FireFit Health & Fitness Report No. 1.

What are the health risks of obesity and how can physical activity be employed to manage body fatness?

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Contents

1.Introduction

The rapid increase in the prevalence of global obesity has sparked huge concerns as to its effects on public health around the world. The UK's Faculty of Public Health defines obesity as "…an excess of body fat frequently resulting in a significant impairment of health and longevity" (House of Commons, 2004). This report identifies the prominent health risks of being obese and looks at how physical activity can be employed in the treatment of obesity.

2. Background

In 1959, the Metropolitan Life Assurance Company suggested that there was a relationship between obesity and mortality, particularly mortality from cardiovascular disease (Metropolitan Life Assurance Company, 1959). Increases in mortality were also reportedly linked with increased body weight in both men and women. A subsequent study in 1979 reported that death caused by heart and circulatory disease, diabetes, and stroke were higher in overweight men and deaths caused by circulatory disease and cancers were higher in women (McCue, 1979).

In 1980, 8% of women and 6% of men were classified as obese in England (Brown, 2000). However, by 1998, the prevalence of obesity had almost trebled to 21% in women and 17% in men (Brown, 2000). This reflects a worldwide trend that is most marked in, though not restricted to developed countries (Brown, 2000).

> The rapid increase in obesity levels has occurred in too short a time for there to have been significant genetic changes within the population. It is therefore likely that the global obesity problem has been brought about primarily by environmental and behavioral changes that have led to a more energy-dense diet and a rise in the level of sedentary behavior (National Audit Office, 2001).

Obesity develops only when there is a sustained imbalance between the amount of energy consumed by a person and the amount used up in everyday life. But what side of this energy balance has been most altered in recent decades to produce such rapid weight gain? (House of Commons, 2004). In 1998, the World Health Organisation identified a number of factors associated with reduced levels of physical activity and ultimately energy expenditure. They include:

- A reduction in occupational exercise;
- A reduction in exercise due to greater use of cars and wider car ownership;
- The decline in walking as a mode of transport;
- An increase in energy-saving devices in public places, such as escalators, lifts and automatic doors;
- Less opportunities for young people to take physical exercise;
- The substitution of physically active leisure with sedentary pastimes such as television, and computer games;
- Fear of racial harassment and cultural beliefs, which may prevent people from certain black and minority ethnic groups from taking exercise (World Health Organisation, 1998).

From a nutritional point of view it is clear that people are overeating in relation to their energy needs, and that the cheapness, availability and heavy marketing of energy-dense foods makes this very easy to do, coupled with an increasing reliance on snacks and ready-prepared meals which makes selecting 'healthy foods' harder (House of Commons, 2004). These changing patterns of consumption and activity are in part a response to the far reaching social changes of the last 50 years, including a greater number of women working outside the home, longer working hours, and higher levels of disposable income (House of Commons, 2004). Less than half a century since the original findings, obesity is now so common within the world's population that it is beginning to replace undernutrition and infectious diseases as the most significant contributor to ill health (Kopelman, 2001). The World Health Organisation has also described obesity as a global epidemic that is attacking both developing and industrialised countries (World Health Organisation, 1998).

Body fatness is commonly assessed by body mass index (BMI), a formula that combines height and weight. Overweight is generally defined as a BMI greater than 25.0 and those with a BMI of 30.0 or more are classified as obese. There are however limitations with this classification system. BMI does not consider the relative percentage of fat and muscle; nor does it reflect the distribution of fat in the body (Ostman, Britton & Jonsson, 2004).

Whilst this is accepted as a limitation of the system, it has become increasingly more relevant since recent research has identified that the risks of obesity-related diseases are considerably higher in those with a high accumulation of visceral abdominal adipose tissue (Ostman et al., 2004). It is acknowledged that more sophisticated methods of body composition are available (American College of Sports Medicine, 2001). "However, in contrast to BMI, there are no clearly agreed upon levels of body fatness that identify the point at which mortality and morbidity significantly increase" (American College of Sports Medicine, 2001).

2.1 Health risks

There is a general stigma associated with being obese. Being overweight or obese usually concerns people because of the way they look. However, the health risks related to excess fat should be the main priority (Eckel, 2005). Obesity causes or exacerbates a large number of health problems, both independently and in association with other diseases (Kopelman, 2001).

It is commonly associated with the development of diabetes mellitus, cardiovascular disease, certain forms of cancer, osteoarthritis and has been shown to associate with a number of systemic complications, liver abnormalities and certain psychological conditions (Kopelman, 2001). In 1998, the World Health Organisation published a paper detailing the relative health risks of obesity. The results are presented below.

Table 1 Relative risk of health problems associated with obesity (World Health Organisation, 1998).

Greatly increased (relative risk > 3)	Moderately increased (relative risk 2-3)	Slightly increased (relative risk 1-2)
Diabetes mellitus type II	Coronary heart disease	Cancer (breast cancer in post menopausal women, Endometrial cancer, colon cancer)
Gallbladder disease	Hypertension	Reproductive hormone abnormalities
Dyslipidaemia	Osteoarthritis (knees, hip)	Polycystic ovary syndrome
Insulin resistance	Hyperuricaemia and gout	Impaired fertility
Breathlessness		Low back pain due to obesity
Sleep apnoea		Increases risk of anaesthesia
complications		Fetal defects associated with maternal Obesity

Diabetes has perhaps had the most dramatic impact on the public's health in recent years. It has increased in the UK by 65% in males and 25% in females since 1991 (House of Commons, 2004). It commonly leads to cardiovascular problems and can also bring about blindness following damage to blood vessels of the eye, kidney failure, stroke, osteoarthritis and damage to the nervous system which can lead to leg ulcers and limb amputation (House of Commons, 2004). Type II diabetes, often called 'late onset' or 'adult onset' diabetes is increasingly being diagnosed in children. Professor A H Barnett, Clinical Director of Diabetes and Endocrine Services at the University of Birmingham reported "that figures from the USA…indicate a very serious long-term health outlook for these children, with significant numbers dying from heart attack or being on kidney dialysis and/or blind before the age of 40 years (House of Commons, 2004). Frighteningly, a study of nurses in the USA revealed that those with a BMI of 35 had a 92-fold increase in the risk of diabetes, compared to those with a BMI of 22 (House of Commons, 2004).

Whilst obesity is known to be a major cause of increased cardiovascular disease in the general population (Garrison, Higgins & Kannel, 1996), it has recently been reported to be equal to the effects of smoking and possibly exceeding the effects of LDL (low density lipoprotein) cholesterol (Allison, Fontaine, Manson et al., 1999). Furthermore, a number of studies have suggested that a BMI of more than 32.0 will increase the relative risk of dying from myocardial infarction by more than 3 times in women and more than 5 times in men aged between the ages of 30 and 44 years (Calle, Thun, Petrelli et al., 1999, Stevens, Cai Pamuk et al., 1998, Rocchini, 1997). Additionally, Ostman *et al.* (2004) has also stated that there was a particularly strong correlation between abdominal fat and myocardial infarction in both men and women (Ostman et al., 2004). Obesity has also been shown to affect blood pressure and associations between weight gain and hypertension has been reported in both longitudinal and cross-sectional studies (Stamler, Stamler, Gosch et al., 1989). Hypertension is reported to be approximately 3 times more common in overweight individuals than in those that are normal weight (World Health Organisation, 1998).

The relationship of obesity and cancer has received less attention than it's cardiovascular effects (Calle & Thun, 2004). One possible explanation this is that as the incidence and mortality of specific types of cancer are less common than the non-cancer outcomes, the relation of obesity to particular cancer sites has become more difficult to study (Calle & Thun, 2004).

Table 1 identifies increased risk of breast, endometrial and colon cancer with obesity. However, accumulating evidence also suggests that increased adiposity may increase incidence and/or death rates from a wide variety of human cancers, including rectum, esophagus, kidney, pancreas, gallbladder, ovary, cervix, liver, prostate, and certain hematopoeitic cancers (Calle & Thun, 2004). Cancer research UK suggests that 1 in 7 cancer deaths in men and 1 in 5 in women are attributable to overweight and obesity (House of Commons, 2004). For these reasons, understanding the associations between overweight and obesity and a wide variety of cancers, as well as the biological mechanisms contributing to these associations remains an evolving and currently very active area of research (Calle & Thun, 2004).

Obesity is frequently accompanied by problems in the spine and the body's joints (Ostman et al., 2004). Weight gain appears to increase the risk of osteoarthritis by placing additional pressure on these joints and wearing away the protective cartilage (House of Commons, 2004) particularly in the hips and knees (Depress & Lemieux, 2001). Previous research suggests that the association between increased weight and developing knee osteoarthritis is stronger in women than it is in men (Felson, Anderson, Naimark et al., 1988). In a study of twin middle-aged women, it has been estimated that the risk of developing osteoarthritis increases by 9-13% with every kilogram increase in weight (Cicuttini, Baker & Spector, 1996).

Due to the insidious nature of weight gain, the adverse effects of excess weight tend to be delayed, sometimes for ten years or longer (Lew, 1985). It is crucial to realise that for many of the conditions listed here - it is not necessary to be obese to increase the risk of morbidity. Risks rapidly accelerate as people become overweight (House of Commons, 2004).

2.2 Treatment

Although there is a considerable amount of agreement about the potential health risks of obesity, there is less agreement about its management (National Heart Lung and Blood Institute, 2000).

> Some have argued against treating obesity because of the difficulty in maintaining long-term weight loss, and because potentially negative consequences of weight cycling, a pattern frequently seen in obese individuals. Others argue that the potential hazards of treatment do not outweigh the known hazards of being obese (National Heart Lung and Blood Institute, 2000).

It is not within the remit of this report to discuss the argument of whether to treat or not. However, if treatment strategies can be employed to maintain weight, slow weight gain and/or bring about indirect benefits then this should be seen as a worthwhile process, considering the relationship with weight gain and health risk. The remainder of this report will focus on the effects of physical activity in reducing and maintaining weight loss and preventing weight regain. Physical activity for the purpose of this report is defined as any bodily movement produced by skeletal muscles that result in an expenditure of energy (www.cdc.gov, 2005).

3. Managing obesity with physical activity

3.1 Background

The importance of physical activity in successful weight control intervention programmes has been widely reported (Miller, Koceja & Hamillton, 1997). However, to date, the emphasis of treatment strategies have focused primarily on dieting as a means of weight control (Abdel-Hamid, 2003, Fox & Page, 2001). "The limited credence given to inactivity as a cause of obesity is not entirely clear" (Fox & Page, 2001) given that numerous reports have identified significant reductions in activity levels in recent years (National Audit Office, 2001, International Obesity Task Force, 2002). The National Audit Office, in it's report on tacking obesity in England state that "the extra physical activity involved in daily living 50 years ago, compared with today was the equivalent of running a marathon a week" (National Audit Office, 2001).

Abdel-Hamid (2003) proposed a number of reasons why decreasing energy intake is favored over increasing energy expenditure through physical activity for weight loss. The first reason is economic; the automation of many jobs in recent years where people were once paid to be physically active has changed to a state where we now pay to engage in physical activity, not so much in money, but in foregone leisure time (Abdel-Hamid, 2003). Secondly, it has been difficult to demonstrate the efficacy of exercise as a treatment strategy for obesity (Abdel-Hamid, 2003). The economic reasons given here associated with weight gain appear to be somewhat simplistic, considering the number of complex factors that have already been identified (World Health Organisation, 1998).

3.1 Reducing body fatness with physical activity

Controlling clinical trials that involve the calculation of food intake and energy expenditure are complicated. Ideally, all studies in this area would be performed in a natural free-living environment in where physical activity and calorie consumption could be measured accurately (Abdel-Hamid, 2003).

Unfortunately, this is not possible as the methods for measuring total energy input and expenditure are often unreliable (Abdel-Hamid, 2003). Conversely, laboratory-based trials are incredibly unpractical especially over long periods and are based in highly artificial conditions (Abdel-Hamid, 2003). For these reasons demonstrating exercise as a treatment strategy for obesity has proven difficult.

Physical activity has been shown to either reduce body mass (Ballor & Keesey, 1991), have a modest effect on weight loss (Andrews, 1991) or have no significant impact on weight loss (Ballor & Poehlman, 1994) in experimental trials. These inconsistent results prompted the American College of Sports Medicine to sponsor a scientific roundtable to review the information in this area (American College of Sports Medicine, 1999). It was reported that there was a distinct lack of statistically significant clinical trials on physical activity in the prevention and treatment of obesity (Grundy, Blackburn, Higgins et al., 1999). There was not however, a lack of research projects *per se*, but a lack of properly controlled trials (Saris, 1996), which is a possible explanation for the variety in observed findings in the literature.

More recent studies that now comply with current recommendations have aimed at improving long-term health and exercise adherence and it has been generally agreed that exercise by itself can evoke weight losses of between 0.5-1kg per month (Wing, 1999, Fox & Page, 2001). Additionally, it appears to be effective for reducing body weight, particularly over the long term (Fox & Page, 2001). However, reports suggest that females tend to lose less weight from exercise regimes than men (Wood, Stefanick, Williams et al. 1991) and it has been suggested that there may be individuals that respond better to weight loss than others (Bouchard, Tremblay, Depres et al., 1994).

The current exercise recommendations for achieving general health benefits for adults are 30 minutes of moderately intense physical activity a day on five or more days of the week. These recommendations are widely agreed (Pate, Pratt, Blair et al., 1995, Department of Health, 2004). Moreover, there is a wide acceptance of an energy expenditure of 1000 kcal/wk as an appropriate physical activity target in both clinical and public health approaches to weight control. However, it has been identified that "…we are aware of no empirical basis for the selection of these energy expenditure levels (Jeffrey, Wing, Sherwood et al. 2003). Furthermore, results from several sources also suggested that considerably higher exercise targets may be more advantageous for long-term weight loss (Jefferey et al. 2003; Jakicic, Winters & Wing, 1999).

In 2003, Jefferey *et al*. reported that prescribing higher levels of physical activity than are conventional in weight loss studies (energy expenditure of 2500kcal/wk rather than 1000kcal/wk) improved weight loss over an 18-month period in males and females (Jefferey et al. 2003), which is consistent with previously reported data (Jakicic, Winters, Lang et al., 1999). Whilst the subjects in the low physical activity group in this study still lost weight, the amount was not statistically significant. It should be noted therefore that marked differences exist in physical activity guidelines for those attempting to improve health and/or physical fitness compared with those wanting to lose significant amounts of weight. This recommendation to progress overweight adults to >2000kcal/wk may present an incredibly difficult challenge for interventionists and public health professionals and should be viewed in the context of the individuals current exercise levels. By prescribing unrealistic exercise goals, individuals may feel that achieving these targets would be almost impossible (American College of Sports Medicine, 1999). It is also worth remembering that even in the absence of weight loss important improvements in health can be achieved through minimum public health recommendations for physical activity (American College of Sports Medicine, 1999). The preservation of fat free mass seems to be an important factor in successful long-term weight loss programmes. This may be because fat free mass largely determines resting metabolic rate, which is responsible for the majority of daily energy expenditure. Research to investigate the effects of resistance training on maintaining and improving fat free mass in addition to weight loss outcomes revealed that weight training was indeed effective at maintaining fat free mass during diet and exercise trials (Garrow & Summerbell, 1995, Ross, Pedwell & Riassanen, 1995).

However, when resistance exercise is combined with dietary energy restriction, there appears to be little benefit in terms of absolute weight loss (Kraemer, Volek & Clark, 1997, Kraemer, Volek & Clark 1999).
Additionally, with the growing support that levels of central adiposity are more highly correlated with diabetes, heart disease and mortality than total body fatness (Hunter, Kekes-Szabo, Snyder, et al., 1997; Williams et al., 1997) a number of studies have focused their investigations in this area. It has been reported that aerobic exercise is associated with significant changes in visceral fat (Schwartz, Shuman & Larson, 1991), yet there is a paucity of data on the effects of weight training on intra-abdominal adipose tissue (IAAT) levels (Hunter et al., 2002).

In 2002, Hunter *et al*. investigated the effect of gender on resistance training-induced changes in IAAT among adults. The results indicated that while both sexes displayed similar and significant changes in fat mass, only the women decreased IAAT significantly during the 16-week programme despite significant reductions in total body mass for both the men and women. It was suggested that viscerally obese women but not men may be better able to improve fat distribution than less viscerally obese women (Hunter et al., 2002) and as previously suggested that visceral fat loss will be a function of total fat loss whether the loss is due to exercise or diet (Ross, Freeman & Jansen, 2001, Hunter et al., 2002).

While these results were consistent with the few previously reported studies in this area (Smith, 1992), it should be noted that there are significant variations in the methodological designs used. In this study, visceral fat volume was not measured. Only IAAT at the level of the $4^{th}/5^{th}$ lumbar vertebrae was established. Additionally, the subjects included in the study were adults aged 60 years and it is possible that older men and women may distribute fat differently in the abdomen than younger men and women (Hunter et al., 2002). Further research in this area is required to identify the possible mechanisms of preferential fat loss in women (Hunter et al., 2002).

3.2 Maintaining weight loss and preventing weight regain with physical activity
There is a general perception that almost no one succeeds in long-term maintenance of weight loss (Wing & Phelan, 2005). However, in the few studies that have shown to have a significant effect on long-term weight maintenance, physical activity is key (Jakicic, Wing & Winters-Hart, 2002; Klem, Wing, McGuire et al., 1997, King & Tribble, 1991).

There appears to be an inverse relationship between physical activity and weight gain (Hill, Holly & Wyatt, 2005), but the reasons to why this is so are not fully understood. It has been suggested that physical activity can improve a number of psychological factors such as mood, which in turn may be responsible for reducing certain eating episodes (Gauvin, Rejeski & Norris, 1996).

A number of studies have also suggested that individuals that increase physical activity during behavioral weight loss programmes also appear to make meaningful changes in eating behaviour, which may affect weight loss (Jakicic et al., 2002, Gillman et al., 2001). Therefore if physical activity is maintained over the long term, the changes in eating may remain as an association to the new behaviour. However, while Jakicic et al. (2002) reported that there was an apparent association between dietary and exercise behaviours within a weight management programme, the results did not indicate that changing physical activity would cause changes in dietary behaviours in overweight adults. Other studies however, do not support these claims and have identified that physical activity behaviours were not associated with changes in dietary habits (Wilcox, King & Colditz 2000). These inconsistencies make drawing conclusions extremely difficult and further research is needed to ascertain whether physical activity has an effect on the behaviour of eating patterns.

Recent results from the United States National Weight Control Registry report that members have lost an average of 33kg and maintained the loss for more than 5 years. In order to maintain their weight loss members reported engaging in over an hour of daily physical activity, eating low-calorie and low fat diets, self monitoring and maintaining a constant eating pattern across weekdays and weekend that which includes breakfast (Wing & Phelan, 2005). Moreover, the report suggests that weight loss maintenance may get easier over time, after individuals have successfully maintained their weight loss for 2-5 years, the chance of long-term weight loss greatly increases. This recent research is extremely significant as it demonstrates significant weight loss over a long period of time. It is important that further research investigates the individual factors involved in long term weight loss so that we have may better understand this global problem.

4. Discussion

While the concept of energy balance appears simple, it is deceptively so (Donnelly, Smith, & Jacobsen, 2004). It has been proposed that humans have evolved to an asymmetry of appetite control (House of Commons, 2004). Whilst we are very good at recognizing hunger, we are very bad at recognizing satiety and as such, we are almost predisposed to storing body fat (House of Commons, 2004). With the plethora of knowledge in this field, we should not be seeing the levels of obesity in the so-called developed and developing world. If a sensible diet and exercise regimen were adhered to, we would be more likely to remain a healthy weight.

References

Abdel-Hamed, T.K. (2003). Exercise and diet in obesity treatment: An integrative system dynamics perspective. *Medicine and Science in Sport and Exercise*. **35**(3), 400-414.

American College of Sports Medicine (2001). Position Stand on the Appropriate Strategies for Weight Loss and Prevention of Weight Regain in Adults. *Medicine and Science in Sport and Exercise*. **33**(12), 2145-2156.

Allison, D.B., Fontaine, K.R., Manson, J.E., Stevens, J., VanItallie, T.B. (1999). Annual deaths attributable to obesity in the United States. *Journal of the American Medical Association*. 282, 1530-8.

Andrews, J.F. (1991). Exercise for slimming. Proceedings of the Nutrition Society. **50**(2), 459-71. Cited in: Abdel-Hamed, T.K. (2003). Exercise and diet in obesity treatment: An integrative system dynamics perspective. *Medicine and Science in Sport and Exercise*. **35**(3), 400-414.

Ballor, D.L., Keesey, R.E. (1991). A meta-analysis of the factors affecting exercise-induced changes in body mass, fat mass and fat free mass in males and females. *International Journal of Obesity*. 15, 717-726.

Bouchard, C., Tremblay, A., Depres, J.P. et al., (1994). The response to exercise with constant energy intake in identical twins. *Obesity Research*. 5, 400-410.

Ballor, D.L., Poelhman, E.T. (1994). Exercise training enhances fat-free mass preservation during diet-induced weight loss: a meta-analytical finding. *International Journal of Obesity*. 18, 35-40.

Brown, B.D. (2000). About Obesity: Incidence, Prevalence and Co-morbidity. International Obesity Task Force. Cited in: National Audit Office. (2001). Tackling obesity in the UK. London: National Audit Office.

Calle, E.E., Thun, M.J. (2004). Obesity and cancer. *Oncogene*. 23, 6365-6378.

Cale, E.E., Thun, M.J., Petrelli, J.M., Rodruigez, C. & Heath, C.W. Jr. (1999). Body-mass index and mortality in a prospective cohort of U.S. adults. *New England Journal of Medicine*. **341**(15): 1097-1105.

Cicuttini, F.M., Baker, J.R., Spector, T.D. (1996). The association of obesity with osteoarthritis of the hand and knee in women: a twin study. *Journal of Rheumatology*, 23:1221-1226.

Department of Health, Physical Activity, Health Improvement and Prevention. (2004). At Least Five a Week: Evidence on the impact of physical activity and its relationship to health. A report from the Chief Medical Officer. Department of Health.

Depress, J.P, Lemieux, I. (2001). Prud'homme D. Treatment of obesity: need to focus on high-risk abdominally obese patients. *British Medical Journal*. 322, 716-20.

Donnelly J.E., Smith B., Jacobsen D.J., Kirk E., Dubose K., Hyder M., Bailey B., Washburn R. (2004). The role of exercise for weight loss and maintenance. *Best Practice & Research in Clinical Gastroenterology*. **18**(6), 1009-29.

Eckel, R.H. (2005). Obesity. *Circulation*. 111, e257-259.

Felson, D.T., Anderson, J.J., Naimark, A., Walker, A.M., Meenan, R.F. (1988). Obesity and knee osteoarthritis. The Framingham Study. *Annals of Internal Medicine*. **109**(1), 18-24.

Fox, K.R., Page, A. (2001). The physical activity approach to the treatment of overweight and obesity. In: Management of Obesity and Related Disorders. London. Martin Dunitz.

Garrison, R.J., Higgins, M.W., Kannel, W.B. (1996). Obesity and coronary heart disease. *Current Opinion in Lipidology*. 7(4), 199-202.

Garrow, J.S., Summerbell, C.D. (1995). Meta-analysis: effect of exercise, with or without dieting, on the body composition of overweight subjects. *European Journal of Clinical Nutrition*. 49, 1-10.

Gauvin, L., Rejeski, W.J., Norris, J.L. (1996). A naturalistic study of the impact of acute physical activity on feeling states and effect in women. *Health Psychology*. 15, 391-397.

Gillman, M.W., Pinto, B.M., Tenstedt, S., Glanz, K., Marcus, B., Friedman, R.H. (2001). Relationships of physical activity with dietary behaviors among adults. *Preventative Medicine*. 32, 295-301.

Grundy, S.M., Blackburn, G, Higgins, M., Lauer, R., Perri, G., Ryan, D. (1999). Physical activity in the prevention and treatment of obesity and its co-morbidities: evidence report of independent panel to assess the role of physical activity in the treatment of obesity and its co-morbidities. *Medicine and Science in Sport and Exercise*. 3, 1493-1500.

House of Commons Health Committee. Obesity. Third report of session 2003-2004. Volume 1. London. The Stationary Office Limited, pp 18.

Hunter, G.R., Bryan, D.R., Wetzstein, P., Zuckerman A., Bamman, M.M. (2002). Resistance training and intra-abdominal adipose tissue in older men and women. *Medicine and Science in Sport and Exercise*. **34**(6), 1023-1028.

Hunter, G.R., Kekes-Szabo, T., Snyder, S., Nicholson, C., Nkitos, L., Berland, L. (1997). Fat distribution, physical activity, and cardiovascular risk factors. *Medicine and Science in Sport and Exercise*. 29, 362-369.

International Obesity Task Force. (2002). International Obesity Task Force and the European Association for the Study of Obesity. The case for action. In: National Audit Office (2001). Tackling obesity in the UK. London: National Audit Office, pp 12.

Jeffrey, R.W., Wing, R.R., Sherwood, N.E., Tate, D.F. (2003). Physical activity and weight loss: does prescribing higher physical activity goals improve outcome? *American Journal of Clinical Nutrition*. 78, 684-9.

Jakicic, J.M., Winters, C., Wing, R.R. (1999). Effects of intermittent exercise and use of home exercise equipment on adherence, weight loss and fitness in overweight women: a randomized trial. *Journal of the American Medical Association*. 282, 1554-60.

Jakicic, J.M., Wing, R.R., Winters-Hart, C. (2002). Relationship of physical activity to eating behaviors and weight loss in women. *Medicine and Science in Sport and Exercise*. **34**(10), 1653-1659.

King, A.C., Tribble, D.L. (1997). The role of exercise in weight regulation in nonathletes. *Sports Medicine*. 11, 331-49

Klem, M.L., Wing, R.R., McGuire, M.T. Seagle, H.M., Hill, J.O. (1997). A descriptive study of individuals successful at long-term maintenance of substantial weight loss. *American Journal of Clinical Nutrition*. 66, 239-246.

Kopelman, P.G. (2001). Defining overweight and obesity. In: Kopelman, P.G. (2001). Management of Obesity and Related Disorders. London. Martin Dunitz.

Kraemer, W.J., Volek, J.S., Clark, K.L et al. (1997). Physiological adaptations to a weight-loss dietary regimen and exercise program in women. *Journal of Applied Physiology*. 83, 270-279.

Kraemer, W.J., Volek, J.S., Clark, K.L et al. (1999). Influences of exercise training on physiological and performance changes with weight loss in men. *Medicine and Science in Sport and Exercise*. 31, 1320-1329.

Lew, E.A. (1985). Mortality and weight: Insured lives of the American cancer study. *Annals Internal Medicine*. 103, 1024-9.

McCue, H. Jr. (1979). The Build and Blood Pressure Study. Cited in: Xavier, F., Sunyer, P.I. (1991). Health Implications of Obesity. *American Journal of Clinical Nutrition*. 53, 1595S-1603S.

Miller, W.C., Koceja, D.M., Hamillton, E.J. (1997). A meta-analysis of the past 25 years of weight loss research using diet, exercise or diet plus exercise interventions. *International Journal of Obesity Related Metabolic Disorders*. 2, 587-99.

National Audit Office. (2001). Tackling obesity in the UK. London: National Audit Office, pp 13.

Metropolitan Life Assurance Company. Build and blood pressure study 1959. Vol I, II. Chicago. Society of Actuaries, 1960. Cited in: Xavier, F., Sunyer, P.I. (1991). Health Implications of Obesity. *American Journal of Clinical Nutrition*. 53, 1595S-1603S.

Ostman, J., Britton, M. & Jonsson, E. (2004). Treating and Preventing Obesity. An Evidence Based Review. Weinheim. WILEY-VCH Verlag GmbH & Co. KgaA.

Pate, R.R., Pratt, M., Blair, S.N. et al. (1995). Physical activity and public health: a recommendation from the Centres of Disease Control and Prevention and the American College of Sports Medicine. *Journal of the American Medical Association*. 273, 402-7.

Rocchini, A.P.(1997). Obesity and blood pressure regulation. In Bray, G.A., Bouchard, C., James, W.P.T. (Eds). Handbook of Obesity. New York. Marcel Dekker, pp 677-95.

Ross, R, Freeman, J.A., Jansen, I. (2001). Exercise alone is an effective strategy for reducing obesity and related co-morbidities. *Exercise and Sports Science Reviews*. 28, 165-170.

Ross, R., Pedwell, H., Riassanen, J. (1995). Response of total and regional lean tissue and skeletal muscle to a programme of energy restriction and resistance exercise. *International Journal of Obesity*. 19, 781-7.

Saris, W.H.M. (1996). Physical activity and body weight regulation. In: *Regulation of Body Weight: Biological and behavioral Mechanisms*, C. Bouchard and G.A. Bray (Eds.). New York: Wiley, 1996, pp. 135-148.

Scwartz, R.S., Shurman, W.P., Larson, V. et al. (1991). The effect of intense endurance exercise training on body fat distribution in young and older men. *Metabolism*. 40, 545-551.

Smith, M.M. (1992). The effects of strength training on body composition in middle-aged and older men using dual-energy x-ray absorpitometry and magnetic resonance imaging. Cited in: Hunter, G.R., Bryan, D.R., Wetzstein, P., Zuckerman A., Bamman, M.M. (2002). Resistance training and intra-abdominal adipose tissue in older men and women. *Medicine and Science in Sport and Exercise*. **34**(6), 1023-1028.

Stamler, R., Stamler, J., Gosch, F.C., Civinelli, J., Fishman, J., McKeever, P. et al. (1989). Primary prevention of hypertension by nutrition-hygenic means. Final report of a randomised controlled trial. *Journal of the American Medical Association*. **262**(13), 1801-7.

Stevens, J., Cai, J., Pamuk, E.R., Williamson, D.F., Thun, M.J. & Wood, J.L. The effect of age on the association between body-mass index and mortality. *New England Journal of Medicine*. 338(1), 1-7.

Wilcox, S., King, A.C., Colditz, G.A. (2000). Do changes in physical activity lead to dietary changes in middle and old age? *American Journal of Preventative Medicine*; 18:276-283.

Williams, M.J., Hunter, G.R., Kekes-Szabo, T., Snyder, S., Treuth, M.S. (1997). Regional fat distribution in women and risk of cardiovascular disease. *American Journal of Clinical Nutrition*. 65, 855-860.

Wing, R.R. (1999). Physical activity in the treatment of the adulthood overweight and obesity: current evidence and research issues. *Medicine and Science in Sport and Exercise*. 31, S547-52.

Wing, R.R., Phelan, S. (2005). Long-term weight loss. *American Journal of Clinical Nutrition*. 82(1), 222S-225S.

Wood, P.D., Stefanick, M.L., Williams, P.T., Haskell, W.L. (1991). The effects on plasma lipoproteins of a prudent weight-reducing diet, with or without exercise, in overweight men and women. *New England Journal of Medicine*; 325:461-446.

World Health Organization. (1998). Obesity: Preventing and managing the global epidemic. Report of WHO Consultation on Obesity. World Health Organisation.

www.cdc.gov. Department of Health and Human Services. Centers for Disease Control and Prevention. Accessed December 2005. www.cdc.gov/nccdphp/dnpa/physical/terms/

www.dictionary.reference.com. Dictionary.com. Accessed December 2005. http://dictionary.reference.com/

Xavier, F., Sunyer, P.I. (1991). Health Implications of Obesity. *American Journal of Clinical Nutrition*. 53, 1595S-1603S.