Reviews of Scientific Evidence and Policies on Nutrition and Physical Activity

Objective Area D: Early Warning Indicators

Written by ICF Consulting Services Ltd

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Preface

About this project

Overweight, obesity and their related diseases represent a leading cause of morbidity and mortality, and pose a major challenge for the sustainability of healthcare systems of EU Member States. The growing prevalence of overweight and obesity among all age groups across Europe constitutes a serious concern for policy makers. Tackling this issue requires a comprehensive response that reflects the multifactorial and complex nature of obesity and overweight. One particularly important area of focus has been on the development of preventative strategies which include nutritional and physical activity interventions.

The European Commission Directorate General for Health and Food Safety (DG SANTE) recognises the significant challenges policy makers face in developing effective and efficient policy interventions relating to diet and physical activity. One such challenge includes the complexity and breadth of the evidence base. By providing independent, accurate summaries of recent and relevant information and statistics on determinants of diet and physical activity and their impact on health, this project aims to support policy makers to continue to develop policy instruments which enable people to make healthier lifestyle choices. In particular, this project aims to support the development of healthier behaviours in vulnerable and/or at-risk subpopulations (including children, pregnant and lactating women, and older adults) and low socio-economic status groups (including low income and education).

About this series

This evidence review is one of eight reviews relating to different determinants of diet and physical activity.

Seven of the reviews are of the scientific evidence and policies in the following areas:

- Knowledge, attitudes and behaviours contributing to positive energy balance (objective area A1);
- Dietary and physical activity patterns in Europe (objective area B1);
- Consumption of fruit juices, artificially and sugar-sweetened beverages and its impact on weight status and health (objective area B2);
- Consumption of high-fructose syrup and its impact on weight status and health (objective area B3);
- Relationship between weight status and physical activity with school and work performance outcomes (objective area C);
- Early warning indicators of obesity and physical inactivity trends (objective area D);
- Nutrition and physical activity guidelines for specific population groups (objective area E).

Building on these seven reviews, the final review (objective area A2) examines specifically the evidence for effective and efficient policies and interventions in terms of promoting, supporting and improving nutritional and physical activity behaviours at both individual and population level.

All reviews, and their summaries, are available on the DG SANTE webpage here.

Approach and purpose

The reviews have been designed to provide policymakers with summaries of recent and relevant evidence in these key areas of interest. Given the broad scope of each of the reviews, it should be stressed that they are not intended to be rigorous systematic reviews of all literature published in this field. Rather, they are intended as pragmatic reviews combining a comprehensive search methodology with expert academic input,

facilitated through workshops, to provide a practical and accurate summary of key issues and tackling broad lines of enquiry, with the greater aim of supporting the development and improvement of policies in this area. Each of the project's eight methodologies and analyses was reviewed by DG SANTE and academic experts in these topics.

While the methods to conduct this comprehensive literature review are systematic, it is *not* a systematic review. This review does not systematically analyse literature to identify *all* relevant published data and/or appraise its quality. Methods to conduct the literature review consisted of five steps: (1) refining the research questions, (2) developing a search approach and databases, (3) conducting literature searches, (4) screening articles for inclusion; and (5) abstracting and synthesising relevant data.

To minimise bias, the literature search approach included identification of a priori search parameters (also considered first level inclusion and exclusion criteria), agreed with DG SANTE, to guide searches and inform screening and selection processes for data inclusion. Due to the immense number of literature search results at step 3, the application of quite limiting exclusion criteria at step 4 was deemed necessary. This may however have resulted in not screening all potentially relevant literature. All relevant articles that were found appropriate for inclusion were reviewed for relevance to each objective area, and the scope of the specific research questions. Furthermore, the inclusion of different types of scientific evidence (from systematic reviews and peer-reviewed original articles down to BSc theses) and the presentation of this scientific evidence next to grey literature information presented a challenge in terms of maintaining an understanding of the quality and weight of the evidence. The authors addressed this to some extent by structuring the document in such a way that peer-reviewed and grey literature are clearly identified. The full methodology and steps taken for each review is included in Annex of this document.

DG SANTE and the Joint Research Centre (JRC) provided input on all stages of the project and comments on the literature reviews. Expert workshops were organised to discuss findings, highlight additional relevant sources to fill gaps and improve the series of reviews. Experts were carefully selected from academic and policy-making fields, based on expertise of the specific topics addressed.

The methodology used across all eight reviews remained consistent, and within each review a detailed summary of the approach is provided, along with a full bibliography for further reading.

Glossary

The following definitions are common definitions that are used across all eight objective areas. Where a study uses a different definition, this will be highlighted on an individual basis in the review.

Table 1. Definitions of terms used across the reviews

Term	Definition	Source
Adult obesity	An abnormal or excessive fat accumulation that presents a risk to health, with a BMI of 30 or more.	World Health Organisation (WHO) (http://www.who.int/topics/obesity/en/)
Adult overweight	An abnormal or excessive fat accumulation that presents a risk to health, with a BMI equal to or more than 25.	WHO (http://www.who.int/topics/obesity/en/)
Alcopops	Pre-mixed beverages containing a spirit, wine or malt combined with a non-alcoholic drink.	1. Anderson, P., Suhrcke, M. and Brookes, C. (2012) An overview of the market for alcohol beverages of potentially particular appeal to minors. London: HAPI.
Artificially sweetened beverages (ASBs)	Beverages sweetened with low-calorie or zero-calories sweeteners such as sucralose, aspartame, saccharin, stevia or sugar alcohols.	ICF definition based on all literature identified in objective area B2 literature review
Body Mass Index	A person's weight (in kilograms) divided by the square of his or her height (in metres).	WHO (http://apps.who.int/bmi/index.jsp?introPage=intro_3.html)
Child/adolescent obesity	There are different systems available to measure child or adolescent obesity for different ages. Children under 5 obesity is weight-for-height greater than 3 standard deviations above WHO Child Growth Standards median; Children aged 5-19 overweight is BMI-for-age greater than 2 standard	WHO http://www.who.int/mediacentre/factsheets/fs311/en/ (Other definitions are available for different national and international systems).

Term	Definition	Source
	deviation above the WHO Growth Reference median.	
Child/adolescent overweight	There are different systems available to measure child or adolescent overweight for different ages. Children under 5 overweight is weight-for-height greater than 2 standard deviations above WHO Child Growth Standards median; Children aged 5-19 overweight is BMI-for-age greater than 1 standard deviation above the WHO Growth Reference median.	WHO http://www.who.int/mediacentre/factsheets/fs311/en/ (Other definitions are available for different national and international systems).
Exercise	Exercise, is a subcategory of physical activity that is planned, structured, repetitive, and purposeful in the sense that the improvement or maintenance of one or more components of physical fitness is the objective.	WHO (http://www.who.int/dietphysicalactivity/pa/en/)
Insufficient physical activity	Physical activity that does not meet WHO recommended levels of at least 60 minutes a day of moderate-vigorous activity for children and adolescents and at least 150 minutes of moderate-intensity aerobic physical activity throughout the week for adults.	WHO http://www.who.int/mediacentre/factsheets/fs385/en/
Physical activity	Any bodily movement produced by skeletal muscles that requires energy expenditure.	WHO (http://www.who.int/topics/physical_activity/en/)
Physical inactivity	A lack of physical activity	WHO (http://www.who.int/dietphysicalactivity/pa/en/)

Term	Definition	Source
Sedentary behaviour	Any waking behaviour characterized by an energy expenditure ≤1.5 metabolic equivalents (METs) while in a sitting or reclining posture.	Tremblay, M. S., et al. (2017). Sedentary Behavior Research Network (SBRN) – Terminology Consensus Project process and outcome. *The International Journal of Behavioral Nutrition and Physical Activity*, *14*, 75. http://doi.org/10.1186/s12966-017-0525-8
Sugar sweetened beverages (SSBs)	Any beverage with added sugars. This includes soft drinks, soda, fruit drinks, punch, sports drinks, sweetened tea and coffee drinks, energy drinks and sweetened milk. These beverages may be sweetened with added sugars such as sucrose (table sugar) or high fructose corn syrup, which is what distinguishes them from 100% fruit juice and beverages with non-caloric sweeteners (e.g., aspartame, saccharin or sucralose).	US Department of Agriculture. 2010. *US Department of Health and Human Services. Dietary guidelines for Americans, 2010.* 7th edition, Washington (DC): US Government Printing Office

Objective D: A comprehensive review of the early warning indicators of obesity and physical (in)activity

This report presents the findings of a peer-reviewed literature and grey literature review on factors associated with overweight and obesity and provides suggestions for reliable early warning indicators for obesity and overweight in children and adolescents and in adults. Because physical (in)activity is so strongly associated with the development of obesity, factors that influence physical (in)activity that could also serve as early warning indicators are also reviewed and explored. In addition, the findings from this review illustrate areas where further research may be useful. The report includes the following sections.

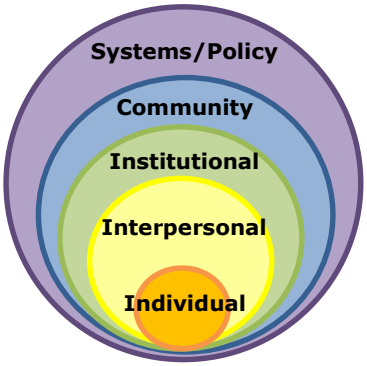
- Introduction, describing the scope of the reviews and the principal research questions;
- Methodology, describing how the reviews were undertaken and relevant findings extracted;
- Findings from the peer-reviewed and grey literature, presented according to each research question; and
- Conclusions drawn from the reviews overall and an assessment of the current scientific evidence, including any gaps in the knowledge.

1 Introduction

Research indicates that there are multiple levels of influence contributing to the epidemic of obesity. At the more sophisticated end of the spectrum, the UK Foresight obesity map (Foresight 2007), provides a visual illustration of 108 variables associated with obesity and their interdependencies, demonstrating the multidisciplinary and complex nature of the issue. It highlights that there is not one single dominant influence; rather the different variables are clustered into seven categories: physiology; individual psychology; food consumption; food production; social psychology; individual physical activity and physical activity environment. The map involves an intricate network of feedback loops between variables and different clusters and the 'engine' at the centre, which is the energy balance equation.

Other models provide a simpler way to conceptualise and comprehend obesity that nevertheless emphasises the multiple influences, echoes these clusters and places the individual at the centre. The Social Ecological theory is one of the most widely accepted models for describing the multiple levels of influence on health (Bronfenbrenner, 1977) and has been adapted to describe the multiple levels influencing obesity (CDC 2013). In this model, an individual's weight status is influenced by individual, interpersonal, institutional/organisational, community and systems/policy levels. Figure 1 illustrates the levels and factors included in each (CDC, 2013).

Figure 1. Social Ecological Model – levels influencing obesity



Systems/Policy: regulations or laws

Community: local infrastructure and environmental characteristics

Institution/Organization: school, health care, businesses, faith organizations, etc.

Interpersonal: individual relationships, support groups, social networks

Individual: Attitudes, knowledge, behaviour or genetic factors

Source: adapted from CDC 2013

Another useful conceptual model for obesity, identified by WHO (WHO Meeting Report 2013, cited in WHO 2016 p.7) is the life-course model. This draws on scientific (animal and human) studies that have shown how causal pathways for obesity begin in the early stages of life and can persist throughout, before being passed onto offspring, affecting the ability to respond to challenges such as an unbalanced diet and likelihood of storing excessive fat. This model emphasises that earlier preventative interventions are more effective than attempting to reduce risks or restore health in adults. This is due to particularly sensitive periods of time when future health can either be adversely affected by unhealthy environments and behaviours or conferred with long-term protection from risk. Pre-conception, pregnancy and post-partum/infancy are established by this model as the optimum times to intervene to prevent the obesity cycle continuing.

These latter two models are introduced here since they are pertinent to the research questions, which consider the multiplicity of factors which are associated with obesity and physical (in)activity, and their respective suitability as predictive factors of potential future trends in obesity and physical inactivity. The socio-ecological model has also been embraced as a way of understanding what drives physical activity and how best to promote it (Mehtälä et al. 2014). It is therefore considered appropriate as a framework for exploring the findings of this review with respect to both weight status and activity level determinants. The life-course model provides a pathway for understanding how measuring certain early life determinants may indicate future trends. For policy-makers, an ability to have timely information that might indicate a change (e.g. an increase) in weight status and physical (in)activity in populations would further support the introduction of important preventative policies or interventions.

1.1 Research questions for this review

In this review, we focus on the most current literature (peer-reviewed original research and systematic reviews, as well as grey literature) that examines factors associated with overweight, obesity, and physical (in)activity structured according to the levels of influence within the social ecological model. The review considers which factors and measures might work as early warning indicators and potential monitoring systems to keep track of prevalence and trends. The research addressed the following questions specified for the review:

- What factors are associated with overweight, obesity and physical (in)activity?
- What factors could be of use as early warning indicators of overweight and obesity and physical (in)activity prevalence and trends?

- How could a feasible, effective and efficient early warning monitoring mechanism be put in place to keep track of these issues?

1.2 Scope of this review

This review considers determinants relating to child, adolescent and adult obesity and subsequently, the determinants for physical (in)activity. Given the breadth of the first line of enquiry some limitations were placed on scope. Particular food consumption patterns and their relationship with obesity such as the consumption of sugar-sweetened beverages (SSBs) and high-fructose corn syrup (HFSC) are discussed in other reviews in this series; B2 and B3 respectively. We therefore considered only the role of diet in a broad way. Similarly, in the A2 review different policies and interventions are considered which have been found to be effective in promoting healthier behaviours. For this reason determinants at the societal or policy level of the socio-ecological model were not considered; rather the focus was on the individual, interpersonal (family and social), organisational (work and school settings) and community (local neighbourhood or environmental) factors.

The concept of 'early warning indicators' was not a common one, although we did find evidence for variables which may predict obesity in later life. We did not find many examples of literature which discussed indicators and monitoring systems; or how these might alert governments to, or predict, changes in obesity and physical (in)activity prevalence. Two conceptual interpretations of 'early warning' are therefore presented. The first, emerging in the peer-reviewed literature, discusses indicators that can be measured using monitoring systems that provide more immediate, or 'early', data than official statistical returns (which often involve a time lag). The second takes the life-course approach discussed above, discussing variables of child obesity and physical (in)activity that might be of use as potential indicators or predictors of trends yet to emerge in the adult population.

2 Methodology

The review is based mainly on peer reviewed literature, with grey literature used to supplement any gaps. For each set of literature, specific search terms, inclusion and exclusion criteria, and quality checks were carried out. The research questions and search terms were confirmed with DG SANTE at the start of the process.

After the initial searching and extraction of literature, expert workshops (with experts from relevant academic and policy-making fields) were conducted to discuss findings, highlight additional relevant sources to fill gaps and improve the series of reviews.

More information on the methodology can be found in the Annexes.

2.1 Peer review method

To search for and extract the most relevant peer reviewed literature the following steps were taken: refining the research questions; developing a search approach and databases; conducting literature searches; screening articles for inclusion; and abstracting and synthesizing relevant data.

A total of 4086 search hits were retrieved. A total of 1577 duplicates were found and removed from the search hits resulting in 2509 search results for D. From the 2509, the team screened 600 of the most recent titles and abstracts (200 for each of the three research questions, to create a manageable amount of material within the resources for the study; and on the premise that the most recent material was most relevant science). From the 600 most recent titles and abstracts screened 70 were deemed of potential relevance and reviewed as full texts. From these full texts 53[1] publications were selected for inclusion, in this final review.

Search terms for the research questions and bibliography of included sources can be found in Annex 1 and Annex 2.

2.2 Grey literature method

To search for and extract the most relevant grey literature the following steps were taken: searching for publications using set keywords and databases; screening of search results and exclusion of less relevant literature; and, extraction and review of remaining documents. The grey literature search process was a more fluid and dynamic process, where hand searching was also utilised to find the most relevant sources.

A total of 20645 search hits were retrieved and saved for D. From the 192 results identified as potential sources and saved in the study library, 123 were excluded based on the relevance to Objective D research questions. Following this, 69 results were extracted fully. An additional 50 publications were then excluded based on inclusion/exclusion criteria, quality of evidence and relevant to the research questions. Supplementary searches were conducted and/or articles recommended by experts during the workshops: these were looked at and four additional relevant references proposed by external experts were included.

The full grey literature searching and extraction methodology is outlined in Annex 4.

[1] The full list of references included from the peer-reviewed literature can be found in Annex 3 and includes one additional publication recommended by the external expert review panel

3 Findings and discussion

The findings are presented in response to each research question, with subsections relating to different themes and illustrated by relevant findings from the peer-reviewed literature review and the grey literature review. For question one, these relate to the different levels of the social ecological model described above – but few variables were identified relating to institutional or organisation level. These were restricted to variables with child obesity. Not all themes emerged in the same way in the two reviews and as a consequence, analysis from either review is presented in the order that best exemplifies the findings.

Where definitions for overweight, obesity and physical (in)activity were given, these are noted in the text. The grey literature was not always specific in how it used those terms, nor the ages that were associated with the terms 'child' or 'adolescent.' Indeed, the conclusions presented in the grey literature tended to be more general than those of peer-reviewed studies although specific information is presented where possible. A summary of key messages for each research question is presented first for ease of understanding.

3.1 Research Question 1: What factors are associated with overweight, obesity and physical (in) activity?

3.1.1 Summary of key Findings

There is a wide variety of variables associated with overweight and obesity and physical (in)activity in children, adolescents and adults. Some key highlights from this section:

- Individual factors that are associated with overweight and obesity among children include:
  - Genetic factors
  - High birthweight
  - Unhealthy diet
  - Physical inactivity
- Short sleep duration is associated with child overweight and obesity but the nature of the association requires further investigation.
- Interpersonal factors that are associated with overweight and obesity among children are:
  - Maternal pre-pregnancy overweight or obesity
  - Maternal smoking or prenatal tobacco exposure or prenatal tobacco exposure
  - Excess maternal weight gain in pregnancy
  - Breastfeeding,
  - Authoritative parenting
  - Modelling healthy behaviours
- At an institutional level, in the school setting, physical activity opportunities and healthy foods/beverages may be important for preventing obesity and increasing physical activity.
- Community-level factors such as access to stores where healthy foods are available or land mix of neighbourhoods show some evidence of being associated with obesity (either positively or inversely) but findings are inconsistent.

Adult overweight and obesity

- Rapid weight gain and early adiposity rebound are positively associated with adult overweight and obesity.
- Maternal BMI and maternal weight gain during pregnancy both have strong positive associations with adult overweight and obesity.
- Maternal smoking has weak-moderate association with increased risk of adult overweight and obesity.

Child and adolescent physical (in)activity

- Physical (in)activity and sedentary behaviour among children and adolescents is associated with age, gender and socio-economic status.
- Parental behaviours (parental levels of inactivity, modelling of TV watching) may have associations with child (in)activity at different ages but the evidence is not conclusive.
- Among children and adolescents, there was evidence of positive associations between environmental factors and physical activity. These include: teacher SES, specific school types, school facilities for physical activity, neighborhood facilities for physical activity and traffic safety.

Adult physical (in)activity

- Socio-economic status (particularly educational attainment) was also found to be associated with physical activity levels in adults, but the relationship is non-linear.
- Being married/co-habiting is associated with more, and having children is associated with less, sedentary time.

The factors that impact or influence overweight, obesity, and physical inactivity are abundant and complex. The factors range from genetic influences, familial environment, behaviour and conditions, and the external environment and represent the multiple levels of influence illustrated in the social ecological model of health. Factors associated with child and adolescent obesity and adult obesity are discussed separately; and the same for physical activity.

3.1.2 Factors associated with obesity and overweight in children and adolescents

Individual-level correlates of child and adolescent obesity

The peer-reviewed and grey literature identified the following individual-level factors associated with obesity in children and adolescents: genetics, birthweight, nutrition, socio-economic status, ethnicity, sleep, and physical (in)activity.

Genetic factors

While genetic factors account for small effect sizes, they are strongly associated with obesity in children. We found review and meta-analysis evidence, including systematic review evidence, of the strong association between genetic factors and child overweight or obesity.(Liu et al. 2013, Silvertoinen et al.2011, Choquet and Meyre 2011). A systematic review and meta-analysis of international twin and adoption studies by Silventoinen et al. (2010) found that among children genetic factors had a consistently strong association with higher body mass index (BMI)[2] no matter the age of the child.

[2] Their review included nine twin and five adoption studies tracking youth up to age 18 and were based in the United Kingdom, the U.S., Canada, Denmark and Korea. The number of families followed within each study ranged from 140

The evidence for particular responsible gene markers is a growing field of research. Liu et al.'s (2013) systematic review and meta-analysis of 23 international studies, published between 2007 and 2013, revealed that the odds of being overweight or obese was 35% higher among those participants (aged from six to 17 years) with the FTO gene variant (Odds Ratio= 1.35 p<0.001).

One explanation (among many possible) for this put forward by Choquet and Meyre (2011), in their overview of lessons learned from fifteen years in the field of genes and obesity research, is that gene variants are also associated with decreased satiety and/or increased feelings of hunger among children. Silvertoinen et al. emphasise that this genetic effect on obesity is not independent of health behaviour but is likely to involve a complex relationship between genetics, behaviour and environment.

Birthweight

Evidence suggests that there is a strong positive association between birthweight and childhood overweight and obesity. We found evidence of this association in both the peer-reviewed evidence (Kapral et al. 2017, Weng et al. 2012, Rooney et al.2011) and the grey literature, which included a technical report from a Scottish national study (Parkes et al. 2012) and a WHO review (Branca et al. 2007). Six of seven studies included in the systematic review and meta-analysis by Weng et al (2012), of risk factors for childhood overweight identifiable during infancy, found the association between high birthweight and overweight later in childhood was significant and strong. In a linear and logistic analysis of birthweight and obesity in later childhood Kapral et al. (2017) evaluated data from 10,186 term- or preterm children in the Early Childhood Longitudinal Study-Kindergarten Cohort 2011. They found significant relationships for higher birthweight (HBW) term children and large-for-gestational age (LGA) pre-term children and later obesity[3], from kindergarten-to-second grade, compared with children classed as normal birth weight at term.

A birth cohort study by Rooney et al. (2011) found that birthweight was a key predictor of child obesity (age 4 or 5). Predictors for obesity at three different developmental points (childhood, adolescence and adulthood) were investigated among a cohort of 777 children by following mothers before pregnancy and 10-15 years later. Birthweight was not the main predictor of obesity in adolescence (age 9-14) but was significant again at early adulthood (19-20 years old).

In the grey literature, a 2012 Scottish Government report from the Growing Up in Scotland (GUS) study (Parkes et al. 2012) found a strong, statistically significant positive association between greater birthweight and being either overweight or obese at age six[4]. Greater birthweight values were strongly positively associated with being overweight or obese (p< 0.001) but the association was weaker between greater birthweight and being obese (<0.1). When all potentially mediating factors (individual, parental and neighbourhood-level) were examined simultaneously as part of a multivariate modelling analysis, the strong positive association with higher birthweight still emerged. Branca et al. (2007) in a review for WHO of the challenge of obesity in the European region, also found that higher birthweight was associated with overweight status later in childhood in cohorts born in Iceland, in 1988 and 1994. Children who weighed above the 85th percentile at birth were more likely than others to be overweight at ages 6, 9 and 15 years.

to 375. Obesity was measured using the z-scores, a measure of relative weight adjusted or age and gender in children and adolescents aged 5-19 years, http://www.who.int/mediacentre/factsheets/fs311/en/.

[3] Measured as higher BMI z-score,

[4] The study uses the term 'overweight' to include all children at or above the 85th BMI percentile (including those classed as obese or morbidly obese) and 'obese' to include all children at or above the 95th percentile (including those who are morbidly obese). Birthweights were standardised for gender and length of gestation.

Nutritional behaviours

The impact of different nutritional behaviours on weight is a well-researched area. Two of the reviews in this series consider aspects of this in more detail[5], on the exact relationship between SSBs and high-fructose corn syrup with body weight. These should be consulted for more information. Here we focus on the broad evidence that emerged from our included sources for these broader research questions relating to children.

Individual level nutritional behaviours such as unhealthy eating patterns are positively associated with obesity. In a non-exhaustive review of epidemiologic evidence published within the last decade, Hruby and Hu (2015) state that overweight and obesity are generally positively associated with unrestricted access to food. The purpose of the review was to examine the extent of the obesity epidemic and its risk factors. The factors they identified as positively associated with overweight and obesity were: overall caloric intake; increasing intake of potato chips and potatoes, sugar-sweetened beverages (SSB), and processed and unprocessed red meats. The authors found caloric restriction (adhering to *any* diet) and intake of vegetables, fruits, whole grains, nuts, and yogurt; were negatively associated with overweight and obesity.

Breakfast may not be protective against excess adiposity but does not increase it. Blondin et al (2016) reviewed 12 studies looking specifically at breakfast consumption and excess adiposity in children and adolescents. While the authors concluded that the evidence is inconclusive whether breakfast is protective against excess adiposity, their review revealed that 10 of the studies did show such an effect. Additionally, they found that none of the studies found that breakfast was associated with increased adiposity. Previously, Rampersaud et al. (2005) found that in 16 of the 47 studies they reviewed on breakfast consumption, children who reported eating breakfast on a consistent basis were less likely to be overweight.

Fruit juice consumption is not positively associated with weight/BMI; however, consumption of SSB is positively associated with weight/BMI. Both primary research by Vågstrad, et al. (2009) and a systematic review by Crowe White et al. (2016), found that there was no association between fruit juice[6] consumption and weight/BMI. Vågstrand, et al. (2009.) examined the relationship between BMI and fruit juice consumption among Swedish adolescents (N=481). The authors did not find an association and hypothesise this could be because adolescents replace beverage consumption, particularly fruit juice, with meals/food. Crowe White et al. (2016) reviewed 22 studies published between 1995 and 2013 and focused on intake of 100% fruit juice and weight status of children between the ages of 1 and 18 years. After controlling for energy intake, the authors did not find any evidence of an association between weight status and 100% fruit juice consumption.

In contrast, positive associations between SSB consumption and body fat and/or weight were found. Papandreou et al. (2013) found that children and adolescents aged 7 to 15 years (N=607) in schools in Thessaloniki, Greece, who consumed SSBs, were 2.57 times more likely to become obese than their peers who did not consume SSBs. Consumption was measured using a 24-hour recall technique over three days, measuring body weight by a digital scale. The authors found no such association with 100% fruit juices and milk; they contrast SSB's "extra empty calories" and "no nutritional benefit" with the former (Papandreou et al., 2013).

[5] B2 and B3,

[6] No definition provided for what author considered fruit juice.

Ethnicity

Risk of obesity can vary with ethnicity but it is likely other variables present explain this variation. Gurnani et al. (2015) indicated that members of certain ethnic minorities (aboriginal, Hispanic, and South Asian) are more prone to obesity, in addition to children in low-income neighbourhoods and those in urban areas. In the grey literature, a recent update briefing from Public Health England (2016) on the National Child Measurement Programme (NCMP) found that among the million children aged four to five years (Reception year) and 10-11 years (Year Six), children in Black African communities were at higher risk (compared to the English national average) of being overweight or obese: 31.2% of children in Reception and 45.9% of children in Year Six (compared to 22.1% and 34.2% respectively). Among children from Indian backgrounds, obesity levels were lowest at 14.5% of children in Reception but higher than average in children in Year Six at 36.3%. A WHO working group evidence review (WHO 2016) found that in the USA there was higher prevalence of obesity among children from Hispanic (22.4%) and non-Hispanic black (20.2%) communities compared with white children (14.1%).

The grey literature suggested different reasons for this effect, which indicate that ethnicity may not be the dominating risk factor. Loring and Robertson (2014) found that childhood obesity among immigrant groups in Germany was due to socio-economic and environmental reasons including lower maternal education and excess television viewing. WHO (2016) attributed ethnic differences in rates of childhood obesity in high-income countries to maternal obesity. They establish this on the basis that pre-pregnancy obesity is more common among non-Hispanic black and Hispanic women, compared with non-Hispanic white women in the USA; non-European migrants compared with European migrants in Netherlands; and among black and south-Asian women (using an Asian-specific BMI criterion) compared with white women in the United Kingdom.

Sleep duration

Short sleep duration is associated with obesity but the exact nature of this association requires further investigation. We found meta-analysis (Cappuccio et al. 2008) systematic review (Patel and Hu 2008) and review evidence (Golem at al. 2014) of an association between short sleep duration and obesity. Cappuccio et al (2008) conducted a meta-analysis of studies looking at the effect of short sleep duration and obesity. They found a significant association between short sleep duration (less than 10 hours) and obesity in adolescents. The odds ratio of obesity to short sleep duration at 1.89 (1.46 to 2.43), was higher (though not statistically different) than that for adults which was 1.55 (1.43 to 1.68).Patel and Hu's systematic review found consistent evidence from 11 international cross-sectional studies (from 1992 to 2006) and two cohort studies (from 2004 and 2006) of this association between short sleep duration and obesity for children. Differences in study design, particularly whether sleep was investigated as a cause or consequence of obesity and the definition of short sleep duration prevent further analysis of this association. Golem et al' also reviewed 17 cross-sectional studies as part of a review and found that this association between short sleep duration (multiple definitions) and elevated weight status is found in different international settings and is not unique to one culture.

Physical (in)activity

Physical activity is negatively associated with obesity, particularly moderate-to-vigorous intensity activity. A systematic review and analysis by Janssen and Leblanc (2010) examined the evidence on the association between physical activity and health

outcomes among children and adolescents. In an analysis of the 25 different intervention studies they reviewed, the authors found that the odds of being obese was 33% higher in the least active group compared with the most active one.[7] The studies used a variety of measures of physical activity including self-report questionnaires, parent surveys, pedometers, accelerometry and cardiorespiratory fitness/physical fitness.[8] Janssen and LeBlanc also noted that relationships between physical activity and obesity were strongest and most consistent when moderate-to-vigorous physical activity was used as the measure of physical activity.

In the grey literature, the GUS study (Parker al. 2012) found no significant relationship between the weight of children in their sweep 6 birth cohort and two factors relating to activity, i.e., meeting the recommended guidelines of 60 minutes or more of physical activity per day and sedentary behaviour indicated by screen time of three or more hours per day. This was still found to be the case after more sensitive analyses excluding school physical activity and extended weekend screen time. The authors cite other studies which did find a link between physical activity and obesity in children and this link is generally accepted; the methodological limitations of relying on parental self-report for children's physical activity measures may explain this discrepancy.

Interpersonal correlates of child and adolescent obesity

A number of factors in an individual's immediate environment can influence obesity and obesity-related behaviours, particularly the home environment, parent behaviours and close family/personal relationships. These findings are discussed below.

Parental health behaviours play a major role in children's risk for obesity particularly during gestation and infancy. We found peer-reviewed review evidence (Brisbois et al. 2012, Baidal et al.2016, Weng et al.2012) and grey literature (Parkes et al.2012) reporting that different parental factors (maternal or fraternal) during gestation and infancy can increase the risk of overweight or obesity in children, e.g.:

- Maternal pre-pregnancy overweight or obesity
- Maternal smoking or pre-natal tobacco exposure or pre-natal tobacco exposure
- Excess maternal weight gain in pregnancy

In their systematic review and meta-analysis, Weng et al (2012) found that maternal pre-pregnancy overweight, and maternal smoking in pregnancy increase the likelihood of childhood overweight. One of the studies in the review was Dubois & Girard (2006), in which maternal smoking or high maternal BMI (overweight or obese) (as well as rapidly gaining weight in the first five months of life) was shown to increase the risk of childhood overweight. For their study, the authors analysed data from the Quebec Longitudinal Study of child Development (1988-2002) and which included a sample of 1550 children aged four and a half years. Results from their analysis showed that having a mother who smoked during pregnancy and having a mother who was overweight or obese all increased the risk of overweight by the age of four years.

[7] Their review included 86 articles, 56 of which included outcomes related to obesity, of which 31 were observational (cross-sectional, prospective cohort, case control or mixed) and 25 intervention studies. The studies involved samples of children and adolescents aged 6-19 from the U.S., Mexico, Canada, China, Portugal, Finland, Spain, Brazil, Europe (12 countries), Australia and Greece.

[8] According to the Centers for Disease Control and Prevention, physical fitness is, "The ability to carry out daily tasks with vigor and alertness, without undue fatigue, and with ample energy to enjoy leisure-time pursuits and respond to emergencies. Physical fitness includes a number of components consisting of cardiorespiratory endurance (aerobic power), skeletal muscle endurance, skeletal muscle strength, skeletal muscle power, flexibility, balance, speed of movement, reaction time, and body composition." https://www.cdc.gov/physicalactivity/basics/glossary/

Baidal et al. (2016) also found that (alongside high birthweight) high maternal BMI pre-pregnancy, excess maternal weight gain in pregnancy, pre-natal tobacco exposure, and rapid weight gain in infancy were consistently associated with childhood obesity. Their review of 282 studies (prospective cohort studies with children between 6 months and 18 years of age) also found evidence to suggest that gestational diabetes, early introduction of solid foods (before four months of age) and less strong mother-infant bonding could be risk factors for child obesity (measured between age six months and 18 years) , although this was not consistent across the studies reviewed.

In the grey literature, Parkes et al's GUS report (2012) identified a number of statistically significant associations between individual parental factors in infancy and children's overweight and/or obesity at age six. These included: maternal overweight or obesity, maternal smoking during pregnancy (measured during sweep one), and poor maternal physical health (ages one, three and five years).

Breastfeeding may have a moderate protective effect on children's weight. In a systematic review and meta-analysis of 25 international studies from 12 countries[9], Yan et al. (2014) found that obesity risk[10] is lower among children who were breastfed. The authors used data about feeding patterns in the first year of life (i.e., formula fed, breastfed, partially breast fed)[11] and weight status. Results from the meta-analysis showed that among children who were breastfed the risk of childhood obesity was 22% lower than those who were not. In addition, the authors noted a dose-response effect as children who were breastfed for seven months or more had a lower risk of obesity than those who were breast fed for a shorter amount of time and the protective effect gradually decreased as the length of time a child was breastfed decreased. Weng et al. (2012) also found breastfeeding[12] during first year of life had a moderate protective effect against childhood overweight.

Authoritative parenting is positively associated with healthy dietary behaviours and negatively associated with child BMI. A systematic review by Berge et al. (2009) found that authoritative parenting style (high levels of demandingness, high levels of responsiveness) was positively associated with the child consumption of fruits, vegetables and dairy products, lower consumption of sugar-sweetened beverages, higher levels of physical activity and negatively associated with BMI. 81 articles published between 2000 and 2008 were reviewed to assess familial correlates of obesity among children and adolescents[13], thirteen of which assessed the association of parenting style and obesity. The authors examined associations between authoritative[14], authoritarian, permissive and neglectful parenting styles and BMI, physical activity and dietary behaviour. They also found that authoritarian and neglectful parenting styles were associated with positive outcomes as findings indicated a negative association with BMI and negatively associated with physical activity and fruit/vegetables consumption. Van der Horst et al.'s (2007) systematic review examining correlates of dietary behaviour found a positive association between controlling or restrictive parenting practices surrounding food and obesity. In their

[9] Countries where the studies included in the meta-analysis took place: Germany (n=5), United States (n=5), Great Britain, (n=3), Australia (n=3), China (n=2), Japan (n=1), Ireland (n=1), Greece (n=1), Brazil (n=1), the Netherlands (n=1), Czechoslovakia (n=1) and Canada (n=1). Ten studies were cross-sectional and 15 were cohort studies.

[10] Measured at ages one to 18 years across the included studies.

[11] Different studies looked at feeding patterns at different points up to age 12 months.

[12] Children who were 'ever breast fed' included those who exclusively breastfed, ever breast fed, or fed a mixture of breast and formula milk during first year of life.

[13] No information regarding the countries where the studies took place was readily available.

[14] An authoritative parenting style balances high levels of demandingness and high levels of responsiveness; an authoritarian parenting style exhibits high levels of demandingness with low levels of responsiveness; a permissive parent expresses low levels of demandingness and high levels of responsiveness; and a neglectful parent exhibits low levels of demandingness and responsiveness.

review of 58 studies focused on youth aged three to 18 years[15], both of the two studies examining parenting style and dietary behaviour found that an authoritative style was associated with greater fruit and vegetable consumption.

More broadly, nutritional and physical activity practices modelled or permitted by parents have an impact on the weight of their children.

Van der Horst et al.'s 2007 review also identified the role of parental modelling around fruit and vegetable consumption in positively influence children's behaviour, and their encouragement to be an important factor in children's consumption. The authors found an inverse relationship for energy intake with encouragement, offering assistance and giving prompts to increase intake during meals. Berge (2009) also noted the parents who had regular family meals had children with a lower BMI and healthier dietary intake.

In the grey literature, Parkes et al. found that alongside the parental influences described above, the following factors had a significantly strong relationship with overweight or obesity age six:

- nutritional practices of children (as controlled/permitted by parents): eating the main meal in a room without a dining area (ages two and five years); Skipping breakfast (age five years); use of a local takeaway restaurant (age six years);
- sedentary behaviour (as controlled/permitted by parents): TV in child's bedroom (ages four and five years); Screen time (ages four to six years); and low levels of parental supervision.

Parental low socio-economic status and educational attainment is associated with increased risk for overweight/obesity and related health behaviours in their children. In their secondary analysis of six cross-sectional European datasets[16] to examine overweight and obesity among pre-schoolers four to seven years of age, Van Stralen et al. (2012) found an association between low parental SES (measured by parental education level) and child overweight.

In the grey literature, a WHO (2017a) a report analysing trend data from the European cross-national Health Behaviour in School-aged Children (HBSC) survey (from 2002 to 2014) found that obesity among European adolescents attributable to household socioeconomic inequalities rose from 18% in 2002 to 22% in 2014. Adjusting for any other. factors, Parkes et al (2012) found a significant association between lower maternal educational attainment and other family constraints and a child being overweight or obese at age six years**.** These included: the absence of a biological father in a household; low average household income (bottom 40% for Scotland) at ages one to five years (only significant for percentage of obese children); and whether the cost of food affected their mother's ability to prepare food (significant at age five years but not age two years). Data from the English NCMP 2013/14 wave reported in Health and Social Care Information Centre (HSCIC) 2015 found that boys and girls from the lowest quintiles (22 and 21 %) were most likely to be obese, compared to boys and girls from the highest quintile (seven and six % respectively). Mean BMI varied from 17.4 for boys and 17.5 for girls in the highest income quintiles rising to 18.7 and 19.2 respectively in the lowest income quintile.

The direction of association between different aspects of socioeconomic status and obesity in children can vary according to national context Hruby and Hu's (2015) review of epidemiological evidence on obesity published within the last decade found that although wealth has historically been positively associated with obesity, this link has reversed in high income countries . Those who are at or below the level of poverty

[15] Studies included in the review took place in North America, Europe, Oceania and Asia and were published between 1980 and 2004.

[16] Belgium (N=1,434); Bulgaria (N=726); Germany (N=2,956); Greece (N=708); Poland (N=375); Spain (N=273)

appearing to have the highest rates of obesity. Higher education seems to play a protective role in high income and transitioning countries.

Family dynamics and sibling behaviour can also influence weight status. De Vet et.al's (2011) review identified family cohesion as an important factor related to dietary behavior in adolescents. Siblings appear to also influence weight status as well. Berge's (2009) systematic review of articles published between 2000 and 2008 that assessed familial correlates of child and adolescent obesity found sibling weight teasing to significantly impact emotional and physical health. Van der Horst et al.'s (2007) review also identified sibling consumption to correlate with dietary behaviour.

Institutional and organizational level correlates of child and adolescent obesity

In contrast to individual and interpersonal factors, our review found limited evidence in the peer reviewed literature relating to associations between different settings and child obesity. No evidence was identified in the grey literature. The settings noted in the limited evidence identified were in the school setting.

School opportunities show evidence of effective physical activity but the role of the school environment is inconclusive. In a study by Drake et al. (2012) the authors examined the influence of physical education, sports and active commuting on weight status among a sample of 1718 adolescents aged eight to 12 years in the U.S. Adolescents were surveyed about their sports team participation, hours of physical education classes, extracurricular activities and commute to school as well as self-reported height and weight. The authors found a negative association between sports team participation (> two teams versus zero), active commuting (> three and a half days versus zero) and overweight and obesity[17] but no association between levels of physical education and overweight or obesity.

Katz et al. (2008) found that school-based nutrition and physical activity interventions resulted in significant reductions in weight, particularly when both physical activity and nutrition interventions were implemented together. They conducted a systematic review and meta-analysis of 19 different international school-based obesity prevention approaches.[18]

Community level factors in child and adolescent obesity

Associations between the food environment and obesity were found in some studies but not all. In a 2014 study by Cetateanu et al. (2014), the authors examined the relationship between food environments, deprivation and childhood obesity in England, finding a significant positive association between fast food density and obesity. Data from the National Child Measurement Programme (NCMP) was used for the study focusing on data collected in 2007-08 and 2009-2010. The study focused on children four or five years old and 10 or 11 years old with an average of 186 four-five year olds and 192 10-11 year per Middle Super Output Area (MSOA).[19] Weight status was recorded at school and measures of the food environment where calculated using a geographic information system (GIS). Findings from Cetateanu et al.'s analysis showed significant positive associations between fast food density and child obesity; however, the relationship was strongest in the older age group (10-11 year olds). In examining the density of healthy food outlets, the authors found an association with prevalence of obesity.

[17] Defined as ≥85th percentile and ≥95th percentile respectively

[18] 21 sources representing 19 studies were included in the review. The studies were focused on assessing the impact of physical activity and/or nutrition interventions in elementary and middles schools in the U.S. (n=10), Thailand, England (n= two), Australia, Jerusalem, Greece, Chile, Taiwan and the United Kingdom. All studies measured BMI as the outcome except for three that used weight alone.

[19] "The MSOA is a UK Census geography designed for small-area statistical analyses (ONS, 2011) with an average population of 7500." (Cetetanua et al. 2014 p. 69)

Cobb et al., (2015) conducted a systematic review of the literature examining the relationship between the food environment and obesity. Twenty two of 71 included studies were of children. Fast food outlets, supermarkets or convenience stores were the elements of the food environment most commonly assessed using measured as counts or proximity. The authors found that the majority of studies did not find a significant association between the food environment and obesity overall. However, there was a significant positive association observed between fast food density/proximity and obesity among low income children.

Survey data in the grey literature indicates that higher levels of deprivation in the local environment correlate with obesity. Data from UK national surveys (HSCIC 2016, Keenan et al. 2011) looked at the NCMP in 2014/15 and identified a similar relationship to that described in the peer-reviewed Cetateanu et al. (2014). 12% children in Reception year (aged four or five years) in the most deprived areas were obese compared to six per cent in the least deprived areas. Among children in Year Six (aged 10 or 11 years) this rose to 25% of children in most deprived areas compared to 12% of children living in least deprived areas. This difference in obesity prevalence among children living in different levels of deprivation has increased over time; between the 2007/8 and 2014/15 waves of the NCMP, the difference between obesity prevalence among children aged four or five in the most and least deprived areas increased from 4.6 to 5.5 percentage points. Among children in Year Six between the same two waves the difference increased from 8.9 to 12.0 percentage points.

3.1.3 Factors associated with obesity and overweight in adults

Individual-level correlates of adult obesity

The peer-reviewed and grey literature identified a variety of individual-level factors associated with obesity in adults, many of which closely resembled those found for children and adolescents. The particular aspects of how they apply to adults are discussed below.

Birthweight

The evidence for an association between high birthweight and obesity is not conclusive for adults. We found evidence of a positive relationship between high birthweight and obesity in early adulthood from a systematic review and meta-analysis (Yu et al. 2011) and cohort study (Rooney et al.2011). Another systematic review and meta-analysis established a similar relationship between high birthweight and long-term overweight risk but did not specify this as obesity (Schellong 2012). As part of their systematic review Schellong et al. found that 94 of the 108 studies included (87%) reported a positive association between birthweight and later risk of overweight while only 7 studies (6.5%), reported no relation between birth weight and later risk of overweight. They subsequently conducted a meta-analysis of 66 studies from 26 countries and five continents, including 643,902 persons aged 1 to 75 years. This analysis found a significant positive relationship between birth weight and later overweight risk ($p<0.001$). Rooney et al. in their 2011 cohort study of 777 children found that higher birthweight was a main predictor of obesity in young adulthood (19-20 years) (Rooney et al.2011). However, in their systematic review of early markers of obesity Brisbois et al. (2011), found no clear conclusion for a positive association between higher birth weight and either higher adult BMI, overweight or obesity. While 25 studies they reviewed showed this positive association, 18 did not.

The relationship between birthweight and adult obesity may vary by gender but this is also not conclusive Jornayvaz et al (2016) looked at women and men in Switzerland and found associations between low and high birthweight and a lower likelihood to be normal weight as middle aged (35 – 75 years old) adults. Further, they found that high birthweight was associated with a greater propensity for abdominal obesity in adulthood. While they observed these findings for both women and men, the results were

statistically significant only for women. However, Curhan et al (1996) did find that high birthweight was associated with an increased risk of obesity in men.

Weight gain and obesity in early childhood

Rapid weight gain in early childhood, early adiposity rebound and childhood obesity may have strong associations with adult overweight or obesity A review by Brisbois et al. (2012) of potential early markers for adult obesity found a strong, consistent association between rapid weight gain in early childhood, early adiposity rebound[20] and childhood obesity with obesity later on in life. They considered 16 studies which explored child growth variables relating to children under 5 compared with adult cohorts aged 18-50. All of them except one found some association between rapid growth in early childhood and adult obesity. Two studies found this association for females only while others found it for both sexes. Among the large number of studies reviewed about childhood obesity (n=24) a consistently significant positive association was reported between childhood obesity aged less than 5 years old and adult overweight or obesity. Both Brisbois et al. (2012) and Small et al. (2007), highlight the adiposity rebound period during childhood as one of increased risk for the development of obesity. If a child is already overweight when adiposity rebound occurs or rapidly gains weight during this period, they have an increased risk of becoming obese (Small et al. 2007). Additionally, adiposity rebound occurring before the age of 5 years is also associated with an increased risk of adult obesity.(Brisbois et al. 2012)

Medical conditions

Medical conditions and medications can make it difficult to maintain a healthy weight for adults. In a clinical review of obesity prevalence and risk factors, Haslam et al. (2008) identified diabetes and polycystic ovarian syndrome (PCOS) as possible medical conditions that make it difficult to reduce one's weight. Additionally, they found that mental illnesses such as depression can make it difficult to maintain a healthy weight and the medication used to treat mental conditions may also contribute to overweight and obesity. This was reinforced by Gurnani et al. (2015) who identified antipsychotic and high dose glucocorticoids as particular medications that may contribute to obesity.

Nutritional behaviours

We acknowledge there is a large body of evidence relating to different eating patterns and their relationship with weight status. Therefore q we present here that the evidence which emerged from our included sources. As with children and adolescents, the relationship between certain nutritional behaviours and weight status is explored in further detail in two other reviews in this series, B2 and B3.

A similar positive association between increased SSB consumption and increased body fat and/or weight was found among adults. We found a systematic review and longitudinal evidence that established this association in adults (Malik et al. 2016, Funtikova et al. 2015). Malik et al. in a systematic review of research from 1966 to 2005 concluded that, though there remained a need for more research, "sufficient evidence" exists linking SSB consumption to weight gain and obesity.[21] Funtikova et al. (2015) conducted a longitudinal study in Girona, Spain that found an increase of 100 kcal of SSB consumption

[20] Adiposity rebound is defined by Brisbois et al as the' physiological milestone whereby child growth (BMI) reaches a minimum level (usually between 4 and 8 years of age), and then BMI starts to increase again.'Early adiposity rebound was classed as younger than 5 years of age by studies considered in this review. http://onlinelibrary.wiley.com/doi/10.1111/j.1467-789X.2011.00965.x/full

[21] From 264 results (from MEDLINE keyword and Medical Subject Headings (MeSH) searches) they reviewed 30 English-language studies of at least six months' duration that included at least one endpoint measurement of weight or body size. They avoided a quantitative meta-analysis, since the diversity of study designs (particularly between their samples and/or populations of interest) made useful comparisons difficult. Instead, they discussed common themes and gave particular attention to large cross-sectional (with over 10,000 participants), prospective cohort, and experimental studies.

was associated with a 1.1 cm increase in waist circumference among 2,181 Spanish men and women aged 25 to 74 years.[22] The authors also found that substitution of 100 kcals of SSBs with 100 kcal of milk was associated with a 1.3cm decrease in waist circumference and substitution with 100kcal of juice was associated with a 1.1 cm decrease in waist circumference.

The association between consumption of artificially sweetened beverages (ASB)/diet soda and body fat appears less well established. Evidence from two longitudinal studies (Fowler et al. 2015 and Ma et al. 2016) reported conflicting findings on the association between artificially sweetened beverages (ASB)/diet soda consumption and body fat. Fowler et al. were concerned strictly with the ASB consumption of an older (at least 65 years of age) cohort (n=749), reporting a mean change in waist circumference over the study period of almost three times as great among ASB consumers compared with non-consumers; among daily consumers, this increase was four times as great. By comparison, Ma et al. (2016) found a positive relationship between increased SSB consumption and body fat (visceral abdominal adipose tissue (VAT) ($p < 0.001$), but no relationship for ASB ($p=0.38$). As these two studies on ASB incorporated different outcome measures (waist size versus CT measurement of VAT) among different groups of people, they are presented to highlight the complexity of the relationship between ASB consumption and overweight and/or obesity, rather than make firm conclusions.

Socio-economic status

Socio-economic status was also highlighted as being an important determinant of weight for adults, but potentially affected by gender as well as national socio-economic influences. In our included grey literature findings we identified several sources including a review of reviews and survey data that found the association between socioeconomic status and obesity was stronger for women than men, and that national context may affect whether this association is positive or negative. (Aguirre et al. 2016, Health and Social Care Information Centre (HSCIC) 2016, HSCIC 2015,Loring and Robertson 2014, Keenan et al.2011, Robertson et al.2007) Robertson et al. (2007) found that over 20% of the obesity found among men and over 40% of the obesity found among women was attributable to inequalities in socio-economic status.[23] Loring and Robertson's (2014) report on obesity and inequities for WHO Regional Office for Europe found that people in lower socio-economic groups (SEGs) are getting heavier at a faster rate than those in higher SEGs, being more than two-thirds more likely to be obese; and that 50% of obesity in women is associated with low educational attainment.

A UK statistical analysis of Health Survey for England (HES) 2014/15 data (Health and Social Care Information Centre HSCIC) 2015, 2016)[24] found no relationship between having a lower income and higher mean BMI for men but found a stronger inverse association for women, with women in the lower income quintiles having a higher mean BMI and also higher waist circumferences. This pattern was also described in the Scottish Health Survey (Keenan et al. 2011) special report on obesity which in its analysis of data from the 2008, 2009 and 2010 surveys found that income was more strongly associated with obesity in women than men. The proportion of women with BMI>30 rose significantly as income

[22] The sample was randomly generated and population-based and studied in 2000 and 2009, with 2,181 individuals participating in both rounds of examination. Assessments comprised of waist circumference measurements and self-reports of diet via a food frequency questionnaire listing 166 food items.

[23] They conducted an evidence review for the European Commission of systematic reviews from 1997 to 2007 on obesity interventions (controlled and non-controlled studies).

[24] HSCIC 2016 updates some of the information in HSCIC 2015 but not all the same areas are covered. Both reports are therefore discussed, indicating where information appears in both or only one.

decreased, peaking in quintile four[25], whereas there was a much weaker association in men, with no clear pattern.

This particular impact on women was also emphasised in Aguirre et al.'s (2016) review (for WHO Regional Office for Europe) on determinants of health for women. They caution though that this gendered effect may not be evident across all EU Member States; they identified Eurostat data which found higher rates of overweight adults and children in the richest quintiles of eastern Europe.

Sleep duration

The relationship between short sleep duration and obesity in adults may be less conclusive than for children. Cappuccio et al (2008), in their meta-analysis of studies looking at the effect of short sleep duration and obesity, also found a significant association between short sleep duration (less than 6 hours) and obesity in adults. The odds ratio of obesity to short sleep duration was 1.55 (1.43 to 1.68). Patel and Hu (2008) in their systematic review of cross-sectional studies of the link between sleep duration and weight gain, did find the existence of an association between these variables for adults- there was a clear association found in 11 of 19 studies reviewed. However, they found the findings to be less consistent for adults than in the paediatric literature: the inconsistency in study design, the nature of the association being modelled and differences in definition of sleep duration led them to conclude that quantitative synthesis through meta-analysis was not possible.

Interpersonal factors in adult obesity

The association between some parental influences and obesity is maintained into adulthood. Of 42 variables that Brisbois et al. (2012) considered as part of their review of potential early markers of obesity, they found seven to have consistent relationships with adult obesity. Three maternal influences for adults had positive associations with adult obesity: maternal BMI (significantly positively associated with development of adult obesity in their children), maternal weight gain during pregnancy (strongly associated with higher adult BMI) and maternal smoking (weakly-to moderately associated with increasing risk of developing adult obesity for their children.) Father's lower employment status (taken as a proxy for SES, measured as type of employment).was also found to be associated with increased risk of adult obesity in offspring. More evidence was found for the association between maternal obesity and adult obesity and father's employment and adult obesity, but the associations identified in the studies relating to maternal smoking and maternal weight gain was still of a consistent nature. Rooney et al. (2011) also found that maternal smoking and maternal weight gain are main predictors of obesity in early adulthood (19 – 20 years). Across their review of predictors of obesity at three developmental points, Rooney et al. found that maternal obesity was the strongest predicator of obesity at all three points.

Community level factors in adult obesity

The variation in evidence for environmental influence on child obesity was also found in literature looking at adult obesity. Among disadvantaged groups (low SES, African ancestry, or Hispanic ethnicity) Lovasi et al. (2009), in a systematic review of 45 US studies (from 1995 to 2009), found consistent associations between a number of environmental correlates of obesity or related health behaviors and BMI. Studies examined the following environmental features: food environment (presence of supermarkets, convenience stores, restaurants and fast food) (n=20), walkability (n=10), places to exercise (parks and trails, sidewalks) (n=18), or aesthetics and safety (n=15). These environmental factors were assessed in relation to BMI, dietary intake (e.g., fruit and vegetable consumption) and/or physical activity among these groups. The review found

[25] Quintiles relate to Scottish Indices of Multiple Deprivation.

fairly consistent associations between lack of supermarkets and higher BMI within disadvantaged populations. In contrast, 47 of the 71 studies reviewed by Cobb et al. (2015) examining the relationship between the food environment and obesity relating to adults did not find a significant association between the food environment and obesity overall. However, there was a trend toward a negative association between supermarket proximity or density and adult obesity.

In the grey literature, data from UK national surveys (HSCIC 2016, Keenan et al. 2011) found obesity prevalence increased with the level of area deprivation but was only significant for women, thus mirroring the relationship between individual socioeconomic status and obesity. Thirty-three per cent of women surveyed in the Health Survey for England (HSE) 2014 who lived in the most deprived areas were obese compared to 22% of women living in the least deprived areas.[26] In the Scottish Health Survey (Keenan et al 2011) report on obesity, the proportion of women BMI>30 rose across deprivation quintiles. The proportion with BMI>30 was approximately 50% higher in the most deprived quintile than the least deprived quintile (33% vs. 19%). Men had a similar pattern but the increase was of a lower magnitude.

3.1.4 Factors associated with physical (in)activity in children and adolescents

Individual-level factors in child and adolescent physical (in)activity

The peer-reviewed and grey literature identified a variety of individual-level factors associated with physical activity. These included demographic and ethnic factors.

Demographic characteristics

Findings suggest that physical (in)activity and sedentary behaviour among children and adolescents is associated with age, gender and socio-economic status. Kopcakova et al. (2017), using data from the 2014/15 Health Behaviour in School-aged Children (HBSC) survey, found that younger adolescents, boys, and adolescents from families in higher socio-economic positions were more likely to meet physical activity recommendations. They also found that older adolescents and boys tend to participate in more excessive screen-based activities. They analysed data from 13,800 13 to 16-year-old school children (average age 14.4, 49.4% male) in four countries (Czech Republic, Germany, Poland, and Slovakia).

Ethnicity

The relationship between ethnicity and physical activity levels among children appears inconclusive and highly varied in the grey literature. Analysing data from the HES 2004, the UK National Obesity Observatory (Gatineau and Mathrani 2011) reported a wide variation in physical activity and dietary patterns in minority ethnic groups, but that there are particular issues affecting those of South Asian origin. The GUS study (Parkes et al op. cit.) found that children age six years from minority groups in Scotland were significantly less likely than their white counterparts to meet the recommended guidelines of 60 minutes physical activity per day ($p<0.001$) but given the very small sample of children from ethnic minority backgrounds within the birth cohort being measured(3% of total sample) , the strength of these findings is limited.

Interpersonal factors in child and adolescent physical (in)activity

Parental behaviours may have an association with child (in)activity at different ages but the evidence is not conclusive. Ferreira et al. (2007) conducted a systematic

[26] Based on UK Government's Department of Communities and Local Government Index of Multiple Deprivation quintiles.

review of 150 cross-sectional and longitudinal studies published between 1980 and 2004[27] to examine the environmental correlates of physical activity among youth. The authors examined a variety of environmental factors including those in the home environment. Considering parenting behaviour specifically, Ferriera et al. found evidence to suggest the father's physical activity behaviour is positively associated with child physical activity, whether the child is male or female. However, findings examining the influence of mother's physical activity was more often associated with girls' physical activity than boys'. Several studies included in the review assessed the influence of parent behaviour on future physical activity (prospective studies) and did not find an association but more research is needed.

In a 2015 systematic review of 37 studies from 1990-2014, examining sedentary behaviour and socio-economic status, Gebremariam et al. found that parental modelling regarding television viewing was an important correlate of children's viewing behaviour and was also correlated with socio-economic position. The studies included in the review were cross-sectional and longitudinal and included samples of children and adolescents between the ages of three and 17 from North American and Europe. Findings from the study indicate that parents of lower socio-economic position are more likely to model higher levels of TC viewing, more likely to spend time watching TV with their child and more likely to eat meals in front of the TV all of which increase total sedentary time.

De Vet et al. (2011) conducted a systematic review of 18 reviews representing 671 studies to identify environmental correlates of physical activity and diet among youth (children <12 years; adolescents >12 years). The authors found that parent modelling and support was not consistently associated with physical activity. However, the three reviews examining if child age moderated the relationship between parent physical activities/modelling and child physical activity all found that parent activity seemed to have a consistent association among children but not adolescents. With regard to parent modelling and dietary behaviour, de Vet al al. found consistent positive associations with child dietary behaviors across the reviews included in their synthesis. They also found modelling and parental monitoring to correlate with physical activity.

In the grey literature, Parkes et al (2012.) also analysed links between parental factors and physical activity levels (in terms of the recommended guidelines of 60 minutes or more per day) and screen time of children (interestingly, they found no significant association between maternal obesity levels and the physical activity behaviour of their children). For physical (in)activity, of the many different variables and influences they analysed, they found significant associations between:

- Maternal levels of physical activity (less than the recommended levels, longer screen time)[28]
- Less warmth in the mother-child relationship
- Maternal attitudes that less than 60 minutes per day? is sufficient activity for children.

Community level factors in child and adolescent physical (in)activity

Among children and adolescents, two reviews found evidence of positive associations between environmental factors and physical activity. De Vet et al.'s (2011.) systematic review of 18 reviews examined a variety of interpersonal (e.g., SES, family size, parental modeling, home environmental), school (school type [private versus public], school facilities, school location) and neighbourhood environment (SES, infrastructure, facilities, safety) factors, as well as climate and geographic location (e.g.,

[27] Studies were conducted with children aged 3-12 years and adolescents aged >12-18 years from North America, Europe and Oceania.

[28] This was measured at sweep 5

rural/urban) for their relationship with physical activities. The review found the following environmental factors as having consistent positive associations with physical activity among children and adolescents: teacher SES, specific school types (i.e. public schools, higher level schools), school facilities for physical activity, neighborhood facilities for physical activity and traffic safety. In addition, school and neighborhood level factors were more consistently related to physical activity than interpersonal factors, climate or geographic location.

Kopcakova et al. (2017.) in their review of HBSC data found that a higher perception of the environment as more activity-friendly was significantly associated with greater likelihood that adolescents meet the recommendations for the amount of daily physical activity in the four countries included. The perception of a more activity-friendly environment was also associated with lower odds of excessive screen-based activities. The perceived environment was measured using a five-item scale based on the European Youth Heart Study.

While the statistical bulletin did not speculate on reasons for this link, other grey literature looked at environmental factors which may have a negative impact on levels of physical activity. The GUS study (Parkes et al 2012.) found significant associations between children's physical (in)activity, their access to leisure facilities (green spaces and swimming pools),their length of daily screen time and both access to a garden and parent's rating of neighbourhood facilities. Children aged six who were active for less than 60 minutes a day (including school activity) were more likely to live in areas without playgrounds or parks ($p<0.05$) and without swimming pools ($p<0.01$). Children aged six who had weekday screen time of three hours or more: were less likely to have a garden ($p <0.001$); more likely to live in areas that their parents felt did not have good green spaces; had fewer safe places to play; and spaces that were less safe and child-friendly. ($p<0.001$). The methodological difficulties, in ensuring consistent understanding of terms and rating of local areas by parents makes these findings hard to replicate but they do illustrate how the local environment can potentially impact on the health behaviours of children.

3.1.5 Factors associated with physical (in)activity in adults

Individual-level factors in adult physical (in)activity

Socio-economic status (particularly educational attainment) was also found to be associated with physical activity levels in adults, but the relationship is non-linear. Aguirre et al (2016) reviewed Eurostat data that showed women in selected countries in the WHO Europe Region with only primary or lower-secondary education had lower rates of physical activity than those with higher levels of education. However they also found that women with tertiary education were less physically active than those with secondary, suggesting that this relationship is not straightforward. A WHO 2006 (Cavill et al. eds. 2006) literature review reports that this is because people with lower incomes have less free leisure time, poorer access to leisure facilities and living environments that do not support physical activity. This environmental aspect is discussed further below in the section on community-level factors.

Interpersonal factors in adult physical (in)activity

Social support has a positive influence on physical activity. In their national cross-sectional panel survey of U.S. adults (n=5,914) over a three-month period, Blanchard et al. (2005) measured the effect of weight, social support, self-efficacy, and access to workout facilities on physical activity. The authors found that the level of social support received by each weight group (healthy weight, overweight, obese) was similar and had a significant positive association with physical activity for all three weight groups. Results also showed that for normal weight and overweight individuals, as the level of social support increased, the number of days of physical activity engagement was greater if they reported higher

levels of self-efficacy. Self-efficacy was significantly lower in obese participants compared to the normal weight and overweight participant groups.

Being married/co-habiting is associated with more, and having children is associated with less, sedentary time. Wendel-Vos et al. (2007) reviewed 47 publications to identify determinants of physical activity in adults. Social support and having a companion for physical activity were found to be convincingly associated with different types of physical activity. O'Donoghue et al. (2016) conducted a review of 74 studies to identify determinants or correlates of physical inactivity (sedentary behaviors) among adults aged 18-65 years. A trend towards increased amounts of leisure screen time was identified in those married or cohabiting while having children resulted in less total sitting time.

Community level factors in adult physical (in)activity

There is some evidence that environmental access influences physical activity levels, however the relationship between varies in strength and measurement and by population group. De Bourdeaudhuij et al. (2005) conducted a cross-sectional study (N=526) in two cities, one in Portugal (n=526) and one in Belgium (n=279), to investigate the environmental and psychosocial variables in explaining physical activity levels of adults. Though there were differences in the two European cities, adults in both sites reported environmental factors, such as sidewalk availability, higher connectivity of streets, and higher residential density, as facilitators of walking or cycling for transportation, exercise, and recreation. Leisure-time physical activity was more related to the presence of recreational resources, either in the home or the community, as well as social support and social norms that increased the pleasure of physical activity during leisure-time for adults in both cities. De Bourdeaudhuij et al., also found that leisure time/ recreational physical activity was also associated with perceived benefits and barriers and self-efficacy.

Wendel-Vos et al.'s (2007) systematic review of 47 international articles on determinants of physical activity among adults found that access to trails was consistently associated with greater active commuting and access to physical activity equipment was consistently associated with vigorous activity. [29] Access, availability and convenience of recreational opportunities was also positively associated with physical activity and this relationship between the environment and physical activity did not differ by gender. Similar to other reviews however, the authors noted the literature included in the review presents limitations given that studies use a variety of environmental and behavioural measures to assess relationships, some of which are not validated, and much of the research was focused on cross-sectional designs.

In contrast to the associations described above, O'Donoghue et al. (2016) found inconsistent associations between sedentary behavior and the following environmental factors:

- Neighborhood SES;
- Highly walkable neighborhoods;
- Presence of aesthetic features in the environment;
- Close proximity/access to destinations or facilities; and
- Perception of a safe environment.

[29] Studies included in the review were conducted with adults 18 years or older and were based in the U.S. (n=23), Australia (n=12), Europe (n=6) Canada (n=3) and Indonesia (n=1). Across the studies included in the review, physical activity outcomes were assess as walking, general physical activity, moderate activity, vigorous activity, cycling and sedentary time. Environmental factors assessed in the studies included those in the physical environment (aesthetics, accessibility of facilities, availability of recreational facilities, urban sprawl, traffic volume/safety, or streetlights), socio-cultural environment (safety from crime, social support, unattended dogs), and economic environment (costs associated with physical activity, household income).

However, the authors did find that presence or proximity of green space was negatively associated with sedentary behavior; and weather, when reported as a barrier, was positively associated with sedentary behaviour. The authors noted that some of the inconsistency in findings across studies might be explained by the different measures of sedentary time, physical activity and environmental factors used.

3.1.6 Early warning indicators

From this wide overview of different factors associated with child and adult overweight, obesity and physical (in)activity, several appear to be more suitable for use as early warning indicators for obesity, because either they link childhood characteristics with adult obesity (e.g. early weight gain or early adiposity rebound) or a relationship with child obesity continues into adulthood. (maternal BMI and maternal smoking). As birthweight is only consistently associated with child rather than adult obesity, this has less value. There are fewer obvious candidates for predicting physical inactivity. This is discussed further in the next review question.

3.2 Research Question 2: What factors could be of use as early warning indicators of overweight and obesity (and physical inactivity) prevalence and trends?

3.2.1.1 Summary

- Little evidence was found in either the peer-reviewed or grey literature that answered this question directly – the concept of an 'early warning' indication system was not a common one.
- One interpretation of 'early warning', following the life-course conceptual framework, is that variables and measures of child overweight, obesity and physical (in)activity prevalence and trends might serve as providing indications of trends in the adult population yet to come.
- The grey literature on obesity surveillance, ideal and existing, suggests some variables which might be suitable for trend monitoring, but do not match variables identified as suitable for predicting adult obesity
- Determinants found to be predictors of adult obesity – maternal smoking and maternal BMI are potentially suitable indicators if measured nationally.
- Genetic variables have found to be unsuitable for measuring population health trends while the association between socioeconomic factors and ethnicity and obesity are not sufficiently closely associated to be suitable.
- We might also consider measures of overweight, obesity and physical (in)activity that can be measured using monitoring systems that provide more immediate, or 'early', data than official statistical returns (which often involve a time lag). The mechanisms for doing this are considered in relation to question three.
- These variables include BMI levels, adiposity rebound, nutritional and physical activity behaviour, and greater birthweight of children.
- Although the standard recommended measure, both the peer-reviewed and grey literature express some caution on suitability of using BMI as a way of measuring overweight and obesity, finding that it may produce false categorisations of obesity among athletic individuals; other measures of

overweight and obesity are considered instead.

- The lack of evidence dealing with the concept of 'early warning indicators' would appear to be a gap that would benefit from further research and analysis beyond the scope of this review.

Despite the extensive number of variables of overweight, obesity and physical (in)activity discussed above relating to research question one, and some literature which explored 'predictors' or 'early markers' of obesity, there was limited evidence in the peer-reviewed and grey literature that discussed which of these variables might work as 'early warning indicators'. We therefore approached these questions in different ways by (i) considering existing indicators of child obesity which might be understood (according to the life course model), to be strongly predictive of adult obesity and (ii) discussing measures which might provide 'early' information about obesity trends before release of official statistics. We did not identify literature that discussed which variables can be used to predict physical activity trends.

3.2.2 What are indicators?

A definition for indicators was provided in the grey literature. Drawing on lessons from the wider literature Vershuuren et al. (2014), in their chapter on monitoring health in Rechel and McKee's (eds.) book on public health in Europe, define indicators as "a concise definition of a concept meant to provide maximal information about an area of interest." (p.29). They stipulate therefore that indicators should:

- Provide a specific target action; and
- Do so in the most efficient way, using the "simplest possible numerical presentation, calculated from basic data, to give a robust view of the situation." (Vershuuren et al. 2014)

We concluded therefore that one way of understanding early warning indicators is via evidence of factors (variables or behaviours) with a concise numerical relationship with either child obesity or adult obesity whilst also suggesting a clear area for intervention.

3.2.3 Measures of child obesity and their suitability as early warning indicators

The peer reviewed literature considered that rapid growth or early adiposity rebound may be important predictors of future obesity among children. Brisbois et al found that the association between both rapid growth in infancy and early childhood and early adiposity rebound with adult obesity was a strong one – the review by Small et al (2007) also emphasised this association. Closely monitoring children's growth patterns during this period therefore may give parents and clinicians insight in to potential long term risks for children to develop obesity - this could be the target action of this indicator.

3.2.3.1 Existing health indicators and their suitability as early warning indicators

In the grey literature, the 2013 evaluation of the European Core Health Indicators (ECHI) (Public Health Evaluation and Impact Assessment 2013) found many health systems across Europe use descriptive indicators for monitoring and forecasting, rather than action-orientated indicators. These would therefore not necessarily require the specific target policy actions described by Vershuuren et al. (2014.). The ECHI, which were developed between 1997 and 2002, cover all areas of public health. The indicators relating to obesity and physical activity include BMI, fruit consumption; vegetable consumption; breastfeeding; physical activity levels and social support, all of which we have described above in relation to question one. The evaluation found that the indicators are general widely used across Europe suggesting that monitoring these behaviours among children (including levels of breastfeeding among their mothers) as early warning indicators of adult population trends might be accessible and achievable for European Member States.

NHS Health Scotland (Scottish Government 2016) introduced an Indicator Framework to measure the success of their Prevention of Obesity Route Map. Indicators are categorised as short-term, intermediate and long-term and include:

- Prevalence of adult overweight and obesity (measured by BMI);
- Prevalence of children at risk of overweight (including obesity);
- Prevalence of Type 2 Diabetes
- Total and saturated fat, added sugar consumption levels per household
- Adult and child physical and sedentary activity levels
- Volume of sales of soft drinks with added sugar; and confectionary biscuits, cakes and pastries
- Adult and child active travel to work and school

These indicators reflect the different levels of determinant discussed in question one, and relate to information already collected by national surveys and agencies in Scotland.

While useful for understanding current trends, from our review in question one however, it does not appear that any of these indicators can be used to predict adult obesity. They are therefore not suitable as early warning indicators.

3.2.3.2 Variables with adult obesity and their suitability as early warning indicators

Maternal BMI and maternal weight gain during pregnancy may be useful early warning indicators given their strong associations found with both child and adult obesity. Maternal BMI was highlighted by Brisbois et al. (2012) and Rooney et al. (2011) as key predictor of obesity in adulthood (although this was young adulthood for Rooney et al.). Brisbois et al. 2012 also found a strong association between maternal weight gain and obesity in adulthood. Both these variables can be captured as simple numerical figures (BMI or percentage weight gain) and suggest a key area for action – promoting good dietary and physical activity among pregnant women.

Maternal smoking may have a weaker association with adult obesity but would be easy to measure. Maternal smoking was also identified by both Brisbois et al and Rooney et al as a key predictor of adult obesity but Brisbois et al found that across studies they reviewed, the association was weak to moderate. Nevertheless, this is a health behaviour that can be measured easily and numerically (numbers of women smoking at birth).It is measured by at least one national surveillance systems e.g. Smoking Status at Time of Delivery collection in England,(SATOD).(NHS Digital 2017)

Genetic factors placing individuals at greater risk for obesity have been identified but do not seem to be an effective and efficient early warning indicator at this time. In their articles on genetic testing and predicting obesity, Ng and Bowden (2013) note that although genetic factors such as the FTO gene have shown significant associations with obesity, the effect is small and varies among populations with different ancestral histories (e.g., East Asians, South Asians, Europeans, Pima Indians, Hispanics, and African-Americans). They conclude that assessment of obesity-associated genetic factors could be useful in treating individuals but is not useful for predicting/assessing obesity at a population level.

The associations between other variables and child, adolescent and adult overweight and obesity are too complex to work as simple indicators. Given the different relationships found in high-, low- and mid-income countries with relation to socioeconomic factors and obesity, and the complicated relationship between ethnicity and obesity it would not appear that measuring these variables (that is levels of deprivation and size of different ethnic group populations) would serve as a straightforward indicators of potential obesity trends. However, gathering this demographic information among sufficient

sized samples whose obesity is being measured would allow further analysis of the links between these variables and obesity to be established.

3.2.3.3 Alternative understanding of 'early warning indicators' – information available earlier

The literature also suggested an alternative way of understanding early warning indicators – health monitoring information that is available more quickly or more sensitively than current national indicators.

BMI continues to be the standard for measuring obesity; however, more precise and more novel approaches could serve as early warning indicators for overweight and obesity. According to Gurnani et al. (op cit.), BMI and growth chart monitoring are recommended by the U.S. Obesity Task Force as screening tools for children 6 years and older; however, there is currently insufficient evidence for these screening tools for children younger than 6 years. The U.S. Preventive Service Task Force has also recommended the use of BMI to screen for obesity among adults (Yao 2013). Other methods have been used to assess adiposity given that BMI is not always an accurate measure of body fatness and obesity. Methods used to measure weight status include skinfold thickness, waist-to-height ratio (WTHR), waist circumference, waist-to-hip ratio and bioelectrical impedance analysis (Gurnani et al., 2015). A description of the different measures are provided in Table 2 below.

Table 2. Measures of Adiposity

Measure	Description
BMI	An index of weight to height calculated as a person's weight in kilograms divided by the square of height in meters. BMI of 30 or above is categorised as obese.
Skin-fold thickness	Assessment used to measure the percent of body fat with greater than 32% for women and greater than 25% for men placing an individual as obese.
Waist-to-height ratio	A measure calculated by dividing waist size by height, a ratio greater than 50% is overweight or obese.
Waist circumference	A waist circumference greater than 101 cm for men and 89 cm in women is associated with obesity/risk of developing obesity-related conditions.
Waist-to-hip ratio	An index calculated as the ratio of waist circumference to hip circumference. The index is broken down by age but in general, a ratio greater than .90 for men and .78 for women reflects high risk for obesity-related conditions.
Bioelectrical impedance	A measure that uses the flow of electrical current to assess percent of body fat given that fat and bone impede the flow of electric current.

Source: Gurnani et al 2015

As noted by researchers such as Etchison et al (2011), BMI may misrepresent weight status, particularly in athletic individuals. In their 2006 study of 33,896 student athlete data, the authors found that a higher percentage of the sample (13.1%) was defined as obese using BMI while six per cent were identified as obese when using skinfold thickness to determine percentage of body fat.

However, in the grey literature, a briefing paper on obesity and overweight surveillance from the National Obesity Observatory in England (Townsend 2009) argues that waist measurements are susceptible to the same criticisms about insensitivity to variations in body types, particularly among different ages and ethnicities. It argues that BMI remains the best measure of obesity for population surveillance, due to its ease and prevalence of use as well as the evidence base for the links between BMI and ill-health. Nonetheless, it suggests that adding waist measures to population weight monitoring, along with BMI, would enable more accurate description of trends with little difficulty or expense needed to do so. This is also empathised in the report from the Scottish Health Survey (Keenan et al2011.) with a special focus on obesity, which notes that combining BMI with waist circumference measures (the WHO have introduced such a combined measure) enables more accurate relative risks of type 2 diabetes, hypertension and CVD to be assessed. For example, people who have BMI of 25-30 but normal waist circumferences[30] have been found to have no increased risk, and those with normal BMI but very high waist circumferences[31] have been found to have an increased risk.

From our limited findings, rapid weight gain in infancy or early adiposity rebound; maternal BMI, maternal weight gain during pregnancy and maternal smoking appear to be most suitable for use as early warning indicators, However, -the lack of evidence dealing with the concept of 'early warning indicators' explicitly presents challenges for considering how these indicators might be used for monitoring. This is explored in the next section of this review.

3.2.4 Research Question 3: How could a feasible, effective and efficient early warning monitoring mechanism be put in place to keep track of these issues?

3.2.4.1 Summary

- Existing child health or obesity measurement systems give some insight into what is possible, but there was limited implementation detail available to assess their feasibility, effectiveness and efficiency objectively.
- Electronic health records (EHRs)/ electronic medical records (EMRs) can be a promising approach to monitoring obesity/risk for obesity at the population level, particularly given that height and weight are objectively measured and demographic data may be readily available to track risk in specific populations (e.g., low SES, pregnant women, minority groups, etc.).
- Developing systematic ways to collect physical activity holds promise including regular fitness assessments in schools.

Just as with the limited usage of the concept of 'early warning indicators' there was therefore limited explicit evidence on how an effective and efficient monitoring mechanism that uses such indicators could be implemented. However, in the sections below we highlight examples of existing surveillance and/or monitoring systems that have been implemented to track obesity/risk for obesity, and where available, the feasibility and effectiveness of such system. . It is important to note that this kind of implementation detail was not readily available in either the peer-reviewed literature or grey literature and did not discuss monitoring systems for predicting physical activity trends.

[30] Men WC <93cm, Women WC <81cm.

[31] Men WC > 102cm, Women > 89cm

As discussed, the analysis is framed by two different interpretations of 'early warning': one looking at how child overweight and obesity trends can be understood to provide insight into future adult trends. and the second, data that can be accessed more quickly than standard national population health survey monitoring;

3.2.4.2 Different types of monitoring mechanisms for obesity

The peer-reviewed literature distinguished between measures that can be used for screening (individual-level) or surveillance (population-level). A comparison using BMI as an indicator is provided in Table 3 below, reproduced from Longjohn et al. 2010.

Table 3. Comparison of Body Mass Index (BMI) Screening and BMI Surveillance

	BMI Screening	BMI Surveillance
Purpose	Clinical focus where an individual's BMI is measured and used to compare against benchmarks for diagnosis and treatment of obesity. If data is collected for BMI screening is done systematically and entered into a database, it could also be used for surveillance.	Public health focus where BMI reported at a population level can detect trends, disparities and causes when reported at the population level.
Approach to data collection	Routine screening of BMI during appointments with health providers. This practice is recommended by many professional medical organizations.	Can be either collected directly from individuals and aggregated or come from existing electronic medical records or similar databases (if data are easily aggregated and anonymised).
Benefits	Inexpensive, quick, non-invasive, sensitive screening tool to assess health risk at the individual level.	Associations and trends with environmental contexts (physical and/or social) can be examined. Surveillance data can also be used to evaluate the effects environmental and policy change aimed at addressing obesity prevention.
Limitation	Value of BMI in clinical setting is low in that it only informs weight status and possible risk for chronic disease if in the overweight or obese categories. accumulated	High-quality, representative data needed to track trends or use for the purposed of evaluation.

Source: Longjohn et al. 2010

3.2.4.3 Monitoring child obesity

For policy-makers, early warning indicators would be more effective as part of a surveillance system. We identified some limited evidence of types of surveillance that might be appropriate, but this was relating to the monitoring of child obesity in general rather than variables of obesity.

Monitoring height and weight/BMI or BMI percentiles in the clinical or school settings can be an effective and efficient mechanism to track child obesity and identify obesity risk. Fayter et al. (2007) conducted a review of 31 studies up to July 2005 to determine the clinical impact and cost-effectiveness of routinely monitoring growth (height and weight) in children between the ages of 4 and 11 years in order to identify growth-related conditions, including obesity. Reviewed studies were broadly representative of the U.K. population. Economic modelling based on the data from the studies included in the review indicated that growth monitoring increased detection of conditions such as obesity and was cost effective. This could potentially therefore be extended to include the measurement of rapid weight gain among infants and early childhood.

In the grey literature a WHO (2012.) report on population approaches to preventing child obesity suggests that monitoring and surveillance can be best achieved using population health surveys. The grey literature included details of several existing child obesity surveillance initiatives or health surveys which provide at least some limited insights into what a feasible monitoring mechanism might look like. In the main, the effectiveness and efficiency of these systems was not described in great detail – the details below focus on methodological considerations and resource use where noted.

European Child Obesity Surveillance Initiative (COSI)

This initiative was developed by the WHO Regional for Europe and is described in Wijnhoven et al. 2014 and the WHO regional Office for Europe website (WHO 2017b). The BMI prevalence and other nutritional and physical activity measures of children[32] aged 6.0-9.9 from countries across the WHO region was first collected in 2007/8 and the fourth wave of collection took place across the 2015/6 school year. Nationally representative samples[33] and standardised weight and height measurements are used, with measurements and analyses conducted according to common protocols. While it does not aim to replace national health, body measurement and dietary surveillance projects, it seeks to enable a harmonisation of data across the region in order to aid policy implementation and evaluation. Wijnhoven et al (2014) also note that, at least when it was introduced, child nutritional surveillance was not common across the Member States. Other grey literature (WHO 2012) highlighted that intercountry comparisons of obesity trends can be hindered by differences in BMI calculations so this standardisation process is to be welcomed.

Other useful elements of implementation detail include:

- Informed consent is gathered from parents for their child's voluntary enrolment in the system on either an opt-in or opt-out basis (depending on local sensitivities).
- Individual countries are also able to adapt the measurement period, professionals undertaking the measurement and language of data collection and administrative materials to their local circumstances.
- Materials do not refer to overweight or obesity prevalence.

[32] Including school and home environment factors: (school, mandatory).frequency of physical education lessons, availability of playgrounds, possibility of obtaining food and drink items on school premises, school healthy lifestyle initiatives; (School, optional) availability of safe routes to school, transport to school, availability of nutrition education or physical education in the curriculum, provisoin of school meals, availability of vending machines on school premises and the availability of fruit/vegetable/milk schemes; (home, voluntary) usual transport to school, membership of sport or dancing club, time outside and screen time, frequency of food consumption.

[33] For most countries except Belgium and Malta, where whole populations were measured

- In order to sign up to COSI, a Member state identifies a particular national institute to take on coordination responsibilities, and a principal investigator to serve as the institute's authorised COSI representative.
- Technical support with implementation is provided by the WHO Regional Office, with annual meetings held to share findings.
- According to WHO (undated) the COSI system does not consume many resources.

National Child Measurement Programme (NCMP,England)

The NCMP was established in 2005 and is administered by Public Health England (PHE) (PHE 2016). The heights and weights of more than one million children in Reception (aged four or five) and Year Six (aged 10 or 11) are taken each year, used to calculate their BMI and recorded alongside their names, dates of birth, sex, ethnicity, address and National Health Service (NHS) number. Guidance materials are provided to local authorities in England whose responsibility it is to engage with schools, where the measurement takes place.

Other useful details of implementation include:

- Explicit consent is not needed for children to take part in NCMP but local authorities are required to ensure parents have a full understanding of the importance of having their child measured and give them at least two weeks' notice of measurement as an opportunity to withdraw their children (template letters are available from PHE).
- Registered health professionals, nurses or dietitians must manage the arrangements of the programme, including training of staff, but measuring may be undertaken by healthcare assistants or staff of a similar grade (who are not registered).
- Standard equipment and a centralised IT system are used to record measurements.
- It is only mandatory for state-maintained primary and middle schools – home schooled children do not take part, while the participation of non-state-maintained and special schools is encouraged.

A longitudinal study of the NCMP by the London School of Hygiene and Tropical Medicine (reported in PHE 2016) found that 72% parents, after receiving NCMP feedback on their children's measurements, signalled their intention to change health-related behaviours and 55% reported a change in behaviour including an improved diet, less screen-time, less health service use and increased physical activity. This indicates that a surveillance system has the potential to act as intervention in itself (although the self-reporting methodology limits the strength of these findings).

The literature did not comment on whether measurement of early weight gain or early adiposity rebound could be incorporated into national monitoring mechanisms – this would benefit from wider discussion.

3.2.4.4 Monitoring other potential early warning indicators

There was limited evidence for how to establish an effective and efficient monitoring system of maternal level variables. We did not find examples of national population-level surveillance of maternal BMI or maternal weight gain during pregnancy, this appeared to be mainly done at an individual level. This is an area that would benefit from further exploration. However, in England maternal smoking is measured by the Smoking Status at Time of Delivery (SATOD) data collection.(NHS Digital 2017) Local health authorities are subject to a mandatory requirement to send through the following figures each quarter:

- Number of maternities (number of women giving birth at at least 24 weeks gestation)
- Number of women known to be smokers at the time of delivery
- Number of women known to be non-smokers at the time of delivery
- Number of women whose smoking status was not known at the time of delivery

Local health authorities are given the flexibility to decide on the mechanism for collecting and sharing SATOD data. Further details were not available for assessing whether this is an effective or efficient system; however – it does indicate that maternal smoking is something that could potentially be incorporated into any early warning monitoring mechanism – as good practice lessons could potentially be shared.

3.2.5 Systems enabling earlier access to information

Electronic medical record monitoring could serve as a real-time surveillance system for obesity trends at a community or local population level. Birken et al. (2017) used EMRALD, an electronic medical record database in Ontario, Canada, to examine the prevalence of overweight and obesity in children 0-19 years old for 167 participating family physicians. The authors abstracted the heights and weights for children having at least one well-child visit between January 2010 and December 2011 and used the most recent visit to determine those who were considered overweight and obese. Of the 20,083 well-child visits, 84.7% had a height and weight measurement. Rates of overweight and obesity ranged from 12.1%-31.8% and 2.3% to 12%, respectively. This study demonstrates that because of the high percentage of documented height and weight measurements, this approach to surveillance of overweight and obesity prevalence may be feasible. According to the authors, if this effort were to be scaled-up to include a larger sample of primary care providers, it could provide a close to real-time data source to conduct population-based surveillance of obesity in children.

Davidson et al., (2014) used electronic medical records from a network of urban 'federally qualified health centres' (FQHCs) in Denver, Colorado to examine BMI measurements in sequential outpatient visits over an eight year period to assess prevalence of overweight and obese children. They examined children aged 2-11 who had at least two visits over the study period. The authors used changes in BMI z-scores to assess change in weight over time. Of the 33,542 children who had at least two measurements, more than one third of children were overweight or obese. Seventy-five percent of these children stayed in same weight status category from first to last visit; however, 40% of obese children saw a decrease in their BMI z-score over the follow up period, and more obese children improved their weight status as compared to overweight or normal weight children. These trends would not be observed if the researchers only used the standard weight status categories and this approach provides a more precise method to monitor children's weight status trends. According to the authors, EHR data provide community-level BMI trends that may serve as an early warning system for obesity risk and eventual obesity-related costs.

These examples of health or obesity surveillance and monitoring programmes provide some useful details of how a monitoring mechanism might be administered and what is feasible. Further research into the concept of early warning indicators and how other variables might be incorporated into a monitoring mechanism is needed to fully answer this question.

3.3 Conclusion

There is a wide variety of variables that have been found to correlate with overweight, obesity and physical (in)activity, acting on different levels of the social ecological model (Figure 1). The strongest evidence has been found for individual and interpersonal factors such as birthweight, dietary and physical activity behaviours and parental (particularly maternal) weight status and socioeconomic status. However, sex, ethnicity and location of populations (in terms of national economic circumstances) may need to be taken into consideration. High levels of inconsistencies in measures used (e.g. objective versus subjective), for studying the relationship between overweight, obesity and physical (in)activity and community level factors, (e.g. enablers of healthy eating or physical activity in a neighbourhood) makes the evidence for associations at this level more complex. For example, there is a particular difficulty in generalising conclusions from studies that

measure neighbourhood determinants of physical (in)activity based on resident self-report of their perceptions, rather than number of facilities available. Methodological variation may explain why relationships found in the peer-reviewed literature differed in some cases with those reported in the grey literature or individual rather than review studies.

Due to the limited amount of evidence found relating to the concept of 'early warning indicators', it was not easy to identify suitable variables that might be used to give some indications of future changes in weight status. However, based on the strength of association with overweight and obesity in adulthood identified by the literature, we propose that the following be considered as potential population-level measures:

- early weight gain;
- early adiposity rebound;
- maternal BMI; and
- maternal weight gain during pregnancy.

Despite a weaker association, maternal smoking status may also be suitable as an indicator – this is measured by at least one national surveillance system.

While population health surveys have been recommended as the best monitoring mechanisms for obesity and obesity-related behaviours, other methods such as electronic health record monitoring may provide data at a quicker rate and give early indications of trends yet to be established by national-level statistics. Meanwhile, at a population level, existing child obesity surveillance initiatives provide some useful insights into how a feasible early warning monitoring mechanism could be established, but more evidence on their (cost) effectiveness is required. The feasibility of incorporating other potential early warning indicators such as maternal BMI, maternal weight gain during pregnancy and maternal smoking should also be explored in further primary research. Qualitative research methods or seeking expert advice may be the most suitable methodology for establishing effective best practice for implementation given the lack of research in both the current grey and peer-reviewed literature.

ANNEXES

Annex 1 Peer reviewed literature review methodology

This sub-section describes the approach taken between March 2016 and January 2018 to gather and synthesise the evidence.

A1.1 Research questions for this review

In this comprehensive review, current literature was gathered and synthesised, addressing objective D. This literature review provides a review of relevant, recent studies using the methodology presented below to summarise this topic. While the methods to conduct this comprehensive literature review are systematic it is not a systematic review. Note that unlike a systematic review, this review does not systematically analyse literature to identify *all* relevant published data and/or appraise its quality

To explore the above stated topics, the literature review was conducted around the following agreed upon questions.

- What factors are associated with overweight and obesity, and physical (in)activity?
- What factors could be of use as early warning indicators of overweight and obesity and physical (in)activity prevalence and trends?
- How could a feasible, effective and efficient early warning monitoring mechanism be put in place to keep track of these issues?

The methodology for the peer-reviewed literature is described in brief below, with greater detail on search terms provided in other Annexes.

A1.2 Peer-Reviewed Literature

Methods to conduct the literature review consisted of five steps: (1) refining the research questions, (2) developing a search approach and databases, (3) conducting literature searches (Stage 1 below), (4) screening articles for inclusion (Stage 2 below); and (5) abstracting and synthesizing relevant data (Stage 3 below).

In step 1, in partnership with DG SANTE the research questions above were confirmed. In step 2, the 3 stage approach noted below and databases were confirmed. To minimise bias, the literature search approach included identification of a priori search parameters (also considered first level inclusion and exclusion criteria) to guide searches and inform screening and selection processes for data inclusion. Steps 3, 4 and 5 followed the process below:

- Conduct searches and document results (Stage 1)
- Screening search results (title and abstract) for relevance (Stage 2)
- Review full publication and abstract key characteristics and study findings (Stage 3)

Searches were conducted in multiple databases and screened following the procedures below.

Following the literature review pilot, it was agreed to merge Stages 1 and 2.

A1.3 Stage 1: Conduct Searches and Document Results

In Stage 1, searches were conducted using search terms and criteria agreed with DG SANTE, with filters set for databases to ensure accurate inclusion and exclusion of literature, as shown in tables below. The search terms used were specific to each of the 3 research questions. Literature searches were conducted in PubMed, EBSCO (CINAHL, ERIC, PsycInfo) and Embase. Searches included publications with all availability types (i.e. free full text and pay/subscription access).

Table 1. Inclusion and Exclusion Criteria Applied at Stage 1

Set Database Filter to Include:	Set Database filters to exclude:
• Published between 1/1/2005-5/31/2016	• Articles published before 1/1/2005
• Peer-reviewed scientific publications - Original research - Systematic reviews - Meta-analyses - Human focused research	• Editorial comments/commentaries • Dissertations • Theses • Opinion articles
• Article published in English, French, German, Italian Polish and/or Spanish	• Article not published in English, French, German, Italian Polish and/or Spanish

In addition to reviewing studies in databases noted above, in order to help ensure inclusion of high quality literature (e.g., literature having gone through more formal quality assessments) systematic reviews and meta-analyses were reviewed for inclusion in the literature review. Searches for systematic reviews were conducted in Cochrane Review and healthevidence.org.

As noted a separate search was carried out for each research question, resulting in 3 groups of publications for screening for D. After the searches, the results were reviewed to ensure they accurately met search parameters and duplicates were removed for screening in Stage 2.

A1.4 Stage 2: Screening search results (title and abstract) for relevance

At stage 2, two screening levels were used: level 1 quality check and level 2 screening. Stage 2 screenings were done simultaneously. These screening inclusion and exclusion criteria are shown below.

A1.4.1 Stage 2 Level 1 Initial Screening (Quality check)

Search hits from all databases searched in Stage 1 were grouped by the 3 research questions and search terms to which they were related. Duplicate hits were deleted, and search hits by research question were organised from the most recent publications in 2016 going back in time to 2005, saved in an Excel file for that specific research question, and provided to reviewers for screening. These date parameters were agreed with DG SANTE as part of the pragmatic approach to managing the review material.

Using screening criteria in Table 1 reviewers screened the title and abstract of up to the first 200 hits per research question in each Excel file to identify literature to move forward for review. This was done to ensure the screening process was manageable given project timelines yet captured the most recent and relevant literature.[34]

A1.4.2 Stage 2 Level 2 Subsequent Screening

Simultaneous with the Level 1 initial screening check, more detailed overall inclusion and exclusion criteria were applied by the reviewers to the title and abstract to screen

[34] Results for each research question were screened separately, however, as screening took place, team members considered if articles might be relevant to other research questions, and if so, coded the article as such.

publications. These criteria, which were used for reviews of all objectives, are shown in Table 3 below under Level 2.

Table 2. Stage 2 Inclusion/Exclusion Criteria: Levels 1 and 2 Screening

Stage 2 – Level 1		
Category	**Inclusion Criteria**	**Exclusion Criteria**
Date	Published between 1/1/2005-5/31/2016[35]	Articles published before 1/1/2005
Publication Type	Peer-reviewed scientific publications - Original research - Systematic reviews - Meta-analyses - Human focused research	Editorial comments/commentaries Dissertations Theses Opinion articles Non-academic journal
Language	Article published in English, French, German, Italian Polish and/or Spanish	Articles in all other languages

Table 3. Overall screening criteria for stage 2

Stage 2 – Level 2		
Category	**Inclusion Criteria**	**Exclusion Criteria**
Geography	Studies conducted in America, Australia, Canada, European Countries, Great Britain, Mexico or Brazil	Studies in all other countries
Human subject	Human-focused research	Animal-focused research
Behavior/ Outcome	Studies specific to correlates of obesity Studies specific to correlates of physical (in)activity Studies specific to screening or surveillance of obesity and physical (in)activity	

[35] During screening, publications prior to 2005, and publications such as commentaries, dissertations or editorials were screened out, as were publications focusing on animals (rather than humans). Also note that ad hoc searches conducted post screening to supplement screened literature could have include literature post 2016.

From 600 publications screened in stage 2, 70 publications were deemed of potential relevance, coded as "Include" and selected for full article review after stage 2 screening.

A1.4.3 Stage 3: Full Article Review and Synthesis

70 were exported for review of full text in this D literature review. After reading the full text, if the article was still deemed relevant for inclusion (based on consideration of the objective and if the article helped answer research questions), it was saved for use and reference in the bibliography. Following reading articles full text in this stage, 50 publications were selected for inclusion.

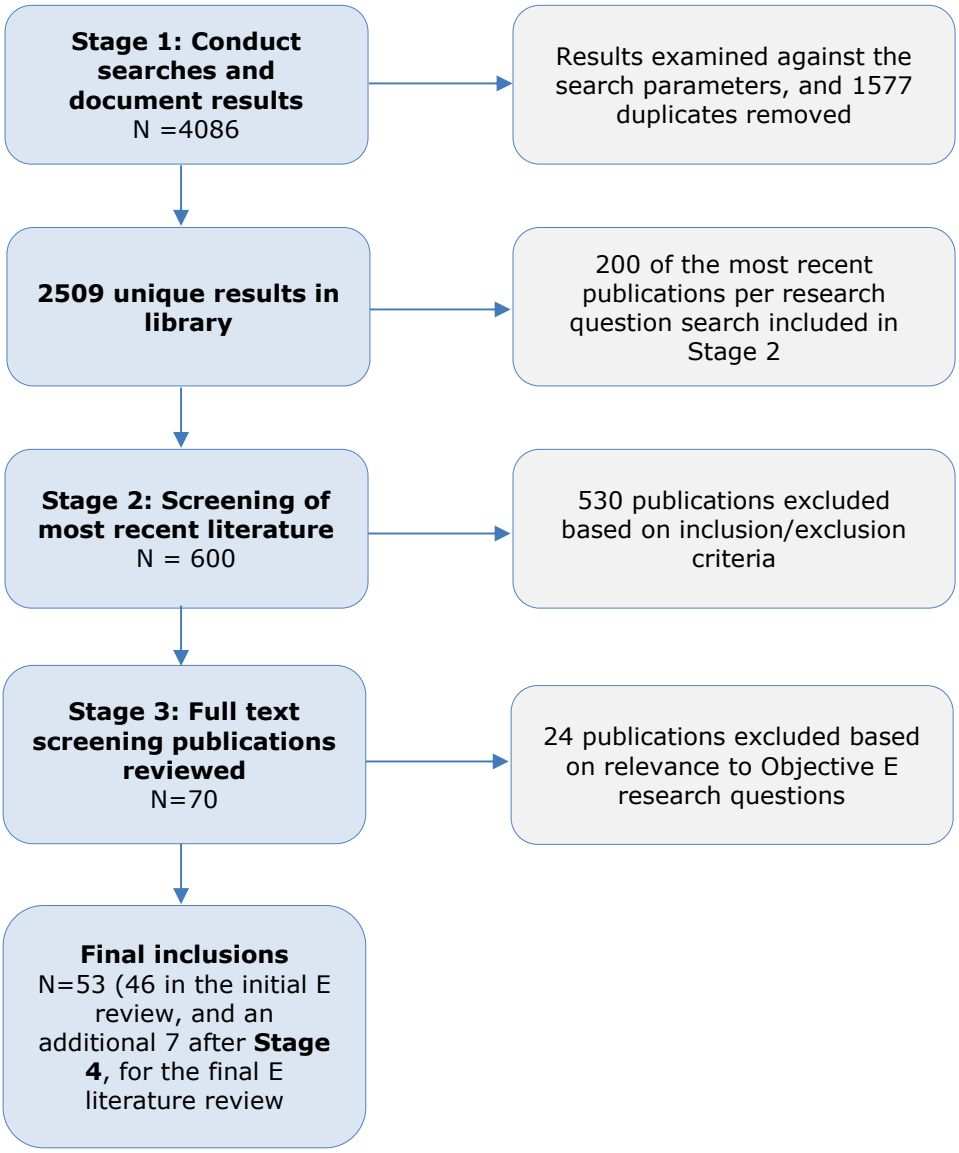
At each stage in this process, the team met to discuss successful strategies, challenges, and recommendations to improve the literature review processes. Note that although this is a comprehensive literature review and does not include a formal quality assessment process commonly conducted in systematic reviews, the team documented study designs (e.g., cross sectional, experimental) and the articles were checked by reviewers for signs of bias and poor quality research design. Further, the lead reviewer for each objective area conducted blind quality assurance checks for up to 10% of the coded articles. Any disagreements were discussed as a group and resolved with the review task lead.

A1.4.4 External expert reviews and input

Upon completion of the draft set of comprehensive literature reviews, expert workshops were organised to discuss findings, highlight additional relevant sources to fill gaps and improve the series of reviews. Experts were carefully selected from academic and policy-making fields, based on expertise of the specific topics addressed. As a result of this exercise, 7 additional references were screened and incorporated into these reviews.

The diagram in Figure 2 below shows the number of articles identified in peer-reviewed literature searches, and the filtering out of literature at successive stages to arrive at the final number of 53 publications whose full text was reviewed and summarised for this review. The diagram also includes additional relevant references proposed by external experts, and incorporated into this final comprehensive review.

Figure 2. Diagram showing number of included and excluded publications at each stage – peer reviewed literature



As shown in Figure 2 above, a total of 4086 search hits were retrieved. A total of 1577 duplicates were found and removed from the search hits resulting in 2509 search results for D. From the 2509, the team screened 600 of the most recent titles and abstracts (200 for each of the three research questions, to create a manageable amount of material within the resources for the study; and on the premise that the most recent material was most relevant science). From the 600 most recent titles and abstracts screened 70 were deemed of potential relevance and reviewed as full texts. From these full texts 53[36] publications were selected for inclusion, in this final review.

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[36] The full list of references included from the peer-reviewed literature can be found in Annex 3 and includes one additional publication recommended by the external expert review panel

Annex 2 Search terms

Objective D Search Terms Per the 3 Research Questions			
What variables correlate with overweight, obesity and physical (in) activity?			
Primary Term		**Combined with:**	
"Exercise"	[mh]	"Correlates"	[mh]
"Sedentary lifestyle"	[mh]	"Correlate"	[mh]
"Exercise"	[tiab]	"Predictor"	[mh]
"Physical Activity"	[tiab]	"factors associated with"	[mh]
"Leisure-Activit*"	[tiab]	"Physiological determinants"	[mh]
"Screen-time"	[tiab]	"Environmental determinants"	[tiab]
"Sedentary-time"	[tiab]	"Social determinants"	[tiab]
"Physical-Inactivity"	[tiab]	"Socio-economic determinants"	[tiab]
"Leisure-time"	[tiab]	"Demographic"	[tiab]
"Obesity "	[tiab]	"Socio-economic factors"	[tiab]
"Obese"	[tiab]		
"Overweight"	[tiab]		
"Population overweight"	[tiab]		
"Population obesity"	[tiab]		
"Sedentary"	[tiab]		
"Sedentary Lifestyle"	[tiab]		
What variables could be of use as early warning indicators of overweight and obesity (and physical inactivity)?			
Primary Term		**Combined with:**	

Objective D Search Terms Per the 3 Research Questions			
"Exercise"	[mh]	"indicat*"	[tiab]
"Sedentary lifestyle"	[mh]	"monitor*"	[tiab]
"Exercise"	[tiab]	"surveillance"	[tiab]
"Physical Activity"	[tiab]	"measur*"	[tiab]
"Leisure-Activit*"	[tiab]	"assessment"	[tiab]
"Screen-time"	[tiab]	"biomarker*"	[tiab]
"Sedentary-time"	[tiab]	"Health Status Indicators"	[mh]
"Physical-Inactivity"	[tiab]	"Risk Factors"	[mh]
"Leisure-time"	[tiab]		
"Obesity "	[tiab]		
"Obese"	[tiab]		
"Overweight"	[tiab]		
"Population overweight"	[tiab]		
"Population obesity"	[tiab]		
"Sedentary"	[tiab]		
"Sedentary Lifestyle"	[tiab]		
How could a feasible, effective and efficient early warning monitoring mechanism be put in place to keep track of these issues?			
Primary Term		**Combined with:**	
"Exercise"	[mh]	"indicat*"	[tiab]
"Sedentary lifestyle"	[mh]	"monitor*"	[tiab]
"Exercise"	[tiab]	"surveillance"	[tiab]
"Physical Activity"	[tiab]	"measur*"	[tiab]
"Leisure-Activit*"	[tiab]	"assessment"	[tiab]
"Screen-time"	[tiab]	"biomarker*"	[tiab]
"Sedentary-time"	[tiab]	"Health Status Indicators"	[mh]
"Physical-Inactivity"	[tiab]	"Risk Factors"	[mh]
"Leisure-time"	[tiab]		
"Obesity "	[tiab]		
"Obese"	[tiab]		
"Overweight"	[tiab]		
"Population overweight"	[tiab]		
"Population obesity"	[tiab]		
"Sedentary"	[tiab]		
"Sedentary Lifestyle"	[tiab]		

Annex 3 Peer-reviewed literature bibliography

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Annex 4 Grey literature review

This sub-section describes the approach taken between March 2016 and January 2018 to gather and synthesise the evidence.

A4.1 Detailed search and review methodology

The review followed a process with five main stages:

- Searching for publications using set keywords and databases;
- Screening of search results for relevance;
- Screen results against inclusion/exclusion criteria, quality and relevance;
- Extraction of full texts and final screening process; and
- External expert reviews and input.

A4.2 Stage 1: Conducting searches and documenting results

A4.2.1 Searching for grey literature

The search terms initially used for objective D, were agreed upon in the inception phase (Table A2.1). The main key words were either specific to the objective or broader thematic terms; for objective D the main key words included both 'Obesity' and 'Physical activity'. A second list of search terms was also used – these combination words were used to guide the search and produce the most relevant results; for objective D, the key word 'Obesity' would be combined with the broader term 'Indicator'.

Table 4. Search terms used for objective D grey literature review

Suggested Search Parameters	
Parameters	
• Scientific evidence and policies of EU Member State initiatives • Published in English, French, German, Italian, Polish and/or Spanish • Date range (1995 – 2017)	
Key Words and Suggested Combinations of Search Terms	
Key Words	**Combined With**
Physical activity	Prevention programs (programmes)
Obesity	Prevention policies
Overweight	Surrogate
Population overweight	Proxy
Population obesity	Indicators
Body Mass Index (BMI)	Biomarkers
Health inequalities	Physiological determinants
Specific population groups: children, elderly (old or older adults), pregnant and breastfeeding women.	Physical determinants: access, education, skills, time
	Social determinants: culture, family, peers and meal patterns
	Socio-economic terms: living conditions, employment, poverty, low income

	External economic determinants: cost, income, availability of food Health outcomes Trends Early warning indicators Early warning monitoring system Member States (of the EU) / Country (Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, The Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom)

A4.2.2 Using set key words in databases, search engines and websites

In order to appropriately link and define the relationship between the key and combination search terms, the Boolean operators 'AND', 'NOT' and 'OR' were used in the search engines. In particular, the use of 'AND' helped to narrow the number of hits to ensure that only documents which included all the search terms showed up. Further, if a search led to a high number of irrelevant hits, a repeat search was conducted and key words which were separated by spaces or other characters (e.g. Health impacts) were enclosed in quotation marks (e.g. "health impacts") to return only those documents that matched the search terms exactly.

The set key words and combination words were used to generate results in databases, search engines and websites recommend by the pilot review:

- Search Europa
- European Sources
- Eurostat
- NICE
- Open grey
- WHO websites

Search Europa and NICE Evidence Database yielded the most results for objective D.

The grey literature review was a dynamic and fluid process. After the initial searches and extraction of sources, hand searching on Google was used to produce specifically relevant results. This is described further in the section below.

A4.2.3 Additional hand searching

As per the recommendation made in the pilot review, hand searching was also used to supplement the key word searches. Hand searching involved extending the basic key word searches by using additional, contextual information. For example, in objective D, phrases such as "What individual (knowledge, attitudes, behaviour), social (peers, family) and environmental (access, policy) factors are associated with overweight, obesity and physical activity?" were used to generate the most applicable results. This process ensured that highly-focused and relevant search results were generated for the original key words, in this case, "indicators", "obesity", and, "physical activity". All hand searches for this objective were completed on Google. For question three additional hand searches were completed in order to find more implementation detail about specific examples of surveillance systems e.g. "NCMP".

A4.3 Stage 2: Screen Search Results for Relevance

Most databases, search engines and websites offered the use of a relevancy filter[37] which automatically sorts results in order of their applicability to the key terms in the search engine. When a relevancy filter was not available, the links were manually screened by the appearance of the key search terms in the title of the source and the abstract (where available). For database and search engines, initially the top 50 most relevant search results were looked at per search string. If there were less than 50 results, all were looked at. The titles and abstracts were then examined for key search terms in the grey literature and relevance to the research questions.

Extra hand searching was conducted when search strings did not produce enough relevant information, and/or, when the top 50 results did not produce the most relevant literature. Hand searching involved extending the basic key word searches by using additional, contextual information. For example, for objective D, when the search terms 'Obesity' AND 'Biomarkers' were used in NICE Evidence Database there were 2234 number of hits, so the first 111 results were looked at. In total 1032 results were included.

Following the expert workshop (see stage 5 below), experts recommend further sources which were reviewed in the final redraft of the review.

Overall 192 results from the searching for objective E were saved into an Excel spreadsheet.

A4.4 Stage 3: Screen results against inclusion/exclusion criteria, quality and relevance

Results were then screened against agreed inclusion and exclusion criteria detailed in Table 5 below.

Table 5. Grey literature inclusion and exclusion criteria

Inclusion	Exclusion
Published between 2005-2017	Published or enacted prior to 2005
Government reports from European Commission, European Parliament and EU Member States.	Non-nutrition and physical activity themed/focused
Think tank reports/publications	Industry-produced publications
Academic papers, conference papers and abstracts	Industry-produced project evaluation reports
Bibliographies	Industry-produced good practice reports
Programme evaluation reports[38]	Publications focusing on animal nutrition and physical activity
Standard/best practices documents	Blog or personal think thought pieces
Policy initiatives at European and/or	Newsletters or news articles

[37] 'Sorting by relevance' on databases and search engines enables a connection to be established between the information in the database, the search string entered and any search filters chosen. If the keywords appear in a Title or Author field, the system shows these results first in the list of search returns. Less relevant articles e.g. ones where the keyword appears less often or may only appear in the actual content, appear later in the list of search results.

[38] For example: Hallsworth M, Ling T. (2007) *The EU platform on diet, physical activity, and health: second monitoring progress report. Cambridge: RAND Corporation*, http://www.rand.org/content/dam/rand/pubs/technical_reports/2008/RAND_TR609.pdf

Inclusion	Exclusion
national level- run by governments, not-for profit organisations	
Industry funded publications (As regards the grey literature reviews, particular care will be exerted in assessing any inclusion of industry-funded literature. These will be justified and discussed with the client).	Theses and dissertations (2010 and older)
Primary theme/focus is human nutrition and physical activity	
Publication available via accessible databases	
Published in English, French, German, Italian, Polish and/or Spanish	
Theses and dissertations (post-2010 only)	

Due to the large number of results still returned after this screening the data parameters were further refined to only include those reports published 2005-2017.

Following this criteria screening and exclusion of search results, the remaining results were checked for quality and relevance.

A4.4.1 Exclusion based on quality checklist

The quality check was based on the AACODS checklist (AACODS)[39] which included:

- Authority
  - Is the author credible?
- Accuracy
  - Is the document supported by documented and authoritative references?
  - Is there a clearly stated methodology?
  - Is the document representative of work in the field?
- Coverage
  - Have limitations been imposed and are they clearly stated?
- Objectivity
  - Can bias be detected (if so the bias was clearly stated in the extraction form)?
- Date
  - Does the document have a clearly stated date relating to the content?
- Significance
  - Is the document relevant?
  - Would the document enrich the findings?

[39] Please see the full outline of the AACODS checklist here: https://dspace.flinders.edu.au/jspui/bitstream/2328/3326/4/AACODS_Checklist.pdf

A4.4.2 Exclusion based on relevance to research questions

The remaining grey literature was examined further so that only results most relevant to the objective were extracted. In particular, each article was examined for text relating to the key terms and questions under the objective. For example, in objective D, the text was examined for reference to the research question *'What variables could be of use as early warning indicators of overweight and obesity (and physical inactivity) prevalence and trends?* 'In total 123 results were excluded during this screening process; 69 results were extracted.

A4.5 Stage 4: Review and extraction of full texts

A data extraction template in Excel was used to capture the following categories of information: 1) identifying information for each publication, 2) study design characteristics, 3) sample characteristics, 4) intervention characteristics, 5) content (behaviour/outcome) focus, 6) description of results, 7) assessment of rigour/bias and 8) objective specific information.

A4.5.1 Final screening process

After extraction, the review author read through all of the extracted data and a final screening process excluded more results due to quality or a lack of enough relevant information, now made obvious after extraction. Sources were also excluded from the grey literature where this was superseded by either more rigorous peer reviewed research on the same theme, or more recent statistics.

A thematic analysis was applied to the remaining extracted data and their findings synthesised with those of the peer reviewed literature. Any identified bias in sources which passed the inclusion criteria is highlighted in the analysis.

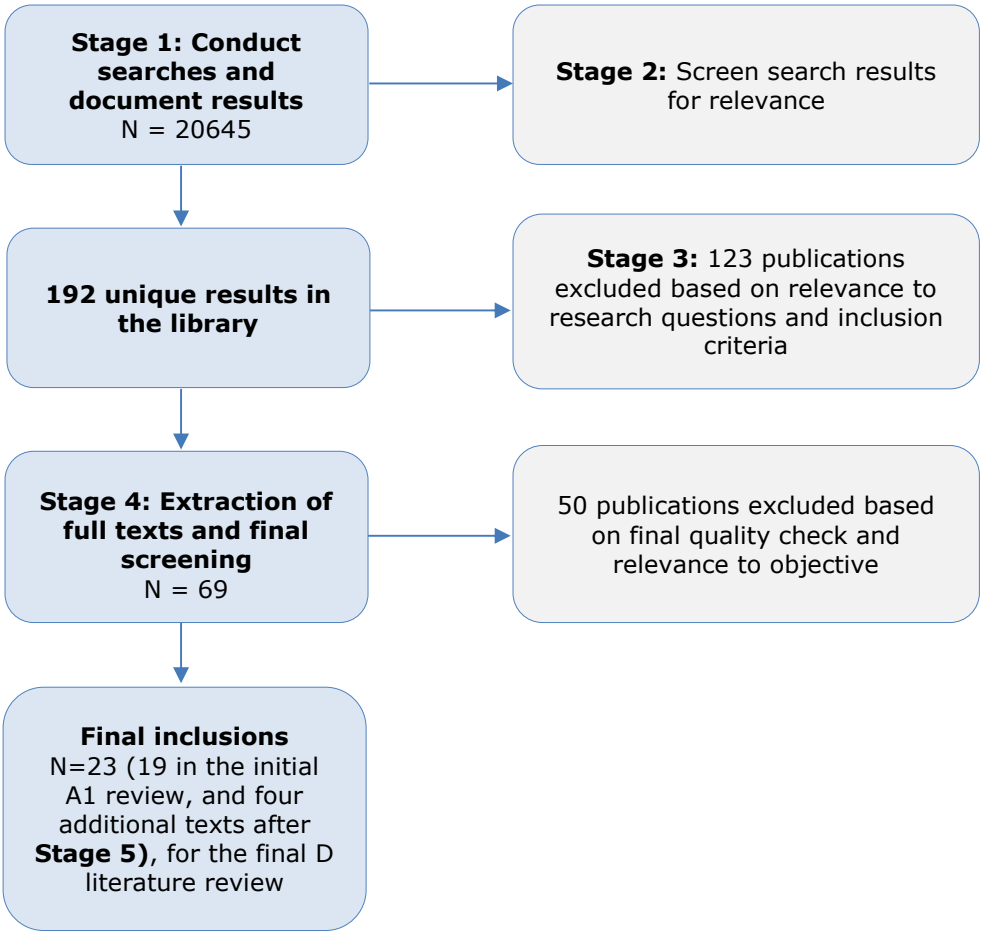
A4.6 Stage 5: External expert reviews and input

Upon completion of the draft set of comprehensive literature reviews, expert workshops were organised to discuss findings, highlight additional relevant sources to fill gaps and improve the series of reviews. Experts were carefully selected from academic and policy-making fields, based on expertise of the specific topics addressed. As a result of this exercise, four additional references were screened and incorporated into these reviews.

A4.7 Number of included and excluded references

The diagram in Figure 3 below shows the number of articles identified in grey literature searches, and the filtering out of literature at successive stages to arrive at the final number of 23 publications whose full text was reviewed and summarised for this review. The diagram also includes additional relevant references proposed by external experts, and incorporated into this final comprehensive review.

Figure 3. Diagram showing number of included and excluded grey literature publications at each stage



As shown in Figure 3 above, a total of 20645 search hits were retrieved and saved for D. From the 192 results saved in the library, 123 were excluded based on the relevance to Objective D research questions. Following this, 69 results were extracted fully. An additional 50 publications were then excluded based on inclusion/exclusion criteria, quality of evidence and relevant to the research questions. In Stage 5, supplementary searches were conducted and/or articles recommended by experts during the workshops were looked at, and four additional relevant references proposed by external experts were included.

Annex 5 Grey literature bibliography

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