vegetable acceptance [139], while providing children with complementary foods high in sugar may predispose them to a higher sugar intake [140]. Thus, a child's early feeding experiences may shape their future preference for UPFs. For example, picky eaters may favour hyperpalatable UPFs over unprocessed foods, such as vegetables, with more complex and unpredictable flavour and texture profiles [141, 142].

As children get older and more independent, one important way in which parents shape their dietary behaviour is through the foods they make available and accessible to children at home [143], the environment in which children spend the most amount of time and consume the greatest amount of energy [144]. A greater availability at home of both unhealthy foods such as sugar-sweetened beverages, and heathy foods such as fruit and vegetables, is associated with greater consumption in children [143]. The accessibility of foods at home is also important, as unprocessed foods are generally less accessible to children (e.g. fruit and vegetables may require washing, peeling and cutting before they can be eaten) than UPFs such as biscuits, chips and single-serve yoghurt products, which are highly accessible.

The family meal is an important setting in which parents influence dietary behaviour in children. The frequency of family meals positively impacts nutritional intake and eating behaviour in children [145, 146]. Family meals may act as a key time at which children are exposed to unprocessed foods such as vegetables, and repeated exposure is one the most effective strategies for increasing vegetable acceptance in children [147]. However, in a recent meta-analysis from 43 countries in Europe and North America, only half of families reported having a family meal everyday [148], suggesting many children are missing out on these exposures. Furthermore, barriers parents describe to cooking family meals are the cost of fresh ingredients, time, busy family life and limited facilities to cook [149-151], all of which could promote the use of UPFs in place of made-from-scratch meals due to their convenience and low-cost.

Other aspects of meals are associated with effects on children's diet. Consuming breakfast is associated with better nutritional quality in children [152-154], while snacking has been found to have both positive and negative effects on nutritional quality [155, 156]. More regular meal timing is associated with better diet quality [157]. Eating meals out of the home was associated with less healthy dietary choices in children compared with eating at home or school [158]. Thus, a meal pattern characterised by breakfast skipping, snacking, irregular meal timing and eating out of the home could promote a diet higher in UPF.

Parents have considerable influence over young children's screen time through the controls they put in place regarding use [159]. There is fairly consistent evidence of a relationship between screen time and unhealthy dietary patterns in children. In an analysis of 10,453 children aged 6 to 9 years in Europe, 1-hour of additional screen time per day was associated with higher intake of a range of foods, most of which would be classified as a UPF, including 'soft drinks containing sugar', 'diet soft drinks', 'flavoured milks', 'potato chips, corn chips, popcorn or peanuts' and 'biscuits, cakes, doughnuts or pies', and with a lower intake of vegetables and fruit [160]. This relationship also exists for screen use during meals. In a systematic review of 13 studies, screen use during meals was associated with higher intakes of sweetened beverages, fried foods and sweets, and a lower intake of fruits and vegetables [161]. Screen time could promote higher intakes of UPFs through increased exposure to food advertising, as UPFs are the most heavily advertised type of food on TV [83]. Energy intake is also higher while watching a screen [162], as screens may act as a distraction from hunger and fullness cues. This is particularly concerning if the food being consumed is a UPF, as these already promote overconsumption [70].

2.7.2.2 *Parent health, behaviour and psychosocial factors*

Parents own health knowledge and health behaviours are associated with children's dietary patterns. Higher parent health and nutrition literacy is associated with improved nutrition in children [163], while having a parent who smokes is associated with lower diet quality in children [164]. Mothers with better nutrition knowledge feed their children less sugar-sweetened beverages, and more fruits, vegetables and legumes [165]. However, UPF products may undermine health and nutrition literacy by featuring confusing health and nutrition claims that are not related to their actual nutritional quality [87, 100]. Thus, reducing UPF intake may require even greater levels of education and nutrition literacy than that required to reduce foods more generally recognised as being less healthy.

Whether parents own dietary habits influence those of their children is unclear. Parent diet quality and energy intake have been correlated with their children's diet quality and energy intake [166]. This resemblance may be explained by parent modelling of dietary behaviours to children. Positive parent modelling is associated with lower intakes of sugar-sweetened beverages in children [41], and children whose parents role model fruit and vegetable consumption are more likely to meet the meet daily fruit and vegetable recommendations [167]. However, a recent meta-analysis of 45 studies on familial resemblance of aspects of diet such as nutrients and foods (e.g. fruits and vegetables, and confectionery) found only weak to moderate correlations between parents and children.

2.7.2.3 *Family demographics*

Aspects of family structure appear to influence children's diet. For example, single-parent households report more difficulty in establishing family meals [168], while children from two parents households are more likely to consume breakfast [144]. As these differences presumably relate at least in part to less time available for meal preparation, the convenience of UPFs could promote their consumption in single-parent households.

Parents SES is well recognised to be an important influence on diet in children. SES may impact a family's food intake through their ability purchase healthy food [169], as healthier food tends to cost more than energy-dense, nutrient-poor foods. Low SES families tend to have a lower frequency of family meals than high SES families [148], which, in addition to the high cost of fresh ingredients, may be due to factors such as less time to prepare meals and a lack of suitable facilities for food storage and cooking [170, 171]. Low SES families are also more likely to select foods that are nonperishable and that children are likely to eat, in order to reduce waste [172]. These factors could result in low SES groups relying on UPFs, due to their low-cost, convenience, long-shelf life, and high palatability to children.

As mentioned previously, the relationship between SES and diet varies by country and will depend on the stage of the nutrition transition that country is in. In Mexico, for example, lower SES was associated with higher diet quality, due largely to higher consumption of wholegrain cereals and legumes in low- versus high-SES groups [173]. This reflected adherence to a more "traditional" dietary pattern among low-SES groups, who may lack the resources to purchase UPFs, which in middle-income countries, tend to be more expensive than unprocessed food [92].

Within countries, there are differences among ethnicities in dietary intake. In a survey of 15,000 children in the US, compared with white children, Asian children were more likely to have a low consumption of vegetables and fruit, while Latino children were more likely to have a high intake of fast food and fruit juice but a lower intakes of sweets [174]. Ethnic differences in dietary intake may reflect differences in traditional diets, SES, food availability and differences in the home food environment [175, 176].

2.7.3 Community factors

After home, schools are the environment where children spend the greatest amount of time [177]. Food at school is made available through school meal programmes, cafeterias, vending machines, tuck shops, fundraising events and food bought from home. The presence of free or subsidised national school meal programmes varies among countries and these programmes are generally means-tested and offered only to low-income students, although a small number of countries offer universal school meals. School meal programmes have been associated with higher diet quality compared with when food is brought from home [178-180]. Indeed, food brought from home tends to consist of high proportions of discretionary items high in energy, sugar, fat and salt [181, 182], with ultra-processed style foods the most frequent items in children lunch-boxes [183]. The availability of foods through canteens and vending machines also affects children's dietary behaviour at school, with greater availability and lower-costs of both unhealthy and healthy foods associated with greater purchasing of these items [184, 185].

Recognising the importance of the school food environment in influencing children's diet, many schools now have food policies in place, which aim to provide guidance on the nutritional quality of food available at schools. A meta-analysis of such policies [186] found they had positive effects on targeted aspects of children dietary behaviours, whether they were related to the provision of healthy food and drinks, nutritional standards for competitive food and drinks, or nutritional standards for schools. As UPF may be engineered to meet nutritional guidelines (e.g. by replacing sugar with artificial sweeteners, or adding certain micronutrients) while still retaining potentially undesirable aspects [187], school policies that directly address food processing may be needed in order to reduce UPFs. Brazil has targeted this issue in their school meal program that serves >80% of school aged children [188]. Regulations for procurement specify that >75% of school meal funds must be spent on unprocessed or minimally processed foods, up to 20% on processed foods and 5% on processed culinary ingredients.

The retail environments surrounding homes and schools also influence dietary behaviour. Proximity to convenience stores and fast-food outlet can increase children's intake of less healthy foods and/or decrease their intake of foods such as fruit and vegetables [189-191]. Rurality has been associated with increased difficulty in accessing fresh food [192, 193], which could promote intakes of shelf-stable foods such as UPFs. Neighbourhood food availability is of particular relevance for families in low-income areas [194], which have less healthy food retailers, promoting the purchasing of less healthy foods or necessitating residents to travel longer distances to access healthy food [195, 196]. Residents of these neighbourhoods are less likely to have access to a car and to therefore rely on walking or public transport [197, 198], which may reduce their ability to transport perishable foods like fruit and vegetables (which must be purchased frequently) and heavier items like grains and legumes. For those with young children, these impediments are compounded due to the difficulties and costs associated with travelling with children [197]. The neighbourhood retail environment for low-income families may therefore encourage the purchasing of shelf-stable and easily transportable food products such as UPFs.

2.7.4 Policy factors

Healthy food policies are those implemented by governments or organisations in order to support populations to purchase and consume healthier food and drinks [199]. Healthy food policies include measures such as front of pack labelling/warnings on food products, restricting unhealthy food advertising to children, and the provision of healthy food in public facilities. Policies that improve diets may relate to factors across the spectrum of the socioecological model and include policies not specifically related to food. For example, consuming a diet based on unprocessed foods requires access to places for storing and cooking food [200], and government policies affecting access to affordable and good quality housing could thereby influence diets, particularly for low-income groups. Children's dietary behaviour is also likely to be directly affected by policies around unhealthy food advertising targeted at children. Children are uniquely sensitive to food and drink advertising, with unhealthy food advertising increasing food intake and preference for the advertised foods [201]. As most food advertising is for UPF [81, 83], exposure of children to unregulated food advertising is likely to promote UPF intake. Policies to restrict unhealthy food advertising to children have been shown to be effective in reducing children's exposure to food advertising and may result in reduced purchasing of these foods [113, 202].

2.8 Intervention studies

Intervention studies targeting UPF intake in children also inform our understanding of which factors influence UPF intake. To our knowledge, only four intervention studies targeting UPF intake in children have been conducted. A school-based trial in the US examined the effect a gardening, cooking and nutrition education intervention on UPF intake in predominantly low-income Hispanic children [203], finding a decrease in UPF intake among children at study completion. A study in Brazil of 96 children with obesity provided children and their guardians with education on how to reduce UPF intake, with half the sample also receiving tailored food plans [204]. This study found that UPF decreased at the 2 month time-point in all children and then returned to baseline at 6 months. Another study in Brazil evaluated the effect of an educational intervention on breastfeeding and complementary feeding for teenage mothers on children's UPF intake at 4 to 7 years of age [205]. Children in the intervention group had a 35% lower risk of having a high intake of UPF compared to children whose mothers did not receive the intervention. Finally, in a cross-over study of 105 children in New Zealand [206], 8 to 12 year old children were exposed to sleep extension or sleep restriction conditions for 1 week. UPF intake was found to be higher during the sleep restriction period compared with the sleep extension period by 523 kJ, or 4.0% of total energy intake.

The findings of these studies suggest that breastfeeding and/or complementary feeding, sleep duration, and possibly nutrition knowledge and cooking skills among children or their parents may influence UPF intake children, although the effect of improved nutrition knowledge alone was less clear.

2.9 Summary

In summary, a wide range of factors operating across all levels of the socioecological model have the potential to influence UPF intake in children. We are not aware of any previous studies that have reviewed the body of knowledge of factors associated with UPF intake in children. One systematic review focused only on sociodemographic determinants of UPF intake using nationally representative samples [50] and included 55 papers spanning 32 countries. Younger age, urbanisation, and being unmarried, single, separated or divorced were associated with higher UPF intakes; education, income and SES had varying associations depending on the country; and household status and gender were generally not associated with UPF intake. A systematic review of variables associated with UPF intake, in Brazilian adolescents only, included 11 reports from nine original studies [207]. UPF intake was associated with sedentary time (particularly screen time), studying at a private school, having a higher BMI and being female.

In order to inform future interventions aimed at reducing UPF intake, a comprehensive understanding which factors are associated with UPF intake in children is needed. We therefore conducted a systematic review of factors associated with UPF intake in children, with a narrative synthesis informed by the socioecological model.

CHAPTER 3: FACTORS ASSOCIATED WITH ULTRA-PROCESSED FOOD INTAKE IN CHILDREN: A SYSTEMATIC REVIEW OF OBSERVATIONAL STUDIES

3.1 Introduction

Poor diet is a leading contributor to the global burden of disease, responsible for 22% of deaths and 15% of disability-adjusted life years lost among adults in 2017 [1]. To-date, research has focused on identifying nutrients, foods and dietary patterns associated with the development of diet-related disease [1-5]. More recently, the effect of food processing on human health has come under scrutiny [6, 7]. This is in light of a global shift over the preceding decades from diets consisting largely of unprocessed and minimally processed foods to those containing a substantial proportion of ultra-processed foods (UPF), as a result of an increasingly industrialised global food system [10, 15].

The classification system most widely used to define UPF is NOVA, which categorises foods into one of four groups depending on their degree of processing [9]. Group one refers to '*unprocessed or minimally processed foods*', such as fruits, vegetables, legumes, grains meat and dairy; group two to '*processed culinary ingredients'* such as sugar, salt, vegetable oil and butter; and group three '*processed foods*' such freshly made breads, cheeses, canned fruit and vegetables and cured meat. NOVA group 4, '*UPF*', includes foods that have undergone industrial processing techniques such as extrusion and hydrolysis, and that contain industrial ingredients not used in domestic kitchens such as maltodextrin, modified starches, flavouring agents and cosmetic additives such as artificial sweeteners, dyes and emulsifiers. Foods in this group include instant noodles, dehydrated soups, packaged bread, sweetened yoghurts, processed meats and both sugar and artificially sweetened beverages. UPF products tend to be ready-to-consume, hyper-palatable, and low-cost, making them convenient and attractive for consumers, and, as they are made from low-cost ingredients, highly profitable for producers.

UPFs now contribute to more than 50% of total energy intakes in high-income countries [11, 12] and up to 30% in middle-income countries [13, 14]. The latter figure is projected to rise in the coming years [15]. UPF consumption tends to be much higher in younger, compared with older, age groups [16, 17]. Concerningly, recent meta-analyses have identified associations between UPF intake and adverse health outcomes in adults including cardiovascular disease [18], type 2 diabetes, [19, 20], cancer [21, 22], mental disorders such as anxiety and depression [208] and mortality [25, 26]. In children, UPF intake has been associated with adiposity [209], altered lipid profiles [210, 211] low-grade inflammation [30] and poor sleep [32].

The rising consumption of UPF globally and evidence of harm has led to calls for interventions to reduce UPF consumption [33, 34]. Childhood represents an ideal time for interventions targeting UPF intake, as evidence suggests that this is the time during which dietary behaviours develop [101]. However, in order to inform the development of effective interventions, an understanding of the factors which influence UPF intake in children is needed. As dietary behaviour is complex, UPF intake will be explained by a wide range of factors, from those proximal to the individual to those in the social and physical environments in which they live. The socio-ecological model [44] provides a framework for conceptualising the range of factors contributing to complex health behaviours such as dietary choice, and will be useful for understanding UPF intake in children.

To inform the design of interventions and identify gaps in knowledge of factors influencing UPF intake, we carried out a systematic review of observational studies on factors associated with UPF intake in children and performed a narrative synthesis across levels of the socio-ecological model.

3.2 Methods

A systematic review was conducted to identify factors associated with UPF intake in children aged 5 to 12 years. The protocol for this review was registered on PROSPERO (International Prospective Register for Systematic Reviews, Registration Number: CRD42024518504). Procedures described in the Joanna Briggs Institute Manual for Evidence Synthesis for systematic reviews of aetiology and risk [212], with the exception that only person (SM) performed the screening, data extraction and critical appraisal of studies.

3.2.1 Search strategy

A search of three databases (Medline, Scopus and CINAHL) was performed in February 2024. This range of databases was selected as they index journals in scientific, medical and social sciences fields (Scopus), the biomedicine field (Medline), and the nursing and allied health fields (CINAHL). To identify all studies on UPF in children, the search was designed to be as broad as possible. The following keywords were used: “ultra-processed”, “ultraprocessed” or “ultra processed” and “children” or “adolescents”. Manual searches of reference lists of literature reviews were also carried out to identify relevant studies. The search was limited to studies in humans and reports in English. As the NOVA classification system was first proposed in 2009, the search was limited to studies published in 2009 or later. Reports identified in the search were downloaded to Endnote X9 and duplicates removed. Reports were manually screened by title and abstract, and then by full text by one author (SM). Criteria for inclusion in the review were: most participants aged 5 to 12 years; the study had a prospective cohort or cross-sectional design; UPF was defined using the NOVA classification system; the study was available in English and the association between one or more potential factors and children's UPF intake had been statistically analysed. The exclusion criteria were intervention, qualitative, laboratory or animal studies; most participants aged <5 years or >12 years; and where a clinical population had been studied (i.e. all participants had coeliac disease or diabetes). The 'factors' considered in this review were any demographic, physiological, psychological, behavioural, social or environmental factor for which an association with UPF intake in children was analysed. Associations between UPF intake and children's weight or BMI, other aspects of their diet (e.g. total energy intake or sugar intake), and health outcomes were not considered in this review.

A flow diagram adapted from the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines is presented in Figure 1.

3.2.2 Data extraction

The following information was extracted from each eligible study: author and year published, country, study design, number of participants, information about the study population including sex and age, sampling methods, method of dietary assessment, average UPF intake for the total sample, all factors that were analysed in relation to UPF intake, and the direction and significance of the association between each factor and UPF intake. Where unadjusted and adjusted associations were reported, the most adjusted association was extracted. Multiple reports from the same study were referenced separately but considered as one study. Where two or more reports from the same study reported the same factor (e.g. age), the association with UPF intake from the report with the largest number of participants was extracted. Two reports were excluded from the review as they only reported factors that had been described in other reports (with larger samples) from the same study (Figure 1).

3.2.3 Data synthesis

The high degree of heterogeneity between studies in how the factors (i.e. the exposures) were examined and reported, how UPF intake (i.e. the outcome) was reported (tertiles and quintiles, grams/day, % total energy intake and number of UPF foods or UPF subgroups) and how analyses were performed meant meta-analysis would not have been possible. A narrative synthesis of the data (including tables) was therefore planned. To improve clarity, conceptually similar factors were combined. For example, the factor 'parent smoking' reflected maternal smoking, parent smoking and child tobacco exposure; while 'SES' reflected parent or maternal education, occupation, household income and SES. Factors were grouped by levels of the socioecological model. The number of studies that had examined each factor, and the association they identified, was described in the text and summarised in a table. The socioecological model as proposed by the McLeroy et al [105] was used, with the exception that the institutional and community levels were combined as ‘community’. To improve clarity within the interpersonal level, the subheadings “parent-child interactions”, “parent health, behaviour and psychosocial factors” and “family demographics” were included, as used in previous studies in children [41, 213].

3.2.4 Risk of bias

Critical appraisal of studies was performed using the Joanna Briggs Institute checklists for analytical cross-sectional studies and cohort studies [214]. Two studies included prospective and cross-sectional analyses and were assessed using both critical appraisal tools. The critical appraisal involved assessing whether the criteria for inclusion in the sample were clearly defined; whether the study subjects and the setting were described in detail; whether the exposure (i.e. the factor assessed) was measured in a valid and reliable way; whether objective, standard criteria used for measurement of UPF (i.e. the NOVA definition); whether confounding factors were identified; whether strategies to deal with confounding factors were stated; whether the outcome (i.e. UPF intake) was measured in a valid and reliable way; and whether appropriate statistical analysis was used. The checklist for cohort studies also assessed whether groups were similar and recruited from the same population, exposures were measured between groups, groups were free of the outcome at the time of exposure, whether loss to follow-up occurred and whether reasons for loss to follow-up were determined. A total score of 8 was possible for the cross-sectional studies. A score of 7- 8 was considered high quality, 5-6 medium quality and <5 low quality. A total score of 11 was possible for the prospective cohort studies. A score of 9 – 11 was considered high quality, 7-8 medium quality and <6 low quality. To provide a more comprehensive assessment of bias, whether each study used sampling methods designed to be representative of the general population was also assessed. To do so, we considered whether efforts were made to reflect the general population in terms of factors such as ethnicity, socioeconomic status and geographic location, or whether no attempt to represent the national population was made (e.g. the sample was drawn from private schools only).

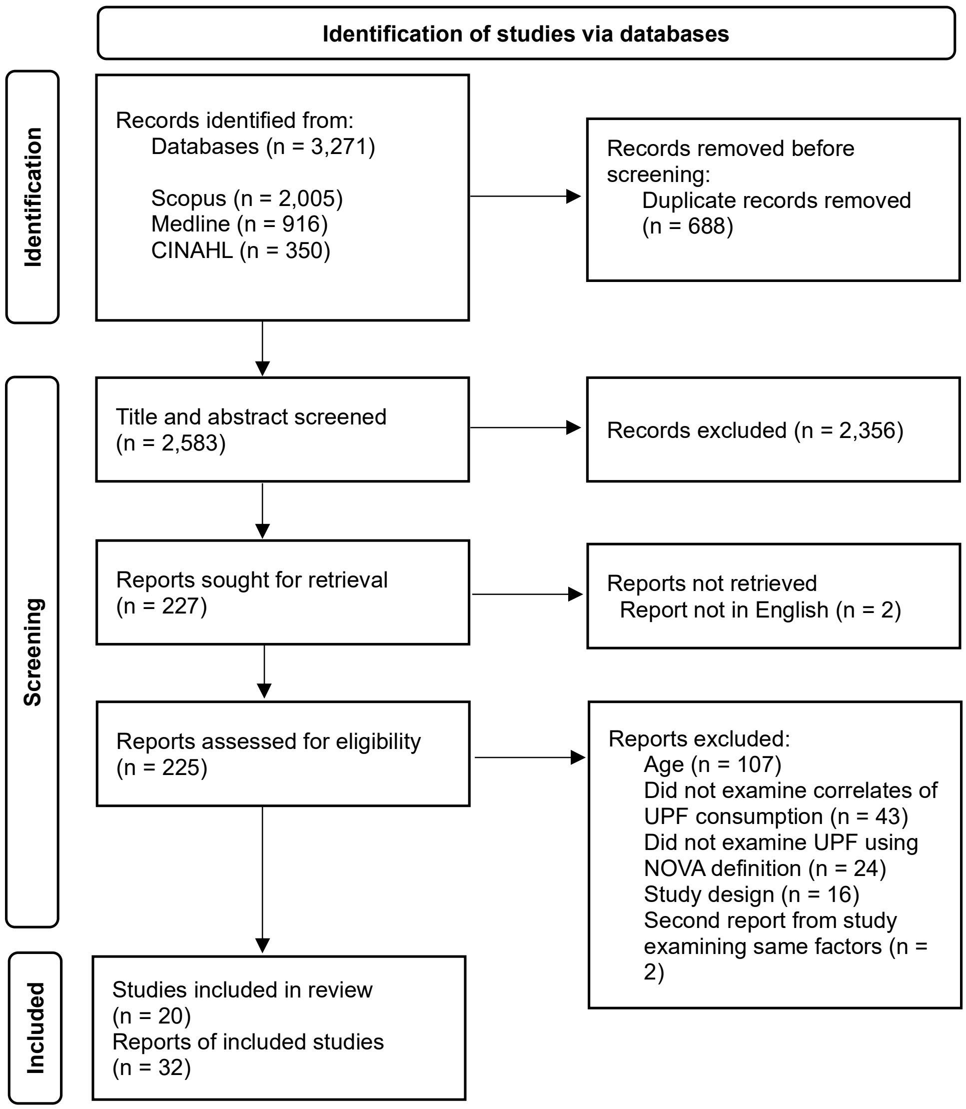

Figure 1. Flow diagram of search. PRISMA flow diagram illustrating the number of reports identified, screened and included in the systematic review of factors associated with UPF intake in children

3.3 Results

3.3.1 Study characteristics

Thirty-two reports from 20 studies were identified. The characteristics of the studies are presented in Table 1. Two studies were prospective cohort studies which included cross-sectional analyses [215, 216]. The remainder of studies (n = 18) were cross-sectional. The reports were published between 2018 and 2023. Ten studies were carried out in Brazil, three in the United Kingdom, and one in each of Iran, Chile, Mexico, Spain, Portugal and Malaysia. The range of ages was within 4 to 13 years in 19 studies, with one study having an age range of 7 to 16 years.

3.3.2 Risk of bias

The quality assessment is presented in Appendix A. For the appraisal of cross-sectional studies, twelve studies received a score of 8/8 (high quality), six studies received a score of 6/8, and two studies received a score of 5/8 (medium quality). Eight studies lost two points for not identifying confounders and not stating strategies to deal with confounders. For the appraisal of cohort studies, one study received a score of 8/11 and one a score of 7/11 (medium quality). Both studies lost three points for not identifying confounders, not describing strategies to deal with confounding, and not describing strategies to deal with incomplete follow-up. One study lost another point for not examining reasons for loss to follow-up. Five studies drew their samples of children from nationally representative samples [51, 217-220]. Eight studies used sampling methods that attempted to reflect the region in which they were performed [215, 216, 221-226]. Six studies had non-representative samples (i.e. they were performed in only public or private schools, in areas with a specific income, or in local schools or a single hospital) [227-233].

Table 1. Characteristics of studies included in systematic review of factors associated with UPF intake in children.

Study #	Author name and year	Country	Study Design / name	N	Population and duration f/u (if relevant)	Age	% female	Diet assessment method	UPF intake (% of total daily energy intake)
C1	Asgari 2022 [221]	Iran	Cross-sectional	788	Children from healthcare centres across Tehran identified through random cluster sampling. Six-year-old children within each centre were randomly selected.	6 y	-	168-item semi-quantitative FFQ	57.3%
P2, C2*	Bielemann 2018 [215]	Brazil	Prospective cohort study, includes cross-sectional analyses *Pelotas Birth Cohort Study*	3427	Children and their mothers in a population-based birth cohort study, into which all children born in 2004 in Pelotas were enrolled at birth. Included reports are based on the 6 and 11y follow-ups.	6y	48.3%	54-item FFQ	40.3%
	dos Santos Costa 2021 [234]			3514		11 y	48.3%	88 item semi-quantitative FFQ	33.6%
	Azeredo 2020 [235]			2190		6y and 11y	50.6%	54-item FFQ at 6 y 88-item FFQ at 11 y	6 y: 42.3% 11 y: 33.7%
C3	Bento 2018 [227]	Brazil	Cross-sectional	1357	Children from public elementary schools. Schools were randomly selected from all public schools within Belo Horizonte, Brazil. All fourth-year children within each school were enrolled into the study.	8 – 12 y	50.7%	Two non-consecutive 24-h recalls	Median: 157.2g / 1000 kcal
	Horta 2019 [236]			1357			49.0%		251.1 - 305.7 g/d across subgroups
	Fraga 2020 [237]			797			50.7%		Not reported
	de Lacerda 2020 [238]			322			53.4%		25.2%
	do Carmo 2021 [239]			322			53.4%		25.2%
P4, C4*	Chang 2021 [216]	United Kingdom	Prospective cohort, includes cross-sectional analyses *Avon Longitudinal*	9025	Children from a population-based birth cohort study that enrolled pregnant women in Avon, England. Included reports describe the population at 7, 10 or 13y of age.	7, 10 and 13 y	49.7%	3-day food diary over 2 weekdays and 1 weekend day	44.7% total food intake
	Handakas 2022 [240]			4528		7 y	47.9%		61.1 ± 11.6% total energy intake

			Study of Parents and Children						
C5	Correa 2018 [222]	Brazil	Cross-sectional	1307	Children selected by stratified random cluster sampling from public and private schools in Santa Catrina, Brazil.	7-10 y	52.3%	Single day QUADA-3 dietary recall	98.4% had eaten ≥ 1 UPF the previous day.
C6	de Albuquerque 2023 [223]	Brazil	Cross-sectional *Schoolchildren Health Assessment Survey*	367	Children selected by stratified random sampling from urban schools in Vicosa, Minas Gerais, Brazil.	8 - 9 y	51.8%	Three 24-hour recalls on non-consecutive days	45.2%
C7	de Almeida 2023 [228]	Brazil	Cross-sectional of intervention study	120	Children from two schools in a low-income area in Sao Paulo, Brazil. Children were overweight and participating in an intervention study to lose weight.	9 - 11 y	53.4%	Semi-quantitative FFQ	Not reported
C8	de Almeida Fonseca 2019 [229] de Almeida Fonseca Viola 2023 [241]	Brazil	Cross-sectional	403	Children born in a single maternity hospital in Vicosa, Brazil and monitored by a lactation support program. All children with compatible ages were invited to participate.	4 - 7 y	44.9%	Three non-consecutive food records	38 ± 14%
C9	de Melo Fonseca 2023 [230]	Brazil	Cross-sectional	326	Children selected via random cluster sampling from four public schools in Barbacena, Brazil.	7 - 9 y	51.8%	Previous Day Food Questionnaire (QUADA) version 3	70% of children consumed ≥ 1 UPF daily
C10	Ferreira 2019 [224]	Brazil	Cross-sectional	206	Children selected by stratified cluster sampling from three private and six public schools in Uberlandia, Brazil.	10 - 12 y	53.0%	Single 24-hour recall	Median: 31%

C11	Fretes 2023 [233]	Chile	Cross-sectional *Food Environment Chilean Cohort (FECHIC)*	428	Children from 55 public schools in low- and middle-income neighbourhoods in Santiago, Chile.	8 - 10y	53.3%	NOVA screener - a self-report questionnaire that asks whether each of 20 subgroups of UPF have been consumed in the past 24 h	4.3 ± 1.9 UPF subgroups per day
C12	Garcia-Blanco 2023 [225]	Spain	Cross-sectional *The SENDO project*	806	Children from an ongoing prospective cohort study in Navarra, Spain. Children are recruited at the age of 4-5 y through their primary health centres or early childhood centre.	4 - 5 y	49.0%	149-item semi-quantitative FFQ	37.6 ± 9.59%
	Oliver Olid 2023 [242]			806			-		Not reported
	Moreno-Galarraga 2021 [243]			513			48.2%		39.9%
C13	Hou 2023 [226]	China	Retrospective / cross-sectional *Multicity Cohort Study*	1370	Children randomly selected from nine primary and secondary schools from regionally representative cities in eastern China.	7 - 16 y	46.9%	142-item FFQ completed by children and parents	27.7 ± 12.3%
C14	Magalhaes 2021 [217]	Portugal	Cross-sectional *National Food, Nutrition and Physical Activity Survey*	521	A subgroup of children from a nationally representative sample of the population in Portugal.	3 - 9 y	51.2% for total cohort	Two non-consecutive food diaries	Median 414 (273 - 595) g/d
C15	Martins 2020 [231]	Brazil	Cross-sectional analysis of intervention study at baseline	657	Children identified by random cluster sampling from a chain of private schools in Sao Paulo, Brazil and participating in a trial teaching cooking skills.	6 – 9 y	-	Two non-consecutive food recalls of dinner	31.3 (29.5 – 33.1) %
	Martins 2021 [244]			551					“One-third”
C16	Oliveira 2024 [218]	Brazil	Cross-sectional	2,021	A representative sample of children in nationwide public	6 - 11y	48.3%	QUACEB - a self-reported recall for	3.5 ± 2.1 UPF groups/d

			Schoolchildren Nutrition Survey		and private primary schools in Brazil.			children with 43 illustrated foods	
C17	Onita 2021 [219]	United Kingdom	Cross-sectional *National Diet and Nutrition Survey 2008 – 2014*	1,772	Subsample of children from a nationally representative sample of the population in the United Kingdom.	4 - 10 y	48.8%	4-day food diary	65.40%
	Martines 2019 [245]		*National Diet and Nutrition Survey 2008 - 2012*	1,277			51.2%		65.8 (SE 0.45) %
C18	Oviedo-Solis 2022 [220]	Mexico	Cross-sectional *Mexican National Health and Nutrition Survey*	11,008	Subsample drawn from nationally representative samples of Mexican children surveyed in 2006 and 2016.	5 - 11y	2006: 50.3% 2016: 48.6%	2006: 101-item semi-quantitative FFQ 2016: 140-item semi-quantitative FFQ	2006: 27.3% (95%CI: 26.5, 28.2%) 2016: 30.1% (95%CI: 28.7, 31.6%)
C19	Souza 2022 [51]	United Kingdom	Cross-sectional *National Diet and Nutrition Survey 2014 - 2016*	509	Subsample of children from a nationally representative sample of the population in the United Kingdom.	4 - 10 y	Total sample (including adults): 50.6%	4-day food diary	65.70%
C20	Yang 2023 [232]	Malaysia	Cross-sectional of intervention study *PREBONE-Kids study*	243	Children recruited from three schools in Kuala Lumpur, Malaysia to participate in a clinical trial of bone health.	9 - 11 y	47.80%	7-day diet history	31.8 ± 14.2%

C = cross-sectional, P = prospective cohort. * Included both prospective and cross-sectional analyses.

3.3.3 Factors associated with UPF intake

A summary of associations between factors and UPF intake is presented in Table 2. A full list of the factors from each study that were included in this review and their association with UPF intake is presented in Appendix B.

3.3.3.1 Individual factors

Sex

The most studied individual factor was a child's sex. Ten studies did not find an association [216, 217, 223, 225, 230, 232-234, 238, 241] and one reported that boys had a higher intake of UPF than girls [226].

Age

Associations between age and UPF intake were analysed in seven studies, with inconsistent findings. As this review only included studies where most children were aged 5 to 12 years, associations between age and UPF intake were only examined within this age range. Most reported no association between age and UPF intake [216, 234, 238, 241], but two studies reported that older primary school children had higher intakes of UPF [225, 226], and one that younger primary school children had higher intakes [233].

Physical activity

Six studies examined whether UPF intake varied according to how physically active children were, with inconsistent findings. One study reported that physical activity levels were higher among children with higher UPF intakes [225], conversely, another reported that physical activity levels were lower among children with higher intakes of UPF [240]. One further study reported a significant association between daily physical activity, but the direction of association across categories of physical activity and quartiles of UPF intake was unclear [226]. The remaining studies did not identify an association between physical activity and UPF intake [221, 230, 241].

Birthweight

The association between birthweight and UPF intake was examined in two prospective studies [216, 234] and two cross-sectional studies (which collected information on birthweight retrospectively) [225, 226]. No study identified an association between children's birthweight and their UPF intake later in childhood.

Gestational age

The association between gestational age and UPF intake was examined in a prospective cohort study [215] and two cross-sectional studies (which collected information retrospectively) [225, 226], none of which identified an association between gestational age and UPF intake in childhood.

Ethnicity

The association between ethnicity and UPF intake was examined in three studies located in Brazil [234], the United Kingdom [216] and Spain [225], none of which identified differences in UPF intake according to child's ethnicity.

Other factors

A relationship between food addiction and UPF intake was examined in one study [228], which found that children who presented with food addiction had a higher intake of UPF than children who did not.

3.3.3.2 Interpersonal factors

Parent-child interactions

Factors examined at the interpersonal level of the socioecological model within the 'parent-child interactions' subdomain focused on early feeding, screen use and different aspects of meals.

Breastfeeding

Duration of breastfeeding and children's intake of UPF was examined in four studies. One prospective study reported that the duration of exclusive, but not total, breastfeeding was inversely associated with children's intake of UPF [215]. Two cross-sectional studies reported inverse associations between the duration of exclusive breastfeeding [229] and total breastfeeding [242] and children's UPF intake. One further cross-sectional study identified a difference of borderline significance ($p = 0.05$) in the duration of total breastfeeding across quartiles of UPF intake [226].

Screen time

Three studies examined the association between the time children spent using screens and their intake of UPF, all of which identified a positive association between screen time and UPF intake [218, 225, 240].

Screen use during meals

Screen use during meals were examined in three studies, all of which reported that children who used screens during main meals had higher intakes of UPF[218, 238, 245]. One study compared lunch and dinner meals, and only identified this association for the dinner meal or the lunch and dinner meals combined [245]

Other factors

In terms of the meals consumed by children, one study found that children who reported consuming breakfast on the previous day had a higher intake of UPF [230] while another study found no association [218]. The aforementioned study also identified that children who reported consuming an afternoon snack or supper on the previous day had higher intakes of UPF [230], while another study found no association between 'snacking' and UPF intake [233]. Consuming lunch and dinner on the previous day was not associated with UPF intake [230]. Having consumed all three main meals on the previous day was also not associated with UPF intake [218].

For the context in which meals were eaten, adherence to patterns of "eating with family watching TV", "eating away from home" and "eating alone in bedroom" were associated with higher intakes of UPF; and adherence to a pattern of "eating at school with friends" was associated with a lower intake [219]. Another study reported that eating in company versus eating alone was not associated with UPF intake [218]. In terms of eating location, a higher contribution of 'home' to total energy intake was associated with lower UPF intake, while a higher contribution of 'sports and leisure centres' was associated with higher UPF intake. The contribution of other locations (institutional places, restaurants, on-the-go, coffee shops, fast food restaurants, friends and families houses, other places) to total energy was not associated with UPF intake in this study [51].

Children who were introduced to solid food, but not semi-solid food, earlier had higher intakes of UPF [215]. Children who reported a habit of buying food advertised on TV had higher intakes of UPF [237]. Eating at regular times versus irregular times was associated with a lower intake of UPF [218]. Children whose parents reported that they adhered to their normal daily routine for eat, sleep and play during the COVID19 pandemic had lower intakes of UPF during this time [233]. Children who spent more time at school during the day had lower intakes of UPF [241]. Whether or not a child participated in meal preparation was not associated with their intake of UPF [218].

One study in Brazil, where children receive a free school meal programme, found that children with high social vulnerability who regularly consume school meals (≥3 times/week) have lower intakes of UPF than children who do not [236]. Another report from this study found that children who consumed 2 or 3 school meals a day had lower intakes of UPF than children who did not consume school meals [227].

Parent health, behaviour and psychosocial factors

Factors grouped at the interpersonal level within this subdomain were those related to parents own health behaviours, knowledge and abilities.

Parent BMI / obesity

One study reported that UPF intake was higher in children whose mothers had a higher BMI [240], while two reported no association [215, 226]. One further study reported that a family history of obesity was not associated with children's UPF intake [225].

Parent smoking

Three studies examined whether having a parent who smokes is related to UPF intake in children, with all three identifying that children who have a parent who smokes have higher intakes of UPF [235, 240, 243].

Other factors

The remaining factors were examined in one study each. A family history of asthma was not associated with children UPF intake in the two studies which examined this [235, 243]. A positive association between a mother's UPF intake and her child's UPF intake was identified [239]. Children whose parents had better knowledge of children's nutritional recommendations and who perceived their child's diet to be healthy were found to have lower intakes of UPF [225]. Children from parents who had higher confidence in their cooking skills [231]. In another report from this study, following a 'Healthy' cooking pattern (defined by confidence to cook using fresh foods and healthy cooking techniques) was inversely associated with children's intakes of UPF, while following a 'Convenience' cooking pattern (less frequency and time to cook, using a microwave or ready-to-heat meals) was positively associated with children's UPF intake [244]. A relationship between a family's use of a variety of food outlets (supermarkets, mini-markets, bakeries, butchers, public-markets, street vendors, fast food outlets and restaurants) and children's UPF intake was not observed [222]. There was also no relationship between parents' perception of how difficult school closures were during the COVID19 pandemic and children's intake of UPF at that time [233].

Family demographics

Factors at the interpersonal level within this subdomain were those related to the demographics of the child's family.

Socioeconomic status

Ten studies examined whether measures of a family's SES were related UPF intake in children. Three studies reported a positive association between at least one measure of SES and children's UPF intake. One study in Iran and one in Mexico reported positive associations between SES and children's intake of UPF [221]. One study in Brazil reported a positive association between household income and children's intake of UPF, but no association between parents level of education and UPF intake [241].

Four studies located in Brazil, the United Kingdom, China and Portugal reported an inverse association between measures of SES and children's UPF intake [216, 217, 226, 234].

A prospective study in Brazil reported that maternal education level at birth was inversely associated with children's intake of UPF, but no association between family income (current or at birth) and children's intake of UPF [234]. A prospective study in the United Kingdom identified an inverse association between maternal socioeconomic classification (based on occupation) at birth and children's intake of UPF [216]. In another report from this study, inverse associations between maternal education at birth and current household income and children's UPF intake were also identified [240]. A cross-sectional study in China identified inverse associations between both maternal education level and family income and children's UPF intake [226]. A cross-sectional study in Portugal reported that parents' education level was inversely associated with children's UPF intake [217].

Three cross-sectional studies did not identify significant associations between measures of SES and UPF intake. One study in Brazil did not identify an association between maternal or guardian education level, income or occupation and children's intake of UPF [238]. One study in Spain reported that children's UPF intake was not related to whether or the child's mother or father had higher education [225]. One study located in Malaysia reported that household income was not related to children's UPF intake [232].

Parents age

Associations between parents age and UPF intake were examined in five studies. Three found no association [238, 240, 241], one found that children with younger parents had higher intakes of UPF [234], and one found that children with older parents had higher intakes of UPF [225].

Other factors

Number of people in the family was found to be positively associated with children's UPF intake [225] and not associated with children's UPF intake [217]. Maternal parity was inversely associated with UPF intake in one study [235]. Two studies examined children's UPF intake by their parents marital status, and both reported no association [217, 238]. One study from Brazil examined parent ethnicity and found that children whose mothers self-reported as black had a higher intake of UPF than children whose mothers identified as white [234].

3.3.3.3 Community factors

Two studies examined whether UPF intake was related to urbanisation level: one study in Portugal reported no difference in children's UPF intake according to their level of urbanisation [217] and one study in Brazil reported that UPF intake was not different according to whether children attended central or peripheral schools [230] [217, 230]. One study located in Brazil found that children attending private schools had higher UPF intake than those attending public schools [224], while another study located in Chile reported no difference in UPF intake between public and private school students [233]. However, the latter study only examined the association with UPF consumption at the time when schools were closed due to COVID19, and thus did not assess the school environment. This same study also reported that the percentage of students who were eligible to receive meals at the school the child attends (a marker of the school's demographic as only low-income students were eligible for the meal programme) was not associated with the child's UPF intake during the pandemic [233]. A study from Portugal reported that certain regions of the country (Lisbon and Algarve) had higher intakes of UPF relative to the North [217]. A study in Brazil found that whether the local neighbourhood was "obesogenic" (based on the number of UPF stores, crime, traffic accidents and walkability) or "leptogenic" (based on facilities for physical activity, green spaces and neighbourhood income) was not associated with UPF intake [223].

Table 2. Summary of factors associated with UPF intake in primary school aged children.

	Positive association with UPF intake	Negative association with UPF intake	No association with UPF intake
INDIVIDUAL (CHILD)			
Sex	**C13** Boys		**P2, C3, C4, C6, C8, C9, C11, C12, C14, C20**
Age	**C12, C13**	**C11**	**C2, C3, C4, C8**
Ethnicity			**C2, C4, C12**
Gestational age			**P2, C12, C13**
Birthweight			**P2, P4, C12, C13**
Physical activity	**C12**	**C4**	**C1, C8, C9, C13***
Food addiction (ref: no)	**C7**		
INTERPERSONAL			
Parent-child interactions			
Delivery mode (reference: vaginal)	**C13** Caesarean		
Breastfeeding duration		**P2, C8, C12**	**C13**
Age of introduction to solid food		**P2**	
Child screen time	**C4, C12, C16**		**C3, C8**
Child screen use during meals (ref: no)	**C3, C16, C17**		
Types of meals child consumes			
Breakfast (ref: no)	**C9**		**C16**
Lunch (ref: no)			**C9**
Dinner (ref: no)			**C9**
Snacks (ref: no)	**C9**		**C11**
Three meals a day (ref: no)			**C16**
Child eats at regular times (ref: no)		**C16**	
Child regularly consumes school meals (ref: no)		**C3**	
Child adhered to daily routine (COVID19) (ref: no)		**C11**	
Child eating context			
Where and who with meals are consumed	**C17** "Eating with family watching TV" pattern **C17** "Eating away from home" pattern **C17** "Eating alone in bedroom" pattern	**C17** "Eating at school with friends" pattern	

Eating in company (ref: eating alone)			**C16**
Child eating location	**C19** Sports and leisure centres	**C19** Home	**C19** Institutional places, restaurants, on-the-go, coffee shops, fast food restaurants, friends and families' houses, other places
Child participates in meal preparation (ref: no)			**C16**
Child habit of buying food advertised on TV (ref: no)	**C3**		
Time child spends at school		**C8**	
Parent health, behaviour and psychosocial factors			
Maternal BMI / family history obesity	**P4**		**P2, C12, C13**
Parent smoking (ref: no)	**P2**, **C4, C12**		
Family history asthma (ref: no)			**P2**, C**12**
Maternal UPF consumption	**C3**		
Use of various food outlets (ref: infrequent use)			**C5** Supermarkets, mini-markets, bakeries, butchers, public-markets, street vendors, fast food outlets, restaurants
Parent knowledge of nutrition		**C12**	
Parent perception of child's diet (ref: unhealthy)		**C12**	
Parent cooking skills confidence		**C15**	
Parent cooking pattern	**C15** Convenience	**C15** Healthy	**C15** Usual
Perceived difficulty of school closure (COVID19)			**C11**
Family demographics			
Maternal ethnicity (ref: white)	**P2** Black		
Parent age	**C12**	**C2**	**C3, P4, C8**
Parent marital status			**C3, C14**
Socioeconomic status	**C1, C8, C18**	**P2, P4, C13, C14**	**C3, C12, C20**
Maternal parity / family size	**C12**	**P2**	**C14**
Child position among siblings			**C12**
COMMUNITY			
School type (ref: public)	**C10** Private		**C11** (with intake during COVID19)
% of students at school eligible for meals			**C11** (with intake during COVID19)

Neighbourhood			
"Obesogenic" neighbourhood			**C6**
"Leptogenic" neighbourhood			**C6**
Urbanisation level			**C9, C14**
Region in Portugal (ref: North)	**C14** Lisbon, Algarve		

C = cross-sectional, P = prospective cohort. * Significant association but direction of association unclear

3.4 Discussion

This is the first systematic review of potential factors associated with UPF intake in primary school aged children. Most of the associations examined were cross-sectional in nature, but two birth cohort studies also reported longitudinal associations. Most of the factors examined were at the interpersonal and individual levels of the socioecological model, with few factors at the community level examined and no factors at the policy level. A wide range of factors were examined in only one or two studies. Of factors which were examined in three or more studies, studies tended to report a positive association with children's UPF intake for screen time, screen use during meals and having a parent who smokes, a negative association with breastfeeding duration, and no significant association for sex, ethnicity, gestational age or birthweight. Associations between age, physical activity, SES and parent's age varied among studies.

3.4.1 Individual factors

Most studies did not find an association between sex and UPF intake. While there is evidence that girls have a greater preference for fruit and vegetables and overall healthier dietary patterns than boys [123], our findings are consistent with a recent systematic review of sociodemographic factors associated with UPF intake in nationally representative cohorts, which found that sex and UPF intake were not related [50]. Previous studies have suggested that birthweight (reflecting the intrauterine environment the child was exposed to) and being born preterm may influence taste preferences and dietary habits during childhood [118-120], but we did not find evidence of an association between these factors and UPF intake.

The reported associations between age and UPF intake were inconsistent. UPF intake is known to be higher among children and adolescents than adults [50], but as the present review was based on children aged 5 to 12 years, we could not make this comparison. Diet has been shown to change over childhood. For example, a decrease in fruit intake during the primary school years has been reported [124, 125] along with a substantial increase in soft drink consumption [126]. However, we were unable to confirm a similar change in UPF intake with age, with only two out of seven studies finding an increase in UPF intake in older primary school age children, while one study identified a higher intake among younger primary aged children.

Associations between physical activity and UPF intake in children were also inconsistent. Previous studies have suggested that physically active children have healthier dietary habits [131, 132], however in one of these studies physically active boys did have higher intakes of breakfast cereals and confectionary [132], examples of UPF products. The association between physical activity and healthier diets may be undermined by UPFs are heavily advertised and promoted at sporting events [246], and through the availability of UPF products such sugar sweetened beverages, artificially sweetened beverages and sports drinks at sports and recreation centres [247-249]. Indeed, one study in the present review found that children who consume a greater proportion of their energy at sports and leisure centres have higher intakes of UPF [51].

3.4.2 Interpersonal factors

Studies reported a positive association between having a parent who smokes and UPF intake in children. Adult smokers have multiple adverse health-related behaviours, poorer dietary quality, and are less likely to adhere to dietary recommendations than non-smokers [250]. UPF intakes have been shown to be higher in adults who smoke [217, 251, 252]. For children, having a parent who smokes has been associated with higher screen time and higher fat intake [253] and with higher energy and sodium intakes [254]. Preschool children with mothers who smoke had lower intakes of fibre and were more likely to have consumed sugar sweetened beverages than children whose mothers did not smoke [255]. The positive association between parent smoking and children's UPF intake in this review are thus consistent with evidence of less healthy dietary patterns in the children of smokers.

Positive associations between screen time and screen use during meals were reported. These findings are consistent with previous evidence of a relationship between screen time and unhealthy dietary behaviours in children. Among 10,000 children aged 6 to 9 years from five European countries, each additional hour of screen-time was associated with greater consumption of foods such as sugar-sweetened beverages, artificially-sweetened beverages, crisps and bakery items, and with a lower consumption of fruit and vegetables [160]. Among 15,000 children aged 2 to 9 years in eight European countries, 'high-risk' television behaviour was associated with increased consumption of high-sugar and high-fat foods [256] and sugar-sweetened beverages [257]. The association between screen time with UPF intake in children may reflect confounding by factors such as SES, as low SES has been associated with both higher screen time [258] and higher intakes of UPF [50]. Alternatively, screen time may directly influence UPF intake in children through exposure to increased food advertising, as UPF products are the most advertised food items [86] and children are particularly sensitive to the effects of food advertising [201] . One study included in our review found that children who reported a habit of buying food advertised on television had a higher intake of UPF [237]. The findings of this review suggest that screen time may provide a target for interventions which aim to reduce UPF intake.

Breastfeeding was inversely associated with UPF intake three studies, with one further study reporting a non-significant inverse association ($p = 0.053$). In addition, one intervention study has shown that UPF was lower at 4 to 7 years of age in children whose mothers received one-on-one breastfeeding and complementary feeding education and support sessions [205]. Only one study in our review examined complementary feeding in relation to UPF intake, finding that children who had started complementary feeding early had a higher intake of UPF when they were 6 years old [215]. Children appear to have an innate preference for energy dense, high-sugar and high-fat foods, but there is evidence that exposure to flavours in breastmilk, and later through the timely exposure to textures and flavours in complementary foods, increases the acceptance of foods such as vegetables [259-261]. How accepting children are of less processed foods may influence their intake of UPF. For example, picky eating in children has been identified by parents as a barrier to cooking family meals [149, 262], and low-income families report fear of wasting money on foods that are likely to be rejected by children as a reason for purchasing more UPF products [172]. Thus, while the association between breastfeeding and UPF intake in this review may again reflect confounding by factors such as SES, it is possible that breastfeeding (and complementary feeding) may influence children's acceptance of less processed foods and therefore their intake of UPF. An improved understanding of how early feeding practices influence later diet is needed, particularly in the context of a high proportion of infant foods now being ultra-processed [263].

As expected, the association between SES and UPF intake in children varied among studies. There was a positive association between SES and UPF intake in three studies located in Iran, Brazil and Mexico; a negative association between SES and UPF intake in four studies located in Brazil, the United Kingdom, China and Portugal; and no association among three studies located in Brazil, Spain and Malaysia. Similarly, varied associations between SES and UPF intake among countries were identified in a systematic review of sociodemographic factors [50]. Differences in the association between SES and UPF intake among countries will be partially explained by differences in economic development and the stage of the nutrition transition they are in, as UPF intake tends to increase initially among higher socioeconomic groups, before shifting to lower socioeconomic groups as the country grows wealthier [15]. In middle-income countries, the cost of highly processed foods still tends to be higher than that of unprocessed foods [92], and lower socioeconomic groups tend to consume more traditional unprocessed diets [173]. However, even between countries with similar *per capita* incomes there exist differences in UPF consumption, and factors such as variations in food prices and availability, how integrated the country is in the global economy, and urbanisation levels will also influence the relationship between SES and UPF consumption [15]. It is thus important to understand the local socioeconomic drivers of UPF consumption within countries.

Overweight and obese adults tend to have higher intakes of UPF [264]. However, most studies in our review did not find an association between maternal BMI/family history of obesity and their children's UPF intake, although one reported a positive association. Parent diet and modelling of healthy eating behaviours has been suggested to influence child behaviour [166], although a recent review reported only modest associations between child and parent diets [265]. Only one study included in the present review examined whether parents own intake of UPF was associated with their child's intake, finding a positive association.

Various factors related to children's meal patterns were examined in one or two studies. Overall, these provided an indication that adhering to a routine, regularly consuming school meals, and eating at home or at school were associated with lower UPF intake, while eating at irregular times, eating away from home and eating alone in the bedroom or in front of a screen may promote higher UPF consumption. Eating patterns have undergone changes in the previous decades; for example, less time is now spent in organised shared meals [266], only around half of children across 43 countries have daily family meals [148] and more meals are eaten out of the home [267]. While adhering to a more traditional meal pattern may reduce UPF intake, this would require addressing barriers such as limited time and skills to prepare meals, the cost of fresh ingredients and children's food preferences [149, 150, 268]. One study included in this review identified that parents cooking skills were inversely associated with their children's UPF intake [231], suggesting that interventions aimed at improving cooking skills, and thereby removing a barrier to family meals, could be effective in reducing UPF intake.

Only one study in this review examined the effect of parent's nutrition knowledge, finding an inverse association between parent's nutrition knowledge and their children's intake of UPF. In addition, two intervention studies have assessed UPF intake following nutrition education interventions for children and their parents. One found no difference in UPF intake after 6 months [204], while the other (which combined education sessions alongside cooking activities, taste tests and exposure to a school garden) found a significant reduction in UPF [203]. Parents nutrition knowledge could be an important factor influencing UPF intake, particularly in light of UPF packaging featuring misleading health and nutrition claims [87, 100]. In a survey in the United Kingdom, a large number of participants reported avoiding UPFs, but most participants were not able to correctly identify which foods were UPFs [269]. How parents' knowledge of nutrition and ability to identify UPFs influence their children's intake of UPFs requires further study.

We did not identify any studies that had examined the availability and accessibility of UPF foods at home, despite this being a key factor influencing children's consumption of foods such as fruit and vegetables and sugar-sweetened beverages [143]. As UPFs are highly accessible to children due to their ready-to-eat nature, how available they are at home could be an important factor influencing their intake.

3.4.3 Community factors

Only two studies included in this review examined the relationship between urbanisation and UPF intake in children, finding no association. This is in contrast with the review of sociodemographic correlates of UPF intake by Dicken et al [50], who found that urbanisation was generally positively associated with UPF intake. However, this relationship was not observed in every country and will depend on factors such as the types of food available in rural areas. For example, in countries such as Australia, rural populations tend to have less access to affordable fresh, healthy food [193], and rurality may therefore promote the consumption of shelf-stable, easily transportable foods such as UPF.

Only one study examined whether different regions of a country had different intakes of UPF, finding that children in the North of Portugal had lower intake of UPF than those in Lisbon and Algarve. Similarly, a study in the Spanish population found that UPF intakes were 5% higher in North Spain than in South or Central Spain [270]. The authors suggested this could be related to known differences in economic growth and adherence to the Mediterranean diet between the regions. Only one study examined the local neighbourhood environment and UPF intake, finding no association between an 'obesogenic' food environment (number of UPF stores, crime, traffic accidents and walkability) or a 'leptogenic' food environment (facilities for physical activity, green spaces and neighbourhood income) and UPF intake in children. However, a study not included in the present review, which examined 'ready-to-consume' products (likely to be UPFs), reported that their availability in neighbourhood stores was associated with increased consumption among children aged <10 y [271]. Furthermore, studies in adults have found that factors such as the local availability of affordable fruit and vegetables may influence UPF intake [272, 273]. More research is needed to understand how children's local and regional food environments influence their intake of UPF.

Despite the school environment being recognised as having an important influence on children's diets, few studies had examined its impact on UPF intake in children. One study from Brazil found that private school students had higher intakes of UPF than public school students, which the authors believed was due to public school students receiving school meals via the National School Feeding Programme (PNAE) [224]. One study in Chile reported no difference in UPF intake among public and private school students, but this study assessed UPF intake when schools were closed during the COVID19 pandemic, and thus did not assess the school environment [233]. Two further studies from Brazil included in our review (presented within the interpersonal level) found that children who regularly consume school meals [236] and those who spend more time at school [241] had lower intakes of UPF; while a study from the UK (also described within the interpersonal level) found that a pattern of eating at school with friends was associated with lower intakes of UPF [219]. Thus, these findings collectively provide support for the idea that schools could be an important setting for reducing UPF intake in children.

3.4.4 Policy factors

We did not identify any studies which had examined the effect of policies on UPF intake in children. This may be due to the fact that most countries do not currently have policies directly addressing food processing, and for those that do, these have only been recently implemented [274]. One example of this is a new policy in Niterói, Brazil that directly prohibits the sale of UPFs in all public and private schools [275]. The influence of more traditional nutrient based food policies (e.g. targeting sugar or salt) on UPF intake is also of interest, as UPF may be reformulated to meet nutrient guidelines while still retaining potentially undesirable attributes such as the presence of artificial sweeteners and other industrial ingredients, and breakdown of the food matrix. For example, the US introduced school-based nutrient recommendations in 2014 for snacks sold in schools which simply resulted in the reformulation of UPF snacks to create look-alike products which met the guidelines [276]. Thus, such policies may not reduce UPF consumption. The effect of policies related to food advertising is also of great interest, due to the widespread marketing of UPF [81, 83] and the sensitivity of child to food advertising [201]. The United Kingdom has introduced a ban from 2025 on the advertising of junk food before 9pm in order to restrict exposure of children [277], and the effects of this ban on UPF intake in children will likely be examined in the coming years.

3.4.5 Strengths and limitations

This is the first study to systematically review potential factors associated with UPF intake in primary school aged children. Systematic review procedures, including predefined inclusion and exclusion criteria, were adhered to in order to reduce reviewer related biases. Broad search terms were used to attempt to identify all studies that had examined associations between a range of factors and UPF intake in children. However, publication bias cannot be excluded. Eight studies did not identify confounders or describe strategies to deal with confounding, and confounding bias may be present among a high proportion of studies included in this review. Only one reviewer performed the screening of studies, which increases the likelihood that some studies were missed [278, 279] . Studies based on participants from one city or region, or those based on participants from one school or hospital, may not be generalisable. Selection bias will also have occurred if selected participants did not respond, resulting in certain groups to be underrepresented or excluded. As discussed for SES, the association between individual factors and UPF intake are likely to vary among countries, and findings from one country may not be applicable to another. Differences in the association between UPF intake and factors between different regions and countries may explain the heterogeneity observed for many factors. Most associations were cross-sectional in nature, and do not imply causality. The small number of studies for each factor means any conclusions should be interpreted with caution. Finally, categorisation of each factor within levels of the socioecological model was subjective.

3.4.6 Conclusions

The findings of this review support the idea that UPF intake in children is related to a multitude of factors operating across the socioecological model, although few studies had examined factors at the community level and none at the policy level. Evidence is currently most consistent for a positive association between UPF intake and screen time, screen use during meals and having a parent who smokes; and a negative association between UPF intake and breastfeeding duration. How these factors relate to UPF intake in children requires further study. There was some indication that aspects of meal patterns and the school environment may be associated with UPF intake, but this was based on factors examined in single studies and requires clarification. Most studies had examined factors at the interpersonal and individual levels of the socioecological model. Further research is needed to understand the factors contributing to UPF intake in children particularly at the community and policy levels of the socioecological model.

CHAPTER 4: CONCLUSIONS

4.1 Overview

The purpose of this study was to identify factors associated with UPF intake in children. A growing body of evidence has linked UPF intake with adverse health outcomes such as CVD, cancer, type 2 diabetes and mortality [18, 19, 22, 25]. Childhood is the time during which dietary behaviours are developed that can persist into adulthood [101] and could represent an ideal time for interventions aimed at reducing UPF intake. However, in order to inform the development of evidence-based interventions, it is important to understand the range factors contributing to UPF intake. The first objective of this study was thus to identify factors associated with UPF intake in children, which was achieved through a systematic review of observational studies. To conceptualise the range of factors associated with UPF intake in children, the factors identified were synthesised and categorised according to levels of the socioecological model: individual, interpersonal (family), community and policy.

This review provided evidence that UPF intake may be higher in children with higher screen time, children who use screens during meals, and in children with parents who smoke. Conversely, UPF intake may be lower in children who were breastfed for longer. Studies generally did not identify significant associations between children's UPF intake and their sex, ethnicity, birthweight and gestational age. Associations between SES, age, physical activity and parent's age varied among studies. While the factors summarised in this review may provide targets for future studies which aim to reduce UPF intake in children, they are based on small number of studies and require confirmation. Most of the factors studied were at the interpersonal and individual levels of the socioecological model, with few factors examined at the community level and none at the policy level.

4.2 Research contribution

This is the first study to systematically review factors associated with UPF intake in primary school aged children. The findings of this review indicate that screen time and breastfeeding may provide targets for interventions aimed at reducing UPF intake in children. This review also provides direction for future studies aiming to understand factors driving UPF intake. For example, factors such as parents' nutrition knowledge, cooking skills and key aspects of children's meal patterns (e.g. the timing and location of meals) were associated with UPF intake in single studies and should be investigated further. The findings of this review support the idea that schools may be an important setting for influencing dietary behaviour in children. Though few studies had examined the impact of schools on UPF intake, those that did suggested a positive influence (i.e. attending a public school (which had a free school meal programme), regularly consuming school meals, spending more time at school and a pattern of eating at school with friends were all associated with lower UPF intake). This review identified significant gaps in the literature on factors influencing UPF intake in children. These were most apparent at the community and policy levels of the socioecological model.

4.3 Strengths and limitations

Due to the wide range of factors examined, and the heterogenous ways in which their association with UPF intake was analysed, a simple 'vote counting by statistical significance' method was used to synthesise findings where multiple studies had examined the same factor. Vote counting by statistical significance has serious limitations when used to determine the effect of interventions and can lead to erroneous conclusions. 'Vote counting by direction of effect' can be a more appropriate method (when meta-analysis is not possible), but was not possible for the present review which did not assess the effect of an intervention on a health outcome, rather it summarised associations between complex exposures (eating location, frequency of use of food outlets, urbanisation level etc) and outcome measures (quintiles, grams per day, % energy intake, number of UPF foods). We believe the method used was appropriate as the purpose of this review was not to determine whether or not exposure to each individual factor was or was not associated with UPF intake, but to summarise the total body of evidence on potential determinants of UPF intake, providing a reference for future research which aims to understand the determinants of UPF intake or target its reduction.

A strength of this study was the use of broad search terms, which ensured the search was comprehensive. This enabled the identification of not only reports which had specifically examined determinants of UPF intake but also reports from cohort studies and clinical trials on different outcomes that had included analyses between UPF intake and participant characteristics at baseline. However, a key limitation was that due to constraints associated with this being a student thesis, only one person (SM) performed the screening of the studies. Studies examining single versus conventional best-practise double screening have reported that single screening results in 5% [278] and 13% [279] of relevant studies being missed.

The findings of this review may have been affected by publication bias. It is likely that some analyses where no significant associations were found between the studied factors and UPF intake were not published. The consistency of the relationship observed for screen time, screen use during meals and breastfeeding may have thus been overestimated. The included studies will also be prone to selection bias. Only five studies included in this review were in nationally representative samples, although a further eight studies made efforts to reflect the regional population. However, even when sampling is well-planned, selected persons may not take part in the study and the sample may therefore underrepresent or exclude certain groups. The findings of this review may be less generalisable to groups who are commonly underrepresented in research studies, such as lower socioeconomic groups.

The determinants of UPF intake are likely to vary among countries, due to differences in factors such as food pricing, incomes and cultural norms. As discussed, this may have resulted in the inconsistent relationship we observed between SES and UPF intake. However, this may also have contributed to inconsistent relationships for other factors. The findings of this review may not apply to countries outside those of which they were performed in. Moreover, most studies were performed within cities or regions within countries, and the associations identified may not reflect the country as a whole. As discussed, regions within countries may have different intakes of UPFs [217, 270].

The categorisation of factors across levels of the socioecological model was subjective, and it is possible that different authors would have placed factors in different categories. This is most likely to have occurred between the individual and interpersonal levels of the socioecological model (i.e. screen time and screen use during meals could potentially be considered an individual factor) and should not have affected the finding that few factors at the community and policy levels have been investigated.

4.4 Final recommendations

- Studies have identified positive associations between screen time and screen use during meals with UPF intake. While this association may reflect confounding, it could be related to increased exposure of children to food advertising. Whether limiting children’s screen time or exposure to food advertising reduces UPF intake is an area which requires further investigation.
- UPF intake was lower in children who had been breastfed for longer. While again this may reflect confounding, it is possible that early feeding practices may alter children’s future dietary preferences. One intervention study which targeted breastfeeding and complementary feeding found reduced UPF intake later in childhood [205]. These findings, combined with the those in this review, suggest that targeting infants’ diets may influence later UPF intake, but this requires confirmation.

- Studies have identified higher intakes of UPF in children who had a parent who smokes, supporting evidence of less healthy lifestyles in these children. Whether interventions targeting smoking in parents impacts their children's diets could be investigated.
- Though few studies had assessed factors related to schools, the findings of this review provide some support for the idea that schools could be an important setting for influencing UPF intake in children. Future research should examine how interventions such as school meal programmes and/or healthy food policies affect UPF intake.
- Further research is needed to understand how UPF intake in children is influenced by factors operating at the community and policy levels of the socioecological model, such as the availability and accessibility of UPF versus less processed foods in the immediate neighbourhood, school and recreational environments; and policies relating to the exposure of children to UPF advertising.
- Research should continue to clarify the health impacts of UPF consumption. Recent studies have indicated that the adverse health effects of UPF may be related to only certain foods within the UPF category, such as sugar- and artificially-sweetened beverages and processed meats, while other UPF products such as packaged breads, breakfast cereals and yoghurts may have health-promoting effects [18, 26]. Advice to avoid all UPFs should be based on evidence that this is of greater benefit to health than avoiding particular foods (i.e. processed meats and sugar-sweetened beverages). Further refinement of the UPF category may also be possible, as foods such as packaged wholemeal bread appear to be different from other UPF foods in that they are not designed to be hyper-palatable. Understanding the mechanisms by which UPF affect health (i.e. through their nutritional composition, food matrix, additives or compounds formed during processing) will also be important and may enable the formulation of healthier processed foods.
- Finally, it is imperative that research and debate on UPF consumption does not stigmatise dietary behaviours in children or other groups. As reviewed in Chapter 2 of this thesis, the UPF category may provide an important affordable and accessible source of food for certain groups such as low-income populations, who may have difficulty accessing less processed foods due factors such as their cost, reduced local availability and short shelf life, and poorer access to facilities to cook and store food. It is important that structural barriers to consuming less processed food are understood and targeted.

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APPENDICES

6.1 Appendix A

Quality assessment using the Joanna Briggs Institute checklist for analytical cross-sectional studies [214]

Study number	**Author name and year**	Criteria for inclusion in the sample clearly defined	Study subjects and the setting described in detail	Exposure measured in a valid and reliable way	Objective, standard criteria used for management of the condition	Confounding factors identified	Strategies to deal with confounding factors stated	Outcomes measured in a valid and reliable way	Appropriate statistical analysis used	Total score
C1	Asgari 2022	Y	Y	Y	Y	N	N	Y	Y	6/8
C2, P2	Bielemann 2018 dos Santos Costa 2021 Azeredo 2020	Y	Y	Y	Y	N	N	Y	Y	7/8
C3	Bento 2018 Horta 2019 Fraga 2020 de Lacerda 2020 do Carmo 2021	Y	Y	Y	Y	N	N	N	Y	5/8
C4, P4	Chang 2021 Handakas 2022	Y	Y	Y	Y	N	N	Y	Y	8/8
C5	Correa 2018	Y	Y	Y	Y	Y	Y	Y	Y	8/8
C6	de Albuquerque 2023	Y	Y	Y	Y	Y	Y	Y	Y	8/8
C7	de Almeida 2023	Y	Y	Y	Y	Y	Y	Y	Y	8/8
C8	de Almeida Fonseca 2019 de Almeida Fonseca Viola 2023	Y	Y	Y	Y	Y	Y	Y	Y	8/8
C9	de Melo Fonseca 2023	Y	Y	Y	Y	Y	Y	Y	Y	8/8
C10	Ferreira 2019	Y	Y	Y	Y	N	N	N	Y	5/8
C11	Fretes 2023	Y	Y	Y	Y	Y	Y	Y	Y	8/8
C12	Garcia-Blanco 2023 Oliver Olid 2023 Moreno-Galarraga 2021	Y	Y	Y	Y	Y	Y	Y	Y	8/8
C13	Hou 2023	Y	Y	Y	Y	N	N	Y	Y	6/8
C14	Magalhaes 2021	Y	Y	Y	Y	Y	Y	Y	Y	8/8
C15	Martins 2020 Martins 2021	Y	Y	Y	Y	Y	Y	Y	Y	8/8
C16	Oliveira 2024	Y	Y	Y	Y	Y	Y	Y	Y	8/8
C17	Onita 2021 Martines 2019	Y	Y	Y	Y	Y	Y	Y	Y	8/8
C18	Oviedo-Solis 2022	Y	Y	Y	Y	N	N	Y	Y	6/8
C19	Souza 2022	Y	Y	Y	Y	Y	Y	Y	Y	8/8
C20	Yang 2023	Y	Y	Y	Y	N	N	Y	Y	6/8

Quality assessment using the Joanna Briggs Institute checklist for cohort studies [214]

Study number	Author name and year	Groups were similar and recruited from the same population	Exposures measured similarly to assign people to groups	Exposure measured in a valid and reliable way	Confounding factors identified	Strategies to deal with confounding factors stated	Groups free of outcome at the time of exposure	Outcome measured in valid and reliable way	Follow-up time reported and sufficient for outcomes to occur	Follow-up complete or reasons for loss to follow-up examined	Strategies to address incomplete follow-up utilised	Appropriate statistical analyses used	Total
P2, C2	Bielemann 2018 dos Santos Costa 2021 Azeredo 2020	Y	Y	Y	N	N	Y	Y	Y	Y	N	Y	8/11
P4, C4	Chang 2021 Handakas 2022	Y	Y	Y	N	N	Y	Y	Y	N	N	Y	7/11

6.2 Appendix B

Factors examined in each study and their association with UPF intake.

	Author name and year	Outcome	Factors identified each report included in review	Association with UPF intake*
C1	**Asgari 2022**	g per day of UPF	SES Physical activity (MET/h)	**Positive** Nil
C2, P2	**Bielemann 2018**	% of total daily energy intake from UPF at 6y	Gestational week (31-36, 37-38, ≥39 wk) Maternal BMI (normal, overweight, obese) Birthweight (<2500, ≥2500 g) Exclusive breastfeeding (≤7 d, 8 d to <1 mo, 1-2.9 mo, ≥3 mo) Total breastfeeding (< 1 mo, 1 – 2.9 mo, 3 – 5.9 mo, 6 – 11 mo, ≥ 12mo) Age at introduction of semi-solid foods (<3 mo, 3-3.9 mo, 4-5.9 mo, ≥6 mo) Age at introduction of solid foods (<3 mo, 3-3.9 mo, 4-5.9 mo, ≥6 mo)	Nil Nil Nil **Negative** Nil Nil **Negative**
	dos Santos Costa 2021	% totally daily energy intake from UPF at 11y	Maternal skin colour (white, black, brown/yellow/indigenous) Maternal age at child's birth (≤24, 25-34, ≥35 y) Maternal education at child's birth 0-4, 5-8, 9-11, ≥12 y) Monthly family income at birth (quintiles) Monthly family income current (quintiles) Sex of child (male, female) Child skin colour (white, black, brown/yellow/indigenous) Child year/ grade at school (≤3, 4-5, 6-7)	**Positive (black)** **Negative** **Negative** Nil Nil Nil Nil Nil
	Azeredo 2020	% of total daily energy intake from UPF at 6 or 11y	Parity (0, 1, ≥2) Maternal asthma perinatal (yes, no) Smoking during pregnancy (yes, no) Maternal smoking at 6 y (yes, no) Paternal smoking at 6 y (yes, no)	**Negative** Nil **Positive ('yes' 11y)** **Positive ('yes' 11y)** Nil
C3	**Bento 2018**	grams UPF/ 1000kcal	Number of school meals (2 or 3 versus 0 school meals/day)	**Negative**

	Horta 2019	g per day of UPF	Regular school meal consumption (≥3 meals/wk) in children with high social vulnerability (yes, no) Regular school meal consumption (≥3 meals/wk) in children with low social vulnerability (yes, no)	**Negative (‘yes’)** Nil
	Fraga 2020	High UPF intake (>80th percentile of total energy intake)	Habit of buying television advertised foods (yes or no)	**Positive (yes)**
	de Lacerda 2020	% daily energy intake from UPF	Age of child (y) Sex of child (male, female) Habit of eating in front of the TV (yes, no) Screen time (≤ 2h, >2h) Maternal / guardian age group (<30, 30-60, ≥60 y) Maternal / guardian education level <9, ≥ years of study) Maternal / guardian per capita income (≤0.5, >0.5 minimum wage) Maternal / guardian marital status (married, single/divorced/widowed) Maternal / guardian occupation (employed, unemployed)	Nil Nil **Positive (yes)** Nil Nil Nil Nil Nil Nil
	do Carmo 2021	High UPF intake (>80th percentile of total energy intake)	Mother's UPF intake (<80th , ≥80th percentile of UPF intake as % of total energy intake) Child's screen time (<60 min, >60 - ≤120, >120 - ≤240, >240 min/d) Socioeconomic status (based on income, education, housing type and assistance programs)	**Positive** Nil Nil
P4, C4	**Chang 2021**	% of total daily food intake	Sex of child (male, female) Age of child (7, 10 or 13 y) Ethnicity (non-white, white) Birthweight (<2500, 2500-3999, ≥4000 g) Maternal socioeconomic classification (based on NSSEC (higher managerial/administrative/professional, intermediate, routine/manual occupations))	Nil Nil Nil Nil **Negative (higher SE classification)**
	Handakas 2022	% total daily energy intake from UPF	Child watching TV on weekdays (less than 1 h, 1-2 h, 3 h or more) Child watching TV on weekends (less than 1 h, 1-2 h, 3 h or more) Child weekly physical activity (every day, 2-6 times/wk, once wk or less) Maternal age at pregnancy (years) Family income at 7 y (low, medium, high) Smoker at home (yes, no) Maternal education at birth (low: O level/vocational/no qual, medium: A level, high: degree) Maternal pre-pregnancy BMI (kg/m^2)	**Positive** **Positive** **Negative** Nil **Negative** **Positive (yes)** **Negative** **Positive**

C5	**Correa 2018**	Frequency of intake of UPF	Frequent use by family of supermarkets (yes, no) Frequent use by family of mini-markets (yes, no) Frequent use by family of bakeries (yes, no) Frequent use by family of butchers (yes, no) Frequent use by family of public-markets (yes, no) Frequent use by family of street vendors (yes, no) Frequent use by family of snack bars / fast food outlets (yes, no) Frequent use by family of restaurants (yes, no)	Nil Nil Nil Nil Nil Nil Nil Nil
C6	**de Albuquerque 2023**	% total daily energy intake from UPF	Sex Neighbourhood obesogenic environment (latent variable consisting of UPF stores, crime, traffic incidents, walkability) Neighbourhood leptogenic environment (latent variable consisting of public facilities for physical activity, green spaces, neighbourhood income)	Nil Nil Nil
S7	**de Almeida 2023**	Energy intake from UPF	Food addiction (defined by Yale Food Addiction scale; yes, no)	**Positive (yes)**
S8	**de Almeida Fonseca 2019**	% total daily energy intake from UPF	Duration of exclusive breastfeeding (months)	**Negative**
	de Almeida Fonseca 2023	% total daily energy intake from UPF	Sex of child (female, male) Child's age (4-5, 6-7 y) Mother's level of education (≤8, 9-11, ≥12 years of study) Mother's age (<30, ≥30 years) Father's level of education (≤8, 9-11, ≥12 years of study) Father's age (<30, ≥30 years) Mothers job (yes, no) Per capita household income (tertiles) Child's screen time (<2, ≥2 hours) Child's active play (<2, ≥2 hours) Child's time spent at school (≤5, >5 hours)	Nil Nil Nil Nil Nil Nil Nil **Positive** Nil Nil **Negative**
S9	**de Melo Fonseca 2023**	% of children who consumed at least one UPF daily	Sex (female, male) Geographic region of school (central, peripheral) Consumed breakfast previous day (yes, no) Consumed mid-morning snack previous day (yes, no) Consumed lunch previous day (yes, no)	Nil Nil **Positive (yes)** Nil Nil

			Consumed mid-afternoon snack previous day (yes, no) Consumed dinner previous day (yes, no) Consumed supper previous day (yes, no) Physical activity level (little active, moderate/very active)	**Positive (yes)** Nil **Positive (yes)** Nil
S10	**Ferreira 2019**	% total daily energy intake from UPF	School type (public, private)	**Positive (private)**
S11	**Fretes 2023**	Number of UPF subgroups consumed (out of 20)	Age of child (y) Sex of child (female, male) School type (public versus private) Snacking (yes, no) Eligibility for school meals (yes, no) Child daily routine during COVID 19 (construct reflecting how much child had adhered to usual routine for eating, studying and playing, higher = greater adherence) School preparedness for online teaching during COVID19 (construct based on parents perception of how well prepared schools and teachers are for online teaching) School closure difficulties for caregivers during COVID19 (construct based on parents perception of how difficult school closures had been for them)	**Negative** Nil Nil Nil Nil **Negative** Nil Nil
C12	**Garcia-Blanco 2023**	% total daily energy intake from UPF	Maternal age (<35, 35-40, 40-45, >45 y and years) Paternal age (years) Maternal high education (yes, no) Paternal high education (yes, no) Number of children in family (1-2, 3-4, 5 or more) Family history of obesity (yes, no) Parental attitude towards child's diet (unhealthy (0-3 points), average (4-5 points), healthy (6-8 points)) Parental knowledge about child's nutritional recommendations (low score (<40%), medium score (40-70%), high score (>70%) Child sex (female, male) Child age (years) Child race (white, non-white) Gestational age (<38, 38-40, >40 wks) Birthweight (<2500, 2500-3000, 3000-3500, 3500-4000, >4000g) Child's position among siblings (oldest/singletons, $2^{nd}/3^{rd}/4^{th}$, youngest or below 4^{th})	**Positive** Nil Nil Nil **Positive** Nil **Negative** **Negative** Nil **Positive** Nil Nil Nil Nil **Positive**

			Physical activity (moderate-vigorous h/d) Child's screen time (h/d)	**Positive**
	Oliver Olid 2023	Actual and % energy intake from UPF	Total breastfeeding duration (no breastfeeding, <6 mo, 6 - <12 mo, ≥12 mo)	**Negative**
	Moreno-Galarraga 2021	Low consumption UPF (≤829 kcal/d) versus high consumption UPF (>829 kcal/d)	Family history of asthma/allergy (yes, no) Child exposed to tobacco (yes, no)	Nil **Positive (yes)**
C13	**Hou 2023**	% total daily energy intake from UPF	Age(y) Sex (female, male) Birthweight (low, normal, high) Delivery mode (vaginal, caesarean) Gestational age (pre and early term, full term, late or post term) Duration of breastfeeding (never, > 6 mo, ≥6 mo) Physical activity (<30, 30-60, ≥60 min) Maternal BMI status (underweight, normal, overweight, obese) Maternal education (<high school, high school or equivalent, college graduate and above) Family income (low, middle, high)	**Positive** **Positive (male)** Nil **Positive (caesarean)** Nil Nil **Sig but unclear** Nil **Negative** **Negative**
C14	**Magalhaes 2021**	UPF intake in grams	Sex (female, male) Parental education (<6, 7 to 12, >12 years) Urbanisation level (predominantly urban, medially urban, predominantly rural) Civil status (single/divorced/widowed, married/couples) Number of household members 1 to 2, 3 to 4, ≥5) Region (North, Centre, Lisbon, Alentejo, Algarve, Autonomous Region of Madeira, Autonomous Region of Azores)	Nil **Negative** Nil Nil Nil **Positive (Lisbon and Algarve)**
C15	**Martins 2020**	% intake of UPF at evening meal	Parents Cooking Skills Index (index based on confidence in 10 different skills)	**Negative**
	Martins 2021		Parents adherence to "Healthy" cooking pattern Parents adherence to "Usual" cooking pattern Parents adherence to "Convenience" cooking pattern	**Negative** Nil **Positive**
S16	**Oliveira 2024**	NOVA score (the sum of reported	Screen time (acceptable, excessive) Eating main meal with distractions (with watching TV and using phone, without watching TV and	**Positive (excessive)**

		groups of UPF ranging from 0 to 10).	using phones) Eating main meals in company (with company, alone) Eating at regular times (at the usual time, at a different time than usual) Participating in household activities involving meal preparation (yes, no) Consumed all three meals on previous day (yes, no) Consumed breakfast on previous day (yes, no)	**Positive (with TV and phone)** Nil **Positive (at different time)** Nil Nil Nil
S17	**Onita 2021**	**% total energy intake UPF**	Eating context patterns: Adherence to "Eating with family watching TV" pattern at lunch (tertiles) Adherence to "Eating at school with friends" pattern at lunch (tertiles) Adherence to "Eating away from home" pattern at lunch (tertiles) Adherence to "Eating with family watching TV" pattern at dinner (tertiles) Adherence to "Eating alone in the bedroom" pattern at dinner (tertiles)	 **Positive** **Negative** **Positive** **Positive** **Positive**
	Martines 2019	**% total energy intake UPF**	Watching TV during main meals (never (reference), during lunch, during dinner, during lunch and dinner)	**Positive (during dinner and during lunch and dinner)**
S18	**Oviedo-Solis**	**% total energy intake UPF**	Socioeconomic status (tertiles)	**Positive**
S19	**Souza 2022**	**% total energy intake UPF**	Dietary contribution (%) of the eating location 'home' to total energy intake Dietary contribution (%) of the eating location 'institutional places' to total energy intake Dietary contribution (%) of the eating location 'sit-down restaurants' to total energy intake Dietary contribution (%) of the eating location 'on-the-go' to total energy intake Dietary contribution (%) of the eating location 'coffee shops' to total energy intake Dietary contribution (%) of the eating location 'leisure and sports centres' to total energy intake Dietary contribution (%) of the eating location 'fast-food restaurants' to total energy intake Dietary contribution (%) of the eating location 'friends and relatives houses' to total energy intake Dietary contribution (%) of the eating location 'other places' to total energy intake	**Negative** Nil Nil Nil Nil **Positive** Nil Nil Nil

S20	**Yang 2023**	**% total energy intake UPF**	Household income (lower 40%, upper 60%) Sex of child (female, male)	Nil Nil

***Direction of association with UPF intake for which a significant association was reported**