Prevalence and Social Determinants of Overweight and Obesity in Adolescents in Saudi Arabia: a systematic review

By

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A thesis submitted in conformity with the requirements for the degree of MSc – Nutritional Sciences
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Abstract

Background: The prevalence of obesity in adolescents is increasing globally at an alarming rate. Objectives: Our aim was to evaluate the prevalence of overweight and obesity (Ow/Ob) in Saudi adolescents and to construct an ecological model of social determinants of Ow/Ob and evaluate current evidence of their effect on Saudi adolescents. Methods: A systematic review of literature reported up to 31/12/2018 on Ow/Ob and factors that can influence them in Saudi adolescents was conducted. Results: Fifty-one studies with n=97,666 adolescents (56.9% males) were reviewed. The prevalence of Ow/Ob started off high and continued to increase over time. Most of the 49 reviewed social determinants reports, from 19 studies, showed positive association between social determinants and Ow/Ob in Saudi adolescents. Conclusion: Adolescents’ Ow/Ob is a major public health problem in Saudi Arabia and is growing. Social determinants play a significant role in this problem and should be considered in all strategies targeting it.
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Table of content

Chapter 1

1 Introduction .................................................................................................................. 1
  1.1 Why obesity? ........................................................................................................... 1
  1.2 Why adolescents? .................................................................................................. 2
  1.3 Why Saudi Arabia? ............................................................................................... 3
  1.4 Why social determinants? ....................................................................................... 5
    1.4.1 Individual lifestyle factors ................................................................................ 6
    1.4.2 Social and community network ....................................................................... 7
    1.4.3 Living and working conditions ....................................................................... 8
    1.4.4 General socioeconomic, cultural and environmental conditions ................. 8
  1.5 Social determinants of overweight and obesity in adolescents ......................... 10
    1.5.1 Dietary habits (patterns/contents) .................................................................. 10
    1.5.2 Physical activity ............................................................................................. 10
    1.5.3 Sedentary behavior ......................................................................................... 11
    1.5.4 Sleep patterns/Stress/Smoking ....................................................................... 11
    1.5.5 Family history of obesity/Family size .............................................................. 12
    1.5.6 Household income .......................................................................................... 13
    1.5.7 Parental education ........................................................................................... 13
    1.5.8 Working mother .............................................................................................. 14
    1.5.9 Health/literacy ................................................................................................. 14
    1.5.10 School food/environment ............................................................................. 14
    1.5.11 Urbanization .................................................................................................. 15
  1.6 Defining overweight and obesity in adolescents ................................................... 15
    1.6.1 International Obesity Task Force system ...................................................... 15
    1.6.2 Centers for Disease Control and Prevention system .................................... 15
    1.6.3 World Health Organization system ............................................................... 16
  1.7 Objectives ................................................................................................................ 16
Chapter 2

2 Methods ........................................................................................................... 17
   2.1 Selecting Determinants of overweight and obesity relevant to Saudi adolescents ............................................. 17
   2.2 Protocol and Search strategy ........................................................................ 18
   2.3 Analysis ........................................................................................................ 20

Chapter 3

3 Results ............................................................................................................. 23
   3.1 Included studies ............................................................................................ 23
   3.2 Study population .......................................................................................... 24
   3.3 Determining Overweight and Obesity ......................................................... 25
   3.4 Prevalence Rates of Overweight and Obesity ............................................. 25
      3.4.1 Prevalence Rates of overweight and obesity from national surveys ......................................................... 25
      3.4.2 Prevalence Rates of overweight and obesity from regional and multiregional studies ........................................... 27
   3.5 Social Determinants of overweight and obesity ....................................... 29
      3.5.1 Diet patterns/contents ............................................................................ 29
      3.5.2 Physical activity ..................................................................................... 31
      3.5.3 Social media/Screen time ...................................................................... 33
      3.5.4 Sleep patterns/ Stress/smoking ............................................................... 35
      3.5.5 Family size & Family history of obesity .............................................. 36
      3.5.6 Economics/Household factors ................................................................. 37
      3.5.7 Parental Educations ................................................................................ 39
      3.5.8 Working mother .................................................................................... 42
      3.5.9 Label literacy/general education .............................................................. 43
3.5.10 School/food environment .............................................43
3.5.11 Urbanization .....................................................................44

Chapter 4

4 Discussion ..................................................................................45

4.1 Prevalence Rates ......................................................................45

4.1.1 Prevalence Rates of overweight and obesity from national surveys ....................................45

4.1.2 Prevalence Rates of overweight and obesity from regional and multiregional studies ...............46

4.2 Social Determinant of overweight and obesity in adolescents .........................................................47

4.2.1 Identifying and constructing an ecological model .................................................................47

4.2.2 Determinants of overweight and obesity in Saudi adolescents ..................................................48

4.2.2.1 Dietary habits (patterns/contents) ..................................................................................48

4.2.2.2 Physical activity .............................................................................................................48

4.2.2.3 Sedentary behavior .......................................................................................................49

4.2.2.4 Sleep patterns/Stress/Smoking ......................................................................................50

4.2.2.5 Family history of obesity/Family size ...........................................................................52

4.2.2.6 Household income .......................................................................................................53

4.2.2.7 Parental education ........................................................................................................53

4.2.2.8 Working mothers ..........................................................................................................54

4.2.2.9 Health literacy ..............................................................................................................54

4.2.2.10 School/Food environment ............................................................................................55

4.2.2.11 Urbanization .................................................................................................................55

4.3 Social Policy and Structural Measures ........................................56

4.3.1 Types of interventions to tackle obesity .................................................................................56

4.3.2 WHO Recommendations on policy action and interventions: ....................................................57

4.3.3 Relevant policies in Saudi Arabia ............................................................................................60
4.4 Strengths and Limitations ................................................................. 61
   4.4.1 Strengths .............................................................................. 61
   4.4.2 Limitations ........................................................................... 61
4.5 Conclusions ................................................................................ 62

References .......................................................................................... 63

Appendices ....................................................................................... 77
List of Tables

Table 1. Comparison of the prevalence of Overweight and Obesity according to BMI by sex in Saudi Arabia between 1975 and 2014 ........................................ 4

Table 2. Key variables data extraction form (see Appendix 1) ........................................ 21

Table 3. Type of publication journals used in the review ................................................. 24

Table 4. Distribution (number & %) of subjects included the studies per region ............ 24

Table 5. BMI reference standards used to define overweight and obesity in Saudi Arabian adolescents in the reviewed studies ........................................ 26

Table 6. Yearly mean prevalence (%) rates standards used to define overweight and obesity in Saudi Arabian adolescents in the reviewed regional and multiregional studies ........................................ 28

Table 7. Number of reviewed reports for each determinant of overweight and obesity... 29

Table 8-A. Fast food and soft drink intake and the prevalence (%) of overweight and obesity in Saudi adolescents ........................................ 30

Table 8-B. skipping breakfast and vegetable intake and the prevalence (%) of overweight and obesity in Saudi adolescents ........................................ 31

Table 9-A. Duration of physical activity and the prevalence (%) of overweight and obesity in Saudi adolescents ................................. 32

Table 9-B. The practice of physical activity and the prevalence (%) of overweight and obesity in Saudi adolescents ........................................ 33

Table 10-A. TV/Computer screen time and the prevalence (%) of overweight and obesity in Saudi adolescents ........................................ 34
Table 10-B. TV/Computer screen time spent by Saudi adolescents in relation to body weight………………………………………………………………………………………… 34

Table 11. Sleep pattern and the prevalence (%) of overweight and obesity in Saudi adolescents………………………………………………………………………………………… 36

Table 12. Family size and the prevalence (%) of overweight and obesity in Saudi adolescents………………………………………………………………………………………… 37

Table 13. Family history of obesity and the prevalence (%) of overweight and obesity in Saudi adolescents………………………………………………………………………………………… 37

Table 14. Economic/social class and the prevalence (%) of overweight and obesity in Saudi adolescents………………………………………………………………………………………… 38

Table 15. Mother education and the prevalence (%) of overweight and obesity in Saudi adolescents………………………………………………………………………………………… 39

Table 16. Father’s education and the prevalence (%) of overweight and obesity in Saudi adolescents………………………………………………………………………………………… 41

Table 17. Working mother and the prevalence (%) of overweight and obesity in Saudi adolescents………………………………………………………………………………………… 42

Table 18. School environment and the prevalence (%) of overweight and obesity in Saudi adolescents………………………………………………………………………………………… 44

Table 19. Urbanization and the prevalence (%) of overweight and obesity in Saudi adolescents………………………………………………………………………………………… 44
List of Figures

Figure 1: Determinants of Determinants of the general health of population…………… 6

Figure 2: Berkman and Glass’s conceptual framework of how social networks have
an impact on health…………………………………………………………………….. 7

Figure 3: Ecological model of Social Determinants of Overweight and Obesity
in Saudi Adolescents……………………………………………………………………. 18

Figure 4: Search strategy for review on prevalence and social determinants of
overweight and obesity in adolescents in Saudi Arabia…………………………… 19

Figure 5. Key variables data Screening form……………………………………………. 20

Figure 6. Administrative (A) and provincial (B) regions of Saudi Arabia……………… 22

Figure 7. Study population compared to total and adolescent populations of
Saudi Arabia………………………………………………………………………………… 25

Figure 8. Prevalence rates of overweight and obesity reported in the 2002 and
2010 national (population based) surveys in Saudi male (A) and female
(B) adolescents. …………………………………………………………………………27

Figure 9. Trend of overweight and obesity in Saudi male and female adolescents
estimated from calculated yearly mean prevalence rates reported by reviewed
regional studies …………………………………………………………………………28

Figure 10. Meta-analysis: Fast food/Soft drinks and prevalence (%) of overweight
and obesity in Saudi adolescents…………………………………………………………30

Figure 11. Meta-analysis: Physical activity and the prevalence (%) of overweight
and obesity in Saudi adolescents………………………………………………………33
Figure 12. Meta-analysis: TV/Computer screen time and the prevalence (%) of overweight and obesity in Saudi adolescents..........................................................35

Figure 13. Meta-analysis: Economic/Social class and prevalence (%) of overweight and obesity in Saudi adolescents.................................................................38

Figure 14. Meta-analysis: Mother’s education and prevalence (%) of overweight and obesity in Saudi adolescents.................................................................40

Figure 15. Meta-analysis: Father’s education and prevalence (%) of overweight and obesity in Saudi adolescents.................................................................42

Figure 16. Meta-analysis: Working mothers and prevalence (%) of overweight and obesity in Saudi adolescents.................................................................43

Figure 17 Different types of interventions to tackle obesity.................................57
List of Appendices

Appendix 1. Summary of Reviewed Articles & Social Determinants of Overweight and Obesity……………………………………………………………………………………………… 76

Appendix 2. Summary of Reviewed Articles & Prevalence Rates of Overweight and Obesity………………………………………………………………………………………… 77
Chapter 1
INTRODUCTION

1 Introduction.

1.1 Why obesity?

Overweight and obesity are defined as abnormal or excessive fat accumulation that may impair health. In adults, overweight is defined as body mass index (BMI) $\geq 25$ \[\text{BMI} = \frac{\text{weight (kg)}}{\text{height (m}^2\text{)}}\] and obesity is defined as BMI $\geq 30$. Raised BMI is a major risk factor for non-communicable diseases (NCDs) such as cardiovascular diseases (mainly heart disease and stroke), which were the leading cause of death in 2012; hypertension, diabetes; musculoskeletal disorders (especially osteoarthritis); and some cancers (including endometrial, breast, ovarian, prostate, liver, gallbladder, kidney, and colon) \(^{(1)}\).

In children aged between 5–19 years, the overweight classification is BMI-for-age $> 1$ standard deviation ($\geq 85$th percentile to $< 95$th percentile) and obesity is $> 2$ standard deviations ($\geq 95$th percentile) above the WHO Growth Reference median \(^{(2)}\). Childhood obesity is associated with increased future risk of hypertension, breathing difficulties, fractures, psychological effects, insulin resistance and early markers of cardiovascular disease. In addition, an obese child is more susceptible to develop obesity, disability and premature death in adulthood \(^{(1)}\).

Obesity has nearly tripled worldwide since 1975. More than 1.9 billion (39%) adults (18 years and older) were overweight in 2016, out of which $> 650$ million (13%) were obese. Similarly, the prevalence of overweight and obesity among children and adolescents aged 5-19 years has risen significantly from 4% in 1975 to over 18% in 2016, with $> 340$ million children and adolescents being overweight or obese \(^{(1)}\). The prevalence of obesity varies across different nations, ranging from below 5% in Japan, to over 60% in Nauru. Obesity prevalence among children and adolescents aged 5-19 is extending into the developing world from the developed nations.

Obesity is a key risk factor for many non-communicable diseases (NCDs), and the risk increases with increase in the level of obesity \(^{(3)}\). NCDs have become the world’s leading causes of death, accounting for 71% of all deaths globally in 2016, claiming the lives of 40.5 million people \(^{(3)}\). It
is very important to note that overweight and obesity, along with their related NCDs, are mostly preventable \(^{(1)}\).

In 2015, more than 190 world leaders committed to 17 Sustainable Development Goals (SDGs) to help end extreme poverty, fight inequality & injustice, and fix climate change \(^{(4)}\). The 2030 Agenda for Sustainable Development adopted at the United Nations Summit on Sustainable Development in September 2015, recognizes NCDs as a major challenge for sustainable development. Goal 3-Target 3.4 of the SDGs is to reduce by one third premature mortality from NCDs through prevention and treatment and promote mental health and wellbeing by 2030. NCDs were not addressed in the Millennium Development Goals (MDGs). Both for SDG 3 and also for other SDGs, increased consideration of the needs of adolescents and groups that have been traditionally disadvantaged is critically needed \(^{(5)}\).

### 1.2 Why adolescents?

Adolescence (the period between ages 10 and 19 years) is the sensitive phase, during which the quality of the physical, nutritional and social environments may change patterns of health and development into later life \(^{(6)}\). Currently, there are about 1.2 billion adolescents in the world \(^{(7)}\). Overweight and obesity increase markedly across adolescence, from age 10 to 19 years. This increase is more evident in obesity that has a tenfold increase in four decades \(^{(8)}\). Adolescents who are obese are five times more likely to be obese in adulthood than those who were not obese, representing a lifelong personal burden and long-term societal impacts. Around 80% of adolescents who are obese will still be obese in young adulthood, and around 70% will be obese over age 30 \(^{(9)}\).

Until recently, adolescent health was neglected in global health and adolescent health services were almost absent in most of the developing world \(^{(10)}\). In the last few years the importance of adolescent health became under focus. This was clearly evident in the Global Strategy for Women’s, Children’s and Adolescents’ Health initiated by the UN Secretary-General in
September 2015\textsuperscript{(11)} and in the very comprehensive reports that followed\textsuperscript{(6,8,12)}. However, practical programs are still weak and poorly implemented\textsuperscript{(6)}.

In many countries, the focus of health policy is shifting from infectious diseases in early life to NCDs in older adults\textsuperscript{(12,13)}. Adolescence largely determines the life course routes of health and wellbeing. Reasons behind bringing adolescents into more focus include the subject of optimizing health, fitness, and capabilities in addition to minimizing risks to health and wellbeing, and the knowledge that disparities established by young adulthood persist and account for many of the inequalities in health (including type 2 diabetes, cardiovascular disease, cancer, and other NCDs) and wellbeing in later life\textsuperscript{(14)}. The ageing populations with a disease burden dominated by NCDs made the subject of addressing adolescent health risk factors very critical\textsuperscript{(15)}. These risk factors include physical inactivity, poor diet, obesity, tobacco use, and alcohol and illicit substance use\textsuperscript{(6)}. Specific policy interventions are needed to control the continuous rise in prevalence of adolescent health risks, including obesity, due to the combination of increasing wealth and unrestrained marketing. International best practice for adolescent NCD risks, such as tobacco and alcohol control and taxation of unhealthy food, should be identified and adopted by all countries, in addition to evaluating new interventions\textsuperscript{(6)}.

\subsection*{1.3 Why Saudi Arabia?}

In 2014, Saudi Arabia became the world’s 19th-largest economy (up from 27th largest in 2003) making it one of the fastest growing economies\textsuperscript{(16)}. Saudi Arabia’s household income rose by 75% during the decade 2003 to 2013 driven by higher public-sector employment and wages\textsuperscript{(16)}. It also underwent a significant modernization that brought prosperity and change to Saudi society. In addition, about 83 percent of the Saudi population lives in cities, a degree of urbanization that is larger than in some Western European countries\textsuperscript{(16)}. These changes were accompanied with dietary changes which lead to greater consumption of foods high in added sugars, salt, and unhealthy fats, and low in important micronutrients\textsuperscript{(6)}. Combined with decreases in physical activity, these patterns have fueled the increasing rates of obesity in Saudi Arabia shown in table 1\textsuperscript{(8)}.
Table 1. Comparison of the prevalence of Overweight and Obesity according to BMI by sex in Saudi Arabia between 1975 and 2014. BMI-body mass index. (Cited from reference 5, appendix table 5).

<table>
<thead>
<tr>
<th>Prevalence of BMI</th>
<th>Men</th>
<th></th>
<th>Women</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>25 ≤ BMI &lt; 30 kg/m²</td>
<td>28.1%</td>
<td>37.4%</td>
<td>26.9%</td>
<td>30.1%</td>
</tr>
<tr>
<td>30 ≤ BMI &lt; 35 kg/m²</td>
<td>5.8%</td>
<td>19.5%</td>
<td>16.5%</td>
<td>23.3%</td>
</tr>
<tr>
<td>35 ≤ BMI &lt; 40 kg/m²</td>
<td>0.8%</td>
<td>5.8%</td>
<td>3.9%</td>
<td>11.2%</td>
</tr>
<tr>
<td>BMI ≥ 40 kg/m²</td>
<td>0.2%</td>
<td>2.7%</td>
<td>1.8%</td>
<td>6.2%</td>
</tr>
</tbody>
</table>

Obesity is a key risk factor for many NCDs, and the risk increases with increase in the level of obesity (17). NCDs are an increasing public health and development challenge in Saudi Arabia. They kill more than 90,000 people per year in Saudi Arabia and are responsible for 78% of all deaths. Cardiovascular disease alone accounts for nearly half (46%) of all deaths in Saudi Arabia (18). In addition, NCDs in Saudi Arabia are causing a surge in health care costs and social care and welfare support needs, as well as putting an increasing burden on school and work absenteeism, presenteeism and employee replacement costs (19). These indirect costs reduce productivity and economic competitiveness. While the current epidemiological picture is alarming, and the future projections are cause for an emergency response, significant health and economic losses can be mitigated by implementing a set of proven interventions. Since adolescents are adversely affected by NCDs and vulnerable to risk factors, including obesity, leading to unhealthy transitions to adulthood, they are a key stakeholder group at the center for tackling NCDs (20) and achieving sustainable development in Saudi Arabia.
The SDG review reaffirms Saudi Arabia’s commitment to the 2030 Agenda for Sustainable Development and the achievement of the SDGs, both at the national and international levels. Vision 2030 of the Kingdom of Saudi Arabia was launched and approved by the Council of Ministers in April 2016 (21). The underpinning quest of Vision 2030 is to address current regional and international challenges, maintain development gains, diversify and stimulate economic growth and end its reliance on oil as the mainstay source of income. Vision 2030 gives due attention to the promotion of preventive care under the Vision’s theme of “vibrant society”. The theme includes several educational and other initiatives and programs. In this regard, several initiatives have been prepared with respect to cardiovascular diseases, diabetes, respiratory disease and obesity. Under these initiatives, campaigns were launched to promote awareness as to the health risks and the bad health habits associated with these diseases, along with the proper healthy practices to prevent and eliminate related health risks, including obesity (21).

1.4 Why social determinants?

Social determinants of health are the conditions in which individuals are born, grow, develop, live, work, and age (22). They are the root causes of observed social inequities in health and understanding them is needed before effective policies can be formulated to deal with them (23). These determinants of the general health of the population were conceptualized by Dahlgren and Whitehead as rainbow-like layers of influence that emphasize interactions. The individual lifestyles in this model are surrounded by social norms and networks, followed by living and working conditions, which are linked to the wider socioeconomic and cultural environment (Figure. 1) (23).
Figure 1: Determinants of the general health of population.

The center of this model represents factors that influence individual’s health, such as, age, sex and constitutional characteristics that are largely fixed, surrounded by 4 influential categories that are theoretically modifiable by policy.

1.4.1 Individual lifestyle factors:

The innermost layer represents personal behavior factors, such as smoking, drinking, diet and physical activity. These personal behaviors are socially patterned, contributing to some of the observed social inequities in health. In lifestyle-related health, the reasons why lifestyle is socially patterned need to be understood for reducing social inequities.
1.4.2 Social and community network:

The second layer represents the nature of human relationships and how individuals interact with their peers and immediate community and are influenced by them. The health and well-being of an individual and the health and vitality of entire populations depend on the degree to which an individual is interconnected and embedded in a community\(^{(24)}\). Berkman & Glass proposed a conceptual model that sums up the body of evidence on this layer. This model visualizes social networks and their relation to the upstream social and cultural context that determines their extent, nature and shape\(^{(24)}\). Accordingly, the network structure and function influence downstream social support, access to resources, engagement, and social and person-to-person contact behavior, which are shown in Figure 2. Potential policy entry points along the pathways from macro- to micro-level be identified by this model.

![Figure 2: Berkman and Glass’s conceptual framework of how social networks have an impact on health.](image)
1.4.3 Living and working conditions:

This third layer reflects the ability of a person to maintain their health, which is influenced by their living and working conditions, food supply, and access to essential goods and services. Over many decades, it has been shown that population health can be improved by improvements in living and working conditions, food supply, and access to essential goods and services, such as education and health care (23). Actions on this layer of determinants are very important for reducing social inequities in health, as there are strong social gradients in these factors. Policies concerning these determinants, however, span several sectors, and the response needs to be equally multisectoral.

1.4.4 General socioeconomic, cultural and environmental conditions:

The outermost layer contains the influences that prevail in the overall society, whether economic, cultural, environmental or mediator of population health (23). These influences are the main driver for the generation of social inequities in health and are related to the macropolicy environment, which includes neo-liberal economic growth strategies that have widened income inequalities and increased poverty. The increasing globalization of national economies has reduced the possibilities for national governments to influence these trends. At the same time, the actions of major players on the financial markets are of increasing importance, not only on these markets, but also on economic and social development in general. From an equity-in-health perspective, this calls for intensified efforts to strengthen international organizations and cooperation, focusing on how economic policies can promote human development and reduce social inequities (23). Assessments of the impact of these broader upstream determinants of health and social inequities in health are often lacking, while the focus of assessments of the problem is generally only on the effects of interventions in specific downstream determinants. Intensified efforts must therefore be made to identify and, whenever possible, quantify the effects of different economic growth strategies, income inequalities and poverty on the health of different socioeconomic groups (23).

The determinants of health that can be influenced by individual, commercial or political decisions that can be positive health factors, protective factors, or risk factors.
Positive health factors: These contribute to the maintenance of health. Fundamental positive health factors are, for example, economic security, adequate housing and food security. Control over life outcomes and enjoying good relationships in the home and other emotionally rewarding social relationships are also important positive health factors (25).

Protective factors. These are factors that eliminate the risk of, or facilitate resistance to, disease. The classical example is immunization against a variety of infectious diseases. Psychosocial factors, such as social support and a sense of purpose and direction in life, are also increasingly recognized as factors that protect health (26). Healthy diets, such as the Mediterranean diet with a high consumption of fruit and olive oil, are also considered to be protective (27).

Risk factors or risk conditions: These cause health problems and diseases that are potentially preventable. These risk factors or risk conditions can be social or economic or can be associated with specific environmental- or lifestyle-related health hazards, such as polluted air and smoking.

Social determinants of adolescent health lie largely outside the health service sector with major influences of peers, media, education, and the beginning of workplace influences (6). They contribute to the dramatic increase seen within specific countries or globally. These determinants vary between countries depending on the social status of each country (28). A full understanding of the relationships between the selected determinants and obesity can provide the foundations for developing interventions promoting healthier individuals and decreasing the prevalence of obesity in a given country. Therefore, identifying such determinants is important to help inform recommendations for policy makers, practitioners and researchers for implications for health promotion and prevention and for further research.

1.5 Social determinants of overweight and obesity in adolescents.
It is well known that imbalance between energy intake and expenditure can lead to increase in overweight and obesity, and that positive energy balance is closely related to dietary intake preferences and lifestyle adopted (29). However, these factors are modulated by many other determinants related to the individual’s genetic background and lifestyle as well as to their socioeconomic and cultural environment. Social determinants related to overweight and obesity in adolescents are reported in the literature separately or in small groups, and we summarize them in the following:

1.5.1 Dietary habits (patterns/contents)

Diet plays a major role in the development of obesity and healthy diet helps protect against NCDs, including diabetes, heart disease, stroke and cancer (30). The type and amount of food that the individual eats are affected by availability, pricing, and personal choices, in addition to advertising, social customs and cultural influences. Adolescents globally have experienced considerable changes in their diet over the last few decades due the fast-growing economies, urbanization, and globalization. These changes resulted in a shift away from healthier diets that consist of whole grains, vegetables, fruits with small amounts of meat and fat, to a diet rich in calories with highly processed food containing large amounts of salt, sugar, and saturated fat. In addition, the great and easy access of adolescents to soft drinks and other sugar-sweetened beverages added considerably to their caloric intake (30). The dietary factors that can be examined include consumption of vegetables, fruits, breakfast, fast food, sugary beverages, snack foods and sweets intake.

1.5.2 Physical activity

There is a strong relationship between health outcomes and PA that persists throughout life, including adolescence. Being a key determinant of energy expenditure, regular and adequate levels of physical activity are essential to energy balance and weight control in adolescents. In addition, they can improve mental health by reducing stress reactions, anxiety and depression, which are becoming common among adolescents (31). Furthermore, they can improve functional health and reduce the risk of NCDs (32).
The term "physical activity" does not essentially mean "exercise". Exercise represents a subcategory of physical activity and is defined as planned, structured, repetitive, and purposeful movements that aim for the improvement or maintenance of one or more components of physical fitness. In addition to exercise, physical activity includes other activities which involve bodily movement and are done as part of playing, working, active transportation, house chores and recreational activities \(^{(33)}\). Therefore, increasing physical activity is a social, not just an individual problem and it demands a population-based, multi-sectoral, multi-disciplinary, and culturally relevant approach \(^{(33)}\). With the recent socioeconomic development, adolescents became less physically active and the activity levels required for work and transportation were significantly reduced. In addition, several environmental factors linked to urbanization, such as high-density traffic, limited sport/recreation facilities, lack of parks and sidewalks, air pollution, fear of crime and violence in outdoor areas discouraged adolescents from becoming more active \(^{(33)}\). The physical activity factors that can be examined include physical activity/physical exercise practice in minutes or METS/ day or week.

### 1.5.3 Sedentary behavior

Sedentary behavior is not the lack of Physical activity but is a group of individual behaviors that are dominated by sitting or lying with very low energy expenditure that can take place at home, school or work \(^{(34)}\). Furthermore, it was shown that sedentary activity, in the form of television (TV) viewing and physical activity are different entities in terms of associated metabolic risk in children and adolescents \(^{(35)}\). With the improvements in socioeconomic status, sedentary behaviors have increased dramatically among adolescents and they include watching TV, using computers, playing video games and surfing the internet, and use of "passive" modes of transport \(^{(36, 37)}\).

### 1.5.4 Sleep patterns/Stress/Smoking

Multiple reports suggest that chronic sleep restriction can lead to obesity in adults, adolescents and children \(^{(38-40)}\), and that the duration of sleep is an independent risk factor for overweight and obesity in children \(^{(41, 42)}\). The link between sleep duration and obesity can be explained by several mechanisms \(^{(43)}\). Studies have shown that sleep is an important regulator of many biological and
physiological functions, such as appetite, energy balance, and weight maintenance, and that control of body weight and nutrient metabolism are greatly affected by the number of hours of sleep \(^{(40,44)}\). Both short and long periods of habitual sleep are linked to obesity \(^{(45)}\). Short sleep duration can lead to a reduction in the satiety hormone leptin and an increase in the hunger hormone ghrelin that cause an increase in appetite \(^{(44,45)}\). The fast-growing economies and rapid advancement in technology have resulted in extensive television viewing and use of other electronic media (computers, videogames and the internet), which made short sleep duration a major problem among adolescents.

Evidence is accumulating that stress is linked to the development of obesity via the chronic increase of cortisol (the glucocorticoid stress hormone) \(^{(46)}\). In a modern society, the high prevalence of obesity goes hand in hand with chronic stress, consuming food containing large amounts of sugar and decreased hours of sleep, suggesting a close relation between these conditions \(^{(47,48)}\) that are common among adolescents. Also, recent studies in adolescents reported a bidirectional (cause and effect) relationship between eating disturbances and depression and a high rate of anxiety disorders among obese adolescents \(^{(49-50)}\).

Adolescence is the critical period during which health habits, including eating behaviors, physical activity and smoking are established. In a follow-up study in adolescents, smoking was reported as a risk factor for adulthood abdominal obesity in both males and females and for overweight only in females \(^{(51)}\). Mechanisms of the possible causal link between smoking and body weight are not clear. Changes in cortisol metabolism and/or psychosocial stress related to smoking might represent a possible explanation \(^{(52-54)}\).

1.5.5 Family history of obesity/Family size

Family factors play an important role in the development of overweight and obesity in children and adolescents. In addition to the genetic effect, food preferences and availability and habits within a family can easily influence what children and adolescents eat. Also, family lifestyle and habits (physically active or sedentary) can influence children and adolescents \(^{(55)}\). High rates of
overweight and obesity are observed in adolescents with a family history of obesity (56), which can be related to the mentioned family factors as well as to genetic factors.

Studies suggest that family size also has a role in the development of overweight and obesity. The higher the number of siblings the lower the BMI and the lower the chance of overweight and obesity in a family, which could be due to family mealtimes, reduced maternal work and less eating out. Also, children with siblings watch less television and have healthier diets (57).

1.5.6 Household income

Lower income households tend to have higher rates of obesity in the United States and other developed countries (58,59). A possible explanation is that the low-income families are more exposed to junk food and other cheap calories including processed sugars (69). However, Analysis of data from the 2011–2014 National Health and Nutrition Examination Survey (NHANES) demonstrates that adolescent obesity prevalence patterns by household income are less consistent by race (61).

1.5.7 Parental education

It is assumed that parental education is supposed to improve awareness of all family members on healthy food selections (62). However, recent studies suggest that parental education is associated with increased rate of overweight in children and adolescents (63). This association seems to vary according to the developmental stage of different countries. In higher economic status countries, paternal rather than maternal higher education is associated with more positive influence on lowered child overweight. On the other hand, a more negative influence of maternal higher education on increased child overweight is observed in lower economic status countries (63). These varied associations make it crucial to further examine familial factors when investigating overweight in children and adolescents.
1.5.8 Working mother

Studies have shown that when both parents are working away from their children, there is a high chance that their children will develop overweight and obesity. Working mothers spend less time on preparing food for their children who will eat more restaurant made fast food meals, which are known to increase of overweight and obesity in children and adolescents\(^{64,65}\). In addition, there will be less supervision and more sedentary behaviors (watching television, using the computer, playing passive video games and surfing the internet) among children and adolescents, which will add to the problem\(^{66}\). It was estimated that 10% of the rise in childhood obesity is related to maternal employment\(^{67}\) however, recent studies showed that the size of the problem is more than that\(^{68}\).

1.5.9 Health literacy

Low food label literacy can lead to increased risk of obesity, high blood lipids, and high blood pressure\(^{69}\). Also, low level of health literacy is related to many aspects of adolescence health including their body weight. Studies have shown that low health literacy is significantly associated with overweight or obesity in adolescents, which should be considered in all strategies combating adolescence weight problem\(^{70,71}\).

1.5.10 School food/environment.

School food represents 35-47% of the daily intake of children and adolescents\(^{72}\). While at school, students are exposed to all types of unhealthy food (such as french fries, chips, pizza, and candies) and beverages (mainly sugar-sweetened beverages)\(^{73-76}\), all of which can lead to high rate of overweight and obesity in adolescents.

1.5.11 Urbanization.

Recent studies suggest that rapid urbanization accounts for significant shifts in dietary patterns and physical activity\(^{77}\). Several environmental factors are linked to urbanization, such as high-density
traffic, limited sport/recreation facilities, lack of parks and sidewalks, air pollution, fear of crime and violence in outdoor areas discouraged adolescents from becoming more active (33).

1.6 Defining overweight and obesity in adolescents:

As BMI varies with age during childhood and adolescence, the cut-off values used for adults can produce misclassifications of overweight and obesity among 5–19-year-old subjects. Currently, three growth references are commonly considered when assessing weight status in this age group:

1.6.1 International Obesity Task Force system:

International Obesity Task Force (IOTF) system, which is based on data from 6 large, nationally-representative, cross sectional surveys on child growth in Brazil, Great Britain, Hong Kong, the Netherlands, Singapore, and the United States (78). The 2005 IOTF cut-off values are extrapolations of adult BMI cut-off points for overweight (25 kg/m²) and obesity (30 kg/m²) at age 18 years (78) and are widely used internationally.

1.6.2 Centers for Disease Control and Prevention system:

Centers for Disease Control and Prevention (CDC) system (79), which is developed from 5 nationally representative surveys of American children – from the National Health Examination Survey and NHANES (79). The CDC defines overweight as 85th ≤BMI< 95th percentiles, and obesity as BMI ≥95th percentile of the 2000 CDC gender-specific BMI-for-age growth charts (79).

1.6.3 World Health Organization system:

World Health Organization (WHO) system (80) is derived from a combination of United States National Centre for Health Statistics 1977 pooled child growth data, and the WHO Multicenter Growth Reference Study in six countries (Brazil, Ghana, Norway, India, Oman, and the United States) (80). The 2007 WHO classification system defines BMI-for-age >+1 standard deviation
(SD) of the WHO growth standard median as overweight (equivalent to BMI=25 kg/m² at 19 years) and >+2 SD as obesity (equivalent to BMI=30 kg/m² at 19 years) \(^{(80)}\).

Since the prevalence rates of overweight and obesity differ according to these BMI systems \(^{(81,82)}\), the choice of BMI system is critical in assessing excess childhood weight at a population level.

### 1.7 Objectives.

This review aims to highlight the magnitude and to assess the trend of overweight and obesity in Saudi adolescents over the reviewed period, as well as, to look at this problem from behavioral and social standpoint by identifying and constructing an ecological model for social determinants of overweight and obesity in adolescents and discussing them in relation to the Saudi setting.
Chapter 2
METHODS

2 Methods.

2.1 Identifying and constructing an ecological model for Social determinants of overweight and obesity relevant to Saudi adolescents:

The social determinants of overweight and obesity used in this review are the ones we extracted from the literature (section 1.5.5-1.5.11) as factors that can influence body weight (those related to physical activity or diet) as well as potential causes or preventive aspects of overweight and obesity in adolescents that are related to the fast-growing economy of Saudi Arabia (such as large household income, significant modernization, high degree of urbanization...etc) and they included:

1. Dietary habits (patterns/contents).
2. Physical activity.
3. Sedentary behavior (TV/computer screen time, playing video games and surfing the internet time, and use of "passive" modes of transport).
4. Sleep pattern/ Stress/Smoking.
5. Family history of obesity/Family size.
6. Household income (economic/social class).
7. Parental education.
8. Working mother.
9. Health and label literacy.
10. School food/environment.
11. Urbanization.
We grouped these determinants of overweight and obesity in adolescents in an ecological model (Figure 3) to show their relation to the categories of social determinants of health that include; age, sex and constitutional characteristics, individual lifestyle factors, social and community networks, norms and networks, living and working conditions and socioeconomic, cultural and environment conditions.

Figure 3: Ecological model of Social Determinants of Overweight and Obesity in Saudi Adolescents.

2.2 Protocol and Search strategy:

This review was conducted using standard searching methods. The search engines PubMed, Medline, EMBASE, and PsycINFO were searched up to Dec 31, 2018. Search terms were a combination of [“family size” OR “parents employment” OR “economics” OR “household factors” OR “food security” OR “social media” OR “diet patterns” OR “diet content” OR “physical activity” OR “stress” OR “smoking” OR “sleep patterns” OR “urbanization” OR “region” OR “school/food environment” OR “label literacy” OR “gender” AND “overweight” OR “obesity” OR “obesity”.]
AND “adolescents” AND “Saudi Arabia”]. No language or publication date restrictions were applied. Studies dated back to 1982. Studies were considered for inclusion if they present qualitative or quantitative data on adolescents in the including relevant study designs. These included peer-reviewed studies that reported on prevalence, and/or characteristics of overweight, and/or obesity in adolescents in Saudi Arabia. Studies unrelated to obesity and that did not provide data on the determinants of overweight and/or obesity in adolescents in Saudi Arabia were excluded. Non-adolescent studies (younger than 10 and older than 19), duplicates, reviews, and studies on non-Saudi adolescents were further excluded. PRISMA statement in reporting systematic reviews from the observational studies was used (83). Based on the PRISMA criteria, the flow chart in figure 4 shows the search strategy for identification of the databases, screening studies, assessing for eligibility, and the final studies that met selection criteria.

Figure 4: Search strategy for review on prevalence and social determinants of overweight and obesity in adolescents in Saudi Arabia.
2.3 Analysis:

All studies identified through the database searches were analyzed. The titles, abstracts, and full texts of these papers were screened for the inclusion criteria. Included studies were screened and abstracted (Figure 4).

Figure 5. Key variables data Screening form.

A summary was created by tabulating data to facilitate comparison between studies. Data extraction form (Microsoft Excel spreadsheet) was created and data was presented based on the following key variables, (i) author; (ii) year of publication; (iii) number of subjects; (iv) number of males; (v) number of females; (vi) population age range; (vii) type of publication journal; (viii) study design; (ix) region of study; (x) BMI reference standards of overweight and obesity assessment criteria (xi) related social determinants (Appendix 1) (Table 2). STROBE guidelines were applied on the studies that provided data on the social determinants of overweight and obesity in Saudi adolescents to demonstrate how much these studies fulfill the reporting requirements.\(^{(84)}\)
This review was designed to evaluate and assess the trend of overweight and obesity in Saudi adolescents and to identify and construct an ecological model for social determinants of overweight and obesity in adolescents and discuss them in relation to the Saudi setting. Saudi Arabia is divided into 13 administrative regions (figure 6-A), which are described 5 provinces (Northern, Southern, Eastern, Western and Central) that are used in both national and multiregional studies (85,88,93,111,112, 117,1121-23) (figure 6-B). To evaluate the trend of the prevalence of overweight and obesity in Saudi male and female adolescents, prevalence rates reported from national (population based) surveys were compared with each other. Also, yearly mean prevalence rates calculated from regional and multiregional relatively small studies were estimated and compared to examine the trend over the reviewed period.

Table 2. Key variables data & Social determinants of Overweight and Obesity in Saudi Adolescents. (see Appendix 1).
The frequency of each individual determinant was calculated based on the data extracted from each study. When possible, a mean value was calculated for the determinant using values reported in different studies for that determinant. Determinants were presented with their mean prevalence values to reflect the significance of their effect. When possible, a meta-analysis of the studies reporting the determinant and prevalence (%) of overweight and obesity in Saudi adolescents was done with pooled prevalence estimates that were generated using RevMan V.5.3 software. Forest plots were generated to display the overall random-effects pooled estimates with confidence intervals (CIs). Statistical heterogeneity was assessed using the result of the chi-squared test and the value of $I^2$. 

Figure 6. Administrative (A) and province (B) regions of Saudi Arabia.
Chapter 3
RESULTS

3 Results.

3.1 Included studies:

The search identified reports that dated back to 1982 and included studies reported before December 31, 2018 (the date of the search). A total of 810 records were initially identified through database search (PubMed, 303; Ovid MEDLINE, 124; PsycINFO, 198, and EMBASE, 185). All study titles and abstracts were screened for inclusion/exclusion criteria and 676 were excluded (Figure 4) because they examined diseases or symptoms related to overweight and obesity (e.g. metabolic syndrome, asthma, sleep…etc.), investigated medical treatment and surgical intervention studies related to overweight and obesity, described biochemical markers related to overweight and obesity, were off topic or duplicated studies, non-Saudi Arabian studies, and non-adolescent studies (younger than age 10 and older than age 19). Full-text assessment of the 134 included articles were performed to identify eligible studies; 83 records were further excluded because they used the same data set of other reports, were review and growth chart reports, or were studies that did not report on prevalence or determinants of overweight and obesity in Saudi adolescents. Finally, 51 studies met the inclusion criteria and were included in the literature review. All these studies were observational studies, 50 were cross-sectional \(^{(17, 85-118, 120-134)}\) and one was a case-control design \(^{(119)}\) (Appendix 1). Seventeen were published in national journals and 34 in international journals (Appendix 1) (Table 3). Out of the 51 reviewed studies, 41 were single-region (11 central, 10 eastern, 11 western, 7 southern and 2 northern), 8 were multi-province and 2 were national (Table 4). Nineteen studies described one or more of the selected social determinants of overweight and obesity in Saudi adolescents. STROBE guidelines were applied and demonstrated that these 19 studies met between 77.3% and 95.5% of the reporting requirements.
<table>
<thead>
<tr>
<th>Type of Publication Journal</th>
<th>Number of Studies</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>National surveys</td>
<td>Regional/Multiregional</td>
</tr>
<tr>
<td>National</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>International</td>
<td>1</td>
<td>32</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1</strong></td>
<td><strong>49</strong></td>
</tr>
</tbody>
</table>

*Table 3. Type of publication journals used in the review.*

### 3.2 Study population:

The 51 reviewed studies (17, 85-134) included 97,666 adolescents with 56.9% males (Table 4). The current estimated population of Saudi Arabia based on the 2016 census is 31,742,308 with 57.2% males, out of which 4,638,906 are adolescents with 51.0% males (135) (Figure 7). All province and multi-regional studies included school students, while the national studies were population-based surveys. The distribution (number & %) of males and females in each province/region is shown in Table 4.

*Table 4. Distribution (number & %) of subjects included in the studies per region.*
3.3 Determining Overweight and Obesity:

Different BMI reference standards were used to define overweight and obesity in Saudi Arabian adolescents in the reviewed studies. Sixteen studies used the CDC, 16 used IOTF and 13 used WHO criteria. One study used both WHO and IOTF and another compared CDC with WHO criteria. In 5 studies reference standards were not reported (Appendix 1) (Table 5). One of the national surveys used CDC, the other used IOTF and the third compared CDC with WHO criteria.
Table 5. BMI reference standards used to define overweight and obesity in Saudi Arabian adolescents in the reviewed studies. CDC = Centers for Disease Control; IOTF = International Obesity Task Force; WHO = World Health Organization.

<table>
<thead>
<tr>
<th>BMI Reference Standards</th>
<th>Number of Studies</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>National</td>
<td>Regional/ Multiregional</td>
</tr>
<tr>
<td>- CDC</td>
<td></td>
<td>16</td>
</tr>
<tr>
<td>- WHO</td>
<td></td>
<td>13</td>
</tr>
<tr>
<td>- IOTF</td>
<td>1</td>
<td>14</td>
</tr>
<tr>
<td>- Combined</td>
<td>1(WHO+CDC)</td>
<td>1(WHO+IOTF)</td>
</tr>
<tr>
<td>- Not Reported</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>- Total</td>
<td>2</td>
<td>49</td>
</tr>
</tbody>
</table>

### 3.4 Prevalence Rates of overweight and obesity:

Prevalence rates were reported in different ways within the reviewed articles. They were reported as rates of either overweight alone, obesity alone or overweight and obesity together, in either males alone, females alone or males and females together (Appendix 2). The prevalence rates of overweight and obesity for male and/or female adolescents reported in the 50 cross-sectional studies were used for the evaluation of the trend over the reviewed period.

#### 3.4.1 Prevalence Rates of overweight and obesity from national surveys:

There were 2 national (population based) surveys, one in 2002 and the other in 2010 (88,103). Reported prevalence rates of overweight and obesity in Saudi adolescents from these surveys were 16.0% and 6.2% for males and 17.4% and 7.2%, respectively in the year 2002, and 25.7% and 11.5% for males and 27.4% and 10.0%, respectively in the year 2010 (Figure 8, A and B). These numbers clearly show a clear increase in the prevalence of overweight and obesity in both males and females between the years 2002 and 2010, from 22.2% to 36.2% for males and from 24.6% to 38.4% for females, respectively (Figure 8, A and B).
3.4.2 Prevalence Rates of overweight and obesity from regional and multiregional studies:

Although prevalence rates estimated from regional studies with a specific population (e.g. school based, as in the case of all reviewed regional studies) are not as accurate as those estimated from national surveys, we decided to evaluate the trend of prevalence rates of overweight and obesity of male and female adolescents reported in these studies for the following reasons: i- the large number of reviewed studies that were reported from all regions and included a large number of males and females with a ratio close to the that of the total and adolescent populations in Saudi Arabia, ii- the fact that school based adolescent population in Saudi Arabia represents the majority of adolescents in the country, as they exceeded 93% of total adolescent population in the year 2016 for both males and females, and, iii- no national survey of overweight and obesity in adolescents has been reported from Saudi Arabia since 2010.

Yearly mean prevalence rates that were calculated from the regional studies are shown in table 6. Prevalence rates calculated for the years 2002 and 2010 were relatively in line with the prevalence rates estimated from national surveys for males and females, 28.3% and 25.5% vs 22.2% and 24.6%, respectively, for the year 2002 and 39.1% and 42.6% vs 36.3% and 38.4% for the year 2010. It was noticed that prevalence rate continued to increase for males reaching 48.3% in the year 2018, on the other hand, it tended to fluctuate and decreased for females reaching 27.6% in the year 2017.
Table 6. Yearly mean prevalence (%) rates standards used to define overweight and obesity in Saudi Arabian adolescents in the reviewed regional and multiregional studies.

<table>
<thead>
<tr>
<th>Year</th>
<th>Yearly Mean Prevalence (%) of Overweight and Obesity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males</td>
</tr>
<tr>
<td>2002</td>
<td>28.3</td>
</tr>
<tr>
<td>2005</td>
<td>29.5</td>
</tr>
<tr>
<td>2007</td>
<td>24.1</td>
</tr>
<tr>
<td>2008</td>
<td>24.8</td>
</tr>
<tr>
<td>2009</td>
<td>31.2</td>
</tr>
<tr>
<td>2010</td>
<td>39.1</td>
</tr>
<tr>
<td>2011</td>
<td>25.3</td>
</tr>
<tr>
<td>2012</td>
<td>35.2</td>
</tr>
<tr>
<td>2013</td>
<td>41.0</td>
</tr>
<tr>
<td>2014</td>
<td>43.6</td>
</tr>
<tr>
<td>2015</td>
<td>45.3</td>
</tr>
<tr>
<td>2016</td>
<td>47.5</td>
</tr>
<tr>
<td>2017</td>
<td>22.4</td>
</tr>
<tr>
<td>2018</td>
<td>48.3</td>
</tr>
</tbody>
</table>

Figure 9. Trend of overweight and obesity in Saudi male and female adolescents estimated from calculated yearly mean prevalence rates reported by reviewed regional studies.
3.5 Social Determinants of overweight and obesity.

Out of the 51 reviewed studies, there were 49 reports from 19 studies about social determinants of overweight and obesity, as some studies reported information about more than one social determinant (Appendix 1). The number of reports for each determinant were generally small and varied from 0 (for Label literacy and social media) to 9 (for parents’ education) (Table 7).

<table>
<thead>
<tr>
<th>Social Determinant</th>
<th>Diet patterns/contents</th>
<th>Physical activity</th>
<th>Sedentary behavior</th>
<th>Sleep patterns/ Stress/ smoking</th>
<th>Family Hx of Obesity/ Family size</th>
<th>Household income</th>
<th>Parental education</th>
<th>Working mother</th>
<th>Label literacy</th>
<th>School food environment</th>
<th>Urbanization/ Mobility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of reports</td>
<td>6</td>
<td>7</td>
<td>6</td>
<td>3</td>
<td>4</td>
<td>7</td>
<td>9</td>
<td>4</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

*Table 7. Number of reviewed reports for each determinant of overweight and obesity.*

3.5.1 Diet patterns/contents:

There were 5 studies (90,96,110,124,130) on the diet patterns/contents and adolescent overweight and obesity in 8149 subjects (6643 males and 1506 females). Three reports evaluated the effect of fast food and soft drink intake and the prevalence of overweight and obesity (Table 8-A). Meta-analysis results of these 3 studies in male adolescents (Figure 10) indicated a statistically significant positive association between fast food and soft drink consumption 2-4 times/week and odds of overweight and obesity – a pooled odds ratio of 1.62 (95% CI 1.62 to 2.43) with p=0.02. I² was 35% and may suggest low-moderate heterogeneity. Two other reports (Table 1-B) indicated a positive association between skipping breakfast and overweight and obesity in Saudi adolescents with a higher mean prevalence of 30.6% vs 14.7%. Another report (Table 8-B) indicated a negative association between overweight and obesity and vegetable consumption >3 times/week. negatively associated with higher vegetable intake. More studies with standardized format that cover other food contents are needed to further delineate the effect of diet pattern and content on overweight and obesity in adolescents in Saudi Arabia.
Table 8-A. Fast food and soft drink intake and the prevalence (%) of overweight and obesity in Saudi adolescents.

<table>
<thead>
<tr>
<th>Author</th>
<th>Total #</th>
<th>Males</th>
<th>Females</th>
<th>Ow/Ob (%) Fast food &amp; soft drinks 2-4 times/w</th>
<th>Ow/Ob (%) Fast food &amp; soft drinks &lt;2 times/w</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al-Rukban, et al. (90)</td>
<td>885</td>
<td>885</td>
<td></td>
<td>42.7</td>
<td>36.4</td>
</tr>
<tr>
<td>Al Dahi, et al. (130)</td>
<td>2696</td>
<td>2696</td>
<td></td>
<td>60</td>
<td>38</td>
</tr>
<tr>
<td>Alenazi, et al. (124)</td>
<td>523</td>
<td>523</td>
<td></td>
<td>42.1</td>
<td>36.3</td>
</tr>
</tbody>
</table>

Figure 10. Meta-analysis: Fast food/Soft drinks and prevalence (%) of overweight and obesity in Saudi adolescents.
3.5.2 Physical activity:

There were 7 reports \(^{(90,110,113,118,124,130,132)}\) on physical activity and adolescent overweight and obesity in 4571 subjects. Three studies (Table 9-A) evaluated the effect of physical activity duration in minutes. The evaluation parameters varied between studies and included physical activity for >30 minutes/week, >60 minutes/week, and >3 times/week. Meta-analysis results of these 3 studies (Figure 11) indicated a no statistically significant association between less physical activity/week and odds of overweight and obesity – a pooled odds ratio of 0.38 (95% CI 0.12 to 1.23) with \(p=0.11\) and \(I^2 = 88\%\) suggesting considerable heterogeneity. Another report (Table 9-B) used total METS (minute/week) for the evaluation and demonstrated a positive association between less physical activity/week (\(p=<0.05\)) in both males and females. Other 3 reports showed that a high % of adolescents never exercise, mainly females (reached 100% in one study) (Table 9-B). These results might not reflect the current status because of the recent drastic changes in lifestyle and factors/facilities that adolescents, especially females, are exposed to in Saudi Arabia within the past year. More new studies with standardized protocols are needed to further delineate the effect of this determinant on overweight and obesity in adolescents in Saudi Arabia.

Table 8-B. skipping breakfast and vegetable intake and the prevalence (%) of overweight and obesity in Saudi adolescents.
Table 9-A. Duration of physical activity and the prevalence (%) of overweight and obesity in Saudi adolescents.

<table>
<thead>
<tr>
<th>Author</th>
<th>Total #</th>
<th>Male(s)</th>
<th>Females</th>
<th>Ow/Ob (%)</th>
<th>Ow/Ob (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&gt;30 min/week</td>
<td>&lt; 30 min/week</td>
</tr>
<tr>
<td>Al-Rukban, et al.</td>
<td>885</td>
<td>885</td>
<td></td>
<td>46.5%</td>
<td>52%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&gt;60 min/week</td>
<td>&lt; 60 min/week</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.8%</td>
<td>11.9%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&gt;3 times/week</td>
<td>&lt; 3 times/week</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>27.5%</td>
<td>72.5%</td>
</tr>
</tbody>
</table>

Figure 11. Meta-analysis: Physical activity and the prevalence (%) of overweight and obesity in Saudi adolescents.
3.5.3 Sedentary behavior factors:

There were 6 studies on the association between TV/ computer screen time and overweight and obesity in Saudi adolescents with a total of 7784 subjects. Four studies \(^{119,124,130,133}\) investigated the association between TV/ computer screen time and the prevalence of overweight and obesity in 3009 subjects (Table 10-A) and 2 studies \(^{97,110}\) compared the screen time spent by overweight and obese subjects to that spent by normal subjects in 4775 subjects (Table 10-B). The screen time used for the evaluation varied between studies and within the same study from >2 to >6 hours per day, and from weekday to weekend. The prevalence of overweight and obesity was noted to be higher in those with longer time spent on TV/computer. Despite that variation, a meta-analysis was done for these studies (Figure 12) and indicated a statistically significant positive association between longer TV/computer screen time and odds of overweight and obesity – a pooled odds ratio of 1.56 (95% CI 1.18 to 2.06) with \(p < 0.002\) and \(I^2 = 38\%\) and may suggest low-moderate heterogeneity. The other 2 reports (Table 10-B) showed that the number of hours per day of TV/Computer screen time spent by overweight and obese Saudi adolescents was higher than that spent by normal weight adolescents, however only one of these 2 studies showed significant results.

Table 10-A.

<table>
<thead>
<tr>
<th>Author</th>
<th>Total #</th>
<th>Males</th>
<th>Females</th>
<th>Total METs-(min/week) by Ow/Ob subjects</th>
<th>Total METs-(min/week) by Normal subjects</th>
<th>(P) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al-Hazzaa, et al. (^{110})</td>
<td>2906</td>
<td>1400</td>
<td>1506</td>
<td>2861.2 (M)</td>
<td>3365.4 (M)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1237 (F)</td>
<td>1194 (F)</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

Table 10-B. The practice of physical activity and the prevalence (%) of overweight and obesity in Saudi adolescents.

<table>
<thead>
<tr>
<th>Author</th>
<th>Total #</th>
<th>Males</th>
<th>Females</th>
<th>Never practice physical exercise (%) among adolescents</th>
<th>(P) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al Alwan, et al. (^{118})</td>
<td>1243</td>
<td>542</td>
<td>701</td>
<td>38%</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Al Dahi, et al. (^{130})</td>
<td>1832</td>
<td>852</td>
<td>980</td>
<td>31.1% (M) &amp; 100% (F)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Al-Nakeeb, et al. (^{113})</td>
<td>1138</td>
<td>600</td>
<td>538</td>
<td>34.5% (M) &amp; 81.4% (F)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
There were no studies about the effect of rapidly growing social media, playing video games and surfing the internet, as well as the use of "passive" modes of transport, in relation to adolescent overweight and obesity in Saudi Arabia. Studies are needed to properly evaluate the effect of sedentary behavior factors on overweight and obesity in Saudi adolescents.

<table>
<thead>
<tr>
<th>Author</th>
<th>Total #</th>
<th>Males</th>
<th>Females</th>
<th>Ow/Ob (%) &gt;3hrs daily</th>
<th>Ow/Ob (%) &lt;3hrs daily</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al-Ghamdi, S.</td>
<td>397</td>
<td>201</td>
<td>196</td>
<td>56.1</td>
<td>43.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&gt;3hrs weekday</td>
<td>&lt; 3hrs weekday</td>
</tr>
<tr>
<td>Al-Ghamdi, S.</td>
<td>397</td>
<td>201</td>
<td>196</td>
<td>47</td>
<td>53</td>
</tr>
<tr>
<td>Alenazi, et al.</td>
<td>523</td>
<td>523</td>
<td></td>
<td>37.4</td>
<td>28.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&gt;3hrs weekend</td>
<td>&lt; 3hrs weekend</td>
</tr>
<tr>
<td>Al-Ghamdi, S.</td>
<td>397</td>
<td>201</td>
<td>196</td>
<td>56.7</td>
<td>43.3</td>
</tr>
<tr>
<td>Alenazi, et al.</td>
<td>523</td>
<td>523</td>
<td></td>
<td>48.3</td>
<td>41.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&gt;6hrs weekend</td>
<td>&lt; 6hrs weekend</td>
</tr>
<tr>
<td>Al Dahi, et al.</td>
<td>1832</td>
<td>852</td>
<td>980</td>
<td>43</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&gt;2hrs weekend</td>
<td>&lt; 2hrs weekend</td>
</tr>
<tr>
<td>Alazzezeh, et al.</td>
<td>257</td>
<td>257</td>
<td></td>
<td>69</td>
<td>50.4</td>
</tr>
</tbody>
</table>

*Table 10. TV/Computer screen time and the prevalence (%) of overweight and obesity in Saudi adolescents.*

<table>
<thead>
<tr>
<th>Author</th>
<th>Total #</th>
<th>Males</th>
<th>Females</th>
<th># of hours/day spent by Ow/Ob subjects</th>
<th># of hours/day spent by Normal subjects</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al-Hazzaa, et al.</td>
<td>2906</td>
<td>1400</td>
<td>1506</td>
<td>5.9</td>
<td>5.6</td>
<td>NS</td>
</tr>
<tr>
<td>Mahfouz, et al.</td>
<td>1869</td>
<td>1249</td>
<td>620</td>
<td>2.5</td>
<td>2.1</td>
<td>0.038</td>
</tr>
</tbody>
</table>

*Table 11. TV/Computer screen time spent by Saudi adolescents in relation to body weight.*
TV/Computer Screen Time & Prevalence (%) of Overweight / Obesity

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Odds Ratio M-H, Random, 95% CI</th>
<th>Odds Ratio Weight M-H, Random, 95% CI</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al-Ghamdi, S. &quot;(119) &lt; 3hrs Daily</td>
<td>&lt; 3hrs Daily 14.7% 1.76 [1.00, 3.08] 2013</td>
<td>&gt; 3hrs Daily 14.8% 0.79 [0.45, 1.37] 2013</td>
<td></td>
</tr>
<tr>
<td>Al-Ghamdi, S. &quot;(119) &lt; 3hrs weekday</td>
<td>&lt; 3hrs weekday 14.7% 0.79 [0.45, 1.37] 2013</td>
<td>&gt; 3hrs weekday 14.7% 1.62 [0.93, 2.83] 2013</td>
<td></td>
</tr>
<tr>
<td>Al-Ghamdi, S. (119) &lt; 3hrs weekend</td>
<td>&lt; 3hrs weekend 14.7% 0.79 [0.45, 1.37] 2013</td>
<td>&gt; 3hrs weekend 13.6% 1.51 [0.83, 2.74] 2015</td>
<td></td>
</tr>
<tr>
<td>Alenazi, et al. &quot;(124) &lt; 3hrs weekday</td>
<td>&lt; 3hrs weekday 14.7% 0.79 [0.45, 1.37] 2013</td>
<td>&gt; 3hrs weekend 14.7% 1.33 [0.76, 2.32] 2015</td>
<td></td>
</tr>
<tr>
<td>Alenazi, et al. (124) &lt; 3hrs weekend</td>
<td>&lt; 3hrs weekend 14.7% 0.79 [0.45, 1.37] 2013</td>
<td>&gt; 6hrs week day 13.3% 2.39 [1.30, 4.38] 2017</td>
<td></td>
</tr>
<tr>
<td>Al Dahi, et al. (130) &lt; 6hrs week day</td>
<td>&lt; 6hrs week day 14.7% 0.79 [0.45, 1.37] 2013</td>
<td>&gt; 2hrs week day 14.1% 2.23 [1.25, 3.96] 2018</td>
<td></td>
</tr>
<tr>
<td>Alazzeh, et al. (133) &lt; 2hrs week day</td>
<td>&lt; 2hrs week day 14.7% 0.79 [0.45, 1.37] 2013</td>
<td>&gt; 2hrs week day 14.1% 2.23 [1.25, 3.96] 2018</td>
<td></td>
</tr>
<tr>
<td>Total (95% CI)</td>
<td>100.0% 1.56 [1.18, 2.06]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 12.** Meta-analysis: TV/Computer screen time and the prevalence (%) of overweight and obesity in Saudi adolescents.

### 3.5.4 Sleep pattern/ Stress/Smoking:

Only one study (132) about the association between smoking and the prevalence of overweight and obesity was reported that included 257 female subjects. The prevalence of overweight and obesity was 0% in the smokers and 0.7% in the non-smokers. With these small numbers, the association between smoking and the prevalence of overweight and obesity in Saudi adolescents cannot be evaluated. With a tobacco epidemic being on the rise in Saudi adolescents (136), more current studies are needed to further delineate the effect of this determinant on overweight and obesity.

There were 2 reports (101,110) about the association between sleep pattern and the prevalence of overweight and obesity (Table 11) and they included 2852 male subjects. The parameter used to evaluate the effect of sleep pattern on overweight and obesity was < 7 hours in the first study and < 8 hours in the second study. Both studies showed positive association between decreased number of sleeping hours and overweight and obesity with a reported a p-value of <0.005 in one study and <0.006 in the other. More studies with fixed parameters are needed to properly evaluate the effect of this determinant on overweight and obesity.
No studies were reported about the association between stress and the prevalence of overweight and obesity in Saudi adolescents. Therefore, studies are needed.

3.5.5 Family history of obesity/Family size:

The association between family history of obesity and the prevalence of overweight and obesity was reported in 2 studies (90,130) that included 2717 subjects (1737 males and 980 females) (Table 13). Both concluded a significant association between overweight and obesity and a positive family history of obesity with p-value of <0.05. However, no values of prevalence were reported in the second study. More studies with fixed parameters are needed to properly evaluate the effect of this determinant on overweight and obesity in adolescents in Saudi Arabia.

There were also 2 reports (96,133) about the association between family size and the prevalence of overweight and obesity (Table 13) and they included 2634 male subjects. The parameter used for the evaluation of the effect of family size on overweight and obesity was > 6 in the first study and > 8 in the second. A family size <6-8 was negatively associated with obesity with a reported a p-value of <0.001 in one study and 0.05 in the other. More studies with fixed parameters are needed to properly evaluate the effect of this determinant on overweight and obesity.

Table 11. Sleep pattern and the prevalence (%) of overweight and obesity in Saudi adolescents.
Table 12. Family size and the prevalence (%) of overweight and obesity in Saudi adolescents.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Total #</th>
<th>Males</th>
<th>Females</th>
<th>Ow/Ob (%) (Family size &gt;8)</th>
<th>Ow/Ob (%) (Family size &lt;8)</th>
<th>OR</th>
<th>95% CI</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alazzeh, et al.</td>
<td>1495</td>
<td>1495</td>
<td></td>
<td>11.8%</td>
<td>17.3%</td>
<td>0.68</td>
<td>0.48–0.92</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(Family size &gt;6)</td>
<td>(Family size &lt;6)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amin, et al.</td>
<td>1139</td>
<td>1139</td>
<td></td>
<td>15.4%</td>
<td>38.0%</td>
<td>0.3</td>
<td>0.2–0.4</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Table 13. Family history of obesity and the prevalence (%) of overweight and obesity in Saudi adolescents.

<table>
<thead>
<tr>
<th>Author</th>
<th>Total #</th>
<th>Males</th>
<th>Females</th>
<th>Ow/Ob (%) +ve FH of Ob</th>
<th>Ow/Ob (%) -ve FHx of Ob</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al-Rukban, et al.</td>
<td>885</td>
<td>885</td>
<td></td>
<td>52.6</td>
<td>30.8</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Al Dahi, et al.</td>
<td>1832</td>
<td>852</td>
<td>980</td>
<td>More Ow/Ob</td>
<td>Less Ow/Ob</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

3.5.6 Household income (Economic/Social class):

The association between economic/social class and the prevalence of overweight and obesity in adolescents was reported in 7 studies (92,95,97,98,118,132,133) that included 11218 subjects (5564 males and 5654 females) (Table 14). The group with the higher economic/social class (defined by high income, attending private schools or owning a house) (Table 14) had higher prevalence rates of overweight and obesity in all studies and a higher calculated mean prevalence (30.1% vs 15.1%). Meta-analysis results of these 7 studies (Figure 13) indicated a statistically significant positive association between higher economic/social class and odds of overweight and obesity – a pooled odds ratio of 2.66 (95% CI 1.56 to 4.53) with p= <0.0003. However, $I^2$ was 71%, suggesting substantial heterogeneity. Therefore, more studies with fixed indicators are needed to properly evaluate the effect of economic/social class on overweight and obesity in Saudi adolescents.
Table 14. Economic/social class and the prevalence (%) of overweight and obesity in Saudi adolescents.

<table>
<thead>
<tr>
<th>Author</th>
<th>Total #</th>
<th>Males</th>
<th>Females</th>
<th>High class</th>
<th>Low class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Class indicator</td>
<td>Ow/Ob (%)</td>
</tr>
<tr>
<td>Abalkhail, et al. (92)</td>
<td>2860</td>
<td>1403</td>
<td>1457</td>
<td>Private school</td>
<td>34.9</td>
</tr>
<tr>
<td>Al-Saeed, et al. (95)</td>
<td>1610</td>
<td>1610</td>
<td></td>
<td>Income &gt;10000 SR</td>
<td>24.3</td>
</tr>
<tr>
<td>Mahfouz, et al. (97)</td>
<td>1243</td>
<td>542</td>
<td>701</td>
<td>Income &gt;3000 SR</td>
<td>20.5</td>
</tr>
<tr>
<td>Khalid, M. (98)</td>
<td>1884</td>
<td>875</td>
<td>1009</td>
<td>Income &gt;15000 SR</td>
<td>11.7</td>
</tr>
<tr>
<td>Al Alwan, et al. (118)</td>
<td>1495</td>
<td>1495</td>
<td></td>
<td>Income &gt;20000 SR</td>
<td>42</td>
</tr>
<tr>
<td>Adaili, et al. (132)</td>
<td>1869</td>
<td>1249</td>
<td>620</td>
<td>Own a house</td>
<td>43.3</td>
</tr>
<tr>
<td>Alazzez, et al. (133)</td>
<td>257</td>
<td>257</td>
<td></td>
<td>Income &gt;20000 SR</td>
<td>34</td>
</tr>
<tr>
<td>Total</td>
<td>11218</td>
<td>5564</td>
<td>5654</td>
<td></td>
<td>210.7</td>
</tr>
</tbody>
</table>

Mean 30.1% 15.1%

Figure 13. Meta-analysis: Economic/Social class and prevalence (%) of overweight and obesity in Saudi adolescents.

3.5.7 Parental Education:

The association between mother education and the prevalence of overweight and obesity in adolescents was reported in 9 studies (92,95-97,108,118,130,132,133) that included 15001 subjects (9376 males and 3625 females) (Table 15). The group with mothers with the highest level of education
had higher prevalence rates of overweight and obesity in 8 of the nine studies and a higher calculated mean prevalence (29.6% vs 25.8%). Meta-analysis results of these 9 studies (Figure 14) indicated a statistically significant positive association between mothers with the highest level of education and odds of overweight and obesity – a pooled odds ratio of 1.45 (95% CI 1.18 to 1.78) with \( p = 0.04 \). However, \( I^2 \) was 71%, which suggests substantial heterogeneity. It is important to know how much of this effect is confounded by economic/social class. Mother education may not be a risk factor for overweight and obesity, but rates could be higher among higher economic/social class groups who also happen to be more educated. Only 3 out of the 9 reported studies in Saudi adolescents looked at mother education and economic/social class together. Therefore, more studies are needed to properly evaluate the effect of mother education on overweight and obesity in Saudi adolescents, as well as its relation to economic/social class.

### Table 15. Mother education and the prevalence (%) of overweight and obesity in Saudi adolescents.

<table>
<thead>
<tr>
<th>Author</th>
<th>Total #</th>
<th>Males</th>
<th>Females</th>
<th>Ow/Ob (%) Highest level of education</th>
<th>Ow/Ob (%) Lowest level of education/illiteracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abalkhail, et al. (92)</td>
<td>2860</td>
<td>1403</td>
<td>1457</td>
<td>35.2</td>
<td>23.3</td>
</tr>
<tr>
<td>Al-Saeed, et al. (95)</td>
<td>1610</td>
<td>803</td>
<td>807</td>
<td>32.3</td>
<td>26.6</td>
</tr>
<tr>
<td>Amin, et al. (96)</td>
<td>1139</td>
<td>572</td>
<td>567</td>
<td>37.5</td>
<td>30.0</td>
</tr>
<tr>
<td>Al Alwan, et al. (118)</td>
<td>1243</td>
<td>542</td>
<td>701</td>
<td>40.0</td>
<td>19.0</td>
</tr>
<tr>
<td>Al Dahi, et al. (130)</td>
<td>1832</td>
<td>852</td>
<td>980</td>
<td>28.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Alazzez, et al. (133)</td>
<td>1495</td>
<td>708</td>
<td>787</td>
<td>35.0</td>
<td>18.6</td>
</tr>
<tr>
<td>Mahfouz, et al. (97)</td>
<td>2696</td>
<td>1294</td>
<td>1402</td>
<td>36.6</td>
<td>29.9</td>
</tr>
<tr>
<td>Mahfouz, et al. (108)</td>
<td>1869</td>
<td>1249</td>
<td>620</td>
<td>28.4</td>
<td>25.0</td>
</tr>
<tr>
<td>Adaili, et al. (132)</td>
<td>257</td>
<td>127</td>
<td>130</td>
<td>31.1</td>
<td>50.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>15001</td>
<td>9376</td>
<td>5625</td>
<td>266.6</td>
<td>232.9</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td></td>
<td></td>
<td></td>
<td>29.6%</td>
<td>25.8%</td>
</tr>
</tbody>
</table>
The association between father education and the prevalence of overweight and obesity in Saudi adolescents was reported in 6 studies that included 8699 subjects (7121 males and 1578 females) (Table 16). The group with fathers with the highest level of education had higher prevalence rates of overweight and obesity in all studies and a higher calculated mean prevalence (37.6% vs 27.7%). Meta-analysis results of these 6 studies (Figure 12) indicated a statistically significant positive association between fathers with the highest level of education and odds of overweight and obesity – a pooled odds ratio of 1.58 (95% CI 1.22 to 2.05) with p=0.0005. Heterogeneity was low with an $I^2 = 10\%$, suggesting low heterogeneity.

**Figure 14. Meta-analysis: Mother’s education and prevalence (%) of overweight and obesity in Saudi adolescents.**
Table 16. Father’s education and the prevalence (%) of overweight and obesity in Saudi adolescents.

<table>
<thead>
<tr>
<th>Author</th>
<th>Total #</th>
<th>Males</th>
<th>Females</th>
<th>Ow/Ob (%) Highest level of education</th>
<th>Ow/Ob (%) Lowest level of education/illiteracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amin, et al. (96)</td>
<td>1139</td>
<td>1139</td>
<td></td>
<td>50.1</td>
<td>35.1</td>
</tr>
<tr>
<td>Al Alwan, et al. (118)</td>
<td>1243</td>
<td>542</td>
<td>701</td>
<td>40.5</td>
<td>28.0</td>
</tr>
<tr>
<td>Alazzeh, et al. (133)</td>
<td>1495</td>
<td>1495</td>
<td></td>
<td>28.7</td>
<td>24.0</td>
</tr>
<tr>
<td>Mahfouz, et al. (97)</td>
<td>2696</td>
<td>2696</td>
<td></td>
<td>34.2</td>
<td>29.1</td>
</tr>
<tr>
<td>Mahfouz, et al. (108)</td>
<td>1869</td>
<td>1249</td>
<td>620</td>
<td>27.0</td>
<td>26.0</td>
</tr>
<tr>
<td>Adaili, et al. (132)</td>
<td>257</td>
<td>257</td>
<td></td>
<td>45.2</td>
<td>24.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>8699</strong></td>
<td><strong>7121</strong></td>
<td><strong>1578</strong></td>
<td><strong>225.7</strong></td>
<td><strong>166.2</strong></td>
</tr>
</tbody>
</table>

Mean 37.6% 27.7%

Figure 15. Meta-analysis: Father’s education and prevalence (%) of overweight and obesity in Saudi adolescents.
3.5.8 Working mother:

There were 4 reports\(^{(94-96,132)}\) on the association between mother’s work and adolescent overweight and obesity (Table 17) that included 5702 subjects, 2 studies were in males (3835) and 2 in females (1867). The mean prevalence was higher in the group with working mothers (33.1% vs 24.7%). Meta-analysis results of these 4 studies (Figure 16) indicated a statistically significant positive association between mother’s work and odds of overweight and obesity – a pooled odds ratio of 1.51 (95% CI 1.11 to 2.06) with p=0.009 and an I\(^2\) = 0%, suggesting low heterogeneity.

<table>
<thead>
<tr>
<th>Author</th>
<th>Total #</th>
<th>Males</th>
<th>Females</th>
<th>Ow/Ob (%) Working</th>
<th>Ow/Ob (%) Non-working</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al-Saeed, et al.</td>
<td>1610</td>
<td>1610</td>
<td></td>
<td>35.6</td>
<td>23.3</td>
</tr>
<tr>
<td>Amin, et al.</td>
<td>1139</td>
<td>1139</td>
<td></td>
<td>32.1</td>
<td>22</td>
</tr>
<tr>
<td>Mahfouz, et al.</td>
<td>2696</td>
<td>2696</td>
<td></td>
<td>31</td>
<td>30</td>
</tr>
<tr>
<td>Adaili, et al.</td>
<td>257</td>
<td>257</td>
<td></td>
<td>33.8</td>
<td>23.6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>5702</strong></td>
<td><strong>3835</strong></td>
<td><strong>1867</strong></td>
<td><strong>132.5</strong></td>
<td><strong>98.9</strong></td>
</tr>
</tbody>
</table>

Table 17. Working mother and the prevalence (%) of overweight and obesity in Saudi adolescents.
Figure 16. Meta-analysis: Working mothers and prevalence (%) of overweight and obesity in Saudi adolescents.

3.5.9 Health/Label literacy.

No studies were reported about the association between label literacy and the prevalence of overweight and obesity in Saudi adolescents. Therefore, studies are needed.

3.5.10 School food/environment:

There was only one report about the association between School environment and the prevalence of overweight and obesity in Saudi adolescents (Table 18). This study included 1495 males and did not show any significant association between the two. More studies are needed to further delineate the effect of this determinant on overweight and obesity in Saudi adolescents.
**Table 18.** School environment and the prevalence (%) of overweight and obesity in Saudi adolescents

<table>
<thead>
<tr>
<th>Author</th>
<th>Total #</th>
<th>Males</th>
<th>Females</th>
<th>Ow/Ob (%) Private</th>
<th>Ow/Ob (%) Public</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al Alwan, et al.</td>
<td>1495</td>
<td>1495</td>
<td></td>
<td>36.7</td>
<td>32.9</td>
<td>NS</td>
</tr>
</tbody>
</table>

3.5.11 Urbanization:

Only 2 studies about the association between urbanization and the prevalence of overweight and obesity in adolescents in Saudi Arabia were reported and included 2409 subjects (1802 males and 607 females) (Table 19). In the first report, the prevalence of overweight and obesity was significantly higher in urban than rural adolescents (26.9% vs 19.0%, respectively, p=0.011) in both males and females reported together. On the other hand, the second study showed significance only in males (39.4% vs 27.7%, respectively with p=<0.004). These results suggest that Urbanization is possibly associated with overweight and obesity mostly in male adolescents. More studies are needed to further delineate the effect of this determinant on overweight and obesity in Saudi adolescents.

**Table 19.** Urbanization and the prevalence (%) of overweight and obesity in Saudi adolescents.

<table>
<thead>
<tr>
<th>Author</th>
<th>Total #</th>
<th>Males</th>
<th>Females</th>
<th>Ow/Ob (%) Urban</th>
<th>Ow/Ob (%) Rural</th>
<th>P value</th>
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<td></td>
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<td>19</td>
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<td>Al-Nuaim, et al.</td>
<td>1270</td>
<td>663</td>
<td>607</td>
<td>(for both M&amp;F) 39.4</td>
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<td></td>
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<td>(for only M) 39.5</td>
<td>27.7</td>
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</tbody>
</table>
4 Discussion

This review aims to highlight the magnitude and to assess the trend of overweight and obesity in Saudi adolescents over the reviewed period, as well as, to look at this problem from behavioral and social standpoint by identifying and constructing an ecological model for social determinants of overweight and obesity in adolescents and discussing them in relation to the Saudi setting.

4.1 Prevalence Rates:

To highlight the magnitude of the problem in Saudi adolescents, prevalence rates of overweight and obesity were evaluated in Saudi adolescents from national (population based) as well as from regional (specific population) studies and to assess the trend of these rates over the reviewed period.

4.1.1 Prevalence Rates of overweight and obesity from national surveys:

It is clear from this review that overweight and obesity in adolescents represent a rising problem in Saudi Arabia. In the first 2002 survey, the prevalence of overweight and obesity in Saudi adolescents started off high, 22.2% in males and 24% in females. With an increase of 39% in males and 36% in females, the prevalence of overweight and obesity in adolescents became 36.2% in males and 38.4% in females during the second survey of 2010. This falls in line with the increasing prevalence of overweight and obesity among many countries in the Middle East and North Africa region, especially in the Gulf region (137). If continued at the same rate, it is expected to have had reached 50.3% in male and 52.2% at the time of this review. It is well known that obesity in adolescents has a serious impact later in life in the form of disturbances in health, including NCDs, and wellbeing, which translates into a significant decrease in life expectancy and quality of life (14, 138). It is likely that the high prevalence of obesity in Saudi adolescents plays a significant role in increasing NCDs in the country (18). Therefore, the management of adolescent obesity in Saudi Arabia is considered as a public health priority. Knowing that the treatment of obesity after it has
been established is very difficult, early intervention to prevent obesity in adolescents, by identifying and modifying related social determinants, becomes extremely important (\textsuperscript{139}).

4.1.2 Prevalence Rates of overweight and obesity from regional and multi-regional studies:

Calculated yearly mean prevalence rates were used to assess the trend of overweight and obesity in Saudi adolescents over the reviewed period. Cross-sectional comparisons of the prevalence rates of overweight and obesity from different regional studies are challenging due the use of non-representative samples, differences in age and gender of the samples, and the use of different cutoff reference standards for overweight and obesity in this age group. However, we decided to evaluate the trend of prevalence rates using this method for the following reasons: i- the large number of reviewed studies that were reported from all regions and included a large number of males and females with a ratio close to the that of the total and adolescent populations in Saudi Arabia, ii- the fact that school based adolescent population in Saudi Arabia represents the majority of adolescents in the country, as they exceeded 93% of total adolescent population in the year 2016 (\textsuperscript{70}) for both males and females, and, iii- no national survey of overweight and obesity in adolescents has been reported from Saudi Arabia since 2010.

Calculated yearly mean prevalence rates for the years 2002 and 2010 were in line with the prevalence rates estimated from national surveys for males and females. Also, they continued to increase for males reaching 48.3% in the year 2018, which is in line with the projected prevalence rate from the national studies. These observations suggest that the calculated prevalence rates might be acceptable reflections of the true ones. However, one observation was not consistent with the expected value. The calculated yearly mean prevalence rate for females tended to decrease from the highest value of 42.6 in the year 2010, with the main decrease in 2015 (24.4%) and reaching 27.6% in the year 2017. As an acceptable reflection of true values, this observation could be due to the recent drastic changes in lifestyle and factors/facilities that adolescents, especially females, are exposed to in Saudi Arabia within the past few years (\textsuperscript{21}). Also, it could be a result of the commitment of Saudi Arabia to the 2030 Agenda for Sustainable Development and the
achievement of the SDGs at the national level (21). On the other hand, and if it does not represent a reflection of true values, this observation could simply be part of the limitation of using different regional studies for cross-sectional estimation and comparisons of the prevalence of overweight and obesity in adolescents that was used. The only clear answer to this observation can come from a national population-based survey, which is expected in the near future.

4.2 Social determinants of overweight and obesity in adolescents:

This review also aims to look at the problem of overweight and obesity in Saudi adolescents from a behavioral and social standpoint by identifying and constructing an ecological model for social determinants of overweight and obesity in adolescents and discussing them in relation to the Saudi setting.

4.2.1 Identifying and constructing an ecological model:

Social determinants of overweight and obesity are reported in the literature either separately or in small groups. These are usually factors that can influence body weight (those related to physical activity or diet) as well as potential causes or preventive aspects of overweight and obesity. We extracted from the literature social determinants of overweight and obesity that are related to adolescents (section 1.5.5-1.5.11) as well as to the fast-growing economies of Saudi Arabia (such as large household income, significant modernization, high degree of urbanization …etc.). We grouped these determinants of overweight and obesity in adolescents in an ecological model (Figure 3) to show their relation to the categories of social determinants of health that include; age, sex and constitutional characteristics, individual lifestyle factors, social and community networks, norms and networks, living and working conditions and socioeconomic, cultural and environment conditions. This model can serve as a useful exploratory tool to help the investigation of the multifaceted etiology of adolescent overweight and obesity and facilitate the development of effective intervention and prevention programs.
4.2.2 Determinants of overweight and obesity in Saudi adolescents:

4.2.2.1 Diet patterns/contents:

The fast-growing economy has led to clear changes in eating habits and patterns of food consumption among adolescents in Saudi Arabia and the Gulf Region. (96,140). These changes included eating for pleasure and not only for nourishment, increasing daily consumption of fat and decreasing energy expenditure (96), shifting from traditional healthy food, that consists of whole grains, vegetables, fruits with small amounts of meat and fat, to western fast food that is high in sugar, salt and saturated fat and low in fiber, consuming more unhealthy snacks, soft drinks and other sugar-sweetened beverages (141,142). WHO Member States have agreed to reduce the global population’s intake of salt by 30% and halt the rise in diabetes and obesity in adults and adolescents as well as in childhood overweight by 2025 (143). All reviewed reports on diet patterns and contents and overweight and obesity in Saudi adolescents (90,96,110,124,130) (Table 9-A and B) demonstrated a statistically significant (p=0.02) positive association between fast food and soft drink consumption 2-4 times/week and skipping breakfast lower vegetable intake (<3 times /week) and odds of overweight and obesity. Low interstudy heterogeneity was noted (I² = 35%). These results indicate that diet patterns and contents are suitable targets for the intervention and prevention of overweight and obesity in Saudi adolescents.

4.2.2.2 Physical activity:

With the recent socioeconomic development, adolescents became less physically active and the activity levels required for work and transportation were significantly reduced. In addition, several environmental factors linked to urbanization, such as high-density traffic, limited sport/recreation facilities, lack of parks and sidewalks, air pollution, fear of crime and violence in outdoor areas discouraged adolescents from becoming more active (33). Therefore, increasing physical activity is a social, not just an individual problem and it demands a population-based, multi-sectoral, multi-disciplinary, and culturally relevant approach (33). Although the WHO recommends 60 minutes of moderate- to vigorous-intensity physical activity daily for young people ages 5 to 17, >80% of the world's adolescent population is insufficiently physically active. (33). The 2030 SDGs provides an opportunity to refocus and renew efforts at promoting physical activity. The WHO is working on a new global action plan, which aims to benefit from the contributions of all relevant sectors,
including, environment, education, health, sports and technology to accelerate progress in achieving the global voluntary NCD targets set by the World Health Assembly for 2025 (144).

Three out of the 7 reports (90,124,132), 2 in males and one in females, on physical activity and overweight and obesity in Saudi adolescents showed no statistically significant association between less physical activity/week and odds of overweight and obesity. Significant interstudy heterogeneity was noted ($I^2 = 88\%$) owing to differences in evaluation parameters. On the other hand, one other report (110) used total METS (minute/week) for the evaluation and demonstrated a positive association between less physical activity/week ($p<0.05$) in both males and females (Table 9-B). Three other reports showed that a high % of adolescents never exercise, mainly females (reached 100% in one study) (Table 9-B). These results might not reflect the current status because of the recent drastic changes in lifestyle and factors/facilities that adolescents, especially females, are exposed to in Saudi Arabia within the past year (21). The other 2 reports (Table 10-B) showed that the number of hours per day of TV/Computer screen time spent in overweight and obese Saudi adolescents was higher than that spent by normal weight adolescents, however only one of these 2 studies showed significant results. Results from this review suggest that physical activity might be a suitable target for the intervention and prevention of overweight and obesity in Saudi adolescents and that more new studies with standardized protocols are needed.

### 4.2.2.3 Sedentary behavior factors:

With the improvements in the socioeconomic status in Saudi Arabia, sedentary behaviors have increased dramatically among adolescents and they include watching TV, using computer, playing video games and surfing the internet, and use of "passive" modes of transport (36, 37). It was found that each additional hour of sedentary activity per day, in the form of watching television hours, increases the prevalence of obesity by 2% (145). The increase in time spent with sedentary activity leads to a decrease in the time spent in physical activity and an increase in consumption of salty snacks, sweets, and sweetened cereals and beverages (146).

Four studies (119,124,130,133) on TV/ computer screen time and overweight and obesity in Saudi adolescents (Table 10-A) demonstrated a statistically significant ($p= <0.002$) positive association between longer TV/computer screen time and odds of overweight and obesity. Low interstudy
heterogeneity was noted ($I^2 = 38\%$). The other 2 reports (Table 10-B) showed that the number of hours per day of TV/Computer screen time spent overweight and obese Saudi adolescents was higher than that spent by normal weight adolescents, however only one of these 2 studies showed significant results. There were no studies about the effect of rapidly growing social media, playing video games and surfing the internet, as well as the use of "passive" modes of transport, in relation to adolescent overweight and obesity in Saudi Arabia. Studies are needed to properly evaluate the effect of sedentary behavior factors on overweight and obesity in Saudi adolescents. Results from this review suggest that sedentary behavior factors, in the form of TV/Computer screen time, can be suitable targets for the intervention and prevention of overweight and obesity in Saudi adolescents and that more new studies about other sedentary behavior factors are needed.

### 4.2.2.4 Sleep pattern/Stress/Smoking:

Studies have shown that sleep is an important regulator of many biological and physiological functions, such as appetite, energy balance, and weight maintenance, and that control of body weight and nutrient metabolism are greatly affected by the number of hours of sleep $^{40,44}$. Both short and long periods of habitual sleep are linked to obesity $^{45}$. Short sleep duration can lead to a reduction in the satiety hormone leptin and an increase in the hunger hormone ghrelin causing an increase in appetite $^{44,45}$. The fast-growing economies and rapid advancement in technology have resulted in extensive television viewing and use of other electronic media (computers, videogames and the internet), which made short sleep duration a major problem among adolescents. There were only 2 reports $^{101,110}$ in male subjects about the association between sleep pattern and the prevalence of overweight and obesity in Saudi adolescents (Table 11). Both studies showed statistically significant ($p=<0.005$ and $<0.006$) positive associations between decreased number of sleeping hours ($<7$ and $<8$ hours) and overweight and obesity. More studies with fixed parameters are needed to properly evaluate the effect of this determinant on overweight and obesity. Results from this review suggest that sleep pattern can be a suitable target for the intervention and prevention of overweight and obesity in Saudi adolescents and that more studies are needed.
Adolescence is the critical period during which health habits, including eating behaviors, physical activity and smoking are established. In a follow-up study in adolescents, smoking was reported as a risk factor for adulthood abdominal obesity in both males and females and for overweight only in females (51). Mechanisms of the possible causal link between smoking and body weight are not clear. Changes in cortisol metabolism and/or psychosocial stress related to smoking might represent a possible explanation (52-54). Only one study (132) was reported about the association between smoking and the prevalence of overweight and obesity in Saudi adolescents. Because of the small numbers in this study, the association between smoking and the prevalence of overweight and obesity in Saudi adolescents cannot be evaluated. With a tobacco epidemic being on the rise in Saudi adolescents (136), more current studies are needed to further delineate the effect of smoking on overweight and obesity in Saudi adolescents.

Evidence is accumulating that stress is linked to the development of obesity via the chronic increase of cortisol (the glucocorticoid stress hormone) (46). In a modern society, the high prevalence of obesity goes hand in hand with chronic stress, consuming food containing large amounts of sugar and decreased hours of sleep, suggesting a close relation between these conditions (47,48) that are common among adolescents. Also, recent studies in adolescents reported a bidirectional (cause and effect) relationship between eating disturbances and depression and a high rate of anxiety disorders among obese adolescents (49-50). In this review, no studies were reported about the association between stress and the prevalence of overweight and obesity in Saudi adolescents. Stress may be used as a target for the intervention and prevention of overweight and obesity in Saudi adolescents, however, studies are needed.

4.2.2.5 Family history of obesity/Family size:

Family factors play an important role in the development of overweight and obesity in children and adolescents. In addition to the genetic effect, food preferences and availability and habits within a family can easily influence what children and adolescents eat. Also, family lifestyle and habits (physically active or sedentary) can influence children and adolescents (55). High rates of overweight and obesity are observed in adolescents with family history of obesity (56), which can
be related to the mentioned family factors as well as to genetic factors. The association between family history of obesity and the prevalence of overweight and obesity was reported in 2 studies (90,130) (Table 13). Both concluded a significant association between overweight and obesity and a positive family history of obesity with p-value of <0.05. However, no values of prevalence were given in the second study. Therefore, family history of obesity may be used as a target for the intervention and prevention of overweight and obesity in Saudi adolescents, however, more studies are needed to properly evaluate the effect of this determinant.

Studies suggest that family size also has a role in the development of overweight and obesity. The higher the number of siblings the lower the BMI and the lower the chance of overweight and obesity in a family, which could be due to family mealtimes, reduced maternal work and less eating out. Also, children with siblings watch less television and have healthier diets (57). There were 2 reports (96,133) about the association between family size and the prevalence of overweight and obesity in Saudi adolescents (Table 12). The parameter used for the evaluation of the effect of family size on overweight and obesity was > 6 in the first study and > 8 in the second. A family size >6 or >8 was negatively associated with obesity with a reported (p= <0.001 and 0.05, respectively). Therefore, family size may be used as a suitable target for the intervention and prevention of overweight and obesity in Saudi adolescents, however, more studies with fixed parameters are needed to properly evaluate the effect of this determinant in this population.

4.2.2.6 Household income (Economics/Social class):

Lower income households tend to have higher rates of obesity in the United States and other developed countries (58,59). A possible explanation is that the low-income families are more exposed to junk food and other cheap calories including processed sugars (69). However, Analysis of data from the 2011–2014 National Health and Nutrition Examination Survey (NHANES) demonstrates that adolescent obesity prevalence patterns by household income are less consistent
by race \(^{(61)}\). The association between economic/social class and the prevalence of overweight and obesity in adolescents was reported in 7 studies \(^{(92,95,97,98,118,132,133)}\) (Table 14). These studies indicated a statistically significant (p= <0.0003) positive association between higher economic/social class and odds of overweight and obesity. However, significant interstudy heterogeneity was noted (I\(^2\) = 71\%) owing to differences in evaluation parameters. Therefore, results from this review suggest that economic/social class may be used as a suitable target for the intervention and prevention of overweight and obesity in Saudi adolescents and that more new studies with standardized parameters are needed.

### 4.2.2.7 Parental Education:

Although parental education is supposed to improve awareness of all family members on healthy food selections \(^{(62)}\), recent studies suggest that it is associated with increased rate of overweight in children and adolescents and in lower income countries \(^{(63)}\). This association seems to vary according to the developmental stage of different countries. In higher economic status countries, like paternal rather than maternal higher education is associated with more positive influence on lowered child overweight. This might be due to the fact that educated mothers are usually working and bringing more income, both of which are associated with overweight and obesity in children and adolescents. On the other hand, a more negative influence of maternal higher education on increased child overweight is observed in lower economic status countries \(^{(63)}\). The association between mother education and the prevalence of overweight and obesity in adolescents was reported in 9 studies \(^{(92,95,97,108,118,130,132,133)}\) (Table 15). These indicated a statistically significant (p=0.04) positive association between mothers with the highest level of education and odds of overweight and obesity. However, significant interstudy heterogeneity was noted (I\(^2\) = 72\%) owing to differences in evaluation parameters. On the other hand, the association between father education and the prevalence of overweight and obesity in Saudi adolescents was reported in 6 studies \(^{(96,97,108,118,132,133)}\) that indicated a statistically significant (p=0.0005) positive association between fathers with the highest level of education and odds of overweight and obesity (table 16). Low interstudy heterogeneity was noted (I\(^2\) = 10\%). Therefore, results from this review suggest that parental education can be used as a suitable target for the intervention and prevention of
overweight and obesity in Saudi adolescents and that more studies, mainly about mother education, are needed.

4.2.2.8 Working mother:

Studies have shown that when both parents are working away from their children, there is a high chance that their children will develop overweight and obesity (64-66). Working mothers spend less time on preparing food for their children who will eat more restaurant made fast food meals, which are known to increase of overweight and obesity in children and adolescents (64,65). In addition, there will be less supervision and more sedentary behaviors (watching television, using computer, playing passive video games and surfing the internet) will dramatically increase among children and adolescents, which will add to the problem (66). It was estimated that 10% of the rise in childhood obesity is related to maternal employment (67) however, recent studies showed that the size of the problem is much more than that (68). There were 4 reports (94-96,132) on the association between mother’s work and adolescent overweight and obesity (Table 17). These studies indicated a statistically significant (p=0.009) positive association between working mother and odds of overweight and obesity in Saudi adolescents. A very low interstudy heterogeneity was noted ($I^2 = 0\%$). Accordingly, results from this review suggest that parental education can be used as a suitable target for the intervention and prevention of overweight and obesity in Saudi adolescents.

4.2.2.9 Health/label literacy:

Low food label literacy can lead to an increased risk of obesity, high blood lipids, and high blood pressure (69). Also, low level of health literacy is related to many aspects of adolescence health including their body weight. Studies have shown that low health literacy is significantly associated with overweight or obesity in adolescents, which should be considered in all strategies combating adolescence weight problem (70,71). No studies were reported about the association between label literacy and the prevalence of overweight and obesity in Saudi adolescents. Therefore, studies are needed.
4.2.2.10 School food/environment:

School food represents 35-47% of the daily intake of children and adolescents\(^{(72)}\). While at school, students are exposed to all types of unhealthy food (such as French fries, chips, pizza, and candies) and beverages (mainly sugar-sweetened beverages)\(^{(73-76)}\), all of which can lead to high rate of overweight and obesity in adolescents. There was only one report about the association between School environment and the prevalence of overweight and obesity in Saudi adolescents (Table 18). This study did not show any significant association between the two. More studies are needed to further delineate the effect of this determinant on overweight and obesity in Saudi adolescents.

4.2.2.11 Urbanization:

Recent studies suggest that rapid urbanization accounts for significant shifts in dietary patterns and for physical activity\(^{(77)}\). Several environmental factors are linked to urbanization, such as high-density traffic, limited sport/recreation facilities, lack of parks and sidewalks, air pollution, fear of crime and violence in outdoor areas discouraged adolescents from becoming more active\(^{(33)}\). Only 2 studies about the association between urbanization and the prevalence of overweight and obesity in adolescents in Saudi Arabia were reported (Table 20). In the first report, the prevalence of overweight and obesity was significantly higher in urban than rural adolescents (26.9% vs 19.0%, respectively, \(p=0.011\)) in both males and females reported together. On the other hand, the second study showed significance only in males (39.4% vs 27.7%, respectively with \(p=<0.004\)). These results suggest that urbanization is possibly associated with overweight and obesity mostly in male adolescents. Therefore, results from this review suggest that parental education can be used as a suitable target for the intervention and prevention of overweight and obesity in Saudi adolescents and that more studies are needed.

4.3 Social Policy and Structural Measures:

Although many of the reviewed reports highlighted the problem of overweight and obesity in Saudi adolescents, no prevention or management intervention has been reported. This review provided a
summary of current evidence regarding most of the possible social determinants of overweight and obesity in Saudi adolescents. A comprehensive understanding of these social determinants and their influences on overweight and obesity in this population are crucial to developing prevention and management interventions to support Saudi adolescents towards healthy outcomes. It is important to note that most of these determinants are modifiable and that implementing intervention programs have helped in reducing and slowing obesity rates in some Western countries \(^{(147-149)}\). Therefore, it is crucial to design multifaceted, national, obesity prevention programs with special focus on adolescents.

4.3.1 Types of interventions to tackle obesity:

No single intervention can halt the advance of the epidemic of obesity. To challenge adolescent’s obesity successfully requires countering the obesogenic environment and addressing vital elements in the life course through coordinated, multi-sectoral action that is held to account. Interventions to tackle adolescent’s obesity can be integrated into and build upon existing national plans, policies and programs.

Categories of policy action usually include focused initiatives, which are interventions aimed directly at tackling obesity or a particular at-risk group (in this case adolescents). The impact of individual interventions or focused initiatives in isolation is likely to be small. The combined impact might be strengthened by implementing a range of policies that act as ‘enablers’ or ‘amplifiers’ of the core interventions. Alone, such policies have little or no direct impact on obesity but may magnify the impact of other initiatives. Enablers are policies that act as essential underpinning elements of a comprehensive strategy, notably action on education and skills (necessary but insufficient). Other policies may amplify impact, usually by shifting wider perceptions of obesity-related issues and can drive social or cultural norms in a direction that elicits greater support for and adoption of other initiatives (cannot act if the other elements are not in place. Figure 17 shows an example of different types of interventions to tackle obesity \(^{(150)}\).
Figure 17. Different types of interventions to tackle obesity.

4.3.2 WHO Recommendations on policy action and interventions:

Recognizing that progress in tackling obesity in infants, children and adolescents has been slow and inconsistent, the WHO established the Commission on Ending Childhood Obesity in 2014 to review, build upon and address gaps in existing mandates and strategies in order to prevent infants, children and adolescents from developing obesity. In 2016, The report of the Commission presented a comprehensive, integrated package of recommendations to guide countries to address childhood obesity. The recommendations related to obesity in adolescents are summarized as follows:
1- Implement comprehensive programs that Promote the intake of healthy foods and reduce the intake of unhealthy foods and sugar sweetened beverages by adolescent:

1.1- Ensure that appropriate and context-specific nutrition information and guidelines for both adults and children are developed and disseminated in a simple, understandable and accessible manner to all groups in society.

1.2- Implement an effective tax on sugar-sweetened beverages.

1.3- Implement the set of recommendations on the marketing of foods and non-alcoholic beverages to children to reduce the exposure of children and adolescents to, and the power of, the marketing of unhealthy foods.

1.4- Develop nutrient profiles to identify unhealthy foods and beverages.

1.5- Establish cooperation between Member States to reduce the impact of cross-border marketing of unhealthy foods and beverages.

1.6- Implement a standardized global nutrient-labelling system.

1.7- Require settings such as schools, child-care settings, children’s sports facilities and events to create healthy food environments.

1.8- Increase access to healthy foods in disadvantaged communities.

2- Implement comprehensive programs that Promote physical activity and reduce sedentary behaviors in adolescents:

2.1- Provide guidance to children and adolescents, their parents, carers, teachers and health professionals on healthy body size, physical activity, sleep behaviors and appropriate use of screen-based entertainment.
2.2- Ensure that adequate facilities are available on school premises and in public spaces for physical activity during recreational time for all adolescents (including those with disabilities), with the provision of gender-friendly spaces where appropriate.

3- Implement comprehensive programs that promote healthy school environments, health and nutrition literacy and physical activity among school-age adolescents:

3.1- Establish standards for meals provided in schools, or foods and beverages sold in schools that meet healthy nutrition guidelines.

3.2- Eliminate the provision or sale of unhealthy foods, such as sugar-sweetened beverages and energy-dense, nutrient-poor foods, in the school environment.

3.3- Ensure access to potable water in schools and sports facilities.

3.4- Require inclusion of nutrition and health education within the core curriculum of schools.

3.5- Improve the nutrition literacy and skills of parents and carers.

3.6- Make food preparation classes available to children, their parents and carers.

3.7- Include quality physical education in the school curriculum and provide adequate and appropriate staffing and facilities to support this.

4- Provide family-based, multicomponent services on lifestyle weight management for adolescents who are obese:

4.1- Develop and support appropriate weight management services for children and adolescents who are overweight or obese that are family-based, multicomponent (including nutrition, physical activity and psychosocial support) and delivered by multi-professional teams with appropriate training and resources, as part of universal health coverage.
4.3.3 Relevant policies in Saudi Arabia:

Saudi Arabia has witnessed a huge health expenditure accompanied by significant improvement in its health indicators for both curative and public health services. Hundreds of hospitals and primary health care centers were established and many public health programs, such as immunization, health education and environmental sanitation, have been implemented and a good number of policies have been formulated \(^{(152)}\). However, a significant weakness in public health services is still noticed as health plans and expenditure in the health system are mainly concentrating on the curative aspects and allocating most jobs for curative care \(^{(152)}\). As a result, health-related policies, including those related to adolescents, in Saudi Arabia are affected. Most of the adolescent general and topic-specific policies are not implemented (Figure 17) \(^{(153)}\).

<table>
<thead>
<tr>
<th>General Policies Related to Adolescent Health</th>
<th>2018</th>
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<tbody>
<tr>
<td>National policies/guidelines that specifically address adolescent health issues</td>
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</tr>
<tr>
<td>National standards for delivery of health services specifically for adolescents</td>
<td>❌</td>
</tr>
<tr>
<td>National standards for health promoting schools</td>
<td>✔</td>
</tr>
<tr>
<td>National adolescent health programme with a regular government budget allocation</td>
<td>❌</td>
</tr>
<tr>
<td>National policies / guidelines that specify competencies of health workers in adolescent health</td>
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</table>

In addition, policies directly targeting social determinants of overweight and obesity in adolescents in Saudi Arabia are almost non-existent. Policies targeting specific determinants, such as standards for health promoting schools and prohibition of tobacco sales to minors, are the only somewhat related policies \(^{(153)}\). However, these policies still need improvement in terms of implementation and compliance \(^{(154)}\). A recent study investigated the compliance with school nutrition policy in Saudi Arabia and revealed that meals offered in Saudis schools come prepackaged with minimal cooking in schools. From a calorie perspective, there was not a significant difference between the food allowed and food not allowed. For the Saudi policy, 94.7% of the schools scored in between category 2 and 3 (moderate compliance). For the Institute of Medicine (IOM) standards, 96.1% of
the schools scored in category 1 (low alignment). The study concluded, “While the Saudi policy is clear on what should not be served in school cafeterias, it fails to provide guidance on what must be served to improve the nutritional value of meals provided”\(^{(154)}\).

4.4 Strengths and Limitations

4.4.1 Strengths:

This study is the largest systematic review looking specifically into adolescents in Saudi Arabia within the period until December 31, 2018. The large study population of 97,666 subjects is a notable strength and the ratio of males/females (56.9%/43.1%) within this study is reflective of the adolescent population (male/female = 51.9%/49.1%) and the total population (male/female = 57.4%/42.6%) of Saudi Arabia. This systematic review is the first to look at the problem of overweight and obesity in adolescents from behavioral and social standpoint by identifying and constructing an ecological model for their social determinants discussing them in relation to the Saudi setting.

4.4.2 Limitations:

Ethnicity was not deeper looked into in the studies reviewed. Some “Saudi” adolescents may have been from different ethnic backgrounds which may have an impact on their overall genetic dispositions as some ethnicities demonstrate a higher risk for developing overweight and/or obesity. The adolescent age categories were not specified in the reviewed studies (younger vs older adolescents), which limits the effect of some determinants as the adolescent’s body functions and metabolism differs in those two periods. The variability in the type of cut-offs used to define obesity in the studies reviewed (WHO, CDC, IOTF) limits the comparison between these studies. The small number of some studies per determinant is considered a limitation of this review, as it did not allow further analysis, such as, performing meta-analysis in these small studies. The variation in the parameters used for the evaluation of the effects of some determinants on overweight and obesity, such as, type and duration of physical activity, family size, duration of screen time, duration of sleep time etc. Some major social determinants identified in this review
had no studies that evaluated their relation to overweight and obesity in Saudi adolescent, such as, social media, label literacy, and stress. Recent drastic changes in lifestyle and factors/facilities that adolescents are exposed to in Saudi Arabia within the past year may play a large role in influencing the effect of some determinants mentioned in this review. However, this can be considered a strength, as the results of this analysis are up to the date right before these changes occurred and can serve as a good baseline for future studies.

4.5 Conclusions:

This review clearly demonstrates that the prevalence of overweight and obesity among adolescents is a major public health problem in Saudi Arabia and is growing at an alarming rate, and that social determinants play a significant role in this problem and should be considered in all strategies targeting it. Policies directly targeting social determinants of overweight and obesity in adolescents in Saudi Arabia are almost non-existent. The constructed ecological model for social determinants of overweight and obesity in adolescents, reported in this review, can serve as a useful exploratory tool to help the investigation of the multifaceted etiology of adolescent overweight and obesity and facilitate the development of effective intervention and prevention programs.
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## Appendix 1. Summary of Reviewed Articles & Social Determinants of Overweight and Obesity.

| Author                  | Year | Total # | Male #  | Female # | Age (years) | Publication Journal | Study Design | Region       | Family & Food Estate & Income | Parenting Education | Parents' Employment | Economic/ Household Factors | Social Media & Screen Time | Diet Pattern Content | Smoking/ Alcohol Consumption | Physical Activity | Stress/ Sleep Patterns | Mobility | Smoking/ Alcohol Consumption | School Food Environment |
|-------------------------|------|---------|---------|----------|-------------|--------------------|--------------|--------------|-----------------------------|---------------------|----------------------|----------------------------|---------------------------|----------------------|-----------------------------|------------------------|--------------------------|------------------|---------------------------------|
| El-Bayyumi, et al.     | 2002 | 2852    | 1342    | 1510     | 9-18        | International      | CS            | National     | IOTF                        |                     |                      |                            |                           |                      |                             |                        |                         |                    |                                 |
| Shahada, et al.        | 2006 | 1154    | 560     | 594      | 8-18        | International      | CS            | National     | IOTF                        |                     |                      |                            |                           |                      |                             |                        |                         |                    |                                 |
| Al-Khateeb, et al.     | 2007 | 1497    | 774     | 723      | 10-18       | International      | CS            | National     | IOTF                        |                     |                      |                            |                           |                      |                             |                        |                         |                    |                                 |
| Al-Saeed, et al.       | 2010 | 1610    | 808     | 802      | 8-16        | International      | CS            | National     | IOTF                        |                     |                      |                            |                           |                      |                             |                        |                         |                    |                                 |
| Al-Qahtani, et al.     | 2007 | 1110    | 543     | 567      | 9-18        | International      | CS            | National     | IOTF                        |                     |                      |                            |                           |                      |                             |                        |                         |                    |                                 |
| Al-Majid, et al.       | 2010 | 972     | 466     | 506      | 10-18       | International      | CS            | National     | IOTF                        |                     |                      |                            |                           |                      |                             |                        |                         |                    |                                 |
| Al-Mazrou, et al.      | 2008 | 1398    | 693     | 705      | 9-18        | International      | CS            | National     | IOTF                        |                     |                      |                            |                           |                      |                             |                        |                         |                    |                                 |
| Al-Nasara, et al.      | 2010 | 1575    | 778     | 797      | 9-18        | International      | CS            | National     | IOTF                        |                     |                      |                            |                           |                      |                             |                        |                         |                    |                                 |
| Al-Qahtani, et al.     | 2007 | 1378    | 660     | 718      | 9-18        | International      | CS            | National     | IOTF                        |                     |                      |                            |                           |                      |                             |                        |                         |                    |                                 |
| Al-Khateeb, et al.     | 2006 | 1191    | 567     | 624      | 9-18        | International      | CS            | National     | IOTF                        |                     |                      |                            |                           |                      |                             |                        |                         |                    |                                 |
| Al-Majid, et al.       | 2007 | 1160    | 550     | 610      | 9-18        | International      | CS            | National     | IOTF                        |                     |                      |                            |                           |                      |                             |                        |                         |                    |                                 |
| Al-Qahtani, et al.     | 2010 | 1610    | 803     | 807      | 8-16        | International      | CS            | National     | IOTF                        |                     |                      |                            |                           |                      |                             |                        |                         |                    |                                 |
| Al-Majid, et al.       | 2007 | 1398    | 693     | 705      | 8-17        | International      | CS            | National     | IOTF                        |                     |                      |                            |                           |                      |                             |                        |                         |                    |                                 |
| Al-Qahtani, et al.     | 2010 | 1262    | 623     | 639      | 8-17        | International      | CS            | National     | IOTF                        |                     |                      |                            |                           |                      |                             |                        |                         |                    |                                 |
| Al-Majid, et al.       | 2007 | 1191    | 567     | 624      | 8-17        | International      | CS            | National     | IOTF                        |                     |                      |                            |                           |                      |                             |                        |                         |                    |                                 |
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| Al-Qahtani, et al.     | 2010 | 1262    | 623     | 639      | 8-17        | International      | CS            | National     | IOTF                        |                     |                      |                            |                           |                      |                             |                        |                         |                    |                                 |
| Al-Majid, et al.       | 2007 | 1191    | 567     | 624      | 8-17        | International      | CS            | National     | IOTF                        |                     |                      |                            |                           |                      |                             |                        |                         |                    |                                 |
| Al-Qahtani, et al.     | 2010 | 1610    | 803     | 807      | 8-17        | International      | CS            | National     | IOTF                        |                     |                      |                            |                           |                      |                             |                        |                         |                    |                                 |
| Al-Majid, et al.       | 2007 | 1398    | 693     | 705      | 8-17        | International      | CS            | National     | IOTF                        |                     |                      |                            |                           |                      |                             |                        |                         |                    |                                 |
| Al-Qahtani, et al.     | 2010 | 1262    | 623     | 639      | 8-17        | International      | CS            | National     | IOTF                        |                     |                      |                            |                           |                      |                             |                        |                         |                    |                                 |
| Al-Majid, et al.       | 2007 | 1191    | 567     | 624      | 8-17        | International      | CS            | National     | IOTF                        |                     |                      |                            |                           |                      |                             |                        |                         |                    |                                 |
| Al-Qahtani, et al.     | 2010 | 1610    | 803     | 807      | 8-17        | International      | CS            | National     | IOTF                        |                     |                      |                            |                           |                      |                             |                        |                         |                    |                                 |
| Al-Majid, et al.       | 2007 | 1398    | 693     | 705      | 8-17        | International      | CS            | National     | IOTF                        |                     |                      |                            |                           |                      |                             |                        |                         |                    |                                 |
| Al-Qahtani, et al.     | 2010 | 1262    | 623     | 639      | 8-17        | International      | CS            | National     | IOTF                        |                     |                      |                            |                           |                      |                             |                        |                         |                    |                                 |
### Appendix 2. Summary of Reviewed Regional & Prevalence Rates of Overweight and Obesity.

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Copyright Acknowledgements

(None)