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## **Dietary Fiber and its Association with Overweight and Obesity: An Overview**

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### **Abstract**

Overweight and obesity have become major health problems in both developed and developing countries leading to disability and increased number of deaths. This is mainly due to increased energy consumption, lack of physical activity and change in overall lifestyle. They are also referred to as lifestyle disorders affecting all the population of the world. Overweight and obesity are defined as the abnormal or excessive accumulation of body fat which can cause increase in body weight. Body Mass Index (BMI) is an anthropometric measure that estimates body fat and widely accepted method of classifying obesity and is recommended as a general estimate of body fat. Skin fold thickness refers to the measurement of subcutaneous fat located directly beneath the skin by grasping a fold of skin and subcutaneous fat. It is used mainly to determine relative fatness and the percentage of body fat. Waist circumference

estimates central obesity which is now considered as a better indicator for a range of health problems than total body mass. Obesity increases the risk for a variety of chronic diseases including coronary artery disease, strokes, glucose intolerance and some forms of cancer. Also leads to increase in blood pressure and blood cholesterol, which in turn, can lead to cardiovascular disease and strokes. Fiber intake is a dietary factor that has received substantial attention. Considerable evidence supports that increased consumption of dietary fiber was associated with lower risk of obesity in adults. Increasing the consumption of high fiber foods such as whole cereals, millets, whole pulses and dried fruits, will provide the daily requirement of the dietary fibre. With this background, effects of fiber consumption on obesity and related disorders are reviewed in this paper.

**Keywords:** Body Mass Index, Obesity, Cardiovascular Disease, Blood Cholesterol and High Fiber Foods

### **Introduction**

The prevalence of overweight and obesity has increased dramatically during the last three decades with devastating consequences to public health. Women have higher prevalence of overweight and obesity as compared with men in India and obesity are increasing in the youth (Chopra *et al.*, 2013) [7]. Overweight and obesity are the major risk factors causing global deaths. They are linked to more deaths worldwide than underweight. At least 2.8 million adults die each year as a result of being overweight or obese. According to WHO, 2013 [29], most of the world's population live in countries where overweight and obesity kills more people than underweight.

Obesity is a complex physiological disorder mainly caused due to positive energy balance, where, intake of calories is greater than caloric expenditure. Hence, nutrition plays a direct role in determining caloric balance by being the sole variable accounting for caloric intake (Zhang *et al.*, 2011). Obesity is rapidly becoming an emerging disease in developing countries due to the increasing westernization of societies and change in the lifestyle. The etiology of obesity is said to be multifactorial, with a combination of genetic and environmental factors. (Ogunbode *et al.*, 2011) [23].

Due to the important role that dietary fibers play in maintaining human health, these are now recognized as the seventh largest nutrient group in the human body, after proteins, fats, carbohydrates, vitamins, minerals, and water. Dietary fibers can be classified based on their solubility in water as soluble dietary fibers (SDF) and insoluble dietary fibers (IDF). IDF mainly consist of hemicellulose, cellulose, and lignin and cannot be degraded by enzymes in the human body or dissolved in water. SDF include pectin, oligosaccharides, guar, and gums, most of which are dietary and healthy additives (Han *et al.*, 2017) [11].

Diets, deficient in dietary fiber, lead to a number of diseases such as constipation, hiatus hernia, appendicitis, diabetes, obesity, coronary heart diseases, gallstones, etc. (Sudha *et al.*, 2011). Consumption of adequate amounts of dietary fiber reduces the risk of above-mentioned diseases (Olive and Komarek, 2017).

### **“Overweight and obesity:**

Overweight and obesity are defined as abnormal or excessive fat accumulation. Obesity can also be regarded as complex

physiological disorder in which excess body fat accumulated may affect the health adversely (Kopelman, 2000) through several metabolic changes such as hyperinsulinemia, hyperglycemia, hyperlipidemia, altered adipokine profile (higher leptin and lower adiponectin) and generalized inflammation, which increases the risk factor for insulin resistance, type 2 diabetes, heart disease and many other chronic diseases (Cruz-Requena *et al.*, 2016) [8]. Obesity is caused due to consumption of excess energy than the expenditure. This condition is known as “a positive energy balance”, where excess energy gets accumulated in the adipose tissue as triglycerides.

A crude population measure of obesity is the body mass index (BMI), a person's weight (in kilograms) divided by the square of his or her height (in metres). A person with a BMI of 30 or more is generally considered obese. A person with a BMI equal to or more than 25 is considered as overweight (WHO, 2013) [29].

Overweight and obesity are defined as the abnormal or excessive accumulation of body fat which can cause increase in body weight. Obesity is a global pandemic and a major health concern because of the consequent morbidity and premature mortality (Costa *et al.*, 2016) [5].

Obesity is a serious and rapidly growing public health problem in most countries around the world. Obesity is the state of excessive body fat accumulation, which is mainly caused by consuming more calories, especially fatty and sugary foods, than one that burn off through physical activity (Nam *et al.*, 2016) [19].

In children and adults, overweight and obesity are classified by BMI percentile or absolute value. BMI is an anthropometric measure that estimates body fat through a person's weight in kilograms divided by the square of the height in meters. BMI is a practical and widely accepted method of classifying obesity and is recommended as a general estimate of body fat. Skin fold thickness refers to the measurement of subcutaneous fat located directly beneath the skin by grasping a fold of skin and subcutaneous fat and measuring it using calipers. It is used mainly to determine relative fatness and the percentage of body fat. Waist circumferences may be helpful in classifying individuals with atypical muscle-to-fat ratios. BMI overestimates body fat in very muscular persons. Centrally distributed obesity is now considered a better indicator for a range of health problems than total body mass. Above a BMI of 35, abdominal obesity has little predictive power of disease risk beyond that of BMI (WHO, 2008) [28].

Like the waist circumference, the waist-to-hip ratio (WHR) is also used to measure abdominal obesity. It's calculated by measuring the waist and the hip (at the widest diameter of the buttocks), and then dividing the waist measurement by the hip measurement (Anon, 2015) [1].

#### Prevalence:

Overweight and obesity increases the risk for chronic diseases such as diabetes, and cardiovascular diseases. Obese people are at a higher risk of suffering from certain kinds of cancers (including endometrial, breast, ovarian, prostate, liver, gallbladder, kidney, and colon). Moreover, being overweight also places the individual at an increased risk of death due to COVID-19.

Once considered a high-income country problem, overweight and obesity is rising worldwide affecting more than 44% of the world's population. The NFHS 5 data

shows that obesity has increased by 4 per cent in both men and women in India during the last five years. In NFHS-5, the percentage of overweight or obese women is 24, up from 20.6 per cent in NFHS-4 (2015-16) (NFHS, 2019-21). With increase in overweight and obesity, there is a need to focus on prevention of obesity related malnutrition. Many low- and middle-income countries are now facing a "double burden" of disease with the co-existence of under nutrition and obesity.

Children in low- and middle-income countries are more vulnerable to inadequate pre-natal, infant, and young child nutrition. At the same time, these children are exposed to high-fat, high-sugar, high-salt, energy-dense, and micronutrient-poor foods, which tend to be lower in cost but also, lower in nutrient quality. These dietary patterns, in conjunction with lower levels of physical activity, result in sharp increases in childhood obesity while undernutrition issues remain unsolved (Anon, 2015) [1].

The prevalence of obesity is increasing and today more than half of the world's population is considered to be overweight. The increased overweight prevalence within the general population may partly be due to an increased consumption of processed foods with a low intake of dietary fiber (Hardevi *et al.*, 2017) [10].

Obesity is a complex, multifactorial, and largely preventable disease, affecting, along with overweight, over a third of the world's population today. If secular trends continue, by 2030 an estimated 38% of the world's adult population will be overweight and another 20% will be obese (Hruby and Hu, 2015) [12].

#### Causes and consequences:

Obesity results from a positive energy balance, where, intake of calories is greater than caloric expenditure. Nutrition plays a direct role in determining caloric balance by being the sole variable accounting for caloric intake. Caloric output, however is dependent on three specific variables. These include physical activity, resting metabolism, and the thermogenic effect of food. Of the three, physical activity is the most often altered in order to increase caloric expenditure. Psychosocial factors may influence and be influenced by nutrition, physical activity or both (Zhang *et al.*, 2011).

Obesity is rapidly becoming an emerging disease in developing countries due to the increasing westernization of societies and change in the lifestyle. The etiology of obesity is said to be multifactorial, with a combination of genetic and environmental factors. (Ogunbode *et al.*, 2011) [23].

Obesity is a complex disorder that results from a combination of biological, social, environmental and behavioural factors. However, the dramatically increasing prevalence of obesity cannot be attributed to genetics or failure of responsibility in the individuals. The food and activity choices of individuals are influenced convincingly by the toxic and obesogenic environment in which they live. Ceaseless marketing of unhealthy food, paucity of safe areas for physical activity and easy availability of junk food make it difficult for them to opt for healthy choices (Malhotra, 2014).

Overweight and obesity increase the risk of a number of serious health problems. As body weight and body fat increase, disorders such as type 2 diabetes, cardiovascular disease, some cancers, musculoskeletal disorders, and many other deadly diseases become more prevalent (Tucker and

Thomas, 2009)<sup>[24]</sup>.

Obesity increases the risk for a variety of chronic diseases including coronary artery disease, strokes, glucose intolerance and some forms of cancer. Obesity is not a direct cause of most diseases, but unfavorably alters the risk factor profile. For example, obesity may lead to increase in blood pressure and blood cholesterol, which in turn, can lead to cardiovascular disease and strokes (Swallen *et al.*, 2005).

Overweight or obese people are at an increased risk of coronary heart disease, type 2 diabetes, cancers (endometrial, breast and colon), hypertension, dyslipidaemia, stroke, sleep apnea, respiratory problems and osteoarthritis. Moreover, excessive body weight can influence quality of life, education, capacity of work and reproductive performance (Nikooyeh *et al.*, 2016)<sup>[22]</sup>.

Waist circumference, a measure of abdominal adiposity, has become an increasingly important and discriminating measure of overweight/obesity. Abdominal adiposity is thought to be primarily visceral, metabolically active fat surrounding the organs, and is associated with metabolic dysregulation, predisposing individuals to cardiovascular disease and related conditions (Hruby and Hu, 2015)<sup>[12]</sup>.

### Dietary fiber

Codex Alimentarius Commission define dietary fiber as carbohydrate polymers with a degree of polymerization (DP) not lower than 3, which are neither digested nor absorbed in the small intestine and can be found naturally in food consumed or have been obtained from food raw material by physical, enzymatical or chemical ways and gives to organism many health benefits. On the other side, AACC (2001) define dietary fiber as edible part of plants or carbon hydrates analogues that are resistant to digestion and absorption in the small intestine with complete or partial fermentation in the large intestine. Dietary fiber includes polysaccharides, oligosaccharides, lignin and associated plant substances (Cruz-Requena *et al.*, 2016)<sup>[8]</sup>.

With respect to their solubility in water, dietary fiber can be classified as soluble and insoluble. Soluble fibers are mainly composed of non-cellulosic polysaccharides (pectin, gums, mucilage and hemicelluloses) and forms dispersion in water, thereby facilitates formation of viscous gels into the gastrointestinal tract, which slows gastric emptiness. These fermentable soluble fibers are associated with metabolism of carbohydrates and lipids and it is found in large amounts in fruits and seaweed. Furthermore, insoluble fibers increase fecal volume up to 20 times because of its water retention capacity and are mainly composed by cellulose, hemicellulose and lignin. This type of fiber is found mainly in vegetables, grains, legumes and fruits and help to reduce concentration and contact time of potential carcinogens with the intestinal mucosa (Cruz-Requena *et al.*, 2016)<sup>[8]</sup>.

Due to the important role that dietary fibers play in maintaining human health, these are now recognized as the seventh largest nutrient group in the human body, after proteins, fats, carbohydrates, vitamins, minerals, and water. Dietary fibers can be classified based on their solubility in water as soluble dietary fibers (SDF) and insoluble dietary fibers (IDF). IDF mainly consist of hemicellulose, cellulose, and lignin and cannot be degraded by enzymes in the human body or dissolved in water. SDF include pectin, oligosaccharides, guar, and gums, most of which are dietary and healthy additives (Han *et al.*, 2017)<sup>[11]</sup>.

Diets, deficient in dietary fiber, lead to a number of diseases

such as constipation, hiatus hernia, appendicitis, diabetes, obesity, coronary heart diseases, gallstones, etc. (Sudha *et al.*, 2011). Consumption of adequate amounts of dietary fiber reduces the risk of above-mentioned diseases (Olive and Komarek, 2017).

### Development of high fiber mixes

Instant tomato mushroom soup mix was developed using psyllium husk powder and its quality evaluation was carried out by Verma and Mogra (2017)<sup>[26]</sup>. Psyllium husk powder incorporated tomato mushroom soup mix were found to contain 5.14±0.02 g moisture, 7.95±0.03g crude protein 1.46±0.02g crude fat, 2.53±0.01total ash, 7.84±0.03g crude fibre, 75.07±0.11 carbohydrate and 341.29±0.96kcal per 100g. Total dietary fibre content was found to be 11.42±0.02g for psyllium husk powder incorporated tomato-mushroom soup whereas 10.08±0.03g for control sample. Statistically significant difference was observed in the crude fat at 5 per cent level and in the total ash content at 1 per cent level. The total dietary fibre content was observed to be higher than control sample.

Usharani and Lakshmi, (2013)<sup>[25]</sup> carried out the formulation of health mix using foods like Bengal gram dhal, black gram, carrot, tomato and cauliflower leaves. Pepper, cumin seeds and red chillies were added to improve the taste and acceptability of food mixes. Basic Health Mix and variation 1 (Amla) was formulated and developed by using the above functional foods. Amla is highly nutritious and is one of the richest sources of vitamin-C, amino acids and minerals suitable for Diabetic patients. Functional food mixes can be effective for treating patients with chronic diseases like, hypertension, diabetes mellitus, arthritis and cardiovascular disease etc.

A study was conducted by Kadam *et al.*, 2018<sup>[13]</sup> on development and quality evaluation of foxtail millet based extruded products. The study concluded that the rice, maize and foxtail millet based extruded product was found optimum for the consumption by all age groups. The product was rich in protein content (7.02%) and fiber content (2.35%), hence it has a high nutritive value. This study can further be used for developing fiber rich snacks and ready to eat foods. As the fat content (1.42%) was low, thus it can be a good diet food also.

The organoleptic evaluation of common food preparations such as chapathi, poori, idli, dosa with various high fibre foods (fenugreek seeds, wheat bran, horsegram powder, pseudostem powder and lotus stem powder) incorporated at different levels were all accepted. It was found that upto 15 per cent horse gram powder could be incorporated with whole wheat flour, for making various high fibre food preparations. The most suitable level of incorporation of wheat bran was up to 10 per cent. Similarly, incorporation of dry pseudostem powder and dry lotus stem powder was upto 15 percent. Fenugreek powder incorporation was up to 2.5 percent. Hence the study concluded that the wheat bran an industrial byproduct can be effectively utilized and presently underutilized foods such as pseudostem, lotus stem, fenugreek, horse gram can be best used in the dehydrated, powdered form without involving a high cost of production (Kamalasundari and premalatha, 2014)<sup>[14]</sup>.

Sensory characteristics of the products showed that *Idli* prepared by kodo millet incorporating 20 per cent (T1), 40 per cent (T2) and 60 per cent (T3) of millets was found acceptable for color, flavour and taste, texture and over all

acceptability and there was no significant difference between control and all treatments. Sensory score of *Sewai upma* prepared by incorporating kodo millet at 20 per cent (T1), 40 per cent (T2) and 60 per cent (T3) of flour showed that treatment T3 was best for flavour and taste, whereas there was no significant difference between color, texture and overall acceptability (Neelam *et al.*, 2013)<sup>[20]</sup>

Green gram husk could be well incorporated in different snack food item recipes like biscuits, bread, muffin, mathri and pakora and was well acceptable. Nutritional evaluation of the selected fiber rich food item revealed that the fiber rich product have good nutritional value and found to be a good source of minerals. The husk incorporated product have low glycemic index which makes it suitable for the consumption of diabetic subjects (Bora and Kulshreshtha, 2015)<sup>[2]</sup>.

Health mix formulated and developed using bengal gram dhal, black gram, carrot, tomato and cauliflower leaves were examined initially and after a storage period of three months for the microbial content (bacteria, yeast and mould) to evaluate the shelf life of the health mixes. Microbial content was found out by standard plate count, yeast and mould count and the results were compared with the permissible limits. The total bacterial count of the health mixes was nil initially and ranged between  $3 \times 10^3$  and  $4 \times 10^3$  per g at the end of three months storage period which was within safe limits. The yeast and mould counts were found to be below detectable limits in all the food mixes both initially and after a three months storage period. This indicates that the health mixes were free from spoilage and safe for consumption up to three months after preparation (Usharani and Lakshmi, 2013)<sup>[25]</sup>.

### Effect of high fiber on obesity

Fiber intake is a dietary factor that has received substantial attention. Reviews by several scientists indicate that dietary fiber is inversely related to weight gain. Further analysis showed that women who decreased their total relative fiber intake actually tended to gain significantly more weight than their counterparts, whereas those whose total fiber intake increased over time actually tended to lose weight. The relationship was not only significant, but it was also meaningful. For each additional 1 g of fiber consumed per 1000 kcal from baseline to follow-up, participants tended to lose 0.25 kg, and for each 1 g decrease in total fiber intake, women gained 0.25 kg, on average. In short, a daily 8-g increase in total fiber per 1000 kcal was predictive of a 2-kg weight loss in 20 months (Tucker and Thomas).

A decrease in serum cholesterol level was observed after supplementation of high fibre diet. When compared with the control group, there was a decrease of 1 to 15 mg/100 ml in the experimental group as against 2 mg/100 ml increase in the control group. Statistically there was a significant change at 5 percent level. There was no significant change in the HDL Cholesterol value after supplementation. The control group also showed no change. The LDL- Cholesterol level of the experimental group was decreased by 1 to 13 mg/100 ml. The change in the LDL- Cholesterol value was significant at both 5 percent and 1 percent level (Khogare, 2012)<sup>[16]</sup>.

Soluble fibre can contribute to LDL reduction and is now a formal part of hyperlipidemia dietary recommendations. Fresh fruits, vegetables, legumes, cereals, oats and whole grains are good sources of soluble fibre. This type of fibre

helps block cholesterol from being absorbed into the bloodstream. Most fruits and vegetables have 1-3 g of soluble fibre per serving. It is recommended that people who have high cholesterol get a total of at least 30-40 g of fibre each day. Studies also have indicated that plant-based diets are associated with decreases in total cholesterol and LDL cholesterol of up to 15% and eating 2-3 g of phytosterols daily reduces total cholesterol by up to 11% and LDL cholesterol by up to 15% (Karuna *et al.*, 2015)<sup>[15]</sup>.

A study on high fibre and omega-3 rich diet which contained 30-40 g of fibre from sources such as whole grains, whole fruits and vegetables, salads, psyllium, oats, flax seeds, soy etc. and 3-4 g of omega-3 fatty acids from almonds, walnuts and flax seeds proved beneficial in controlling and lowering the total cholesterol and LDL levels significantly in most of the subjects. However, the increase in HDL cholesterol was minimal. This all signifies that the high fibre and omega-3 rich diet indeed play a beneficial role in combating deranged lipid profile and improves them simultaneously but diet along with exercise is necessary to increase the HDL levels. Thus, high fibre and omega 3 rich foods can be incorporated in one's daily diet for the prevention or management of most of the prevalent chronic conditions to lead a healthy lifestyle (Karuna *et al.*, 2015)<sup>[15]</sup>.

Dietary fibers have been shown to have many health benefits. For instance, it can improve the function of the digestive system and are able to reduce the risk of many chronic diseases such as cancer, diabetes and heart disease (Yasin *et al.*, 2017)<sup>[27]</sup>.

Constant supply of the dietary fiber in the diet reduces the risk of chronic diseases in humans. Increasing the consumption of high fiber foods such as whole cereals, millets, whole pulses and dried fruits, will provide the daily requirement of the dietary fibre. Fibre is protective against obesity and obesity is reported to be rare in population that consumed a high fiber diet (Kamalasundari and premalatha, 2014)<sup>[14]</sup>.

A reduction of 2.39 cm in the mean waist circumference was observed in the diet group subjects and an increase by 0.50cm in the control group control. The mean reduction of abdomen circumference was higher in diet group (3.89 cm). Least reduction of 3.02 cm and an increase of 0.31 cm in the control group. The reduction in waist and abdomen circumference may be due to the presence of high fibre and low GI in the diet mix (Kamalasundari and premalatha, 2014)<sup>[14]</sup>.

A study conducted by Narayan *et al.*, 2014 revealed an inverse association of total dietary fiber intake with total cholesterol and LDL cholesterol levels among urban adults with type 2 diabetes. Also showed a decrease of 6.7% in total cholesterol and 12.5% in very LDL levels with a high-fiber diet. There was a reduction in total cholesterol by 4% and LDL cholesterol by 6% in high dietary fiber intake group compared to low dietary fiber intake group. Similarly, a low GI diet having high dietary fiber (34 g/day) showed a significant decrease in total serum cholesterol and LDL cholesterol and no significant reduction was observed in the low dietary fiber diet (20 g/day) in type 2 diabetic men.

Considerable evidence supports that increased consumption of dietary fiber was associated with lower risk of obesity in adults. Consumption of 10 g of  $\beta$  glucan by obese women resulted in significantly decreased glucose response after 30 minutes as well as a delayed glucose response. Furthermore,

increasing cereal fiber by 31.2 g/day for 3 days resulted in improved insulin sensitivity in overweight and obese women (Brauchla *et al.*, 2012)<sup>[3]</sup>.

A systematic review of intervention trials was carried out on the effect of cereal fiber on bowel function by De vries *et al.*, 2015<sup>[9]</sup>. The results of the 65 included publications indicate that wheat fiber promotes healthy bowel function through improvements in total stool weight, dry stool weight, intestinal transit time, and stool frequency. Based on the large volume of available evidence, incorporating wheat fiber, primarily wheat bran fiber, into the diet can positively affect bowel function.

Whole grains like millet have health promoting effects equal to or even in higher amount than fruits and vegetables and have a protective effect against insulin resistance, heart diseases, diabetes, ischemic stroke, obesity, breast cancer, childhood asthma and premature death (Cade *et al.*, 2007)<sup>[4]</sup>.

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