What is Causing the Worldwide Rise in Body Weight?

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Abstract

The worldwide rise in body weight has reached epidemic proportions and this has serious public health consequences. Despite the universal recognition of this problem, its causes are still debated: some attribute it to excess caloric intake; others blame a lack of physical activity (PA); some implicate specific changes to micro- and macro-nutrients. During the past century, government health agencies have developed guidance on healthy eating. These, along with advances in agriculture and food manufacturing, have largely eliminated nutrient deficiencies and helped reduce the consumption of fat. Over the past 60 years, however, technological advances and shifts in the types of occupations prominent in industrialized as well as developing countries have resulted in well-documented decreases in energy expenditure. Energy intake must be balanced with energy expenditure in order to prevent weight gain, and there is increasing evidence that this balance must be at a relatively high level of energy flux. A program that was started in São Paulo in 1996 known as '*Agita*' has sought to motivate populations to engage in small amounts of physical exercise daily to tackle growing obesity levels. This multi-agency initiative is one example of how to successfully increase exercise within a community and scale both within (e.g. all states in Brazil) and across many nations. Reducing caloric intake in whole populations is challenging especially at relatively low levels of energy expenditure, and evidence suggests that there is a critical energy flux threshold for regulating intake to achieve energy balance. Increasing PA, however, may be more achievable than reducing intake. Activity raises caloric expenditure and can offset excess intake. The implementation of programs to achieve greater PA is therefore vital if the worldwide rise in body weight is to be halted, while we also need to implement programs to help people eat smarter.

Keywords

Physical activity, energy intake, energy expenditure, overweight, obesity epidemic, diet, energy balance, energy flux, guidelines

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For several decades human body weight has been increasing worldwide to a point where the prevalence of overweight and obese adults and children has been described as epidemic or even pandemic.[1–6] The statistics are alarming: in 2005 1.6 billion people worldwide were overweight and 400 million people were obese (one in ten adults). This is predicted to rise to 2.3 billion overweight and 700 million obese in 2015.[7,8] The prevalence of overweight people and obesity is highest in the US, Mexico, and parts of Europe (38–70 % overweight) but is lower in South America and Asia (10–20 % overweight), although those regions are also showing increases.[9,10] Obesity is associated with increased risk for a variety non-communicable diseases including coronary heart disease, stroke, diabetes, and cancer, although this association becomes much weaker when physical fitness or accurately measured physical activity (PA) are taken into account in the analyses.[11] Predictions show that body weight increase is set to continue in coming years in most countries worldwide, presenting a major public health challenge.[9,10]

Despite the long-accepted trend in increasing body weight, there is less agreement among experts on the factors that are causing it. Some argue that changes in diet, particularly western fast foods with high caloric content, are to blame and assert that people are eating more than they need to maintain their weight; however, there have been few well-conducted studies that support this hypothesis. Others argue that modern lifestyles involving substantially decreased levels of PA in both work and during leisure time lead to a positive energy balance, and this results in greater fat

deposition and increased body weight. It is also clear that genetic[12] and/or epigenetic factors[13] play a role in weight gain. Others suggest that changes in macronutrients in foods and several lifestyle factors (stress, less sleep, etc.) are responsible for weight increase, but there is little scientific evidence to support this hypothesis. The excess food intake versus PA debate can be countered by the need for 'energy balance' in which the two factors are matched or in the case of being overweight or obese, working to achieve a negative energy balance where fewer calories are consumed and/or more expended to ensure weight loss and prevention of additional weight gain.[14–17] The interactions between caloric intake and energy expenditure are complex and not fully understood, but there is strong evidence that maintaining energy balance and avoiding weight gain likely requires being in balance at a relatively high level. It is unlikely that most people will be able to remain in energy balance at a low level. Research is underway, and more is planned, to more fully elucidate the mechanisms and interactions involved in achieving weight loss through energy balance and energy flux.

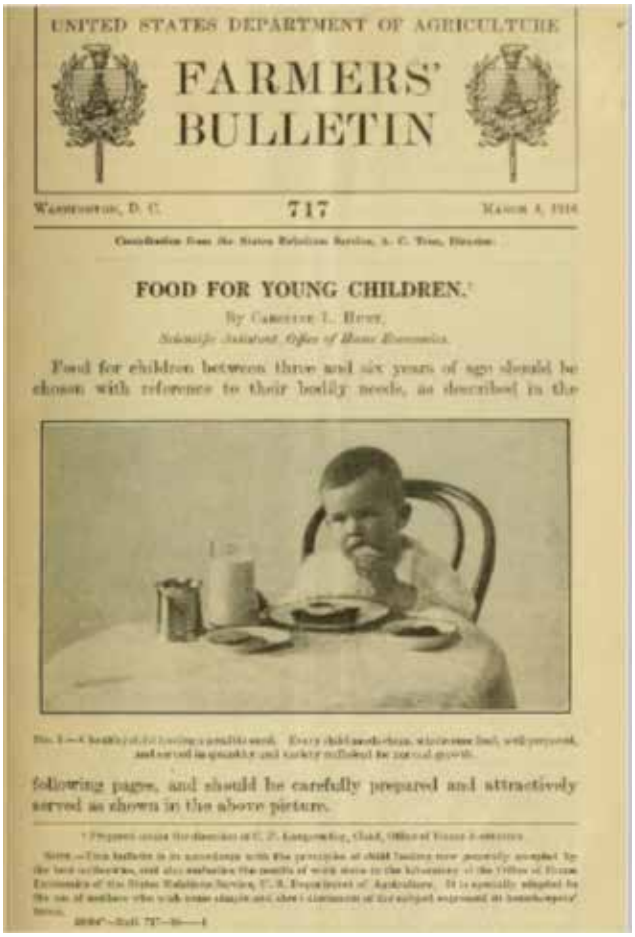
During the past century the US government and health organizations around the world have developed various guidelines on nutrition to address nutrient deficiencies and encourage healthy eating and balanced diets. Many governments have recently promulgated PA guidelines and several are now initiating programs to increase PA along with healthy eating to tackle sedentary lifestyles and excess weight. This purpose of this review is to discuss trends in energy and nutrient uptake, trends in PA, and the importance of international and community initiatives to tackle obesity by increasing PA. One example highlighted in this review is the '*Agita*' program in Brazil and elsewhere. This review is based on presentations at a symposium titled: 'What is causing the world-wide rise in body weight?' that was convened at the 5th International Congress on Physical Activity and Public Health (ICPAPH) in Rio de Janeiro on April 7–11, 2014.

Trends in Energy Intake and Macronutrients—The Development of Dietary Guidelines

Over the past century, nutritionists, governments, and official health agencies have sought to recommend ideal diets and suitable energy and micro- and macro-nutrient intakes to maintain health. This task has been challenging because there is no ideal human diet. Food is central to many different cultures and attempting to force change on different racial and ethnic groups with varying traditions and customs in an attempt to improve health is likely to fail. In nutrition, humans are highly adaptable omnivores; different groups survive and prosper on wide and varying combinations of foodstuffs. Extremes of this variation are illustrated by Eskimos who traditionally consumed up to 80 % of their calories from fat compared with some African populations who derived up to 80 % of their calories from carbohydrate.[18,19]

Attempts to determine the total human caloric requirements were first made over a century ago by Atwater in 1894 who recommended diets for American males based on content of protein, carbohydrate, fat, and mineral matter.[20] Shortly thereafter in 1902, the need for balanced diets and the risks of over-eating were recognized.[21,22] However, the desirable proportions of calories derived from fats versus carbohydrates were not addressed until much later. Dietary directives (guidelines) gradually evolved during the following decades including the first guidance on child nutrition published in 1916 (see *Figure 1*).[23] These guidelines divided food into five categories: milk and meat, cereals, vegetables and fruits, fats and fatty foods, and sugars and sugary foods. This was followed in the early 1920s by guides on the amounts of foods that should be purchased weekly for the average family.[24] The 1930s saw the publication of a buying guide for four food groups based on cost in an effort help maintain nutrition during the economic depression.[25] However, it is important to note the goal of these guidelines was not to reduce levels of obesity, but instead to address health conditions due to poor nutrition.

Figure 1: First Guidelines on Diet—Food for Young Children Published by the US Department of Agriculture in 1916


UNITED STATES DEPARTMENT OF AGRICULTURE

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FOOD FOR YOUNG CHILDREN.

Food for children between three and six years of age should be chosen with reference to their bodily needs, as described in the

following pages, and should be carefully prepared and attractively served as shown in the above picture.

In 1941 the Food and Nutrition Board of the National Academy of Sciences (US) released the first set of recommended daily allowances (RDAs) covering nine essential nutrients: protein, iron, calcium, vitamins A and D, thiamin, riboflavin, niacin, and ascorbic acid (vitamin C).[26] In 1943 the US Department of Agriculture (USDA) proposed the 'basic seven' elements of diet (1. green and yellow vegetables; 2. oranges, tomatoes, grapefruit; 3. potatoes and other vegetables and fruits; 4. milk and milk products; 5. meat, poultry, fish, or eggs; 6. bread, flour, and cereals; and 7. butter and fortified margarine, see *Figure 2*).[27] This was followed in the 1950s and 60s by the 'basic four' that advised consumption of foods from four food groups: milk, meat, fruits and vegetables, and grain products.[28]

In the 1970s there was increasing concern that high dietary fat, and especially saturated fat, consumption was causing substantial increases in cardiovascular disease.[29] As a consequence, guidance from the USDA and

Figure 2: US Department of Agriculture Initiatives on Nutrition in 1943 and 2011

A

B

food labeling encouraged substantially lower fat content in diets, as low as 15 % of calories.[30,31] These initiatives succeeded in reducing fat consumption from 40 % of calories to 32 % but were counterproductive in that carbohydrate consumption increased to over-compensate and that could have helped fuel higher rates of obesity.[32] In 1980 the USDA began publishing its Dietary Guidelines for Americans (DGA) that are updated every 5 years. In 1992 the USDA produced the 'food pyramid' that emphasized eating more bread, rice, cereal, and pasta at the base of the pyramid progressing through fruits and vegetables, dairy products, fish, poultry, beans, and nuts with fats, oils, and sweets in the smallest space at the top representing the lowest consumption.[33] Dietary guidance issued in 2000 for the first time stressed the importance of physical exercise in addition to balanced diets. This was followed in 2005 when the guidance included advice on limiting trans fats.

Today the Dietary Guideline Advisory Committee (DGAC) completes a series of evidence-based systematic reviews using the Nutrition Evidence Library (NEL).[34] Compared with pharmaceutical therapies, the body of evidence supporting the relationship of nutrition and chronic disease prevention is limited. The NEL reviews are based on an agreed series of questions: study data are selected for inclusion according to pre-defined criteria. After synthesizing and summarizing the data, the NEL reaches conclusions. Dietary Guidelines for Americans are based on the science-based reviews conducted by the DGAC, but are developed by the USDA and the Department of Health and Human Services (HHS). Some recommendations from the 2010 DGA are listed below:

- Reduce daily intakes of sodium, cholesterol, and increase intakes of mono/poly-unsaturated fats;
- Limit intakes of refined grains and sugars and limit solid fats, moderate alcohol consumption;
- Increase in fruit, vegetable, and whole grain consumption;
- Increase in fat-free or low-fat milk and dairy products;
- Increase seafood and protein from lean sources;
- Increase in K, Ca, dietary fiber, vitamin D (nutrients of concern in US); and
- Replace solid fat with oils.

The 2015 guidelines are awaited and are expected to promote whole foods and highlight issues including sustainability, gluten, vegan diets, and food processing.

A recent initiative from the USDA in 2011 was the ChooseMyPlate.gov program that replaced the Food Pyramid initiative (see *Figure 2*). The program divides food into five groups: fruits, vegetables, grains, protein, and dairy.[35] This simplifies previous advice and has been used to teach both adults and children about healthy eating.

Within food groups, carbohydrates are the primary food source for active people but those who have a sedentary lifestyle should cut back on carbohydrates to help balance their energy needs and maintain weight. It should be emphasized, however, that weight loss on diets is a result of lower overall caloric intake or diet duration, not just lower carbohydrate intake.[36,37] This lesson was also emphasized in a study of 811 obese adults in the US who were assigned to one of four diets with widely varying fat (20–40 %), protein (15–25 %), and carbohydrate (35–65 %) contents.[38] The results showed that weight loss resulted from caloric restriction not altered macronutrient content.

The concept of caloric balance, not only macro- and micro-nutrient proportions, is challenging and remains poorly understood. The traditional energy requirements of a rural and less industrialized society have changed progressively, but old recommendations (RDAs) on caloric needs of 2,000 kcal/day have not been updated or adjusted to allow for current low caloric expenditure. Furthermore, limited regulation of the human appetite and satiety complex results in poor long-term compliance to dietary restrictions needed to match caloric balance in sedentary individuals.

Overall, dietary guidelines have evolved over the past century and have helped maintain awareness of healthy eating through a balanced diet and promoted the idea of 'eat smarter.' People eat food, not nutrients, and dietary guidelines must take account of cultural diversity in differing populations and their ability to pay for suitable foods. In any diet it is calories that count but protein requirements must be met. Both high-fat and high-carbohydrate diets can be associated with health and weight loss. The ongoing and future challenge will be to help control the epidemic of obesity by promoting moderation in caloric intake coupled with increased PA.

Declining Trends in Energy Expenditure Explain the Obesity Pandemic

The existence of a worldwide epidemic of obesity is supported by various studies including those of the International Obesity Task Force that showed obesity levels rising from 10–14.9 % to 20–24.9 % over the past 20 years in some European countries.[39] While this increase in body weight cannot be disputed,[40] the etiology requires additional research. Although most people think it is due to people eating more, there is scant evidence to support this hypothesis.

In the increased-intake-versus-reduced-energy-expenditure debate there has been much confusion and misinformation. An example was a report that claimed US citizens were eating an average 3,800 calories per day, which was twice the amount required.[41] If this claim were true, the excess 1,900 calories beyond previously reported levels would result in people gaining an extra 90 kg in body weight every year, which is clearly erroneous. Press reports have suggested that PA has not changed since 1980 but caloric intake has risen to 3,500 calories per day both of which cannot be correct. It is critically important that public policy on obesity is based on valid information and not incorrect data, false assumptions, and wild speculation that regularly appears in the general media and even in the scientific literature.

To address the cause of increasing body weight it is necessary to accurately determine energy balance. The National Health and Nutrition Examination Survey (NHANES) is a long-running series of surveys conducted in the US that was designed to assess the health and nutritional status of a large population of Americans that started in the early 1960s and has continued to the present day.[42,43] One of the goals of these surveys is to provide estimates of food and dietary supplement intake that could inform dietary assessment, planning, research, and public health policy. However, recent analyses using the mean reported energy intake (rEI) values, basal metabolic rate (BMR) estimates, and habitual PA data suggest that the NHANES values for food consumption substantially underestimate energy intake.[44] The expected value for rEI/BMR is approximately 1.55; values below 1.35 or above 2.40 are implausible. The overall NHANES rEI/BMR values from nine surveys (n=60,716) over a 39-year duration were 1.31 and 1.19 for men and women, respectively, and 1.21 and 1.10 for obese men and women. These results showed that the rEI values were clearly incorrect and the authors concluded that 'the ability to estimate population trends in caloric intake and to generate empirically supported public policy relevant to diet-health relationships from U.S. nutritional surveillance is extremely limited'.[44] A further analysis found a substantial discrepancy between USDA loss-adjusted food availability and Institute of Medicine total daily energy expenditure figures from the nine NHANES surveys. The results indicated that American men and women should have lost an average 32 kg during 1971 to 1980 but gained an average 98 kg during 1988 to 2010, which is certainly false. This analysis further emphasizes the flawed nature of the widely accepted energy intake data.

While the data defining energy intake are of doubtful validity and fail to provide a full assessment of modern eating habits, there is a compelling case that populations have lower levels of energy expenditure. In 2009 the renowned UK epidemiologist, doctor, and researcher on PA, Professor Jerry Morris stated:

'We in the west are the first generation in human history in which the mass of the population has to deliberately exercise to be healthy. How can society's collective adaptations match?'[45]

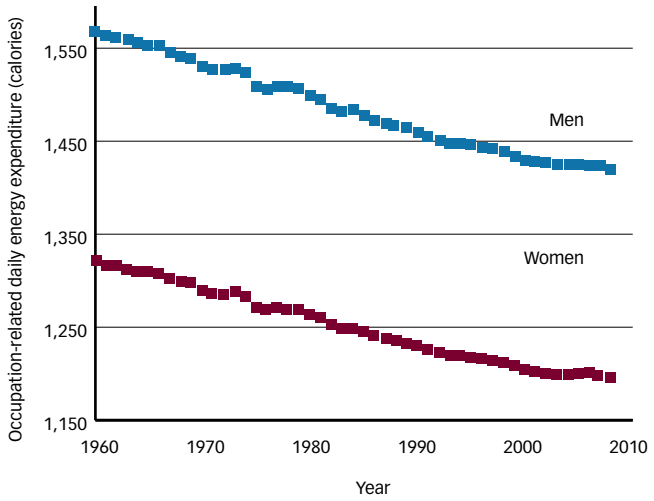
This apposite comment is strongly supported by data from various studies including one showing a decline in agricultural and goods-producing jobs (blue collar) with a rise in service sector employment (white collar) between 1960 and 2006 (see *Figure 3*).[46] This study also showed a 140 and a 120 kcal/day reduction in occupational energy expenditure for men and women, respectively, over the same time interval. In addition, predicted weight based on this reduction in energy expended closely matched actual weight changes recorded by NHANES surveys, suggesting that declines in work-related energy expenditure are a strong determinant of current obesity levels (see *Figure 4*).[46] A further study found that weekly energy expenditure in household management by women in the US (aged 19–64 years) had decreased from 4,663 kcal in the 1960s to 2,806 kcal in 2010.[47] Over the same duration further studies showed that maternal activity had reduced from a mean 32 hours to 21 hours/week and sedentary time had increased from a mean 18 hours to 25 hours/week.[48] Of course, the authors of these studies asserted that they were not advocating a return to 1960s levels of domestic manual work by women to maintain health and weight; the results simply reflected greater automation and a general decrease in activity needed to maintain the home and its occupants.

Transport is another area involving less PA. A recent review of declining PA in the US population found that in 1960 approximately 64 % of journeys to work were by private car with the remainder being public transit and walking.[49] By 2000, 85 % of journeys to work were by private car with a substantial decline in walking and public transit. Similar changes were seen in journeys to school by children in the US.[50]

Trends of declining PA are not confined to the US. A population-based observational study of Chinese adults (4,697 women and 4,708 men) aged 18–55 studied in waves during 1991, 1993, 1997, and 2000 revealed declining occupational and leisure activity in progressive surveys.[51] The study also showed that greater occupational PA resulted in overall lower body weight for both men and women (beta coefficients: –0.46 and –0.36, respectively).

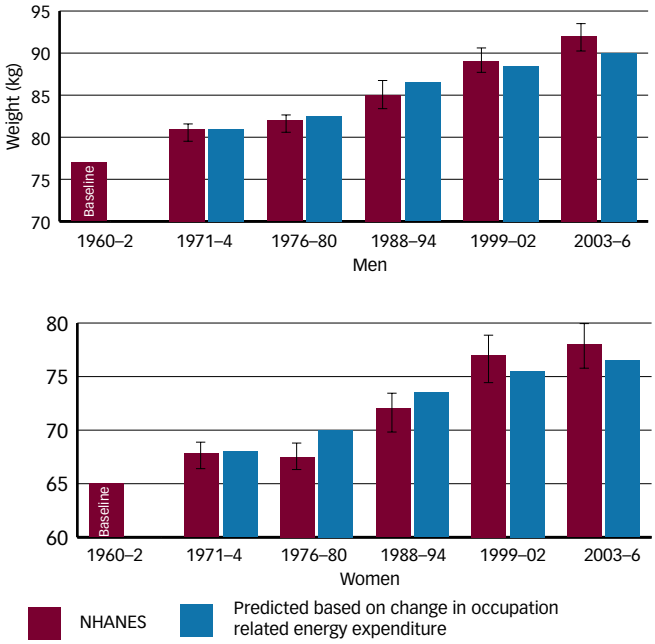
Therefore, in both understanding and tackling the obesity epidemic, it is vital that both sides of the energy balance equation are considered. Increased PA is a critical factor and interventions that only attempt to lower caloric intake are likely to fail. Future studies on health outcomes resulting from increased body weight should measure both adiposity and fat distribution along with PA and account for both factors in the analysis. Clearly, greater research in large populations of subjects is urgently needed to better understand energy balance. Once this is achieved, appropriate interventions will need to be devised and tested. If successful, implementation of these measures will involve changes in in public health policy, educational programs, clinical medicine, and technological lifestyle interventions.

Figure 3: Reduction in Daily Occupational Energy Expenditure among Workers in US Private Industry since 1960



Source: Church et al. 2011.[46]

Figure 4: Actual Obesity and Predicted Obesity based on Occupational Energy Expenditure among Workers in US Private Industry since 1960



NHANES = US National Health and Nutrition Examination Surveys.
Source: Church et al. 2011.[46]

How to Increase Community Energy Expenditure

Physical inactivity is widely recognized as a serious factor in global morbidity. It has been estimated by the World Health Organization (WHO) that 5.3 million people worldwide die annually as a result of diabetes, stroke, ischemic heart disease, falls and hip fractures, and depression that are caused by inactivity.[52] Inactivity is now the second leading risk factor for mortality.[52] In most territories, however, sizable proportions of adults are insufficiently active to avoid these consequences. To reduce body weight in whole populations and decrease the incidence of diabetes and other non-communicable chronic diseases, effective initiatives are required to increase PA but to create such a change in whole populations is challenging. A successful example of such an initiative is the *Agita* São Paulo program that was started in 1996.[53] '*Agita*' means to move but the program is designed to go beyond that and change ways of thinking and encourage people to become more active citizens. The program covered 40 million people in São Paulo State in 645 cities and towns. It was soon copied in other states throughout Brazil and in numerous countries worldwide.

The *Agita* program incentivizes people to accumulate at least 30 minutes a day doing moderate PA for 5 or more days per week as recommended by the Centers for Disease Control/American College of Sports Medicine, which only 13 % of Brazilians previously achieved during leisure-time activity.[54] The key to the continuing success of *Agita* is that this activity goal is achievable by most people and does not require strenuous effort that would deter many unfit people. Such activity has little or no cost and is unlikely to cause injury that may occur in more vigorous activities or sports. Activity is encouraged in three settings: home, work/transport, and leisure time and the initiative is aimed at students, white and blue collar workers, and the elderly. Innovative aspects include: a research center leading the process, scientific and institutional partnerships (over 160 groups), a feasible approach (the 'one-step-ahead' model), empowerment, inclusion, social marketing, and links with different cultures. The programs also aim to promote the enjoyment of exercise to further encourage participation.

A main aspect of the *Agita* São Paulo is that it involves partnerships between various different government department/agencies and local organizations in running the program and promoting it.[55] This involves cooperation between the State Health Secretary of São Paulo and the Physical Fitness Research Center for São Caetano do Sul (CELAFISCS). The Executive Board that coordinates the program meets every month and has a 'two-hat' approach involving representatives from both the public and private sectors with diverse expertise including: sports, education, urban planning, tourism, environment, health, housing, and transport. This diversity ensures that the *Agita* idea is taken into as many areas of life as possible and enables new paradigms in PA.

The promotion of PA in the *Agita* programs in communities follows a strategy described as the 'mobile management of the ecological model' and this is the key to its success.[56] The ecological model identifies three main influences, the first of which is intrapersonal factors and this is composed of demographics, biological, cognitive/affective, and behavioural components.[57] The second influence is social environment factors with components including supportive behaviors, social climate, cultural policies, governing incentives, and resources for activity/inactivity. The third influence is physical environment factors, with components including both natural environment (weather and geography) and the constructed environment (information, urban/suburban, architectural, transport, entertainment, and recreation). During the development of *Agita*, the initiative attempted to reach a population of over 37 million people. To do this, the program developed intervention strategies that targeted almost all components of the ecological model. This innovative management style is called 'mobile' in which the components operate in a dynamic balance (as seen in a suspended mobile).[56] In this approach when one component is successful it 'loses weight' and the other components 'gain weight' and are targeted to help ensure they subsequently succeed.

The *Agita* message is adapted for different target groups e.g. men, women, the young, and the elderly. The program is also sub-divided into three initiatives: '*Agita* Galera' for schools, '*Agita* Worker' for working adults and '*Agita* Older Adult' for the elderly. Within these subdivisions, 'mega-events' are organized at multiple centers in most of the cities of São Paulo to raise the profile and promote participation. In *Agita* Galera, Active Community Days are intended to mobilize schools and involve 250,000 state teachers, 6,200 state schools, and at least six million students. These events in São Paulo involve approximately 10 million people and 300 partner organizations.[58] Measuring the impact of 10 years of these interventions revealed that 44.16 % of state school children and 32.21 % of private school children were sufficiently active.

Agita São Paulo has also taken different types of permanent interventions into the workplace including a Petrobras oil platform, Bank of Brazil offices, medical insurance company offices, and call centers. At work locations various kinds of interventions have been implemented. These include capacity building of health professionals, dissemination of the PA message for health among workers, as well as the construction of facilities enabling workers to incorporate PA into their daily worksite routine. In many towns and cities in São Paulo state, trails and pavements are being built or rebuilt to enable easier, traffic-free walking, running, or cycling.

Participation in *Agita* São Paulo workshops, lectures, and PA counseling has increased from 32,500 in 1998 to 198,857 in 2004. *Agita* is also promoted using an empty pharmaceutical product-type box labeled 'Agitol' that encourages daily physical activities (see *Figure 5*). This demonstrates that *Agita* is allied with the goals of the 'Exercise is Medicine™' (EIM) program that has sought to increase PA to reduce the risk for obesity and related type 2 diabetes and other chronic diseases.[59] The EIM program was launched in 2007 to advance the implementation of evidence-based strategies to elevate the status of PA in healthcare.[60,61] EIM has a presence in 39 countries and is continuing to expand around the world. As a result of the impact and success of the *Agita* São Paulo Program, WHO decided in 2002 to launch the World Day of PA and a Global PA promotion network was also established under the name of '*Agita* Mundo'.

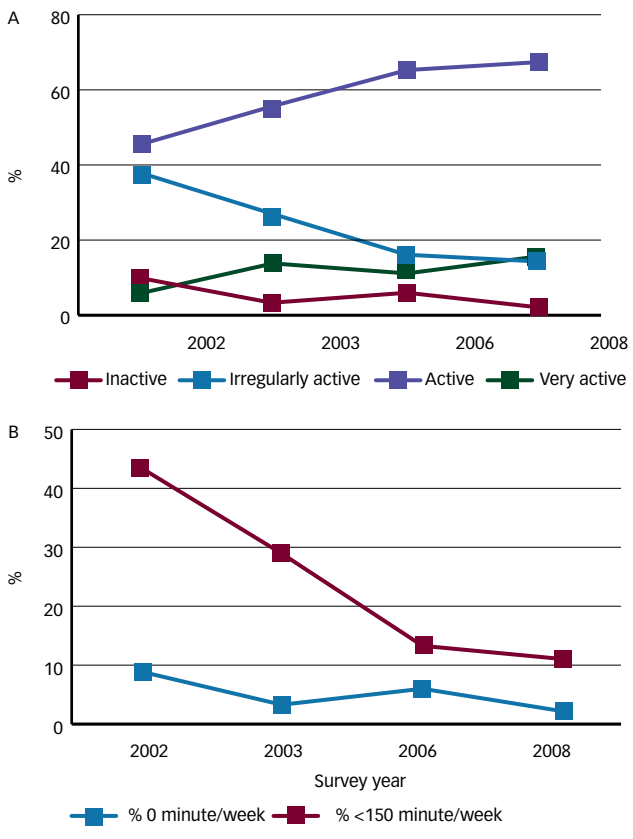
The value of *Agita* São Paulo has been made clear in several studies. Cross-sectional surveys taken across the state between 2002 and 2008 showed increases in active (approximately 45 % to 65 %) and very active individuals (approximately 5 % to 15 %). There were also corresponding decreases in inactive (0 minutes/week, 9.6 % to 2.7 %) and insufficiently active (<150 minutes/week, 43.7 % to 11.6 %) people (see *Figure 6*).[62] These activity improvements were attributed, at least in part, to *Agita* São Paulo. In another study on 1,246 adults in 3 cities in São Paulo state between 1999 and 2007, men of high, medium, and low socio-economic status showed reductions ranging from 32 % to 46 % in physical inactivity and women showed reductions ranging from 43 % to 53 %.

The *Agita* program, therefore, is a practical and successful approach to tackling the obesity epidemic by using partnerships of private and governmental and non-governmental organizations (NGOs) (including civil societies, universities, etc.) in public–private partnerships. The program extends across all the states in Brazil and was responsible for the creation of the PA Network of the Americas ('PANA'—also known as 'RAFA' in Spanish-speaking countries) that widely promotes PA. The initiative has also spread to many other countries and provides a simple and clear message to promote PA and provide facilities to enable it. The activities promoted are multi-level with little or no cost to the individual and the

Figure 5: 'Agitol – A Prescription for Living'—A Medicine Box with a Message

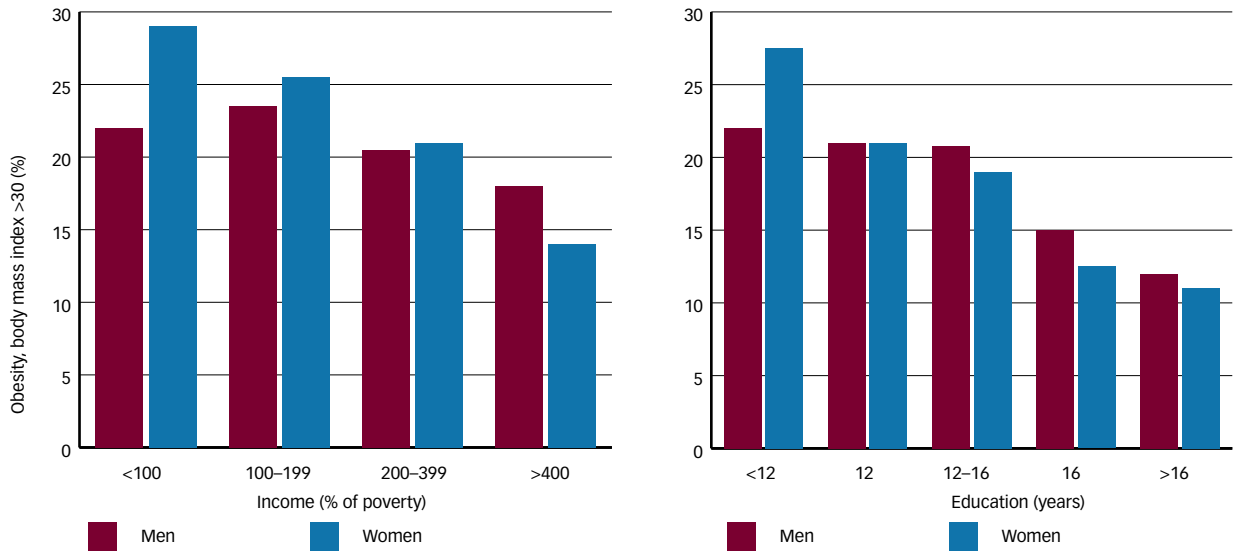
'Agitol' is an empty a pharmaceutical-type box (with 'patient information leaflet') promoting the message that physical activity/exercise is medicine and should be taken daily.

Figure 6: Trends in (A) Physical Activity and (B) People Inactive or Insufficiently Active in the State of São Paulo, Brazil during the Years 2002, 2003, 2006, and 2008



Source: Matsudo et al. 2010.[62]

Figure 7: The Influence of Poverty and Education on Obesity (Body Mass Index >30 kg/m²)



BMI = body mass index. Source: Drewnowski et al. 2004[69] and Schoenborn et al. 2002.[70]

programs are inclusive, attempting to capture as many in the population as possible from many different cultures. Changing exercise habits across entire populations is an enormous challenge but survey data suggest that the *Agita* programs are achieving this goal.

The Role of Diet in the Obesity Pandemic

While declining PA has played a major role in increasing the prevalence of overweight and obesity globally, changes in diet over recent decades also may have had an influence. One of the most disturbing aspects of the current obesity epidemic is the proportion of young children who are becoming obese. This has serious consequences on their future health and development and may be caused, at least in part, by altered levels of energy intake. A large-scale review of various obesity studies showed that in the US, during the years 1971/74–1999 the proportion of obese children aged 6–11 and 12–19 years increased 3.3- and 2.3-fold, respectively (see *Table 1*).[63] In Brazil, during 1974 to 1997 in children aged 6–9 and 10–18 years the proportion of obese children increased 3.6- and 3.4-fold, respectively. Similar trends have been reported in countries in Europe, Asia (e.g. China and Japan), and in African countries such as Egypt, Morocco, and Ghana although the proportions of obese children in some of these territories started from a lower base. During the late 1970s children in the US consumed 17 % of their meals outside the home accounting for 2 % of their total energy intake.[64] By the late 1990s, however, the proportion eaten outside the home had almost doubled to 30 %, which was 10 % of total energy intake. Although the evidence is not conclusive, it is possible that these factors, along with decreased exercise, have helped create an environment that promotes obesity.[64]

An analysis of data from for 190 children at two time intervals in the Prevention and Incidence of Asthma and Mite Allergy (PIAMA) birth cohort study showed that 10 % of children aged 5–7 years were overweight.[65] During a 4-year follow-up period, weight gain among normal weight children was 8.5 kg compared with 13.3 kg among overweight children. The study identified a daily energy gap of 289–320 kJ (69–77 kcal) that was responsible for the excess weight gain or weight maintenance. It was concluded that relatively small changes in diet and/or PA could easily avoid the risk for obesity in children but losing weight after it is gained is more difficult.

Data from the USDA, Economic Research Service show that during the first half of the 20th Century food availability per person in the US declined and intake was driven by energy expenditure.[66,67] In this era people ate less to compensate for reduced occupational energy expenditure (the 'move less stay lean' phase). During the 1960s and 1970s an energy balance 'flipping point' was reached when food availability began to increase.[67] This change was brought about by changes in the mechanization of food production and decreasing relative costs of many foodstuffs.

A study of data from adults aged 20–74 years in the NHANES I 1971/75 (n=13,106) and NHANES 2005-2006 (n=4,381) showed that in the 30 years between these surveys the percentage of energy from carbohydrates increased from 44.0 % to 48.7 %.[68] At the same time the percentage from fat decreased from 36.6 % to 33.7 %, and the percentage of energy from protein decreased from 16.5 % to 15.7 %. The authors concluded that efforts to reduce fat were succeeding but people were substituting fat for a greater quantity of carbohydrates resulting in a greater energy intake leading to obesity. It was also suggested that protein could be used to substitute for carbohydrate or fat as a means of reducing overall energy intake.

Significant factors that increase worldwide obesity are poverty and poor education. This was emphasized by the 1997–98 National Health Interview Survey (NHIS) which surveyed 68,556 adults in the US aged ≥18 years.[69,70] The findings showed that approximately 22 % of males and 28 % of females whose incomes were at or below the poverty level were obese (body mass index [BMI] >30 kg/m²). At higher incomes, however, obesity levels were lower; 18 % of men and 14 % of women with incomes at or above 4 x the poverty level were obese (see *Figure 7*). In addition, in these groups obesity was inversely correlated with the length of time spent in education. The most nutritive foods such as fruit and vegetables or fish, poultry, and lean meats have a lower energy

Table 1: Global Increases in Prevalence of Obesity in Children

Country	Time Interval	Age Range (Years)	Change in % Obese (Fold Increase)	Definition of Obese
Australia	1985–1995	7–15	Boys: 1.4–4.7 (3.4x) Girls: 1.2–5.5 (4.6x)	Age-adjusted BMI cut-off linked to the adult value of 30 kg/m^2
Brazil	1974–1997	6–9 10–18	4.9–17.4 (3.6x) 3.7–12.6 (3.4x)	Age-adjusted BMI cut-off linked to the adult value of 25 kg/m^2
Chile	1985–1995	0–6	4.6–7.2 (1.6x)	Weight-for-height >2 SD from median
China	1919–1997	6–9 10–18	10.5–11.3 (1.1x) 4.5–6.2 (1.4x)	Age-adjusted BMI cut-off linked to the adult value of 25 kg/m^2
Costa Rica	1982–1996	0–6 (1982), 1–7 (1996)	2.3–6.2 (2.7x)	Weight-for-height >2 SD from median
Egypt	1978–1995/96	0–5	2.2–8.6 (3.9x)	Weight-for-height >2 SD from median
England	1984–1994	4–11	Boys: 0.6–1.7 (2.8x) Girls: 1.3–2.6 (2.0x)	Age-adjusted BMI cut-off linked to the adult value of 30 kg/m^2
Ghana	1988–1993	0–3	0.5–1.9 (3.8x)	Weight-for-height >2 SD from median
Haiti	1978–1994/95	0–5	0.8–2.8 (3.5x)	Weight-for-height >2 SD from median
Japan	1970–1996	10	Boys: <4–10 Girls: 4–9	≥120 % of standard weight
Morocco	1987–1992	0–5	2.7–6.8 (2.5x)	Weight-for-height >2 SD from median
Scotland	1984–1994	4–11	Boys: 0.9–2.1 (2.3) Girls: 1.8–3.2 (1.8)	Age-adjusted BMI cut-off linked to the adult value of 30 kg/m^2
US	1971/74–1999	6–11 12–19	4–13 (3.3x) 6–14 (2.3x)	BMI ≥95th percentile

BMI = body mass index; SD = standard deviation. Source: Ebbeling et al. 2002.[63]

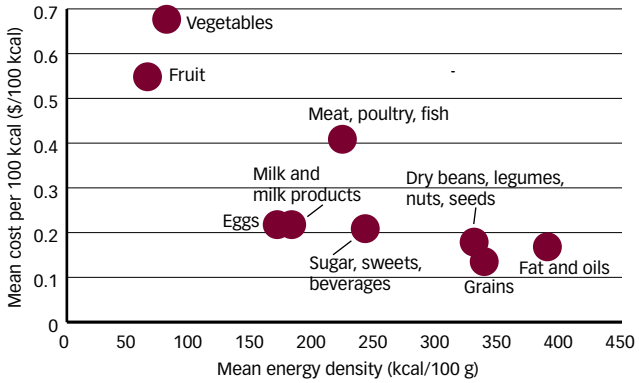
density and are the most expensive per 100 Kcal compared with sugars, fats, and oils (see *Figure 8*).[71] Some believe that a consequence of this is that lower income groups tend to purchase more of the cheaper processed foods with added carbohydrates, fats, and oils and consume proportionally less of the healthy food types, predisposing them to greater obesity levels than higher income groups.[72] This relative high cost of healthy foods is a serious issue in many countries; it hinders initiatives to reduce obesity and will require changes in government food policies to address. Some nutritionists have suggested that fructose, particularly high-fructose corn syrup, has played a significant role in advancing obesity and diabetes. The evidence supporting this claim, particularly for those consuming fructose in moderation and adjusted for total energy intake, however, is weak and needs further investigation.[73]

The neurocognitive link between eating behavior and PA is, as yet, poorly understood. Brain circuits in the prefrontal cortex are believed to be under relentless strain in the current 'obesogenic' environment and this may initiate impulses to overeat, resulting in weight gain and obesity.[74] Such impulsive behavior, however, may be counteracted by PA. It is clear that greater investigation of the neurocognitive control of eating behavior is needed to enable better interventions to be devised. Caloric restriction has been shown to disrupt hypothalamic regulation, driving neuro-hormonal reactions that induce a strong impulse to eat and metabolic adaptations to reduce expenditure, making hipocaloric diets unsustainable.

Conclusion

The worldwide rise in body weight is a serious problem that will have an increasingly negative effect on public health and will greatly increase the burden of weight-associated diseases if it is not urgently tackled. This rise is seen across all ages and cultures but the rapid rise in childhood obesity is particularly alarming. The cause of the problem is that too many people are in positive energy balance (consuming more calories than are expended) on too many days. Energy expenditure has been decreasing

Figure 8: The Relationship between Energy Density (kcal/100 g) and Energy Cost ($/100 kcal) in Nine Major Food Groups



Data from 1,387 different foods. Source: Drennowski et al 2010[71]

with increasingly sedentary occupations and leisure time. The more influential of the two sides of the energy balance equation is debatable, but attempts to impose large-scale change in the eating habits across entire populations and different cultures in pursuit of better health are likely to fail. Some individuals may be persuaded to restrict their caloric consumption in the short term but are unlikely to sustain it, especially at low levels of energy expenditure. Increasing energy expenditure therefore is key. Without such activity, attempts at reducing caloric intake are unlikely to be effective. The *Agita* program is one example of an initiative that has successfully shown that populations can adopt small changes in activity in their daily lives to offset weight gain. This initiative that has expanded widely from its origins in São Paulo encourages participants to both initiate and maintain this activity. It is therefore vital that such programs are vigorously implemented throughout the world to avoid the looming crisis of obesity and associated disease. ■

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