Body Mass Index: A Critical Review

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Abstract

Body mass index (BMI) is a screening tool for the population to classify them into different categories such as overweight or obese. It is an estimate based on a person’s weight and height and assesses their risk for chronic diseases such as hypertension, diabetes, stroke, cancer, and many more. Researchers have been looking into a link between BMI and chronic diseases as well as its association with waist circumference and waist-hip ratio. Childhood BMI is a potential predictor of health later in life. There is increasing evidence of research on BMI of youth and adults to predict the risk of early death. This review has elaborated an association of BMI with waist circumference, waist-hip ratio, and chronic diseases related to obesity such as diabetes, hypertension, and hypercholesterolemia. All the above-mentioned variables related to BMI are discussed in this brief review.

Keywords: Body mass index; Weight loss; obesity; Waist circumference; Waist-hip ratio

Introduction

Body mass index (BMI) is a mathematical calculation that estimates a person’s health status based on his height and weight [1]. BMI is used generally to assess a person’s risk for various chronic diseases such as diabetes, cardiovascular disease, stroke, cancer and numerous more (1). BMI functions by categorizing people into four different weight categories that are used to classify a person’s health and allows physicians and researchers to easily communicate with the public about potential health issues encountered in that category [2]. Much of the initial research was performed over a decade ago, however, there is some still being performed today. Researchers have and continue to look at the link between BMI and chronic diseases such as diabetes, hypercholesterolemia, and hypertension, as well as its association with waist circumference. Along with this, researchers have expanded their research to new areas involving BMI like looking at childhood BMI as a potential predictor of health later in life. This review has illustrated an association of BMI with waist circumference, waist-hip ratio and chronic diseases such as diabetes, hypertension, and hypercholesterolemia. This review also briefly described the childhood BMI as a predictor of health and its limitations to use as a health assessment tool.

Methods of Literature Review

English-language articles on Body Mass Index (BMI) published between 1994 and 2018 were identified via a PubMed search and from references in other articles using the term BMI. The review revealed 26 articles to describe the relationship between BMI and other metabolic syndrome factors such as diabetes, hypertension and hypercholesterolemia, BMI relationship with waist circumference and waist-hip ratio, childhood BMI as a health predictor, and limitation of BMI as a health assessment tool. Based on the studies included in this review, the relationships of BMI with other variables can be extrapolated to the general population.

Results and Discussion

BMI and diabetes

A study by Chan et al. [3] involving 51,529 U.S. male health professionals, 40-75 years of age found that men with a BMI over 35 kg/m² had a significantly higher risk of developing type 2 diabetes than men with BMIs lower than 23 kg/m². Chan et al.’s research supports the conclusion, that obesity heightens risk for disease, however, this study was performed nearly 25 years ago (1994). More recently researchers have considered whether these results are similar across various races.

One study looked at several risk factors for diabetes in 26,499 Turkish individuals [4]. Comparisons were made across regions, North, South, East, West, and Central. The comparisons were further broken down into education, family history, hypertension, waist girth, BMI, smoking, number of meals per day, family size, and age. Across all demographics, one standard deviation in waist circumference resulted in 1.16 times higher likelihood the individual will also be newly diagnosed with diabetes. For men, an increase in one standard deviation resulted in 1.28 times increase in the likelihood the individual will have a new diagnosis for diabetes. They found that BMI was a strong predictor of diabetes. They found that an increase in BMI by one standard deviation (5.9 kg/m²) increased the risk for type 2 diabetes by 1.16 and 1.09 times for men and women across all participants. A longitudinal multi-ethnic study that lasted six years and included 59,824 non-diabetic adults from Canada found that the risk of diabetes increases at significantly lower BMI points in South Asian (24 kg/m²), black (26 kg/m²), and Chinese (25 kg/m²) than in whites (30 kg/m²). This means that individuals of these races increase their likelihood of developing diabetes at a lower BMI than whites do [5].

While BMI does show a correlation with type 2 diabetes risk, some researchers suggest using another method for predicting diabetes risk in the future. According to Lee et al. [6], BMI was the least effective predictor of cardiovascular risk factors including diabetes, hypertension, and dyslipidemia compared to waist circumference, waist to hip and waist to height ratios. Researchers performed a meta-
analysis of ten articles with over 80,000 participants from countries all over the world, where they found that waist-to-height ratio was a significantly better predictor of risk for developing all three diseases. Researchers credited this to waist-to-height ratio considering central adiposity, whereas BMI is unable to do this.

BMI and hypertension

Similar studies have been done searching for a connection between body mass index levels and prevalence of hypertension. Hu et al. [7] examined survey data of 17,441 Finnish individuals from the 1980s and 1990s that examined participants heart rate, height, and weight among other physical factors. From this data, researchers looked at the association between BMI in relation to developing hypertension using hazard ratios and follow up examinations. They found that there was an upward trend that followed BMI (BMI <25=1.00, 25 to 29.9=1.18, and >30=1.66). This meant that a higher BMI was associated with a greater incidence of hypertension. This study also found that physical activity reduced the risk of hypertension significantly, even at a higher BMI.

Gelber et al. [8] evaluated 13,563 healthy, non-hypertensive patients approximately 14.5 years later to see if there was an association between their BMI at that time and the prevalence of hypertension approximately 14.5 years later to see if there was an association between BMI and hypertension. Hu et al. [7] examined survey data of 17,441 Finnish individuals from the 1980s and 1990s that examined participants heart rate, height, and weight among other physical factors. From this data, researchers looked at the association between BMI in relation to developing hypertension using hazard ratios and follow up examinations. They found that there was an upward trend that followed BMI (BMI <25=1.00, 25 to 29.9=1.18, and >30=1.66). This meant that a higher BMI was associated with a greater incidence of hypertension. This study also found that physical activity reduced the risk of hypertension significantly, even at a higher BMI.

BMI and hypercholesterolemia

Fewer studies have been performed looking at the relationship between body mass index and hypercholesterolemia than with other metabolic syndrome factors. However, one study did a six-year survey of 18,827 people from the United States to evaluate the relationship between BMI, HDL-C, cholesterol, hypertension, and dyslipidemia. Researchers found that total mean serum cholesterol increased with increased BMI. Individuals with a BMI less than 25 had an average cholesterol value of 193 mg/dL, while individuals with a BMI over 30 had an average cholesterol value of 211 mg/dL. Based on this study, it is estimated that 96 million Americans from the U.S. were overweight or obese at that time were afflicted with hypertension or dyslipidemia, high cholesterol, and high blood pressure. The researchers also found that though the prevalence for risk factors generally increased as BMI increased, there was a difference in the ratios based on age, race, and gender. As a person ages, their risk factors for high blood pressure and high blood cholesterol increases extensively. Hispanic American women seem to be less affected by high blood pressure, than other populations. Finally, men tend to be less affected by low HDL cholesterol than women, though both see an increase as they age, regardless of race. Researchers did state though that while there was a significant difference between healthy and overweight/obese individuals, there was no difference in cholesterol values between overweight and obese individuals, based on BMI calculations [9].

One potential reasoning for this could be the findings of Feng et al. [10] that stated that waist circumference was a better predictor of hypercholesterolemia than BMI. This study examines 3,960 men and 4,980 women for their BMI, waist circumference, blood pressure, and blood serum levels. Participants came from five regions of China, were randomly selected, and data was collected in a lab. Researchers stated that while BMI was effective and better at predicting hypertension, that it was not as effective at predicting hypercholesterolemia. Overall, waist circumference showed a more significant prevalence ratio for disease than BMI. However, this study looked at Chinese individuals. More studies may be needed to determine if the same applies to individuals from the United States (Table 1).

<table>
<thead>
<tr>
<th>Study, year</th>
<th>No. of participants</th>
<th>Duration</th>
<th>General Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chan et al. [3]</td>
<td>51,529 U.S. male health professionals, 40-75 years of age</td>
<td>5 years of follow-up tracking diagnosed health conditions</td>
<td>BMI ≥ 35 had ↑ risk of developing T2D</td>
</tr>
<tr>
<td>Satman et al. [4]</td>
<td>26,499 Turkish individuals ≥ 20 years</td>
<td>Cross-sectional survey tracking</td>
<td>↑ BMI by 5.9 kg/m² doubled T2D risk in men and women</td>
</tr>
<tr>
<td>Chiu et al. [5]</td>
<td>59,824 nondiabetic adults ≥ 30 years in Ontario, Canada</td>
<td>Cohort study w/ a 6-year follow-up tracking T2D risk</td>
<td>T2D risk ↑ at lower BMI points in South Asians, black, and Chinese than whites</td>
</tr>
<tr>
<td>Lee et al. [6]</td>
<td>Meta-analysis of 10 research articles with 88,514 total individuals ≥ 18 years</td>
<td>Studies were conducted between 1990 and 2004 with no specific duration</td>
<td>Waist-to-height ratio was the best predictor for diabetes, hypertension, &amp; dyslipidemia</td>
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<td>Hu et al. [7]</td>
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<td>Gelber et al. [8]</td>
<td>13,563 healthy, non-hypertensive individuals</td>
<td>Follow-up 14.5 years later looking at prevalence of hypertension</td>
<td>↑ baseline BMI leads to ↑ risk of developing hypertension</td>
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<tr>
<td>Feng et al. [10]</td>
<td>8,940 individuals aged 20-74 years in Northern China</td>
<td>Single survey conducted in 2011</td>
<td>WC is better at predicting hypercholesterolemia than BMI</td>
</tr>
</tbody>
</table>

Table 1: BMI and chronic diseases.
BMI and waist circumference

Body mass index and waist circumference are two measurement tools commonly used to evaluate obesity. Chinedu et al. [11] examined the two tools to see if there was a correlation between them. They examined 489 Nigerian participants aged 18-75 years for waist circumference, height, and weight. The results showed a significant, positive relationship between BMI and waist circumference (r=0.75) indicating that as BMI increased so did waist circumference. Additionally, Gierach et al. [12] found similar results in a study of 839 participants aged 32-80 years diagnosed with metabolic syndrome. Researchers found that waist circumference was significantly associated with BMI (r=0.78) again indicating that with a higher BMI, participants tended to have a larger waist circumference. This correlation was stronger in women compared to men. However, no potential explanation was given for this. Abdominal obesity has frequently been studied and is determined to be a major factor in metabolic syndrome. Nahuelcuera and Barria also found these results in a study of 188 Chilean adolescents and young adults aged 3-25 years [13] which suggests that this relationship may be present throughout the lifespan.

Romero-Coral et al. [14] examined body mass index compared to bioelectric impedance analysis to determine body fat percentage. The cross-sectional study included 13,601 U.S. citizens excluding individuals that were unable to receive bioelectric impedance. This study was done to see how effective BMI was at diagnosing obesity when used against body fat percentage markers created by the World Health Organization. They found that BMI has a high specificity for detecting obesity but has a poor sensitivity meaning it often misses cases of obesity. Researchers found that BMI was better associated with high lean-body mass than body fat in men and that it was less likely to correctly diagnose obesity in the elderly. Conversely, Flegel et al. [15], in a study of 12,901 adults found that waist circumference was a better predictor of body fat percentage than BMI in men compared to women but not vice versa. The researchers also noted that BMI and waist circumference were more related to one another than with the presence of body fat.

BMI and waist-to-hip ratio

While waist circumference is a strong predictor of obesity and a high BMI value, there is another tool that also needs to be examined. Waist-to-hip ratio is an equation used to measure the fat around one's waist as compared to the hips. Bener et al. [16] compared four measures of body composition (BMI, waist circumference, waist-to-hip ratio, and waist-to-height ratio) to see the best predictor of metabolic syndrome. They found that waist circumference was the best predictor in men and women. However, the researchers noted that waist to hip ratio had a significantly greater Area Under the curve (AUC) than BMI in men and was the second-best predictor. Although, for women the difference was not as pronounced. Waist to hip ratio did have a greater AUC, sensitivity, and specificity than BMI in women but no significance was reported so these changes were only minimal. Dalton et al. [17] found similar results in Australian adults after adjusting for age between BMI, waist circumference, and waist to hip ratio. Researchers found that there was no difference in any of the three tools for predicting obesity and related chronic diseases (Table 2).

<table>
<thead>
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</tr>
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<tbody>
<tr>
<td>Chinedu et al. [11]</td>
<td>489 Nigerian individuals aged 18-75 years</td>
<td>Data gathered from April to May 2012 measuring age, sex, height, weight &amp; WC</td>
<td>Strong, positive correlation (r=0.75) between BMI &amp; WC</td>
</tr>
<tr>
<td>Gierach et al. [12]</td>
<td>839 individuals aged 32-80 years diagnosed with metabolic syndrome</td>
<td>Cross-sectional study w/ data gathered in 24-month period</td>
<td>WC has a strong, positive correlation (r=0.78) w/ BMI</td>
</tr>
<tr>
<td>Nahuelcuera and Barria [13]</td>
<td>188 Chilean adolescents &amp; young adults aged 3-25 years</td>
<td>Survey data gathered over an unspecified time period</td>
<td>Strong, positive correlation (r=0.846) between BMI &amp; WC</td>
</tr>
<tr>
<td>Romero-Coral et al. [14]</td>
<td>13,601 individuals aged 20-79 years</td>
<td>Cross-sectional study w/ data gathered from the 3rd NHANES survey</td>
<td>BMI ≥ 30 had a ↓ specificity but ↓ sensitivity for BF% obesity. BMI correlated better w/ LBM in men</td>
</tr>
<tr>
<td>Flegel et al. [15]</td>
<td>12,901 individuals aged ≥ 18 years</td>
<td>Used data collected from NHANES between 1999-2004</td>
<td>WC &amp; BMI were more correlated w/ each other than %BF. WC was better at predicting %BF in men</td>
</tr>
<tr>
<td>Bener et al. [16]</td>
<td>1,552 individuals aged ≥ 20 years</td>
<td>Cross-sectional study between April 2011 &amp; December 2012</td>
<td>WHR was 2sd best in men but not different from WHR or BMI in women</td>
</tr>
<tr>
<td>Dalton et al. [17]</td>
<td>11,247 Australians aged ≥ 25 years</td>
<td>Cross-sectional study w/ data gathered in 2000</td>
<td>No difference between BMI, WC, &amp; WHR for predicting obesity &amp; chronic diseases</td>
</tr>
</tbody>
</table>

Table 2: BMI and body composition evaluation tools.

Childhood BMI as a predictor of health

There is an increasing presence of research looking at the BMI of youth and adults to predict risk of early death. One study looked at the BMI of Israeli adolescents for associations with cardiovascular death later in life. The researchers found a positive correlation with cardiovascular death in adolescents within the 50th to 74th percentile and a significantly stronger association with adolescents above the 95th percentile [18]. As for diabetes, researchers found a strong correlation with high childhood BMI values and prevalence of type 2 diabetes in adulthood [19]. Researchers have also examined childhood BMI as a possible risk factor for endometrial cancer [20]. They found that a higher BMI in childhood is positively associated with a greater risk for endometrial cancer in adulthood [20]. Aarestrup at el. [21] found no correlation between childhood BMI levels and the risk for prostate cancer in men once adjusted for height. Another study examined the
potential relationship between BMI and suicidal behavior [22] on the basis that individuals with a higher BMI have shown an increase in depression and that depression is a known predictor of possible suicidal behavior. All of these studies show the importance of having a healthy BMI in childhood and how the growing epidemic of childhood obesity could affect the health of the U.S. population when these children reach middle adulthood.

Furthermore, researchers are also attempting to associate BMI levels with other factors to correlate those with a high BMI level in the present or future. Pileggi et al. [23] looked at the relationship between chronic low amounts of sleep and BMI in middle-school children. They found that children with short sleep patterns rather than normal sleep patterns had a higher BMI (+0.77 kg/m²) suggesting that sleep be emphasized to help keep BMI at a healthy level. Additionally, one study looked at the correlation between nine different categories and BMI in childhood and adolescence of over 2.9 million children enrolled in Texas schools [24]. They found that socioeconomic status and school enrollment were significantly related with BMI in both boys and girls. Along with this, county-level obesity, income inequality, and college completion were associated with BMI levels either in childhood or adulthood. For boys, income inequality and food availability were correlated. This review indicates that specific factors can affect the health and obesity levels of boys and girls differently.

Limitations of BMI as a Health Assessment Tool

BMI, although widely used, is not without its limitations. BMI is a simple calculation of weight status based on height and weight. Thus, it cannot assess body fat. This is troubling for athletes and others who exercise regularly [25]. A person with a higher level of fat-free mass could be misclassified as overweight or obese. Furthermore, a person with higher amounts of fat mass but little fat-free mass could be identified as healthier than he truly is. Additionally, a disparity in the validity of BMI may be present when comparing BMI across genders, ages, and races [25]. For example, men typically have more fat-free mass than women, and individuals lose fat-free mass with age. Because of this, BMI would be a better tool if it compared similar populations based on age, sex, and race than cross-comparison. One tool that has been shown to increase the validity of BMI, however, is the combination of it with waist circumference [26].

References