The Effect of Exercise and Diet on Glucose Intolerance and Substrate Utilization?

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Physical Activity Has a Protective Effect on Type-2 Diabetes

Intervention studies provide robust evidence of the efficacy of lifestyle intervention, based on diet and exercise, in improving insulin sensitivity and reducing the risk of developing type-2 diabetes in individuals with impaired glucose tolerance (IGT) [1–3]. However, it is difficult to determine the relative importance of weight loss compared with physical activity in improving clinical outcomes. A prospective study in 5,159 men without diabetes at baseline demonstrated a strong inverse relationship between physical activity and the risk of developing type-2 diabetes (table 1), suggesting a beneficial effect of physical fitness on glucose tolerance and insulin sensitivity [4]. Indeed, the prognostic benefits associated with physical activity remained after adjustment for potential confounders, including factors related to lifestyle, body mass index (BMI) and preexisting disease. A further study, which enrolled 8,633 non-diabetic subjects, examined the association of cardiorespiratory fitness, an objective marker of physical activity, with the development of impaired fasting glucose (IFG) which, like IGT, represents a pre-diabetic state, or type-2 diabetes [5]. During an average follow-up of 6 years 593 subjects developed IFG and 149 subjects developed type-2 diabetes. After adjustment for age, smoking, alcohol consumption and family history of diabetes, it was determined that low cardiorespiratory fitness was independently associated with an increased risk of developing IFG and type-2 diabetes.
While physical inactivity undoubtedly promotes insulin resistance, and therefore also type-2 diabetes, the majority of new cases of diabetes may be attributed largely to excessive body weight, with additional exercise producing relatively little additional effect [6, 7]. For example, the Nurses’ Health Study followed 84,941 non-diabetic women for 16 years [6]. At study end 3,300 new cases of diabetes were documented, of which 61% were attributed to overweight (BMI >25 kg/m²; table 2). Furthermore, a combination of being overweight, lack of exercise, poor diet, smoking, and alcohol intake could account for 91% of new cases of type-2 diabetes. These findings support the findings of intervention studies in pre-diabetic subjects, in that the majority of cases of type-2 diabetes could be prevented by weight control together with other components of a healthier lifestyle.

**Table 1.** Relative risk of type-2 diabetes according to activity levels in men free of coronary heart disease, stroke or diabetes

<table>
<thead>
<tr>
<th>Exercise</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inactive</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Occasional</td>
<td>0.65</td>
<td>0.66</td>
</tr>
<tr>
<td>Light</td>
<td>0.60</td>
<td>0.65</td>
</tr>
<tr>
<td>Moderate</td>
<td>0.42</td>
<td>0.48</td>
</tr>
<tr>
<td>Moderately vigorous/vigorous</td>
<td>0.36</td>
<td>0.46</td>
</tr>
<tr>
<td>p value for trend</td>
<td>&lt;0.001</td>
<td>0.005</td>
</tr>
</tbody>
</table>

A = Adjusted for age; B = adjusted for age, smoking, alcohol-intake, social class, BMI and preexisting CHD.
Adapted from data presented by Wannamethee et al. [4].

**Mechanisms of Weight Loss**

While physical inactivity undoubtedly promotes insulin resistance, and therefore also type-2 diabetes, the majority of new cases of diabetes may be attributed largely to excessive body weight, with additional exercise producing relatively little additional effect [6, 7]. For example, the Nurses’ Health Study followed 84,941 non-diabetic women for 16 years [6]. At study end 3,300 new cases of diabetes were documented, of which 61% were attributed to overweight (BMI >25 kg/m²; table 2). Furthermore, a combination of being overweight, lack of exercise, poor diet, smoking, and alcohol intake could account for 91% of new cases of type-2 diabetes. These findings support the findings of intervention studies in pre-diabetic subjects, in that the majority of cases of type-2 diabetes could be prevented by weight control together with other components of a healthier lifestyle.

**How Exercise Changes Fat Oxidation and Energy Balance**

Physical inactivity produces insulin resistance in skeletal muscle. Skeletal muscle insulin resistance entails dysregulation of both glucose and fatty acid metabolism. A number of studies have examined whether a combined intervention of physical activity and weight loss influences fasting rates of fat oxidation and insulin-stimulated glucose disposal. In obese volunteers without diabetes 16 weeks of moderate-intensity physical activity combined with caloric reduction produced both a reduction in fat mass and regional fat depots, and improved VO₂max by 19%, from 38.8 to 46.0 ml × kg fat-free mass (FFM)⁻¹ × min⁻¹. Insulin sensitivity improved by 49%, the rate of fasting fat oxidation increased from 1.16 to 1.36, and the proportion of energy derived from fat increased from 38 to 52%. The strongest predictor of the improved
insulin sensitivity was enhanced fasting rates of fat oxidation, accounting for 52% of the variance. In conclusion, exercise combined with weight loss enhances postabsorptive fat oxidation, which appears to be a key aspect of the improvement in insulin sensitivity in obesity.

During low-intensity exercise a greater proportion of fatty acids is oxidized, primarily as the result of the preferential oxidation of free fatty acids in slow-twitch fibers (type 1). At 30% VO$_{2\text{max}}$, 62% of the total muscle substrate use is typically covered by fat oxidation [8]. At higher levels of exercise intensity, more fast-twitch fibers (type 2) are recruited with a preferential oxidation of carbohydrate. At 80% VO$_{2\text{max}}$, only 20% of the energy expenditure is covered by fat oxidation. However, the increase in total energy expenditure (EE) is more important for the total fat oxidation, and EE increases with increasing intensity of the exercise. Moreover, a better aerobic capacity will increase fat oxidation, which is thought to improve appetite regulation and body weight control. However, many trials have failed to show any important differences in weight loss when comparing the effects of different durations and intensities of exercise on 12-month weight loss and cardiorespiratory fitness. Significant weight loss and improved cardiorespiratory fitness can be achieved through the combination of exercise and diet during 12 months, although no differences are found based on different exercise durations and intensities in sedentary, overweight subjects.

### Table 2. Contribution of factors related to lifestyle to the development of new cases of diabetes

<table>
<thead>
<tr>
<th>Lifestyle factors</th>
<th>New cases of type-2 diabetes, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI &gt;25 kg/m$^2$</td>
<td>61</td>
</tr>
<tr>
<td>BMI &gt;25 kg/m$^2$, exercise and diet</td>
<td>87</td>
</tr>
<tr>
<td>BMI &gt;25 kg/m$^2$, exercise, diet, smoking, alcohol</td>
<td>91</td>
</tr>
<tr>
<td>BMI &gt;23 kg/m$^2$ and all lifestyle factors</td>
<td>96</td>
</tr>
</tbody>
</table>

Adapted from data from the Nurses’ Health Study [6].

#### Obesity Produces Insulin Resistance

Obesity, by definition, implies an accumulation of body fat, and this excess adiposity correlates with the risk of ill-health and disease. The use of BMI as an index of adiposity underpins the current classification system for obesity and is widely used throughout the world. However, like any anthropometric measurement, BMI is only a surrogate measure of adiposity. Indeed, BMI is not always a good predictor of the risk of developing diabetes, and its use can be particularly problematic when comparing populations of different age, gender,
race or physical activity. It has been suggested that surrogate anthropometric measures, including BMI, may be misleading with regard to body fat content in a range of conditions. For example, an individual may have a constant body weight and height, and therefore a constant BMI, throughout adult life, but their body fat composition is likely to increase with age [9]. The proportion of body fat, as a percentage of body weight, may increase by more than 2-fold between the ages of 25 and 75 years, despite body weight and BMI remaining constant. Furthermore, the BMI of people who participate in ‘power’ sports such as American football, shot-putt, or wrestling is likely to classify them as overweight or obese, although these people generally have a low body fat content [9]. Moreover, a retrospective, cross-sectional study evaluated the relationships between BMI and body fatness in a large group of males and females with body weights ranging from very lean to obese and demonstrated a considerable degree of overlap of the body fat compositions of individuals categorized as lean or obese [10]. Thus, the use of BMI as a surrogate marker for adiposity in epidemiological studies may be confounded by marked variations in body fat composition between subjects. Individuals with a similar BMI may have very different visceral fat masses and, by extension, very different metabolic and cardiovascular risk profiles.

Weight loss is associated with improvements in insulin action [11]. The benefits of improved insulin sensitivity and glucose tolerance generated by regular physical exercise are also well established. However, the metabolic benefits of exercise disappear after several days of inactivity, indicating the need for regular exercise as part of a long-term change in lifestyle. Both aerobic and resistance exercise training programs have been shown to be effective in increasing insulin sensitivity, but training programs that combine these approaches may be most advantageous. Physical inactivity may also promote insulin resistance indirectly by promoting growth of visceral fat deposits (fig. 1). It is most likely that the major driver of insulin resistance is a positive energy balance, leading to increased total and abdominal fat, with physical inactivity playing a secondary role. It is unclear, however, whether regular exercise or diet therapy has a significant effect on body fat distribution.

The results of clinical studies underpin the central role of visceral obesity in the development of insulin resistance. A study in volunteers has shown that insulin sensitivity, measured during a glucose clamp, was inversely related to BMI above a critical threshold of approximately 120% of ideal body weight [12, 13]. A further study in obese women showed that insulin sensitivity was inversely related to the extent of visceral adiposity, measured using CT scanning [12, 14]. A cross-sectional study in 445 lean or obese men included measurements of insulin sensitivity index and body fat distribution, which was assessed using dual energy X-ray absorptiometry [15]. The amount of visceral adipose tissue was inversely related to aerobic capacity, so that individuals with the greatest physical fitness usually had the lowest intra-abdominal adipose tissue and the highest insulin sensitivity. Multiple regression analyses of these data support the view
that a positive energy balance (energy intake > EE) promotes obesity, which in turn promotes insulin resistance via the accumulation of visceral fat.

Intervention trials examining weight loss produced by exercise and/or diet suggest that a reduction in intra-abdominal fat may be sufficient to explain the observed improvements in glycemic control. A randomized study in 29 obese men (BMI >27 kg/m²) evaluated the influence of 16 weeks of diet therapy alone, or diet combined with either aerobic or resistance training, on glucose and insulin levels before and after a 75-gram oral glucose tolerance test (OGTT), and on adiposity, measured using magnetic resonance imaging (MRI) [16]. The magnitude of weight loss did not differ significantly between the treatment groups at study end. However, reductions in abdominal adipose tissue, whether located in subcutaneous or visceral depots, correlated more strongly with improvements in fasting or postprandial glucose levels than either total fat or lower body fat composition (table 3). Thus, it appears that a reduction in abdominal obesity occurring in response to diet and exercise is important for achieving improvements in glycemia. These data add further support to the hypothesis that abdominal obesity plays an important role in mediating insulin resistance.

### Table 3. Correlation coefficients obtained between changes in indices of total or regional adiposity and metabolic variables

<table>
<thead>
<tr>
<th>MRI variable</th>
<th>Fasting glucose</th>
<th>Fasting insulin</th>
<th>Glucose AUC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total AT</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>Subcutaneous AT</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>Abdominal</td>
<td>n.s.</td>
<td>0.46†</td>
<td>n.s.</td>
</tr>
<tr>
<td>Lower body</td>
<td>n.s.</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>Visceral AT</td>
<td>0.47†</td>
<td>n.s.</td>
<td>0.38*</td>
</tr>
<tr>
<td>Intraperitoneal</td>
<td>0.42*</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
<tr>
<td>Extraperitoneal</td>
<td>0.47†</td>
<td>n.s.</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

Adapted from data presented by Rice et al. [16]. Glucose AUC = area under the concentration-time curve for plasma glucose following a 2-hour oral glucose tolerance test; AT = adipose tissue.

*p < 0.005; †p < 0.01; n.s. = not significant.
The effects of diet- or exercise-induced weight loss on the reduction of obesity and glucose and insulin sensitivity, were examined independently in a 3-month study in 52 obese men (mean BMI 31 kg/m²) randomized to undergo diet-induced weight loss (subjects were asked to reduce their calorie intake by 700 kcal/day), exercise-induced weight loss (subjects were asked to perform sufficient aerobic exercise to expend 700 kcal/day), exercise without weight loss (these subjects performed the same amount of exercise but adjusted their caloric intake to maintain body weight), or to a standard lifestyle intervention, which served as a control group [17]. Body fat composition was measured using MRI, insulin sensitivity and glucose disposal were measured during a euglycemic hyperinsulinemic clamp, and glucose tolerance was assessed using a 2-hour, 75-gram OGTT.

At study end body weight had decreased by 7.5 kg (8%) in both weight loss groups, whereas no significant change in weight was observed in either the exercise without weight loss group, or in the control group. Weight loss, either through diet or exercise, produced the largest reductions in visceral fat, although exercise without weight loss significantly reduced visceral fat compared with control. Furthermore, exercise-induced weight loss reduced total fat to a greater extent than diet-induced weight loss. Larger increases in glucose disposal occurred in both weight loss groups compared with control, while this parameter did not differ between the exercise without weight loss and control groups. Indeed, glucose disposal was significantly greater in the exercise with weight loss group than in the exercise without weight loss group. Similarly, changes in glucose and insulin responses following an OGTT were greater in the exercise-induced weight loss group than in the exercise without weight loss group.

This study suggests that weight loss due to exercise or diet may induce clinically significant improvements in adiposity and in indices of glucose metabolism. Exercise without weight loss in subjects who adjusted their caloric intake for the additional EE was less effective. However, this intervention apparently prevented further weight gain despite increased caloric intake, and produced some potentially beneficial changes in abdominal fat composition. Overall, this study confirms the importance of weight loss, however achieved, in the management of metabolic disease.

Impact of Weight Loss on Diabetes Risk

Diet and Exercise

Several large outcome studies have examined the effects of exercise in combination with diet on glucose tolerance and the risk of developing type-2 diabetes. The Finnish Diabetes Prevention Study (FDPS) randomized 522 middle-aged, overweight subjects, with IGT based on two OGTTs, to an intensive lifestyle intervention group or to a control group [2]. The intervention group received individual advice and guidance encouraging participants to
reduce their body weight and intake of saturated fat, and to increase their
intake of dietary fiber and levels of physical activity. The control group
received general information about the benefits of weight reduction, physical
activity and healthy diet in the prevention of diabetes. The mean duration of
follow-up was 3.2 years. The cumulative incidence of diabetes after 4 years
was 11% in the intensive lifestyle group and 23% in the control group, repre-
senting a reduction in the relative risk of diabetes of 58% in the intervention
group. Subsequent analysis of the data strongly indicates that weight loss was
the predominant factor for risk reduction of type-2 diabetes in the intensive
lifestyle intervention group (fig. 3). The relative risk of diabetes decreased
proportionally with changes in weight and it was estimated that a weight loss
of 11 kg may be sufficient to prevent more than 80% of new cases of type-2
diabetes. In contrast, a gain in weight of 3 kg may result in a 2-fold increase
in the relative risk of type-2 diabetes. Thus weight loss is an extremely impor-
tant therapeutic goal in the prevention of type-2 diabetes.

A target for weight loss of 7% was included in the intensive lifestyle inter-
tervention arm of the Diabetes Prevention Program Study (DPP) [3]. Subjects in
this group received intensive education and coaching in maintaining a health-
tier diet and in achieving a sustained increase in physical activity. The subjects
receiving this treatment achieved a mean loss of 5% of body weight during the
course of the study, which was accompanied by a 58% reduction in the risk
of developing diabetes. It remains unclear, however, how much of the weight
loss was attributable to diet, and how much to increased physical activity. It
is, perhaps, unlikely that the moderate levels of exercise required by the pro-
tocols of the FDPS or the DPP (typically 20–30 min of brisk walking each day)
were sufficient to achieve the marked weight loss observed in these studies,
and it follows that the hypocaloric diet must have been largely responsible for
the observed improvements in body weight and clinical outcomes.

**Gastric Surgery**

An ongoing intervention study, the Swedish Obese Subjects (SOS) study,
employs the extreme procedure of gastric surgery to generate large weight
reductions in severely obese individuals. Between 1987 and 2001, the SOS
enrolled 2,010 patients who underwent vertical banded gastroplasty, gastric
bypass or banding, and 2,038 control subjects, matched for age and BMI, who
were treated conventionally. After 2 years of follow-up surgically treated
patients had lost an average of 28 kg (p < 0.0001) and the incidence of
diabetes was reduced by 90% compared with the control group [18, 19]. The
10-year follow-up of 385 surgically treated and 367 control subjects showed
that weight loss in the surgery group was largely maintained, while no signifi-
cant weight changes occurred in the control group [19]. Furthermore, in
the surgery group there were improvements in blood glucose and insulin
levels, and in lipid profiles, associated with a 3-fold reduction in new cases of
diabetes (fig. 2). The SOS trial shows that substantial weight loss in obese
subjects causes a marked improvement in metabolic control which ultimately reduces the incidence of diabetes.

Pharmacological Intervention

One would expect that the addition of a pharmacological agent for weight reduction and maintenance to the treatment of obese patients with type-2 diabetes would improve metabolic control in patients previously unable to adhere to a calorie-restricted diet. Sibutramine, a serotonin/noradrenaline reuptake inhibitor, has been evaluated in obese patients with type-2 diabetes. During a 12-week, double-blind study, 91 obese (mean BMI 31 kg/m²) diabetic subjects on a reduced-calorie diet were randomized to receive either sibutramine or placebo [20]. At study end the mean reduction in weight was significantly

Fig. 2. Reduced incidence of diabetes and diabetes risk factors following gastric surgery. Adjusted odds ratios for the surgically treated group versus control are shown above bars. LDL-C = Low-density lipoprotein cholesterol. From Sjostrom et al. [18].

Fig. 3. Relationship between changes in body weight and relative risk of type-2 diabetes from the Finnish Diabetes Prevention Study [2].
greater (p < 0.001) in the sibutramine group (−2.4 kg) than in the placebo group (−0.1 kg). Glycemic control improved in the sibutramine-treated subjects, as shown by modest reductions in HbA1C (−0.3% vs. no change with placebo), fasting glucose (−0.3 vs. +1.4 mmol/l with placebo), and peak plasma glucose following a standard test meal (−1.1 vs. +0.5 mmol/l with placebo). In a further double-blind trial in 175 subjects treated for 24 weeks the mean weight loss was −4.3 kg in patients randomized to receive sibutramine vs. −0.4 kg in the placebo group (p < 0.001). Indices of glycemic control, lipid profiles and quality of life also improved significantly in the sibutramine group [21].

Orlistat, a lipase inhibitor indicated for the treatment of obesity, has also been evaluated in type-2 diabetic patients. A 52-week, double-blind, randomized study compared orlistat with placebo in 322 obese (mean BMI 34 kg/m²) diabetic patients taking oral sulfonylurea medication [22]. In addition to the study medication the patients were placed on a mildly hypocaloric diet (−500 kcal/day energy deficit). Subjects in the orlistat group lost 6.2% of their initial body weight compared with 4.3% in the placebo group. In addition, HbA1C, fasting glucose and lipid profiles improved in the orlistat group.

Other studies also suggest that substantial weight loss induced by orlistat in obese subjects may prevent type-2 diabetes. For example, data were pooled from 675 subjects enrolled in three double-blind, randomized trials evaluating the addition of orlistat to a conventional weight loss regimen over a mean follow-up period of 582 days [23]. Fewer patients in the orlistat group progressed from IGT at baseline to type-2 diabetes (3.0 vs. 7.6% with placebo), and a higher proportion reverted to normal glucose tolerance (71.6 vs. 49.1% with placebo). Finally, the XENDOS trial evaluated the effects of orlistat on body weight and the risk of diabetes. The patient population of XENDOS was at relatively low risk of developing diabetes, as only 21% had IGT [24]. Nevertheless, a reduction in weight of 2.5–3.5 kg was sufficient to reduce the risk of developing diabetes by 37%. The studies with orlistat add further evidence that weight loss, with or without exercise, is the key component of lifestyle interventions for the prevention of type-2 diabetes.

**Conclusions**

It is evident that obesity is a key risk factor for type-2 diabetes and the adoption of a lifestyle that incorporates a healthy diet and regular physical activity may prevent or delay the onset of diabetes and, thus, prolong survival. Exercise is essential for maintaining weight loss and for the prevention of subsequent weight gain. Regular physical activity, independent of intensity and type, has an important effect on glucose tolerance, mainly through a direct effect and possibly through a reduction in insulin resistance which occurs secondarily to a reduction in total and visceral fat. So individuals should undertake at least 3 exercise sessions/week, and each session should be at least 30 min and be of
moderate to high intensity. However, weight loss, whether achieved by diet, exercise, pharmacotherapy or surgery, is more important than exercise per se in the prevention or delay of onset of type-2 diabetes. Physicians need to be proactive in initiating effective lifestyle interventions aimed at reducing weight in obese patients, or suffer the consequences of increased risk of premature death due to diabetes and its cardiovascular complications.

References

The Effect of Exercise and Diet

Discussion

The presentation and the discussion were conducted by
S. Allison (Nottingham)

Dr. James: Unfortunately as you know Dr. Astrup was taken ill and was unable to attend. Nonetheless I think the issue of exercise is important and therefore I want to raise the issue and to ask a number of discussants to comment on this. This morning was originally designed to begin first with the consideration of fat mass and then muscle mass and the interrelationship between the two. So I don’t want to lose that balance altogether. The famous playwright and author, Oscar Wilde, was once asked if he ever felt like taking exercise; he said, ‘Yes, but I always lie down until the feeling wears off.’ This is illustrative of the disinclination of all of us to take more exercise than we have to. When we were hunter-gatherers, we had to take exercise to find food, but as we settled down in comfortable cities and became mechanized then it became less and less necessary to take exercise. I am going to accept the scientific data that Dr. Astrup has presented that exercise is an important preventive. This goes back to a lot of public health work in our country and others, for example the study by Morris that looked at the risks of cardiovascular disease in people who drove buses and bus conductors who collected the tickets. It was shown that the bus drivers of course have more heart disease than the bus conductors. Another study was conducted on civil servants, grading the amount of exercise they took, and found a similar relationship. In his chapter Dr. Astrup refers to the risks of developing type-2 diabetes being inversely related to exercise and he reviewed the substrate utilization and insulin resistance which exercise or its lack induces. What I would like to perhaps focus on is less on the physiology, which he has covered, but on some of the practicalities because we can theorize until the cows come home but can we put this into practice. Now one of the first issues is that of government policy. Our government sold off all the school playing fields so the children have nowhere to take exercise. It shows what foresight they have; of course you can’t expect politicians to have too much foresight beyond the next election. Dr. Allison, can I pick on you first on this question of government policy, because this is an issue that you have been involved in around the world, and how this can be manipulated or altered to address this problem?

Dr. Allison: Some of you will know that over the last 3 years we have done extensive analysis on the relationship between different forms of exercise and the amount of it, and how much it will prevent different diseases and indeed the problem of weight gain. It is quite interesting because if you look at the literature extremely carefully there has been quite a debate going on between Morris and the North American groups where Blair in particular has done some extremely important work looking at the relationship.
during physical fitness and well being. Morris's data, which you beautifully described, were the bus conductors rushing up and down the London buses or the coastal workers as distinct from the telephone operators. Then he went onto Whitehall civil servants, and the interesting thing about these is that he came to the conclusion that if you look at this carefully, and if you are concerned about heart disease, you need vigorous exercise of relatively short duration. For example being English he went in for his weekend gardening, the assumption being that dig like mad and turn the turf and you are therefore inducing quite high levels of short bursts of physical activity, whereas Blair did his analysis and concluded that you drop heart disease by 40% even if you are modestly active. If you look at the debate the heart disease evidence looks as though some benefit is derived from simply being on your feet if you are completely inert, but if you really want to have an impact then you need additional quite sharp exercise periods. Blair produced some very interesting analyses which the US government totally accepted and the world therefore followed on by saying 5 times 30 min walking a day. That was Blair's analysis based on the assumption that you could never get an American to routinely do intense physical activity. So it is a pragmatic way of mixing science and policy, and the evidence is really quite troubling. Now if you want to talk about weight gain, we concluded that in fact you have to do rather more physical activity of a general nature to actually prevent weight gain. So you can actually get a real benefit in heart disease from just getting out of bed and on your feet and walking for a few minutes a day, more than the American can normally do; whereas if you want to prevent weight gain then you have to go for about 80 min, over an hour anyway, and these analyses have now been incorporated into WHO policies. The implications are enormous because if you tell me to go and walk for 30 min/day, I occasionally get round to it and I might do that, but if you are asking me to actually do an extra 1 h/day on my feet walking reasonably briskly then you are asking something quite bizarre of people. If you do an analysis you can show that everybody complains that they can't do this, even 30 min, and you finally conclude that if you think I can do it at weekends, what that actually means is that you have to do a half marathon every Saturday. Now you are asking the total population to do half marathons every Saturday, or alternatively on Sunday, walking vigorously for 7 h to do the equivalent. So it is a bit embarrassing but we are completely crazy in the implications of our policy unless we understand that we have to recreate society so that we automatically are on our feet without realizing it. You can show that in the Netherlands depending upon the way in which you design your tone that it actually alters the whole behavior of the group. Similarly in Copenhagen you find walking and cycle paths, it actually becomes reasonable for a business person. I go to Copenhagen and I get phoned by somebody on their mobile saying that they will be 20 min late because they are cycling several kilometers to the meeting. Therefore we have actually gone the whole of the North American–British type way where our whole society is dominated by one concept, the motorcar. Look at Bangkok, a complete disaster, or Mexico City, absolutely crazy system. Therefore the policymakers of governments haven't yet understood that you are never going to get rid of the mechanical age or computers or indeed the television so the fact is that we have got to go at it in a completely different way. We have been wrong in assuming that all you have to do is to tell people to go to the gym or even go to a leisure center because that actually appears to use sophisticated slightly snobbish professional groups, but you know, give me a break I am a poor housewife trying to cope with all this stuff and my 3 kids, and I can't do it.

Dr. Kopelman: Can I follow on from what Dr. Allison was saying? There are two points, one is looking at the dose response in relation to benefit from physical activity.
Firstly I have been involved in work for the Chief Medical Officer in the UK and Dr. Morris and Dr. Shafer are both members of that group. If ever you want evidence that regular physical activity takes you into your 80s with completely full faculties and indeed make a major contribution, they are the best example. In relation to the other evidence, if you just do some physical activity then certainly you can extend your life if you want to do that, and the cardiovascular benefits are quite compelling. All the other metabolic benefits, the long-term evidence is not there. Certainly for the shorter term, physical activity improves impaired glucose tolerance and diabetes. Moreover, you can improve your lipid profile and reduce blood pressure. The interesting thing is that the least compelling evidence relates to weight loss, certainly weight maintenance is very important. There is some evidence that increasing physical activity reduces certain types of cancer, particularly colonic cancer, although I think that the evidence is less compelling. Of course with bone it is a balance between how much physical activity you do to do damage and how much physical activity you do to actually maintain good bone density. But coming back to policy, the problem certainly in the UK and elsewhere in the world is getting people started. We have a Prime Minister who has actually made a major issue around physical activity, but unfortunately he links this with the London Olympics so it is just that people's idea about physical activity relates to fitness and sport rather than getting started and doing some walking on a regular basis. In the UK what is absolutely frightening is that about 30% of our children and teenagers are physically inactive, that is the boys, and if you look at girls it is near 50%. In other words they are not doing anything at any time during the week.

Dr. James: Thank you very much. Dr. Rock, you have been involved in a number of programs related to diet and presumably exercise comes as part of your package and so you have experience with the practicalities of persuading people to do more. Would you like to comment on this?

Dr. Rock: There is an aspect of exercise that becomes self-perpetuating once people get hooked on it, and perhaps it is the endorphins or something else. I want to challenge a little bit of what often comes out with this issue of weight loss because I have noticed that Americans embrace the idea of exercise having a central role. I think it is because even though there is an action on calorie effect, exercising doesn't look like it would be that great but we know from the long-term maintenance studies that you mentioned that exercise is crucial. What is interesting from a psychological point of view is that people when they are going to weight loss need to identify the factor to which they attribute the weight loss and then when they are trying to maintain this, that is the thing they will go back to. Right now I am in the middle of weight loss interventions with obese breast cancer survivors. I have been working with 85 women for the past 12 months who were extremely sedentary baseline. They have also modified their diet, and have lost on average about 6.5–7 kg. They have modified their diet and from a metabolic point of view that is perhaps the major explanation for their weight loss. We got them exercising and now they are maintaining and so, as they are maintaining, they identify exercise as being the reason why they lost weight, and so it is kind of a psychological thing. The other aspect is that they feel so much better, they have a so much better body image, which in particular is problematic for women and for any group in which we are promising weight loss knowing fairly well that they are not going to get to their ideal weight. They come into the study and they think they are going to a svelte 54.5 kg at the end of the study, but our goal is that they lose 7–10% of body weight. How do we make them happy with losing that 7–10% body weight? Part of that is self-acceptance that they feel so much better, they feel so much more fit, they are really happier to be at a higher weight when they are physically active and they have a better body image. From a metabolic point of view we actually don't see an increase in lean body mass but they have less of a loss in lean body mass and they
are exercising while they are losing weight. You mentioned some of the practical strategies and what we know works. Some of my colleagues like Dr. Sallis and other people have worked hard to get very sedentary people exercising. We actually have a lot of pretty good strategies and one is that one size does not fit all of it. It is a very simplistic statement but there is usually something physically active that everybody likes to do, and it varies a lot from one person to another. Some people love a little quiet walk in the morning and others really have to be in social group settings, and other people, the busy housewives that you mentioned, having TV videos of step exercises and a home gym and even in the United States having one piece of cardiovascular equipment at home, most people sit down and look at TV in the evening or watch TV for an hour in the morning anyway, and if they are riding the bike while they are looking at TV that is something that is convenient, it is comfortable for them, they are home so they can be in their night clothes and it is not a problem. So we spend a lot of time trying to find something that is acceptable and that has the least burden. Then another aspect, and I am speaking mainly for women here, is that some of the studies have shown that one of the crucial issues is social support and that is why when we look at a family unit it is really the family that we are talking about getting more physically active, or if it is a wife that we are trying to get physically active then we have to involve the other members of the family and encourage them to have a group that has a lot of support for that behavior. With the diet changes, it is basically a lot of behavioral strategies which we start with a very small goal. In the United States we now have the Institute of Medicine report [1] and we are trying to get people to do up to 1 h/day of moderate physical activity. Most people can't go from nothing to an hour but if they start at 10 min/day and then they feel comfortable and they get accustomed to it, then we can do a kind of stepwise increase. If they are in a supportive environment that encourages them to continue or at least doesn't put barriers in the way, then our hope is they get to the point where they become habituated. Of these 85 women I have to say there were some correlates which are not catching on really fast but eventually at this point now in the study they are all exercisers, age was inversely related. The older women had a lot harder time and part of that was just mechanical and physiologic problems. We had 2 women who had to get knee replacement surgery, but we know that being physically active will reduce the pain. So there are a lot of problems to be dealt with depending on the target group, but here is my optimism and I think they are not insurmountable. You have to dispense some effort trying to figure it out rather than giving a blanket statement and then people feel like failures because it can suddenly start at behavior.

Dr. James: I think that if we don't have optimism then we are not going to make any progress at all. Dr. Allison, do you want to come back on that?

Dr. Allison: I would like to highlight that it is a brilliant description of how to try to create a microenvironment mixed to a toxic environment. What has been described, and these are excellent studies on how time must be spent nurturing people to cope with this bizarre environment that we have created. So we have a policy where we need to clone you a million times because we have got 1.7 billion people in the world who are overweight or obese and the idea that we could have the quality of care that you are providing is frankly in an Asian context ludicrous. That is what I am concerned with. I completely support what you are trying to do but you are talking about the strategic public health demands of the globe. I went on a tour with British parliamentarians 10 days ago around the US. We finally met one of the most senior members of the White House staff of the last administration. He said you have got to understand that in the United States you will find all the academics and all of us brilliantly describing what he said was downstream efforts: how in an individual capacity you are trying to help people to cope and you will never get upstream because in fact the whole of the motorcar industry, the oil
industry and so on, for example in terms of physical activity, has a complete grip on the
election of the policymakers. So you just literally don’t get any discussion.

Dr. James: I think here we see a very nice balance between the problems of policy
and the problem of individual programs. Dr. Rock, you wanted to come back on that.

Dr. Rock: Just one thing that I have to point out. When I say individualized, we can
actually do it in a more cost-effective way than just me sitting down and working with
subjects. We also use a lot of groups; there are ways that we can make it more cost-
efficient. The group effect is very good too because particularly older individuals share
these challenges and that kind of helps build the idea of social support. But I agree
with you that it is a microcosm because as I mentioned the other day, I think this toxic
environment is something that makes it unusual to be the person who can do this
rather than the average woman.

Dr. Go: I want to move the discussion on to practicality. Perhaps Dr. Basu will be
able to answer the questions about insulin sensitivity in relation to insulin resistance
during exercise. The other question is for Dr. Sitges-Serra: in people who have a gas-
tric bypass, what is the role of exercise in relation to what they are doing?

Dr. Basu: Clearly there is no doubt that exercise has been showed in several stud-
ies to improve insulin sensitivity and improve some of the components of metabolic
syndrome X. Talking about some of the practical aspects of exercise, as Dr. Rock was
saying, we encourage not only the community but the family to be involved. It is a team
effort, not just the mother or father but the children as well. I tried to do it in my fam-
ily too to get the kids off for a walk with the dog, and those things are certainly impor-
tant. A few other simple practical aspects that we employ is to ask our subjects to
invest in something called the pedometer which costs between USD 5 and 10, and to
target walking about 10,000 steps/day. They don’t have to walk the 10,000 steps all at
once but clip the pedometer on first thing in the morning and take it out at night and
see whether they walked the 10,000 steps. Any sort of activity is going to help, there
is no question about it. A few other things that we also ask our patients is when they
go grocery shopping, not to park as close as possible to the door of the grocery store
but to park far away, provided that weather allows them to, and then if possible carry
the groceries unless they are too heavy rather than push the grocery cart to the car.
So these are the simple, practical, cheap ways of doing it, and not everybody has to
run a lot as long as they are active physically. It certainly helped me to relax, helped
me to sleep better, no question about it.

Dr. Allison: These are all what Dr. James calls downstream efforts and are very
much dependent on these people coming into the orbit of people like yourself and
Dr. Rock, but in terms of society in general and politicians setting a circumstance to
induce exercise then we have a problem. What about the problem of the media mod-
els trying to create a fashion for exercise?

Dr. James: The only country that I know that managed to do this seems to be, and
I am far from an expert on this, but I gather that Norway is one of the few countries in
the world where there is not really a major socioeconomic relationship to voluntary activ-
ity and sports, and it appears to have actually put a system on the agenda. I would love
to hear what their primary features were, whereby ordinary people see that it is all right
for example to go out cross-country skiing, and I suspect that in line with your tirade
against selling off playgrounds and so on, I think that the community has to provide
essentially free community recreation spaces. In terms of Norway, the winter activities
and sports, everything is made in an extraordinary conducive way, not for the profes-
sional elite but for the ordinary person, and that is probably very important. The analys-
es throughout Europe and the United States and most Third-World countries that I
know have shown that in terms of physical activity, as Dr. Kopelman was describing, once
you get girls above the age of 8 there is a complete switch off. I think that the British
have a lot to be blamed for in terms of their colonial thoughts because the whole concept was boys play sports and you get this elite-type sports idea, and that is a total turn off for girls and women. When you do an analysis of what they want to do, they have a completely altered perspective on what they like doing. So girls don't like team sports unless they are brain-washed like some groups in Britain and the United States. They actually prefer to do it either with 2 or 3 people and social interaction is far more important in the testosterone-driven male-type approach. If you examine physical activity and sports in adult life it depends on what that person was taught at school, so the skills that we are teaching at school are usually completely inappropriate for the long-term well-being and opportunities for people who have different likes and dislikes. That is the message I have received.

Dr. Allison: You gave the example of Norway which is a country with a very small population, a huge area and colossally rich, probably the richest per capita country in the world from North Sea oil. Now I am going to ask our chairman to comment on the local situation which is rather different from that, a country which is going through the rural to urbanization process, and the growth of obesity. Please tell us something about the local scene?

Dr. Kijboonchoo: Just to follow the last comment about fashion. In Thailand it is now fashionable to do physical activity. The government says please come on Sunday, we are going to have an aerobic dance, and 50,000 people will come and dance. So that is one of the government policies.

Dr. James: Once a year or once a day?

Dr. Kijboonchoo: Once a year; not to mention injury. I think in terms of exercise it is even more difficult than diets. There is no natural urge to do exercise, you sit down relax and that is fine enough. But for food, if you don't eat you feel hungry, you have to have some food; even if you don't feel hungry you can eat, no problem. So to persuade people to do physical activity or exercise you have to know what is in their minds, why don't they exercise. I came across a study by Kearney et al. [2] in 1999 in EU countries. They tried to find out which items people thought were important for health. So they rated diet, fat intake, smoking, whatsoever, and physical activity. Believe it or not, physical activity came in last, only 18% said that physical activity is good for health and weight control. So the perception of physical activity must be fought as well. Even in Thailand, the strategy is that a group of people sits down and talks about physical activity starting with exercise because physical activity is any exercise, sport or even housework, or even walking to school. These kinds of things have to be incorporated into your lifestyle. Adherence is most important, you cannot go once a week to do a half marathon, that is impossible and causes injury. So in terms of exercise in our society we try to create the habit, to create the exercise habit as part of children's lives. So that is what we are trying to do because we know that when they become adolescents they won't listen to you. The boys might play sports because it is fun, it is challenging, but the girls just sit down and do nothing and if they want to control their weight they just go on a diet, and do not to talk about physical activity or exercise. So I think the exercise aspect is very challenging, how to persuade them to exercise and how to get them to adhere to exercise.

Dr. Allison: As Dr. James pointed out the other day you have solved part of your malnutrition problem, so perhaps we should come back in a few years time to see how you have solved the emerging problem of obesity. We were talking to your Princess the other morning about this and she was very well aware of this and the government policy, and pointed out that encouraging people to bicycle to work was fine but they wouldn't probably live very long on your roads. So the motorcar has a dual effect, it makes it dangerous to take exercise as well as being sedentary for the occupants of the car but dangerous for everybody else. Chairman, with your permission I will
create a bridge to the next subject. As one of the older members here I am well aware that from the age of 30 your muscle mass declines and your fat mass increases. Yesterday I was trying to buy a belt and I couldn't find one big enough. This is a really difficult problem because of course if your muscle mass is half what it was, your metabolic rate declines and your capacity to take exercise declines. So I am looking forward to what Dr. Biolo is going to say about that muscle mass and maybe its reflection upon the fat mass.

References
