

BIBILE MEMORIAL ORATION 2015

COMBATING OBESITY IN SRI LANKA – UNDERSTANDING THE ENEMY

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Prof. Senaka Bibile



Senaka William Bibile was born on the 13th of February 1920 at Atadagewatta Walawwa. His parents were Mr. Charles William Bibile, the “Raté mahattaya” of Bibile and Mrs. Sylvia Augusta Ubayasekera. Prof Bibile had his primary and secondary education at Trinity College, Kandy. He graduated from University of Colombo with first class honours obtaining distinctions and gold medals in Medicine and Surgery. He obtained his Ph.D. from the University of Edinburgh and on his return to Sri Lanka, was appointed the Professor of Pharmacology. He was the first Dean of the Faculty of Medicine at Peradeniya from 1967 to 1970. Prof Bibile was also instrumental in initiating the idea of building the Peradeniya Teaching Hospital¹.

He was the founder of Sri Lanka's drug policy, which was used as a model for development of policies based on rational pharmaceutical use in other countries as well

by the World Health Organization, the United Nations Conference on Trade and Development (UNCTAD) and the Non-Aligned Movement. He is best known for his advocacy of the government-controlled pharmaceutical purchasing plans often referred to as "rationalization" of pharmaceuticals and the development of a national pharmaceutical policy. He played the leading role in developing a rational pharmaceutical policy aimed at ensuring that impoverished people would get reasonable drugs at a low price². I hope his dream will soon become a reality with the current government's pledge to draft the Pharmaceutical Bill.

The topic of this oration is on obesity, a condition where the use of drugs has a minimal role to play. Since Prof. Bibile was known as a pharmacologist, one might wonder whether the topic of this oration has any relevance to his work. My work, and the work described in this oration are on Human Nutrition and Molecular Endocrinology. Indeed, Prof. Bibile's earlier work was on Nutrition and Endocrinology. In his earlier research, Prof. Bibile worked with Prof. Harry Cullumbine, the great British Nutritionist, on island-wide nutrition surveys and reported regarding the widespread malnutrition prevalent throughout Sri Lanka at that time. He published nine landmark papers from this study. Later, he carried out his doctoral

research on Endocrinology, which involved work on the human steroidal hormones, leading to publication of two important papers in the prestigious *Journal of Endocrinology* in 1953¹.

The title of this oration is “Combating Obesity in Sri Lanka – Understanding the Enemy”. Since it is essential to understand an enemy before mounting an attack, in this oration evidence for the causes of obesity and its co-morbid conditions especially in the Sri Lankan setting are reviewed. This understanding will help us to tailor interventions to combat obesity, specifically targeting the population of Sri Lanka.

Obesity – Magnitude of the Problem

According to the World Health Organization, in 2008, more than 1.4 billion adults were overweight and more than half a billion were obese in the world³. At least 3.4 million people each year die as a result of being overweight or obese. The prevalence of obesity has nearly doubled between 1980 and 2008. Once associated with high-income countries, obesity is now also prevalent in low and middle-income countries³. According to a study by Dr. Katulanda and colleagues, the prevalence of overweight and obesity in Sri Lanka in 2010 were 25% and 9% respectively⁴. This has increased to 29% and 15% respectively in 2012 according to a study done by Dr. Jayatissa and colleagues⁵.

We have evidence to believe that the prevalence of obesity has further increased specially among young adults. In one of our ongoing studies, we have found that in a sample of 2480 adult males less than 40 years of age in the Central Province, the prevalence of overweight and obesity was 45%⁶. This shows that nearly half of adult males less than 40 years of age are at risk of

chronic diseases related to excess body weight. The prevalence of overweight and obesity appears to be an emerging problem among Sri Lankan adolescents and children as well. In an ongoing study, Dr. Bimba Goonapienuwala, a lecturer at Rajarata University Faculty of Medicine, studied the prevalence of obesity among adolescents in the Anuradhapura district. The other collaborators of this study were Prof. S. Siribaddana and Dr. Suneth Agampodi from the Rajarata University. Using WHO 30 cluster methodology, a sample of schooling adolescents was selected. Anthropometry was carried out using standard protocols and WHO age and gender specific cutoffs were used to determine overweight and obesity. A total of 489 students (191 males) were studied. Mean age was 14.9 years (SD = 0.90). Of males, 8.4% (n=16, 95% CI; 4.5 - 12.3) and of females, 9.6% (n=28, 95% CI: 7.9 - 11.3) were overweight or obese⁷, highlighting that obesity is an emerging problem even in rural areas of this country.

Diagnosis of obesity

Obesity is a condition of abnormal or excessive fat accumulation that may impair health. When the body has surplus energy from excessive food intake, it is converted to fat and stored in a specialized tissue called the “adipose tissue”. This tissue is mainly present underneath the skin, while it is also located inside the abdomen around internal organs of the body. The former is called “subcutaneous fat”, while the latter is termed “visceral fat”. Females in the reproductive age have mainly fat deposition in the subcutaneous compartment, around the hips, thighs and buttocks. In contrast, males have fat deposition predominantly in the visceral compartment, giving rise to central or abdominal obesity. In terms of metabolic health, visceral fat is considered to be worse than subcutaneous fat.

Clinically, several anthropometric measures are used to identify obesity. Body mass index (BMI) is one, which is calculated by dividing weight (in kilograms) by height (in meters) squared ($BMI = Wt \text{ (kg)} / Ht^2 \text{ (m}^2\text{)}$). According to WHO global cutoffs, a BMI between 18.5 and 24.9 is considered to be normal weight, while BMIs between 25 to 29.9 and 30 or above are considered to be overweight and obese respectively. So, how did WHO decide on these cutoffs? When you look at the relationship between BMI and the risk of dying from cardiovascular disease, there is an exponential relationship. The risk of dying from cardiovascular disease increases with a BMI of greater than 25, and this risk is further increased with a BMI of over 30. That is how these BMI cutoffs were decided. However, it was later found that for Asians the relative risk of dying from heart diseases and also developing diabetes is far greater at a given BMI compared to individuals in Western populations (Caucasians)⁸. Therefore, for Asian populations, lower BMI cutoffs were suggested. Last year, a committee appointed by the Endocrine Society of Sri Lanka published BMI guidelines for Sri Lankans. This guideline states that a normal BMI is between 18.5 and 22.9, whereas a BMI between 23 and 24.9 is considered to be overweight and a BMI of more than or equal to 25 is considered obese⁹. I strongly urge our doctors to follow these guidelines to identify individuals who are at a higher risk for metabolic diseases.

While the BMI is a measure of whole body fat content, it does not provide any information with regards to the distribution of fat. Therefore, it is important to use a marker of visceral fat content, such as the waist circumference, when assessing an individual for obesity. Waist circumference is a measure of central obesity, and is measured at a horizontal plane roughly near

the plane of the umbilicus. Measures of more than or equal to 90 and 80 cm are considered to be the cutoffs for abdominal obesity for Asian males and females respectively. Finally, waist-hip ratio (WHR) is also a measure of abdominal obesity, calculated as the ratio between waist circumference and hip circumference (around the buttocks). WHR more than or equal to 0.9 and 0.85 are considered to be the cutoffs for abdominal obesity in males and females respectively.

Co-morbidities associated with obesity

As mentioned above, obesity is associated with increased risk of dying from any cause, and especially cardiovascular disease. Moreover, obesity is associated with numerous other chronic illnesses such as type-2 diabetes, dyslipidaemias, high blood pressure, obstructive sleep apnoea, non-alcoholic fatty liver disease, polycystic ovarian disease, osteoarthritis, depression, and cancers of the breast and colon. Obesity is also associated with metabolic syndrome, which increases the risk for type-2 diabetes and cardiovascular disease. Increased fasting blood sugar, high blood pressure, abdominal obesity, increased plasma triglycerides and decreased HDL cholesterol are features of the metabolic syndrome¹⁰. While obesity is associated with these chronic illnesses, now there is emerging evidence that it is actually obesity which causes most of these conditions.

Role of adipose tissue in the pathogenesis of metabolic syndrome

Recent evidence has uncovered mechanisms by which obesity and excess fat deposition lead to metabolic syndrome and diabetes. We have reviewed these findings in the journals “Advances in Nutrition” and “Molecular Aspects of Medicine”^{11,12}.

Adipose tissue was traditionally considered to be the site for storage of excess fat in the body. With the discovery that this tissue also secretes hormones such as leptin, it is now considered to be a hormone-secreting (endocrine) organ. The hormones secreted from adipose tissue have important physiological roles in regulation of energy balance, blood pressure and blood glucose levels, and are called adipokines¹¹. For example, leptin which is an adipokine secreted exclusively from adipose tissue, regulates energy intake and expenditure. Adiponectin is another adipokine which increases insulin sensitivity. When an individual takes more energy (food) than the body needs, this excess energy is stored as fat in the adipose tissue. Similar to other tissues, adipose tissue also contains several types of live cells (Figure 1).

Fat is mainly stored in the cytoplasm of fat cells (adipocytes). There are other cells such as pre-fat cells (preadipocytes) and immune cells also present in the adipose tissue. When there is excessive fat deposition, the adipose tissue responds in two ways. First, it increases the number of fat cells (hyperplasia). Second, the individual fat cells enlarge (hypertrophy). However, with continuous excessive fat deposition, the fat cells become so enlarged that some of them start to die. Whenever there is tissue damage, the body mounts an inflammatory response. Similarly, the death of adipocytes results in a low-grade inflammation in the adipose tissue. This process is characterized by an increasing presence of immune cells in the adipose tissue. This inflammatory process leads to a dysregulation of the adipose tissue hormone secretion, which will adversely affect various body functions including blood glucose control¹². We have developed techniques to identify these changes in immune cell populations in the adipose tissue. Flow cytometry is a robust

technique by which immune cell populations can be quantified. We have used this technique for several projects¹³, and are now employing it to digest the adipose tissue and identify the different cell types.

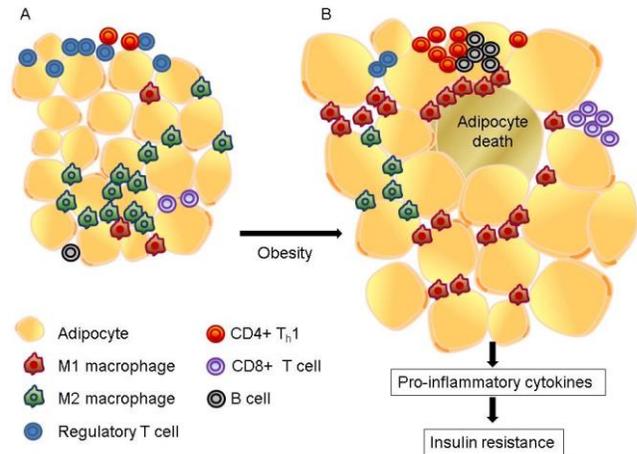


Figure 1. Changes in adipose tissue immune cells in obesity.

Adipose tissue contains fat cells (adipocytes) as well as numerous immune cells such as macrophages and lymphocytes. Obesity leads to adipocyte hypertrophy and adipocyte death which results in changes in immune cell populations. These changes are causally linked to the pathogenesis of insulin resistance.

In obesity the number of pro-inflammatory macrophages and T cells increase in adipose tissue, which contributes to the chronic low-grade inflammation.

Obesity, adipose tissue inflammation and diabetes

It is important to understand the regulation of blood glucose, to appreciate the mechanisms by which obesity leads to diabetes. In the fasting state, liver produces glucose to maintain normal blood glucose

levels, so that organs such as the brain, heart, kidneys and muscles have a regular glucose source (Figure 2).

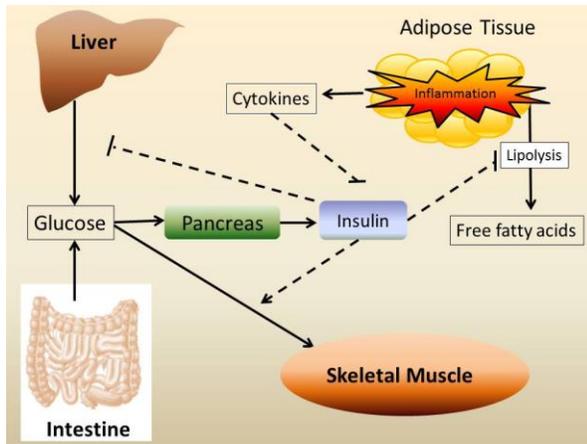


Figure 2. Mechanisms linking obesity to insulin resistance.

Insulin inhibits hepatic glucose production and increases glucose uptake by skeletal muscle. Pro-inflammatory cytokines secreted by obese adipose tissue impairs insulin action leading to a state of insulin resistance.

Following a meal, the carbohydrates in food are digested and absorbed as glucose, leading to increased blood glucose levels. This stimulates the pancreas to secrete insulin, the major hormone responsible for lowering blood glucose. Insulin acts in two main ways to reduce blood glucose. First, it stops the liver from producing glucose. Second, it stimulates the muscle, adipose tissue and liver cells to take up glucose into cells. In order for insulin to perform these functions, it first needs to bind to the insulin receptor, which will activate a cascade of intracellular signaling events. The hormonal changes occurring in obesity will adversely affect this intracellular insulin signaling cascade resulting in impaired insulin action. Because of this impaired insulin action, blood glucose level tends to rise, resulting in a necessity for further increases in

pancreatic insulin release. Thus, obese individuals maintain normal blood glucose levels at the expense of higher pancreatic insulin secretion. This state is known as insulin resistance. With long-standing insulin resistance, the pancreas is unable to maintain these high levels of insulin secretion and pancreatic failure can occur. This will initially give rise to pre-diabetes or glucose intolerance which can later progress to diabetes¹².

It is important to understand that not all obese individuals develop diabetes. Therefore, genetic predisposition might play a role in the relationship between obesity and diabetes. South Asian individuals, unfortunately, have a higher predisposition for diabetes even at lower levels of obesity. In contrast, more than 90% of diabetics have high body fat levels, illustrating the important contribution of obesity to the pathogenesis of diabetes.

The adipose tissue renin angiotensin (RAS) system is also an important link between obesity and its metabolic complications. The RAS is traditionally known for its role in regulation of blood pressure, fluid and electrolyte balance. It is now established that the adipose tissue contains a local RAS which functions independently from the systemic RAS¹⁴. Indeed, the expression of Angiotensinogen, the precursor peptide of this system, positively correlates with obesity. Also, individuals who are on RAS blockers such as ACE inhibitors or Angiotensin receptor blockers have a lower incidence of Type-2 diabetes¹⁵. This led us to hypothesize that over-activation of the adipose tissue RAS is a link between obesity, insulin resistance and metabolic syndrome. Specifically, we hypothesized that overexpression of Angiotensinogen (Agt), the precursor peptide of this system, in adipose tissue will lead to insulin

resistance. To test this, we genetically overexpressed Agt specifically in adipose tissue of mice. These mice developed insulin resistance as indicated by euglycemic, hyperinsulinemic clamp studies, confirming our hypothesis¹⁶. These findings were published in the journal "Obesity". Next, to find out whether the systemic RAS over-activation can also lead to insulin resistance, we genetically overexpressed renin, the rate limiting enzyme of this system, in the liver of mice. While as expected these mice developed hypertension, they did not develop insulin resistance, suggesting that over-activation of the systemic RAS is not linked with insulin resistance¹⁷. We published these findings in "Frontiers in Endocrinology". The last piece of the puzzle to complete our understanding of the contribution of adipose RAS to insulin resistance was to knock down Agt specifically in adipose tissue to observe whether this would protect against insulin resistance in obesity. To test this, first we knocked down the Agt gene in cultured fat cells using si-RNA and found that it leads to reduced secretion of cytokines linked with inflammation¹⁸. These findings were published in "Frontiers in Endocrinology" in 2013. Further research to confirm these findings *in vivo* are currently underway. The overall contribution of the systemic renin angiotensin system and the adipose tissue RAS to insulin resistance and metabolic syndrome are described in detail in two of our publications in "Obesity Reviews"¹⁵ and "Critical Reviews in Biochemistry and Molecular Biology"¹⁴ published in 2012. In summary, adipose tissue dysfunction and over-activation of the adipose renin angiotensin system are two mechanisms which link obesity to adipose tissue inflammation and metabolic syndrome.

While these mechanisms are well studied using animal models and Western

populations, the mechanisms of insulin resistance and Type-2 diabetes are not well elucidated in Asian populations. Why do we think that the mechanisms of these disorders are any different in the Asians compared to Caucasians? First, Asians have a higher risk of developing Type-2 diabetes compared to Caucasians at a given BMI⁸. Although it can be argued that at a given BMI Asians have a higher body fat percentage, it was recently shown that at comparable body fat percentages, Asians have a higher degree of adipose tissue inflammation compared to Caucasians¹⁹. Therefore, it is important to study the mechanisms responsible for insulin resistance and diabetes in Asian populations.

With this objective in mind, we started a project at the Faculty of Medicine, University of Peradeniya to explore these mechanisms. This project is a collaboration between Dr. Sulochana Wijetunga in the Department of Pathology, Dr. Rasika Kotakadeniya in Department of Surgery, Dr. Chathura Ratnayake in Department of Obstetrics and Gynaecology and Dr. Shanthini Rosairo in Department of Radiology. We recruited adult females who underwent routine abdominal surgery at Teaching Hospital Peradeniya for this study. Subjects with inflammatory disorders or past abdominal surgery were excluded. Waist circumference, body mass index and pre-operative fasting blood glucose were measured. Histological sections of adipose tissue obtained from the omentum and anterior abdominal wall were examined for adipose tissue macrophages by Dr. Sulochana Wijetunga, our histopathologist and the number of crown-like structures (CLS-macrophage aggregates) per 25 medium power fields was counted. Adipocyte area was measured using the ImageJ software. The presence of hepatic steatosis and the thickness of the anterior

abdominal wall fat pad were assessed by ultra sound scanning by Dr. Rosairo, our radiologist. The mean age of the study group of 59 subjects was 45.6 years (SD=13). Fasting blood glucose had significant positive correlations with age ($r=0.45$; $p<0.001$), waist circumference ($r=0.38$; $p<0.01$) and anterior abdominal wall thickness ($r=0.53$; $p<0.01$). In contrast, neither crown-like structures nor liver enzymes correlated with fasting plasma glucose levels²⁰. In the subset where ultra sound scanning was performed, all individuals with impaired fasting glucose (FBS 5.6 – 6.1 mmol/l) had evidence of fatty liver, compared to 50% in subjects with normal blood glucose ($p=0.004$ by chi square test). A higher proportion of subjects with impaired fasting glucose also had abdominal obesity (95% in the impaired fasting glucose group vs. 64% in the normal blood glucose group; $p=0.009$)²¹. Mean adipocyte cross-sectional area was higher in the anterior abdominal wall fat when compared to omental fat (8917 vs. 6862 μm^2 ; $p=0.01$). Moreover, overweight or obese women had a significantly higher mean adipocyte area in the omental fat, but not anterior abdominal wall fat, when compared to women with normal weight (7937 vs. 4232 μm^2 ; $p<0.001$), indicating a higher tendency for the visceral adipocytes to hypertrophy with increasing adiposity. Women with fatty liver also had higher mean adipocyte area in both depots (7556 vs. 4488 μm^2 ; $p<0.001$ in the omental and 9097 vs. 6452 μm^2 ; $p<0.01$ in the anterior abdominal wall fat)²². From this study, we concluded that in adult Sri Lankan females, fatty liver, rather than adipose tissue macrophage infiltration is associated with impaired fasting glucose. Further, obesity and hepatic steatosis are associated with visceral adipose tissue adipocyte hypertrophy. These findings were presented at the Annual Academic Sessions of the

Kandy Society of Medicine in 2013 and 2014, at the Diagnostic Pathology Update and Junior Academy International Conference in 2014 and as part of an invited lecture at the FASEB Summer Research Conference on “Nutrient Sensing and Metabolic Signaling” in Montana, USA in 2014.

Causes of obesity

A simplistic view on the cause of obesity is an energy imbalance resulting from excessive caloric intake and low energy expenditure. Although this looks to be a simple concept, in a recent study we found that this was not the case. Human body energy storage operates as a stock-and-flow system with inflow (food intake) and outflow (energy expenditure). In spite of the ubiquity of stock-and-flow structures, evidence suggests that human beings fail to understand stock accumulation and rates of change, a difficulty called the stock–flow failure. In a multi-center international study, we examined the influence of health care training and cultural background in overcoming stock–flow failure. A standardized protocol assessed laymen’s and health care professionals’ ability to apply stock-and-flow reasoning to infer the dynamics of weight gain/loss during the holiday season (621 subjects from seven countries). Our results indicated that both types of subjects exhibited systematic errors indicative of use of erroneous heuristics. Indeed 76% of lay subjects and 71% of health care professionals failed to understand the simple dynamic impact of energy intake and energy expenditure on body weight. Stock–flow failure was found across cultures and was not improved by professional health training²³. We published these finding in the journal “System Dynamics Review” in 2013.

The World Health Organization states that the potential causes of obesity are consumption of foods that are high in energy density; are low in nutrient density, and lack vitamins, minerals, and macronutrients, combined with sedentary lives. While the lifestyle factors which are associated with obesity are well known in Western populations, relatively less data are available in this regard for Sri Lankans. It is important to find this out, as it will help to tailor interventions for our population. In an ongoing study, we are studying adults who present for a routine medical examination at the Driver Testing Center at Peradeniya, with regards to their lifestyle factors and non-communicable disease risk factors. This project was pioneered by Prof. Thilak Jayalath and is now a collaborative effort between Dr. Udaya Ralapanawa from the Department of Medicine, Dr. R.S. Jayasekera, head of the Driver Testing Centre and Dr. Terrance Madhujith from the Department of Food Science. Mrs. Isuri Jayawardena, a lecturer from Rajarata University currently reading for an MPhil was responsible for the data analysis of this project. Thus far, we have included a total of 2694 individuals aged between 17 – 68 years (mean age of 31) in this study. BMI cutoff values for Asians were used to categorize the participants as normal, overweight and obese. The dietary data were collected using a food frequency questionnaire and data on the level of physical activity, smoking, alcohol consumption and sleeping hours were obtained using a self-administered validated questionnaire. After adjusting for potential confounders, overweight and obesity were associated with older age in men and the quantity of lipid intake. Interestingly, the level of physical activity was not significantly associated with the incidence of overweight and obesity. These findings will be presented in detail at the Annual

Academic Sessions of the KSM in 2015. From this study we concluded that consumption of oily food is significantly associated with being overweight or obese. Therefore, it might be important to target interventions for reducing fat intake to combat obesity in the Sri Lankan context.

While traditional research has looked at the causes of obesity, we did a study in USA to look at the factors associated with a healthy weight²⁴. We have previously shown that children participating in a creative after school program exhibit overall healthier lifestyle practices compared to the average pediatric population in USA. This observation led us to investigate the prevalence of overweight/obesity and lifestyle practices of their parents. The objective of this study was to determine the strongest predictors of weight status for female parents whose children were participating in such a creative after school program. We surveyed parents of children who competed in the 2008 and 2009 Destination Imagination Global Finals in Knoxville, Tennessee, USA. A total of 4,608 children participated in data collection, with parental consent. For the combined 2 years, 1,118 parents, 87% of whom were females (n=1,032) completed online questionnaires, which were based on the Behavioral Risk Factor Surveillance System and included self-reported height, weight, dietary intake, physical activity, and socioeconomic status. The majority of this population was white, and less than 5% were African American or Hispanic. We found that only 45.2% of these female parents were overweight/obese, compared to a national average of 64.1% reported by the National Health Nutrition Examination Surveys for 2007, 2008. Furthermore, this population was significantly more physically active compared to national average. Most parents (76%) had completed a college degree and

reported high incomes. Parents with the lowest income were the most obese in this population. Finally, we found a significant association between parent and child weight status. From this study, we concluded that female parents of children who have healthy lifestyles were physically active, which likely accounts for the parents' lower overweight/obesity rates. In addition to physical activity, income and percentage of calories from fat were all predictors of weight status. We published these findings in the journal "Food and Nutrition Research" in 2012²⁴. This study indicates that parental behaviors and modeling may be associated with the weight status of children, and highlights the importance of role-modeling healthy behaviors for children.

Prevention and treatment of obesity

The overall recommendation for weight control is to consume diets that are rich in fiber, fruits, and vegetables and low in fat, especially saturated and trans- fat, while engaging in regular physical activity. The basic principle for weight loss is to induce a negative energy balance via consuming an energy-restricted diet.

Energy-restricted diets

Prevention is the best strategy to combat this emerging obesity / diabetes epidemic. Lifestyle modification including healthy eating, regular exercise and stress management play a key role in this regard. The Diabetes Prevention Program, a landmark study in the area of lifestyle modification, showed that a 5-10% weight loss by healthy eating and regular exercise can cut the diabetes risk by more than half in overweight or obese individuals²⁵. Mechanistically, weight loss also leads to improvements in adipose tissue inflammation and systemic insulin

resistance. For example, we showed that in a mouse model of diet-induced obesity, 30% caloric restriction can lead to significant improvements in insulin sensitivity, hepatic steatosis and adipose tissue inflammation²⁶. We published these findings in the Journal "Obesity" in 2011.

Dietary bioactive compounds to alleviate adipose tissue inflammation

In addition to total energy intake, the composition of a diet can also affect the metabolic and endocrine functions and overall energy balance. Indeed, most health recommendations emphasize diets rich in fruits and vegetables, which have higher nutrient density and lower caloric density, for prevention of chronic diseases. Such diets would provide significant amounts of bioactive components, with known beneficial effects due in part to their anti-inflammatory properties. Since adipose tissue inflammation is causally linked to the pathogenesis of insulin resistance and several chronic diseases, dietary interventions targeted at improving adipose tissue inflammation could be a useful strategy for improving the overall metabolic profile. As we showed in reviews published in "The Journal of Nutritional Biochemistry" in 2012²⁷ and "Advances in Nutrition" in 2012¹¹, dietary omega-3 polyunsaturated fatty acids (n-3 PUFAs) such as EPA and DHA have known cardiovascular benefits and anti-inflammatory activities. We showed that when supplemented to a high-fat diet, EPA can both prevent and reverse high-fat diet-induced insulin resistance in rodents²⁸. EPA also prevented and reversed adipose tissue inflammation and hepatic steatosis induced by high-fat feeding. We published these finding in the "Journal of Nutrition" in 2010²⁸. EPA improves these metabolic parameters by improving adipose tissue function and reducing adipose tissue

inflammation²⁹. We have also previously shown that EPA is able to favorably modify adipokine secretion from cultured fat cells³⁰.

Plant polyphenolic compounds such as curcumin, resveratrol, catechins, quercetin and isoflavones have recently been identified as important bioactive compounds which can act as anti-inflammatory antioxidant agents. Curcumin is the main bioactive compound in turmeric, while resveratrol is mainly present in the skin of grapes. Catechins are tea polyphenols, while quercetin is mainly found in fruits such as apples. Finally, isoflavones are the bioactive compounds in soy products. We have recently reviewed the benefits of these bioactive food components as well as the mechanisms by which these compounds impart their effects in a publication in the "Journal of Nutritional Biochemistry" in 2013³¹.

Conclusions

The increasing prevalence of overweight and obesity has contributed to the recent escalation of the incidence of diabetes and other metabolic disorders. Since these metabolic disorders are chronic diseases with no curative treatments to date, their prevention is of utmost importance. Lifestyle modification, comprising healthy eating and regular physical activity leading to weight loss, plays a major role in obesity prevention and treatment. Dietary bioactive compounds such as omega-3 fatty acids and polyphenolic compounds also impart metabolically beneficial effects. Therefore, a healthy diet with plenty of fruits and vegetables and a moderate amount of fish would provide additional beneficial effects in the prevention of obesity and metabolic diseases. A multidisciplinary approach involving healthcare professionals, the government, media and private

organizations is needed to combat the emerging obesity epidemic in Sri Lanka.

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