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Nutrition interventions for the prevention of type 2 diabetes

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Diabetes mellitus is escalating globally and it is predicted that 200 million individuals worldwide will have diabetes by 2010 and 300 million by 2025. However, there is compelling evidence from many studies that for subjects with impaired fasting glucose or impaired glucose tolerance the presentation of type 2 diabetes can be delayed by lifestyle modification. The aim of the present review is to present a summary of lifestyle modification interventions that have included a dietary component in their overall diabetes prevention programme. Medline, allied health literature and diabetes journals were searched for peer-reviewed literature using the terms 'diet*' and 'diabetes' and 'intervention'. Inclusion criteria were: peer-reviewed studies from 1975 to 2008; a sample of at least fifty subjects; a healthy eating and/or physical activity component; prevention of diabetes as a primary goal. Generally, the participants were in a high-risk category for the development of diabetes. Outcomes were evaluated at two points in time (pre- and post-intervention) in terms of knowledge, behaviour change and clinical improvement, which included weight, blood pressure, BMI, body fat, waist circumference, waist : hip ratio and physiological and/or biochemical measures. Findings indicate that the most successful interventions combine individual dietary counselling with an activity component. Further factors predicting success are weight loss achieved, duration and intensity of the intervention and dietary compliance.

Nutrition interventions: Type 2 diabetes: Diabetes prevention: Lifestyle modification

With the global escalation of diabetes mellitus it is predicted that 200 million individuals worldwide will have diabetes by 2010[1] and 300 million by 2025[2]. The cumulative lifetime risk of developing diabetes for individuals born in the USA in 2000 is 38·5% for women and 32·8% for males[3]. However, there is impelling evidence from many studies that subjects with impaired fasting glucose or impaired glucose tolerance (IGT) can be delayed by lifestyle modification[4].

The Nurses' Study, in which 84 941 female nurses were followed from 1980 to 1996 was one of the first cohorts to provide evidence on the importance of lifestyle and development of type 2 diabetes[5]. A low-risk group for development of diabetes was defined as one with five variables: BMI $<25\,kg/m^2$; diet high in cereal fibre and PUFA and low in *trans*-fatty acids with a low glycaemic load; moderate-to-vigorous physical activity (PA) for ≥ 30 min/d; not smoking; consumption of on average ≥ 15 ml spirits or ≥ 125 ml wine daily. Furthermore, overweight or obesity was found to be the single most important predictor of diabetes. Lack of PA, unhealthy diet, smoking, and abstinence from alcohol were all shown to be associated with an increased risk of diabetes even after adjusting for BMI.

It is generally accepted that β-cell dysfunction and insulin resistance are major factors involved in development of diabetes. It is proposed that subjects at risk of diabetes have β-cell dysfunction before they develop IGT, while insulin resistance can be explained by the presence of obesity[6]. Furthermore, insulin resistance in turn accelerates the progression to diabetes in those subjects with a propensity to β-cell failure[6]. Data on lifestyle modification

Abbreviations: IGT, impaired glucose tolerance; PA, physical activity.

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interventions suggest that reducing insulin resistance protects and preserves β-cell function.

The primary objective of the present review is to assess lifestyle interventions with a dietary component that have aimed at the prevention of type 2 diabetes in order to make practical and sustainable recommendations for primary prevention.

Relationship between lifestyle risk factors and the development of diabetes

Weight status

Overweight–obesity has been recognised as one of the strongest risk factors for the development of diabetes. Prediabetes (IGT and impaired fasting glucose) dramatically increases the risk of diabetes. Consequently, weight loss for individuals with prediabetes may delay or prevent the progression to type 2 diabetes[7]. Even modest weight loss has been associated with a reduced risk of diabetes.

Diet

Numerous studies have shown a decrease in insulin sensitivity with diets high in fat while some have demonstrated positive associations between intake of saturated fat and hyperinsulinaemia[8]. The Nurses' Health Study has additionally reported a positive association between *trans*-fats (*trans*-fatty acids) and development of diabetes[5]. Furthermore, the Nurses' Health Study and the Health Professional's Follow-up Study has found an inverse relationship between cereal fibre and development of diabetes[9]. Hence, whole-grain intake has been recommended as part of lifestyle modifications.

Physical activity

Numerous studies and specifically the Health Professional's Follow-up Study[10] have shown that individuals with a physically-active lifestyle are less likely to develop IGT or type 2 diabetes mellitus than those who are sedentary. Results suggest that exercise training increases tissue sensitivity to insulin[9].

Cigarette smoking

Numerous studies have shown that cigarette smoking may increase the risk of diabetes[9]. Smokers tend to have a higher HbA1c concentration. In the Nurses' Study it was shown that women who smoke twenty-five or more cigarettes per d have a 42% greater risk of developing diabetes[11].

Lifestyle modification of diet, physical activity and weight status

The European Prospective Investigation into Cancer was a prospective study that has evaluated the association between the incidence of diabetes in 25 155 adults aged 40–79 years and the achievement of five behavioural goals: BMI $<25\,kg/m^2$; PA >4 h/week; total fat <30% energy intake; SFA <10% energy intake; fibre intake ≥15 g/4184 kJ. Follow up was at a mean of 4·6 years[12]. Their results show that only 20% of participants met three or more goals and diabetes incidence was inversely related to the number of goals achieved ($P<0{\cdot}0001$). None of the participants who met all five goals developed diabetes. The researchers estimate that if the entire population were able to meet one or more goals the total incidence of diabetes would be predicted to fall by 20%.

Methods

The present objective was to evaluate intervention research programmes that were aimed at preventing type 2 diabetes mellitus. Inclusion criteria were: peer-reviewed studies from 1975 to 2008; a sample of at least fifty subjects; a healthy eating and/or PA component; prevention of diabetes as a primary goal. Generally, the participants were in a high-risk category for the development of diabetes or had prediabetes. Studies of subjects with diabetes were not included nor were interventions aimed only at weight loss or CVD. Studies with pharmacological agents were only included if there was a lifestyle modification arm. Outcomes were evaluated at two points in time (pre- and post-intervention) in terms of knowledge, behaviour change (dietary intake and behaviour) and clinical improvement, which included non-invasive measures (weight, blood pressure, BMI, body fat, waist circumference or waist:hip ratio and physiological and biochemical measures).

A search was undertaken on Medline with the terms 'diabetes', 'intervention' and 'diet*' and/or 'physical activity'. The primary diabetic journals were also individually searched on line: *Diabetes*; *Diabetes Care*; *Diabetic Medicine*; *Clinical Diabetes*; *Diabetologia*; *The Diabetes Educator*; *Diabetes Research and Clinical Practice*; *Diabetes and Metabolism*; *Diabetes, Obesity and Metabolism*. The resulting 634 articles were then individually scanned to ensure that they complied with the search criteria, resulting in 113 publications on interventions. The final group comprised thirty-four interventions complying with the search and inclusion criteria (Table 1). Of these interventions four are large cohort studies, four are in ethnic minorities, eight are in schools and the rest (seventeen) involve adults (in an overweight, high-risk or IGT category). The search also yielded six reviews on diabetes prevention.

Existing reviews on interventions for diabetes prevention

A few reviews have evaluated the effectiveness of lifestyle modification and prevention of diabetes. It has been found that Orlistat, sibutramine and metformin appear to be beneficial in the treatment of obesity in adults[13]. PA appears to improve weight loss when added to a dietary regimen. Low-fat diets together with increased PA are associated with prevention of type 2 diabetes and hypertension.

In a review of school-based diabetes prevention programmes[14] most of the six programmes were aimed at minority groups in the USA and Canada[15–20]. All these studies were considered to be pilot studies and were done in one or two schools and few had control groups or randomly-assigned subjects to treatment. Two of the

Table 1. Summary of diabetes prevention studies

Large cohort studies	
Diabetes Prevention Program[23–26]	*n* 3234, mean age 51 years, mean BMI 34·0 kg/m^2, non-DM, elevated fasting and post-load plasma glucose concentrations Design: RCT, 3 years follow up Aim (for lifestyle modification programme): 7% weight loss and ≥150 min PA per week; goal achievement was assessed at the end of the sixteen-session core curriculum Intervention: RCT with three groups: metformin (850 mg twice daily); lifestyle modification programme; placebo Results: Incidence of diabetes was 11·0, 7·8 and 4·8 cases per 100 person-years in the placebo, metformin and lifestyle groups respectively Conclusions: lifestyle changes and treatment with metformin both reduced the incidence of diabetes in individuals at high risk; the lifestyle intervention was more effective than metformin
Da Qing IGT and Diabetes Study[27,28]	577 with IGT, age >25 years, in thirty-three local health clinics in China Design: RCT over 6 years; examinations were conducted at 2-year intervals over a 6-year period Aim: To determine whether diet and exercise can reduce the incidence of DM Intervention: randomised by clinics into four groups: group A, control group, received general information about diabetes and IGT, also given brochures with instructions for diet and increased PA; group B, diet, received individual counselling by physicians concerning daily food intakes, sessions conducted weekly for 1 month, monthly for 3 months, and then once every 3 months for the rest of the study period; group C, exercise, taught and encouraged to increase the amount of PA, counselling sessions were the same as those of group B; group D, combined diet and exercise, received counselling similar to group B and C Results: each of the active intervention groups differed significantly from the control clinics; both IR and IS were significantly associated with the development of DM; lifestyle interventions were more effective in those with lower IR and higher IS; diet + exercise intervention resulted in a significantly lower incidence of DM Conclusions: both IR and β-cell function were predictors of DM in Chinese individuals with IGT; lifestyle intervention reduced the incidence of DM over a 6-year period
Multiple Risk Factor Intervention Trial[39]	12 866 men, no DM or IGT, age 35–57 years, at risk for CVD, from twenty-two US clinical centres Design: RCT, 6–7 years follow up Intervention: men in the intervention group were counselled to change diet (reduce saturated fat, cholesterol and energy intakes), stop smoking and increase PA Results: in non-smokers DM incidence was 18% lower in the special intervention compared with the usual-care group; in smokers incidence was higher in special intervention than in the usual-care group; weight and BMI was higher among non-smokers *v.* smokers Conclusion: The favourable effect of the special intervention on DM incidence resulted from more favourable weight changes
Finnish Diabetes Prevention Study (DPS)[29–34]	*n* 522, 40–64 years, with IGT, high risk and BMI >25 kg/m^2 Design: RCT over 4 years; with a post-intervention follow up for a median of 3 years with median total follow up of 7 years Aim: to determine whether diet and exercise can reduce the incidence of DM in those with IGT Intervention: intensive intervention group, given detailed individualised counselling to achieve lifestyle goals (weight reduction of ≤5%, <30% daily energy intake from saturated fat, fibre intake ≥15 g/4184 kJ (1000 kcal)); had seven counselling sessions with study nutritionist during the first year and every 3 months thereafter; median no. of counselling sessions per participant was 20; control group, general verbal and written health behaviour information Results: during the total follow up, the incidence in the intervention group was lower compared with that in the control group; reduction in type 2 DM incidence was directly associated with changes in lifestyle Conclusions: lifestyle intervention in individuals at high risk of type 2 DM resulted in sustained lifestyle changes and a reduction in DM incidence, which remained after the individual lifestyle counselling, was over
School programmes	
Kahnawake Schools Diabetes Prevention Project[16,40–42]	Intervention group: 458 children, grades 1–6 (6–12 years of age); two elementary schools; control group: 199 children at one school; Mohawk communities Design: mixed longitudinal and cross-sectional study of 3 years with intervention and control groups; evaluation also at 8 years Aim: in the long term to reduce future occurrence of type 2 DM; in the short-term to reduce the prevalence of obesity, high-energy and high-fat diets and physical inactivity Intervention: based on Ottawa charter, precede–proceed model and social learning theories; intervention group, sixty-three specific interventions including a health education programme, community-based activities, environmental changes, i.e. food service at schools Results: Repeated measures between 1994 and 2002 showed increases in BMI and skinfolds; PA, fitness and TV watching showed improvements by 1999 but these improvements were not maintained by 2002; key high-fat high-sugar foods decreased but so did fruit and vegetables Conclusion: Long-term results disappointing

Table 1. (Continued)

NEEMA*[18,73]	Fifty-eight children, 4th grade from six schools, >40% African-American enrolment Design: pretest and post test, single sample design, 7 weeks Aim: the objectives were to decrease dietary saturated fat intake, increase fibre intake and increase PA in African-American children; regarded as pilot study for African-Americans Intervention: health class and physical education curriculum sessions, school cafeteria intervention, family programme, after-school health club; based on social cognitive and social ecological theory and culturally adapted Results: Fitness laps increased, fasting capillary glucose and percentage body fat decreased Conclusion: The NEEMA pilot study provided teacher feedback useful for revising the NEEMA health curricula and positive preliminary impact of the PA class on children's fitness and blood glucose levels
Zuni Pueblo of New Mexico[45]	Seventy-two Zuni pupils, thirty-seven Anglo pupils (English-speaking Caucasians), two high schools, native American youth Design: multiyear cross-sectional evaluation of 4 years, comparison of Zunis with Anglos Aim: To change behaviours known to influence DM risk, i.e. food intake, PA and knowledge of DM Intervention: development of a youth fitness centre with equipment and instructors at the school; school food service improved healthy foods available and water cooler bottles replaced sugared soft drinks; DM prevention was addressed by the school curriculum Results: Plasma glucose values normal at baseline and no differences between Zuni and Anglos; fasting and 30 min insulin were significantly higher in Zuni at baseline but decreased; at 3 years males (only) values were same as Anglos Conclusion: intervention can improve insulin levels
Junior high school[20]	Seventy-three children (forty-nine in intervention group, twenty-four in control group), 8th grade, one junior high school, predominantly Hispanic Design: RCT Aim: to evaluate the effects of a 3–4 month intervention of health, nutrition and PA on DM risk Intervention: classroom curriculum of fourteen sessions of 45 min each on nutrition education and PA. Three PA sessions per week Results: reduction in body fatness, insulin resistance and C-reactive protein and IL-6 Conclusion: short-term intervention is beneficial and affects multiple DM risk factors
Sandy Lake Diabetes Prevention Programme[15]	122 Ojibway-Cree children; 3–5th grade students from a Native North American reserve in Ontario, Canada Design: pretest and post-test, single sample design, 2 years Aim: focus on knowledge and skill development related to healthy eating, PA and DM education Intervention: mainly a DM prevention curriculum of sixteen weekly 45 min teacher-led sessions; a family and peer component, environment and school meal components; based on social cognitive and social ecological theory and culturally adapted Results: increases in dietary intention, preference, knowledge and self-efficacy and in curriculum knowledge scale after the intervention; % energy from fat decreased in boys; increased exposure to intervention was associated with meeting the fibre recommendation Conclusion: intervention associated with improved knowledge and psycho-social factors related to healthy eating and dietary fibre intake
Bienestar (Well-Being) Health Programme: Diabetes Risk-Factor Prevention Pilot Program[43,44]	1419 children (intervention group, 713 from thirteen schools; control group, 706 from fourteen schools); 4th grade; predominantly Mexican-American Design: RCT, 7 months Aim: the objectives were to decrease saturated fat intake, increase dietary fibre intake and increase PA in Mexican-American children Intervention: health class and physical education curriculum (thirty-two sessions), school cafeteria intervention, family programme, after-school health club; based on social cognitive and social ecological theory and culturally adapted Results: mean fasting capillary glucose levels decreased in intervention schools and increased in control schools; fitness scores and dietary fibre intake increased in intervention group and decreased in control group; percentage body fat and dietary SF intake did not differ between groups Conclusion: some positive results, but long-term benefits, translation and cost-effectiveness need to be evaluated
Action research[47]	3601 pupils, five schools; 7–10 years; and 11–15 years; predominantly South Asian Design: baseline data and follow up Intervention: no preset intervention; focus groups conducted with children and staff at schools and results given to them as feedback; focus groups were about possible interventions and barriers Results: raised awareness of healthy lifestyle issues; some barriers identified to making healthy lifestyle choices Conclusion: action research may have a modest impact on lifestyle behaviours

Jump into Action[48]	1114 students, 5th grade (10–12 years), thirty-nine teachers, nineteen schools (intervention group thirteen schools, control group, six schools), Hispanic and economically disadvantaged Design: quasi-experimental, 3 months Aim: to improve knowledge, self-efficacy and behaviours in relation to DM prevention Results: increased knowledge and self-efficacy for DM prevention; increased diet and PA behaviours at post test; no differences between groups Conclusion: very short intervention and no long-term results available
Indigenous communities	
Indigenous American Indian population in British Columbia[49]	105 high-risk individuals Design: quasi experimental, community-based 2 year programme targeted at the Indian population of rural Okanagan region in Canada Intervention: single intervention community matched to two comparison communities; intervention community, workers conducted interviews of individuals with or at risk for DM for 7 months (pre-intervention phase); programme used a participatory approach and included strategies to improve the environment and to change behaviour; cohorts tracked over a 16-month intervention phase; cross-sectional population surveys of DM risk factors were conducted at baseline and post intervention Results: the project yielded few changes in quantifiable outcomes, which was thought to be a result of the short planning and intervention phases and the level of penetration was too limited
Pilot study in Pima Indians[3]	*n* 95, obese, normoglycaemic, age 25–54 years Design: RCT, 12 months Aim: to determine the relative effectiveness of two interventions in altering risk factors for DM Intervention: two lifestyle Pima interventions: action (intervention group), structured activity and nutrition; pride(control group), activities emphasising Pima history, received basic printed information on healthy eating and exercise habits Results: after 12 months increased physical fitness in both groups; BP, BMI, 2 h glucose and insulin all increased significantly in action members compared with pride members Conclusion: sustaining adherence in behavioural interventions over a long term was challenging; Pima Indians may find a less-direct less-structured approach and more participative intervention more acceptable than a direct and highly-structured approach
Church-based Programme[50]	*n* 78, South Auckland, New Zealand Design: open-prospective non-RCT Aim: to evaluate the impact of a comprehensive DM-related lifestyle programme on DM knowledge, exercise habits, dietary habits and body size among a Samoan church congregation Intervention: two church congregations (one intervention and one control church), intervention congregation coordinated by a DM nurse specialist and one of two Samoan women, one as a DM fieldworker and the other as an aerobics instructor; four DM-awareness sessions held as part of a church service with the DM educator as the main presenter; also formed exercise groups that included sitting exercises, low-impact aerobics, walking and sports; sessions held weekly for the first year and twice weekly thereafter Results: reduction in waist circumference and consumption of fatty foods reduced in the intervention church; increased DM knowledge and an increase in the proportion exercising regularly Conclusion: DM risk-reduction programmes based on lifestyle change, DM awareness and empowerment of high-risk communities can significantly reduce risk factors for future type 2 DM
Looma Healthy Lifestyle[51]	*n* 199, over 4 years in Western Australia, adults aged $\geq$15 years Design: Cross-sectional risk-factor surveys Aim: To evaluate the effectiveness of a community-directed intervention programme to reduce CHD risk through dietary modification Intervention: intervention process included store management policy changes, health promotion, and nutrition education aimed at high-risk individuals; programme focused initially on a group of individuals at high risk of DM and CHD, consisted of education sessions by a DM nurse educator Results: significant reduction in the prevalence of hypercholesterolemia; significant increases in plasma concentrations of α-tocopherol, lutein and zeaxanthin, cryptoxanthin and β-carotene across the population Conclusion: the community-directed intervention programme reduced the prevalence of CHD risk factors related to diet

Table 1. (Continued)

Overweight and high-risk adults	
Eat Well, Live Well Programme[52]	*n* 294, African-American women, age 25–55 years, no DM, not pregnant, BMI >27 kg/m^2 Design: experimental and control group design, before and after study Aim: reduce dietary fat intake and increase low-fat dietary patterns Intervention: 3-month intervention; pre- and post and 3 month follow-up interviews; delivered by dietitians, social workers and health educators over a 4-month period Results: reductions in fat intake among women in the treatment group compared with women in the control group, maintained at 3 months; changes in dietary patterns greater in the treatment group; significant difference between the treatment and control groups in all outcome variables Conclusion: stage-based intervention conducted by trained peer leaders in the community is effective in changing dietary patterns and reducing fat intake among low-income African-American women
Vasterbotten Intervention Programme[53]	186 subjects with IGT and obesity Design: RCT, follow-up carried out after 12 months Aim: to assess the effects of lifestyle intervention on cardiovascular risk factors in general and especially on fibrinolysis Intervention: included a low-fat high-fibre diet and regular PA; intervention group took part in a 1-month learning and training session using different behavioural modification techniques and conducted in a full-board wellness centre; control group had 1 h counselling session with a specially trained nurse Results: intervention group had a mean weight decline by 1 year of 5·4 kg compared with 0·5 kg for the control group; O_2 consumption for intervention group increased by 10% *v.* 1% for control group; plasminogen-activator inhibitor-1 activity significantly decreased by 31% for intervention group *v.* 12% for the control group; tissue-type plasminogen activator antigen reductions were 14% *v.* 6% for intervention and control groups respectively Conclusions: the study showed that an intense lifestyle programme had sustained beneficial effects on fibrinolysis
Overweight individuals[54]	*n* 154, 30–100% above ideal body weight, non-DM, family history of DM, age 40–55 years, BMI 35·9 (SD 4·3) kg/m^2; Design: RCT over 2 years Aim: to assess the effect of lifestyle intervention over 2 years on changes in weight, CHD risk factors and incidence of DM in overweight individuals with a parental history of DM Intervention: three intervention groups: group 1: diet condition, attended weekly for 6 months then two weekly for the next 6 months meetings led by a behaviour therapist and a dietitian; group 2, exercise condition, meetings with a behaviour therapist and an exercise physiologist; group 3 diet + exercise, meetings equivalent in frequency and length to the diet or exercise conditions; control group, no intervention, given a copy of the learn manual with information on healthy eating, exercise and behavioural strategies for weight loss Results: at 6 months the groups differed significantly on measures of eating, exercise, and fitness; weight loss in the diet and diet plus exercise groups were significantly greater than in the exercise and control conditions; differences between groups in risk of developing DM were of border line significance ($P = 0·08$); strongest predictors for DM incidence were IGT (positively related to risk of DM development) and weight loss (negatively related) from baseline to 2 years Conclusions: interventions were not effective in producing long-term effects in behaviour, weight or physiological variables; however, weight loss from 0–2 years reduced the risk of developing type 2 DM
GOAL[55]	352 middle-aged participants at a high risk of developing type 2 DM from sixteen health centres in Finland Design: longitudinal pre- and post-test study Aim: to evaluate whether the results obtained in the DPS could be replicated in routine health care; objectives used in the DPS were implemented Intervention: six group counselling sessions by public health nurses and physiotherapists; lifestyle outcomes analysed from self reports; comparison with DPS Results: after 1-year follow up; 20% of participants achieved four of five key lifestyle outcomes; compared with the DPS success rate in the GOAL sample was significantly decreased for the PA but higher for the fibre objective; weight loss attainment lower in GOAL than in DPS Conclusions: the trial demonstrated that lifestyle counselling can be effective and feasible in real world situations

Relatives of individuals with DM[56]	Seventy-seven healthy first-degree relatives, age 25–55 years Design: 2-year follow-up intervention study; subjects allocated to one of three groups Aim: to study the long-term (year 1 and 2) effect of a lifestyle intervention on non-DM first-degree relatives of patients with type 2 DM Intervention: one group (diet group; D) received dietary education group sessions, 1–2 weeks apart at the start of the study; for the second group (diet and exercise group; DE) the diet was based on current nutrition recommendations including intake of fatty fish and low glycaemic-index foods; the third group was the control group (c); groups D and DE received intensive follow-up through unannounced telephone interviews in the first 4 months Results: dietary changes were significant at 1 year, and to a large extent sustained at 2 years; PA increased in the least-active subjects in group DE; group DE decreased body weight by 2·7% ($P<0·029$) and increased HDL *v.* controls ($P<0·037$); at 1 year reduction in the LDL-cholesterol : HDL-cholesterol in group D; at 2 years cholesterol levels were reduced within group D compared with group DE; fasting insulin reduced within group DE compared with group D Conclusions: positive changes in lifestyle, blood lipids and fasting insulin can be achieved and maintained in a non-DM population at risk of type 2 DM after 2 years
Adults with IGT SLIM[57,58]	*n* 114, BMI $\geq 25\,kg/m^2$ (mean $29·4\,kg/m^2$), age >40 years, OGTT 7·8–12·5 mM, fasting glucose <7·8 mM, Maastricht area in The Netherlands Design: RCT over 3 years Aim: to evaluate the effect of a combined diet and PA intervention programme on glucose tolerance in a Dutch population at increased risk for developing type 2 DM Intervention: intervention group, regular dietary advice, stimulated to increase PA, subjects encouraged to increase their PA to ≥30 min/d on 5 d/week; control group, leaflet about health and diet and increased PA with no individual advice or programmes provided Results: after 2 years (analysis based on eighty-eight subjects; per protocol analysis) subjects in the intervention group had reduced BMI, waist circumference and saturated fat intake and improved their aerobic capacity; 2 h plasma glucose decreased from 8·7 mM to 8·0 mM and increased from 8·6 mM to 9·4 mM for the intervention and control groups respectively; subjects adherent to both diet and exercise showed the largest reduction in 2 h plasma glucose levels Conclusion: changes in dietary habits and PA have shown to reduce the incidence of DM; early interventions are of paramount importance to those at risk for developing DM
Lifestyle intervention in Japanese males[59]	458 subjects with IGT from Toranomon hospital, Tokyo, Japan, BMI $<24·0\,kg/m^2$ for control group and $<22·0\,kg/m^2$ for intervention group; fasting plasma glucose <1400 mg/l Design: RCT over 4 years Intervention: intervention group, intensive lifestyle intervention, detailed instructions on lifestyle repeated every 3–4 months during hospital visits; control group, standard intervention Results: after 4 years a significant reduction in risk of DM by 67·4%; weight decrease in both groups but significantly greater in the intervention group; subjects with a low insulinogenic index† developed DM at a significantly higher rate than those with a normal index Conclusion: lifestyle intervention designed to achieve and maintain a ideal body weight (BMI $<22\,kg/m^2$) is an effective means of reducing incidence of type 2 DM in men with IGT
Japanese male workers[60]	*n* 173, age 35–70 years, workers at high risk for type 2 DM from a centre in Tokyo, Japan Design: RCT with 1 year follow up Aim: to assess the effectiveness of a new dietary education (NDE) programme in reducing plasma glucose levels Intervention: intervention group, NDE through individual counselling by a nutritionist; NDE based on dietary practices by participants, obtained by use of an FFQ; control group, conventional dietary education Results: intervention group had a significantly lower energy intake at dinner daily than the control group; intervention group had a decreased 2 h plasma glucose after 1 year whereas there was an increase in the control group with a significant percentage change Conclusions: the NDE was shown to reduce glucose levels in subjects at high risk for type 2 DM
Malmo Feasibility Study[35]	6956 males from Malmo, Sweden, age 47–49 years Design: 5-year screening including an initial 6 months (randomised) pilot study, consisting of dietary treatment and/or increase of PA Intervention: emphasis on lifestyle changes; group A, patients with newly-detected type 2 DM; group B, with IGT, enrolled in the DM prevention programme; group C, non-randomised, not enrolled in the prevention programme, IGT informed their condition; group D, normal control group with normal OGTT Results: BP, lipids and hyperinsulinaemia were reduced; improvement in glucose tolerance was correlated with weight reduction and increased fitness Conclusion: long-term intervention in the form of diet and PA is feasible even on a large scale and substantial metabolic improvement can be achieved that may contribute to prevent or postpone manifest DM

Table 1. (Continued)

Reduced-fat diet[61]	176 participants with glucose intolerance, 2 h blood glucose (7·0–11·0 mmol), age ≥40 years Design: 5-year follow up of a 1-year RCT Aim: to determine whether reducing dietary fat would reduce body weight and improve long-term glycaemia in individuals with glucose intolerance Intervention: intervention group, advised to consume reduced fat or *ad libitum* diet, small-group sessions conducted monthly for education on reducing dietary fat intake, personal goal setting and self-monitoring; control group, usual diet, received only general dietary advice about healthy food choices at the start of the trial Results: total energy intake and the absolute intake of fat decreased in the intervention group; changes in the other micronutrients and fibre were not different in both groups; increased PA in intervention group *v.* control group; decrease in BMI in intervention group during the 1 year and this was sustained for 3 years; compliers in intervention group showed significantly lower blood glucose levels at fasting, and 2 h at 5 years compared with the control group Conclusion: an intervention aimed at reducing dietary fat alone improved body weight and glucose tolerance over a 2–3 year period but was only sustained in more compliant participants
Diet and PA intervention for adults with IGT[62]	Seventy-eight subjects with IGT, age 24–75 years, undertaken at clinical research centre, Newcastle upon Tyne, UK Design: RCT over 2 years Aim: to evaluate the effectiveness of lifestyle interventions in individuals with IGT Intervention: based on 'stages of change' model of behaviour change; intervention group, regular motivational counseling from a dietitian and physiotherapist; control group, no dietary or physical advice Results: after 2 years a decrease in total fat consumption, decrease in BM and IS improved (0·52 (95% CI 0·15, 0·89) %/min) in the intervention group Conclusions: findings complement the DPS and the American Diabetes Prevention Study, both of which tested intensive interventions by showing that pragmatic lifestyle interventions result in improvements in obesity and whole-body IS in individuals with IGT
Japanese-Americans with IGT[63]	Sixty-four Japanese-American men and women with IGT Design: RCT over 2 years Aim: to determine whether diet and endurance exercise improved adiposity-related measurements in Japanese-Americans with IGT Interventions: group A (intervention), American Heart Association (AHA) step 2 diet (% total energy; <30 as fat, <7 as saturated fat, 55 as carbohydrate and <200 mg cholesterol daily) + endurance exercise for 1 h/d three times per week; group B (control), AHA step 1 diet (% energy; 30 as fat, 10 as saturated fat, 50 as carbohydrate and <300 mg cholesterol daily) + stretching exercise three times per week Results: after 6 months group A had a significantly greater reduction in percentage body fat, BMI, subcutaneous fat (abdomen, thigh, thorax) and skinfold thickness at the bicep and triceps; sustained positive outcomes for the last 18 months Conclusions: diet and exercise improved BMI, body composition and body fat distribution and thus may delay or prevent type 2 DM in Japanese-Americans with IGT
Women in Melbourne[64]	200 women with IGT, Design: RCT Aim: intensified dietary modification for prevention of progression to DM in women with IGT Intervention: Intensified (intervention group) *v.* routine dietary advice (control group) Results: incidence rate of DM was 6·1 in the intervention group and 7·3 in the control group. Over all, there was a return to normal glucose tolerance in 44% of women Conclusions: BMI, fasting and 2 h glucose at trial entry were significantly associated with increased risk of DM
Interventions using technology	
Email intervention[65]	2121 employees with email access Design: RCT over 12 weeks Aim: to evaluate a 12-week workplace email intervention designed to promote nutrition and PA behaviour Intervention: intervention group received one nutrition and one PA email message per week; control group received none Results: intervention group reported better results on self-efficacy, intentions and changes in behaviour related to PA; also more favourable reports on nutrition-related behaviours; however, effect size values for all significant differences were small Conclusions: email is a promising mode of delivery for promoting PA and nutrition in the workplace

Internet weight-loss programme[69]	*n* 808, males and females, age 19–71 years, Design: internet-based weight-loss programme with emphasis on PA and dietary modifications and a short-term qualitative evaluation of the programme was done Intervention: weight-loss intervention was a 10-week interactive internet programme that was self-administered by each participant, independent of the direct involvement of healthcare professionals Results: 808 participants who registered for the programme 683 completed at least one online health risk appraisal; 56% of the clients agreed that the programme helped them achieve their goals Conclusions: the findings indicate that the general public will use an internet-based weight-loss programme that involves PA and dietary behavioural interventions-findings have relevance for development of health promotion policies and practices

RCT, randomised controlled trial; PA, physical activity; IGT, impaired glucose tolerance; DM, diabetes mellitus; IR, insulin resistance; IS, insulin sensitivity; BP, blood pressure; GOAL, Good Ageing in Lahti Region; SLIM, Study on lifestyle-intervention and impaired glucose tolerance Maastricht; OGTT, oral glucose tolerance test.

*'Wellness' in Swahili.

†Area under the curve of insulin level:area under curve of the glucose level during the OGTT.

programmes were successful in improving insulin sensitivity, while others improved dietary or social behaviours. Only two programmes involved the community and/or environment.

A meta-analysis has evaluated nine randomised controlled trials of lifestyle education to patients at high risk of developing diabetes[21]. Lifestyle education intervention was found to reduce 2 h plasma glucose by 0·84 mmol/l compared with the control group. The 1-year incidence of diabetes was found to be reduced by about 50 % (relative risk 0·55).

In a review of recent trials designed to test whether lifestyle, pharmacological interventions or both reduce the incidence of type 2 diabetes[22] it was reported that four major studies (Diabetes Prevention Program[23–26] in the USA; Da Qing IGT and Diabetes Study[27,28] in China; Finnish Diabetes Prevention Study[29–34] in Finland; Malmo Feasibility Study[35] in Sweden) of lifestyle intervention have found a clear benefit for diet and exercise intervention compared with usual care.

A recent review of the literature on the influence of lifestyle and diet in the development of diabetes has provided evidence that type 2 diabetes mellitus, which comprises 95 % of diabetes cases, is a preventable disease[9]. It concludes that in order to reduce the burden of this devastating disease, prevention programmes must target not only the affected individuals but also families, workplaces, schools and communities.

Sixteen evidence-based research intervention studies over the last 10 years that have successfully targeted modifiable risk factors for obesity in children and adolescents has been summarised[36]. These interventions have shown the effectiveness of health education, dietary modification, a decrease in sedentary behaviour and incorporation of moderate-to-vigorous physical activity in schools in reducing unhealthy behaviours among youth.

Findings from trials of pharmacological agents such as metformin, acarbose and troglitazone have been encouraging[37]; however, the American Diabetes Association recommend that drug therapy should not be used routinely to prevent diabetes until there is more information on the cost-effectiveness of such interventions[38].

Diabetes prevention interventions

Large cohort studies

Four studies have clearly illustrated the positive health benefits of lifestyle modification in the prevention of type 2 diabetes. These studies were randomised controlled trials that included high-risk individuals, had large samples and a long follow up over time.

Diabetes Prevention Program. The Diabetes Prevention Program Research Group have reported on a 3-year lifestyle intervention programme[23,24]. A total of 3234 participants without diabetes (mean age 51 years) were randomly assigned to a placebo, metformin (850 mg twice daily) or lifestyle programme group. Initially, there was also a troglitazone therapy arm. However, because of concern with its liver toxicity it was discontinued. The lifestyle group had goals of ≥7 % weight loss and ≥150 min

PA/week. Goal achievement was assessed at the end of a sixteen-session core curriculum over the first 6 months. Thereafter, the participants attended at least once every 2 months for individual or group sessions.

After an average follow up of 2·8 years the incidence of diabetes was found to be 11·0, 7·8 and 4·8 cases per 100 person-years in the placebo, metformin and lifestyle groups respectively. The incidence was reduced by 58 (95% CI 48, 66) % in the lifestyle group and by 31 (95% CI 17, 43) % in the metformin group. Furthermore, it was projected that incorporation of the Diabetes Prevention Program intervention into clinical practice in five developed countries would lead to an increase in diabetes-free years of life, improvements in life expectancy and cost savings[25].

Analysis of another arm of the intervention (*n* 1079) has shown that weight loss is the dominant predictor of reduced diabetes incidence; for every 1 kg weight loss there was a 16% reduction in risk, adjusted for changes in activity and diet[26].

Da Qing IGT and Diabetes Study. In 1986 a total of 110 660 adults from thirty-three health clinics in the city of Da Qing in China were screened for IGT and type 2 diabetes[27,28]. Of these individuals 577 subjects who were classified as having IGT were randomly assigned to a clinical trial or a control group over a period of 6 years. There were three treatment groups: diet; PA; diet + PA. At 6 years the cumulative incidence of diabetes (%) was found to be 67·7; 43·8, 41·1 and 46 in the control group, diet group, PA group and diet + PA groups respectively. Furthermore, it was reported that the diet, PA and diet + PA groups were associated with 31, 46, and 42% reductions in risk of developing diabetes respectively. Both insulin resistance and β-cell function were found to be predictors of diabetes in Chinese with IGT.

Multiple Risk Factor Intervention Trial. A 2-year randomised controlled trial was undertaken in 11 827 men aged 35–57 years (without diabetes or IGT) and they were followed for 6–7 years[39]. The intervention group received nutritional counselling aimed at reducing saturated fat and cholesterol intake. Smokers participated in a cessation programme. Men who were ≥115% expected weight were required to follow a moderate-PA programme and to reduce dietary energy intake. Results indicate a significantly higher hazard ratio for diabetes among smokers (1·26) *v.* non-smokers (0·82). Their results imply that in non-smokers a lifestyle intervention programme comprising nutrition counselling to produce reductions in weight and serum cholesterol reduces the risk for diabetes.

The Finnish Diabetes Prevention Study. An intensive diet and PA programme measured the effectiveness of preventing or delaying type 2 diabetes in 523 overweight subjects with IGT aged 40–64 years[29–34]. An intensive individualised programme was presented by nutritionists during individual sessions. The objectives were: to decrease fat to <30% energy intake; SFA <10% energy intake; minimum of 15 g fibre/4184 kJ; to have ≥4 h PA/week; >5% weight reduction. At 1 year most of the clinical variables were found to be different when compared with the control group. At 1 and 2 years 43·4 and 41·8% of participants were found to have maintained a weight loss of ≥5 kg and this loss was maintained at 2 years. Most of the beneficial changes in risk factors were also maintained at 2 years.

After 3 years individuals with a low-fat intake and high-fibre intake were found to have lost more weight compared with those consuming a high-fat low-fibre diet (3·1 kg *v.* 0·7 kg). Hazard ratios for diabetes incidence at 4·1 years were found to be highest for fat intake and saturated fat intake[34].

School programmes

Kahnawake Schools Diabetes Prevention Project. This project is a 3-year primary diabetes prevention programme targeted at children from grade 1 through to grade 6 (6–12 years of age) in a Mohawk community near Montreal in Canada[16,40–42]. A health education programme was introduced into the curriculum comprising ten 45 min lessons each year in each grade. The lessons covered healthy diet and PA and teachers were trained to deliver the programme themselves by year 3. The intervention focused not only on the school but included activities for the parents and the entire community and was planned taking the local culture into perspective. Results of an 8-year evaluation were reported to be disappointing when compared with control schools; however, the findings can provide many lessons about such interventions[16]. Despite showing some improvements in the short term, these benefits (i.e. PA, fitness and television watching) were not found to be maintained in the long term. The authors ascribe this outcome to some extent to the fact that children are exposed to 20 000–40 000 food commercials annually, many of which promote foods high in sugar and fat by aggressive marketing strategies. They believe that it may be possible to have more beneficial outcomes with a longer intervention of greater intensity coupled with community participation[16].

NEEMA. NEEMA ('wellness' in Swahili) is a 14-week diabetes prevention programme tailored for African-American children with a before and after component and no control schools[18]. The intervention comprises four focus areas: a curriculum (diet and physical activity); home component; food service at school; after school activities (fitness clubs). The programme is based on the Bienestar programme[43,44], which had been implemented with some successful outcomes in Mexican-American children. Follow up of the 14-week programme has shown decreases in fasting capillary glucose and percentage body fat and increased fitness laps. However, the shortness of the evaluation programme and lack of control groups make it difficult to predict long-term sustainability[18].

Zuni Pueblo of New Mexico. A 4-year high school-based intervention programme was tested in the Zuni Pueblo of New Mexico and compared with an Anglo (English-speaking Caucasians) group having no intervention[17,45]. The programme included an educational component targeting decreased consumption of sugared beverages, knowledge of diabetes risk factors and a youth-orientated fitness centre. A healthier school meal service was also achieved with increased fruit and vegetables and decreased sugar and fat in the school meals. Over the intervention period sugared beverage consumption was

found to have decreased and use of the fitness centre created at the school increased. No significant changes were found in BMI or between the Anglo and the Zuni students. However, reductions were found in fasting and 30 min plasma insulin levels in the Zuni group, implying that a lifestyle intervention may suppress markers of type 2 diabetes risk. It should also be noted that sugar beverages were replaced by 'diet' beverages in the vending machines at the school and that water was commonly available from water cooler bottles. The study illustrates the positive outcomes from a simple measure such as replacing sugar beverages with water.

Junior High School (Hispanic Middle School). Eighth grade students in a predominantly Hispanic public school in New York City participated in this randomised controlled trial[20]. A 3-month intervention comprising fourteen 45 min classroom sessions on diet and PA were provided by the investigators. The intervention also comprised a PA programme offered three times weekly. Participation in the intervention was associated with reductions in body fat, insulin resistance and circulating concentrations of IL-6 and C-reactive protein, suggesting that a short-term lifestyle programme can be beneficial in decreasing risk factors of type 2 diabetes[20]. However, the long-term effects of this intervention are not known and should be evaluated before recommendations can be made.

Sandy Lake Diabetes Prevention Programme. This programme was undertaken in 3rd–5th grade Objiway-Cree students (age range 7–14 years) from a Native North American reserve in Ontario, Canada over a 1-year period[15]. The programme comprised: a curriculum component of sixteen weekly 45 min teacher-led lessons; a family component; a peer component; an environmental component; a healthy school lunch programme. The intention was to improve students' knowledge, self-efficacy and skills relating to diet and PA. The curriculum was based on the Child and Adolescent Trial for Cardiovascular Health Study[46] and the Kahnawake programmes[16]. It was shown that mean BMI and percentage body fat increased between 1998 and 1999. However, increases were found in dietary intention, dietary preference, knowledge and dietary self-efficacy between baseline and follow up. Unfortunately, this study did not include a control group in the study design and the PA component was not strong.

Bienestar (Well-Being) Health Programme: Diabetes Risk-Factor Prevention Pilot Program. A pilot study was undertaken in 102 low-income 4th grade American-Mexican children in San Antonio, TX, USA over a period of 7 months[43]. All children were overweight and had a family history of diabetes. The intervention was aimed at decreasing dietary fat intake and reducing body fat and involved a curriculum of twenty-eight lessons. Additionally, there was a parental component and the school cafeteria complied by selling healthy food options. Some promising results were reported but with insufficient evidence to make recommendations. Subsequently, the researchers repeated the study using a control group and including a larger sample (intervention group 619, control group 602)[44]. They included a PA component and a family component. In total fifty health sessions were provided. Modest improvements were found, including decreased fasting glucose levels, increased fitness scores and increased dietary fibre intake. Positive results are thought to be the outcome of culturally-appropriate materials used, multiple systems of delivery and frequency of contacts. It is unknown whether outcomes will be sustained over time.

Action research. An action research programme was undertaken in five inner-city secondary schools serving a predominantly South Asian population in Leicester, UK[47]. Baseline dietary and PA data were collected from children aged 11–15 years, followed by focus groups with children and teachers to provide them with feedback on the baseline results and to identify ideas for interventions and to evaluate barriers to implementation. No preset intervention was planned and it was intended that the schools themselves would initiate and implement interventions based on their participation in the focus groups. At the end of the year the children and staff were re-evaluated. Suboptimal diet and poor activity habits were identified at baseline. Overall, these habits were found to have persisted at follow up, although a few limited positive lifestyle changes were identified.

Jump into Action. A 3-month study (Jump into Action) was undertaken in a school district with a predominantly Hispanic population on the Texas–Mexico border[48]. The study included two groups of teachers and their 5th grade students (n 1114). Teachers were trained to implement the intervention on thirteen campuses. The programme was designed by an interdisciplinary team to improve students' knowledge, self-efficacy and behaviours relating to diabetes prevention with a focus on diet and PA. Positive effects were observed for knowledge and self-efficacy gains and for healthy dietary and exercise-related behaviour changes from pre- to post-test. However, the long-term sustainability of the programme is unknown.

Summary on school studies. The school studies were all undertaken on indigenous or ethnic minorities. Unfortunately, none of the studies were undertaken in developing countries. Only two of eight studies were randomised controlled trials and sample sizes were generally <100 children. Overall, the intervention periods were short (<1 year) and not all included a longer period of follow up. Most school studies showed positive benefits in knowledge, attitudes and/or behaviour. However, few positive physical and/or clinical benefits were shown.

Studies with indigenous adult communities

Indigenous American Indian population in British Columbia. This community-based 2-year programme was targeted at the Indian population of rural Okanagan region in Canada[49]. A single intervention community was matched to two comparison communities. The programme used a participatory approach and included strategies to improve the environment and to change behaviour. Cohorts (105 high-risk individuals) were tracked over 16 months. It was reported that the project yielded few changes in quantifiable outcomes, which was thought to be a result of the short planning and intervention phases and because the level of penetration was too limited[49].

Pilot study in Pima Indians. A lifestyle randomised clinical trial over 12 months was undertaken in Pima

Indians[3]. A group of ninety-five obese normo-glycaemic adults were randomly assigned to an action (intervention) group or a pride (control) group. In the intervention group participants were required to walk 10–12 h/month or the equivalent activity output. Participants were advised by a dietitian to reduce fat and alcohol intake and to increase their fibre intake in line with the American Diabetes Association recommendations at the time (macronutrient recommendations the same as the 2007 recommendations[38]). Subjects also participated in weekly meetings that covered a range of nutrition activities. In the control group participants met once monthly to discuss aspects of Pima culture and history. Participants also received printed materials on healthy eating and PA. After 12 months both groups were reported to have increased levels of PA. However, BMI, blood pressure, 2 h glucose and 2 h insulin were shown to have increased in the intervention group to a greater extent than in the control group.

Church-based programme. A 2-year church-based programme lifestyle intervention to prevent diabetes was undertaken in Western Samoans in South Auckland, New Zealand[50]. The study involved two complete church congregations (intervention group *n* 78; control group *n* 144). The intervention was designed to be culturally appropriate and was provided by a nurse specialist and two Samoans, one of whom was trained to give diabetes education and the other to do PA. The intervention comprised individual and group activities, leaflets and a video. PA sessions were held once weekly in the first year and twice weekly in the second year. Weight was reported to have remained stable in the intervention group but to have increased in the control group. The intervention group was found to have a decrease in waist circumference and intake of key fatty foods compared with the control group. Both diabetes knowledge and proportion exercising regularly was reported to have increased in the intervention group.

Looma healthy lifestyle. This intervention was undertaken in the Looma Aborigine community (*n* 199) over 4 years in Western Australia[51]. The intervention comprised a healthy lifestyle programme aimed at decreasing SFA and sugar intakes, increasing fruit and vegetable intakes and increasing PA. Intervention activities included store policy changes, health promotion activities, regular PA classes and nutrition education by a diabetes nurse educator. Results show an increase in the supply of fresh fruit, vegetables and carotenoids in the food supply at the local store over the period. A reduction was found in the prevalence of hypercholesterolaemia and mean plasma homocysteine concentrations of the participants.

Summary of indigenous minorities. Overall, there were few trials in this category. However, the studies undertaken all showed promise and some positive outcomes. Perhaps the most important lessons to be learned from these studies are the fact that they involved the community in planning and second they developed culturally-appropriate materials.

Studies in overweight and high-risk adults

Eat Well Live Well Programme. This peer-led programme was tailored to the participant's stage of change for individual dietary patterns[52]. The sample comprised 294 overweight African-American women aged 25–55 years who were at risk of diabetes. These women were assigned to intervention and control groups. The peer educators were trained by a multi-disciplinary team. The manual-based programme comprised six group sessions and six individual sessions per peer educator integrated over a 3-month intervention phase. The primary focus of the intervention was to reduce dietary fat intake and increase low-fat dietary patterns by tailoring the intervention to stage of readiness. Reductions were found in fat intake among women in the intervention group and these reductions were maintained at 3-month follow up. Similarly, changed dietary patterns were reported, which were maintained[52].

Vasterbotten Intervention Programme. A total of 186 Swedish adults with IGT and obesity were randomly assigned to an intensive lifestyle group or a usual-care group[53]. The intervention group (*n* 93) stayed at a wellness centre for 1 month, where they were subjected to an intensive lifestyle programme: behaviour modification counselling; a low-fat high-fibre diet; PA sessions. Results after 12 months were reported to show improvements in body weight, systolic blood pressure, waist:hip ratio, fasting plasma glucose, fibrinogen, O_2 consumption and physical fitness. Despite the very promising outcomes this type of intervention will not be cost-effective or sustainable to implement for the general population.

Overweight individuals with a family history of diabetes. Overweight participants (*n* 154) with a family history of diabetes were randomly assigned to a 2-year intervention of diet, PA, diet + PA or no treatment[54]. The intervention comprised weekly group meetings in the first 12 months led by a multi-disciplinary team and refresher courses during the second 12 months. A dietitian and a behaviour therapist served on the team. It was found that only the diet + PA group maintained a weight loss from baseline to 2 years, with other variables showing no sustained loss over 2 years.

Good Ageing in Lahti Region Study. The aim of the study was to evaluate whether the results obtained in the Finnish Diabetes Prevention Study[29] could be replicated in routine health care[55]. The trial was undertaken in 352 middle-aged participants with a high risk for diabetes (i.e. family history and clinical risk). The intervention was based on social cognitive theory and comprised six group counselling sessions of 2 h each over a period of 1 year. The groups were led by public health nurses who had received training from a dietitian. Local sports officers introduced the groups to local sports facilities and guided one exercise session. All clinical and nutritional data were collected by the nurses. The intervention was delivered by the nurses as part of their existing schedule. Results were reported to be similar to those of the Finnish Diabetes Prevention Study, with 20% of participants meeting at least four of the five goals. The trial demonstrates that lifestyle counselling can be effective and feasible in real-world situations[55].

Lifestyle intervention in relatives of patients with diabetes in Sweden. Seventy-seven first-degree relatives of patients with diabetes who did not themselves have diabetes were randomised to diet or diet + PA interventions or

a control group[56]. The diet group received group counselling from a dietitian (1–2 h) on reducing SFA, increasing *n*-3 fat intake, fruit and vegetable intake and foods with a high glycaemic index. Those patients in the diet + PA group were required to increase walking to ≥30 min four to five times weekly. Dietary changes were found to be significant at 1 year ($P<0·05$) and to a large extent were sustained at 2 years. At 1 year the diet only group were reported to show a reduction in LDL-cholesterol : HDL-cholesterol ($P=0·028$) while the diet + PA group were found to have decreased their body weight by 2·7 % and increased HDL *v.* controls. At 2 years cholesterol levels were found to be reduced within the diet only group. Fasting insulin was found to be reduced in the diet + PA group when compared with the diet only group.

Adults with impaired glucose tolerance

Study on lifestyle intervention and impaired glucose tolerance Maastricht. The study was undertaken as a 3-year lifestyle intervention in subjects with IGT[57,58]. Subjects were randomly assigned to an intervention group and control group and eighty-eight subjects completed 2 years of intervention. The intervention comprised dietary and PA components. Dietary recommendations based on the Dutch guidelines for a healthy diet were given at regular intervals by a dietitian. Participants were required to increase PA to ≥30 min five times weekly. The control group received oral and written information and no individual appointments. By 2 years fifty-five subjects in the intervention group were found to have reduced their BMI, waist circumference and SFA intake and improved their aerobic capacity. Plasma glucose levels at 2 h were found to have decreased from 8·7 mM to 8·0 mM in the intervention group and increased from 8·6 mM to 9·4 mM in the control group. Subjects who adhered to both the diet and the exercise components were found to show the largest reduction in 2 h plasma glucose levels.

Lifestyle intervention in Japanese males. A randomised controlled trial of lifestyle modification was undertaken in Japanese males with IGT identified at a health screening centre over a period of 4 years[59]. The intervention group (*n* 102) were required to lose weight or maintain weight at BMI <22 kg/m^2 while the control group (*n* 356) were to reduce or remain at BMI <24 kg/m^2. To achieve this objective the intervention group participants were screened and provided with dietary advice according to individual lifestyle every 2–3 months. Second, they were required to walk for 30–40 min/d. The 4-year incidence of diabetes was reported to be 9·3 % in the control group and 3 % in the intervention group and the reduction risk of diabetes was 67·4 % ($P<0·001$).

Japanese male workers. Males (*n* 173) with a high risk (borderline diabetes fasting plasma glucose values) for type 2 diabetes were randomly assigned to an intervention group or control group over 1 year[60]. The intervention comprised a new dietary education programme based on information on the individual's dietary energy intake for breakfast, lunch and dinner, i.e. the actual dietary practices of the participants as obtained by a specific FFQ. The participant was further motivated to improve dietary practices and helped to realise his need for behaviour modification. A nutritionist encouraged the subject to recognise latent dietary problems and to set his own goals for improvement, i.e. the concept of self-management. The control group received the usual nutrition education component. The intervention group were found to have a decreased 2 h plasma glucose after 1 year, while the value increased in the control group; the percentage change was significant ($P<0·001$)[60].

Malmo Feasibility Study. Forty-one subjects with early-stage type 2 diabetes and 181 subjects with IGT were selected from 6956 men aged 47–49 years in Malmo, Sweden to take part in a programme of diet and PA[35]. At a mean follow up of 6 years the accumulated incidence of diabetes was reported to be 10·6 %, with 50 % of the patients with diabetes in remission. Blood pressure, lipids and hyperinsulinaemia were found to be reduced. Improvement in glucose tolerance was shown to be correlated with weight reduction and increased fitness ($P<0·02$). Body weight was reported to be reduced by 2·3–3·7 % among participants whereas values were increased by 0·5–1·7 % in subjects not undergoing the intervention and normal control subjects. The researchers conclude that long-term intervention is possible even on a large scale.

Reduced-fat-diet intervention. A reduced-fat diet *v.* usual diet was followed by adults (*n* 136) with glucose intolerance[61]. For 1 year the intervention group were required to attend monthly small-group education sessions on reduced-fat eating. It was found that weight decreased at 1 year in the intervention group compared with the control group but this difference was no longer present at 5 years. The same scenario was found for glucose tolerance. However, the most-compliant 50 % of patients in the intervention group were shown to have maintained lower fasting glucose levels at 5 years.

Diet and physical activity intervention in adults with impaired glucose tolerance. Adults with IGT (*n* 78) from Newcastle upon Tyne, UK were randomly assigned to either an intervention group or a control group[62]. The intervention group received individual dietary advice from a dietitian and advice on PA from a physiotherapist. The dietitian used motivational interviewing and the stages of change theory as a model for behaviour change. Twelve individual appointments were scheduled over the 24-month period. A decrease in total fat intake and BMI in the intervention group *v.* the control groups was found at follow up, with whole-body insulin sensitivity improved after 12 months in the intervention group.

Japanese-Americans. A group of sixty-four Japanese-American men and women with IGT followed the American Heart Association step 2 diet of fat <30 % energy intake, SFA <7 % energy intake and cholesterol <200 mg (intervention group) and step 1 (control) diets with three 1 h endurance exercise sessions per week[63]. After 6 months the PA was home-based. At 24 months improvements were found in percentage body fat, BMI and subcutaneous fat. This type of intervention may be effective in retarding the development of type 2 diabetes.

Women in Melbourne. Women with IGT (*n* 200) were randomised to a trial of intensive *v.* routine dietary advice[64]. The annual incidence rate of diabetes for the two

groups were reported to be 6·1 % in the intervention group and 7·3 % in the control group. Overall, a return to normal glucose tolerance was found in 44 % of patients. It was shown by multivariate analysis that BMI, fasting and 2 h plasma glucose levels at trial entry are associated with an increased risk of diabetes.

Interventions using technology

Email intervention. This intervention was undertaken in Alberta, Canada at five workplaces[65]. The intervention, which was conducted by email messages over 12 weeks, targeted the 1566 participants with one message per week. The messages were aimed at prevention of diabetes by promoting a healthy diet and increasing PA. Differences in self-reported healthy eating practices, balanced diet and enjoyment of meals as well as PA measures were reported. This programme may be a cost-effective sustainable programme for worksites where employees have access to emails. Tailoring messages to individuals and increasing message frequency and intervention duration may improve efficacy of intervention. Longer-term effectiveness needs to be evaluated.

Use of the internet. There is increasing recognition that because of the growing burden of diabetes globally it will become more important to develop self-management strategies in order to reach larger segments of the population. Some studies have found limited success in the use of specifically-designed internet programmes[66,67], while others found that long-term maintenance of a weight-loss programme is not as effective as 'in-person' therapist support[68]. More recently, a 10-week interactive internet programme has been developed that is unique by virtue of being based on the goals and needs of the participants and as such can be considered to be a personalised programme[69]. The exercise and diet plans are based on the individual's health risk appraisal. A total of 808 participants registered for the programme, with 683 completing at least one online health risk appraisal and 56 % of the participants agreeing that the programme helped them achieve their goals. It was reported that the average participant used the homepage twenty-nine times, suggesting that the website was used with a high frequency. However, because there are no hard outcomes it is difficult to conclude whether the programme made a difference to clinical outcomes.

Summary of adult interventions. Overall, the majority of lifestyle interventions evaluated had very positive health benefits and most appeared to be sustainable. However, as with all interventions certain crucial aspects need to be clarified, specifically the duration of the intervention period and the period of follow up and re-evaluation. Mostly, the latter were done soon after the evaluation and the longer-term benefits are not known.

Studies on cost effectiveness of interventions

An assessment has been made in Australia, France, Germany, Switzerland and the UK of whether implementing active treatments (metformin or intensive lifestyle change) in the Diabetes Prevention Program would be cost effective[25]. Assuming only within-trial effects, and costs of interventions, both metformin and intensive lifestyle change were found to improve life expectancy *v.* control.

Using a Markov Model[70] and, based on the probabilities, the incorporation of the Diabetes Prevention Program interventions into clinical practice in the five developed countries is projected to lead to an increase in diabetes-free years of life, improvements in life expectancy and either cost savings or minor cost increases compared with standard lifestyle advice in a population with IGT.

A systematic review of economic evaluations of preventive interventions in type 2 diabetes reported between January 1990 and May 2004 (twenty-three studies) has found that cost effectiveness seems possible for strict blood pressure control, with a high number of studies showing cost-effectiveness ratios ranging from cost saving to very low cost per life year gained[71]. Medication to reduce weight and hyperglycaemia simultaneously also seems to be cost effective compared with conventional therapies.

In another evaluation of the economic performance of ten nutrition interventions to prevent diabetes eight of the nutrition interventions were estimated to be highly cost-effective based on societal norms[72]. Population-based interventions were not found to necessarily provide better value for money than targeted interventions. In this exercise targeted interventions were found to be associated with more certain benefits.

Conclusions

Overall, there is a sizeable amount of evidence showing that lifestyle interventions under a number of conditions are beneficial in delaying or reducing type 2 diabetes. Health policymakers need to plan lifestyle modification interventions as part of routine primary health care and in settings such as the school and workplace in order to provide long-term solutions to the burgeoning diabetes epidemic. Furthermore, lifestyle modification in subjects without diabetes should be built on evidence-based principles such as those recommended by the American Diabetes Association[38]:

1. programmes that emphasise lifestyle change including weight loss (7 % body weight) and regular physical activity (150 min/week) with dietary strategies (e.g. reduced intake of fat) to reduce energy intake;
2. individuals at high risk should have a dietary fibre intake of ≥14 g/1000 kJ. Low-GI foods should thus be encouraged, based on their high fibre content.

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References

1. Bastaki S (2005) Diabetes mellitus and its treatment. *Int J Diabetes Met* **13**, 111–134.
2. King H, Aubert RE & Herman WH (1998) Global burden of diabetes, 1995–2025. Prevalence, numerical estimates and projections. *Diabetes Care* **21**, 1414–1431.

3. Narayan KMV, Hoskin M, Kozak D *et al.* (1998) Randomized clinical trial of lifestyle interventions in Pima Indians: a pilot study. *Diabet Med* **15**, 66–72.
4. Makrilakis K & Katsilambros N (2008) Prediction and prevention of type 2 diabetes. *Hormones (Athens)* **2**, 22–34.
5. Hu FB, Manson JE, Stamper MJ *et al.* (2001) Diet, lifestyle, and the risk of type 2 diabetes mellitus in women. *N Engl J Med* **345**, 790–797.
6. Chiasson JL & Rabasa-Lhoret R (2004) Prevention of type 2 diabetes. Insulin resistance and beta-cell function. *Diabetes* **53**, S34–S38.
7. Norris SL, Zhang X, Avenell A *et al.* (2005) Long-term effectiveness of weight-loss interventions in adults with pre-diabetes. *A review. Am J Prev Med* **28**, 126–139.
8. Hu FB, van Dam & Liu S (2001) Diet and risk of type 2 diabetes: the roles of types of fat and carbohydrate. *Diabetologia* **44**, 805–817.
9. Bazzano LA, Serdula M & Liu S (2005) Prevention of type 2 diabetes by diet and lifestyle modification. *J Am Coll Nutr* **24**, 310–319.
10. Manson JE, Nathan DM, Krolewski AS *et al.* (1992) A prospective study of exercise and incidence of diabetes among US male physicians. *J Am Med Assoc* **268**, 63–67.
11. Rimm EB, Manson JE, Stampfer MJ *et al.* (1993) Cigarette smoking and the risk of diabetes in women. *Am J Public Health* **83**, 211–214.
12. Simmons RK, Harding AH, Jakes RW *et al.* (2006) How much might achievement of diabetes prevention behaviour goals reduce the incidence of diabetes if implemented at the population level? *Diabetologia* **49**, 905–911.
13. Avenell A, Broom J, Brown TJ *et al.* (2004) Systematic review of the long-term effects and economic consequences of treatments for obesity and implications for health improvement. *Health Technol Assess* **8**(21), 1–465; available at http://www.hta.ac.uk/fullmono/mon821.pdf
14. Gittelsohn J & Kumar MB (2007) Preventing childhood obesity and diabetes: is it time to move out of the school? *Pediatr Diabetes* **8**, 1–15.
15. Saksvig BI, Gittelsohn J, Harris SB *et al.* (2005) A pilot school-based healthy eating and physical activity intervention improves diet, food knowledge, and self-efficacy for native Canadian Children. *J Nutr* **135**, 2392–2398.
16. Paradis G, Levesque Lucie, Macaulay AC *et al.* (2005) Impact of a diabetes prevention program on body size, physical activity, and diet among Kanien'kehá:ka (Mohawk) children 6 to 11 years old: 8-year results from the Kahnawake Schools Diabetes Prevention Project. *Pediatrics* **115**, 333–339.
17. Ritenbaugh C, Teufel-Shone NI, Aickin MG *et al.* (2003) A lifestyle intervention improves plasma insulin levels among Native American high school youth. *Prev Med* **36**, 309–319.
18. Shaw-Perry MS, Horner C, Trevino RP *et al.* (2007) NEEMA: A school-based risk prevention program designed for African-American children. *J Natl Med Assoc* **99**, 368–375.
19. Grey M, Berry D, Davidson M *et al.* (2004) Preliminary testing of a program to prevent type 2 diabetes among high-risk youth. *J Sch Health* **74**, 10–15.
20. Rosenbaum M, Nonans C, Weil R *et al.* (2006) School-based intervention acutely improves insulin sensitivity and decreases inflammatory markers and body fatness in junior high school students. *J Clin Endocrinol Metab* **92**, 504–508.
21. Yamaoka K & Tango T (2005) Efficacy of lifestyle education to prevent type 2 diabetes. A meta-analysis of randomized controlled trials. *Diabetes Care* **28**, 2780–2786.
22. Kanaya MA & Narayan KMV (2003) Prevention of type 2 diabetes: data from recent trials. *Prim Care Clin Office Pract* **30**, 511–526.
23. Diabetes Prevention Program Research Group (2002) Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N Engl J Med* **346**, 393–403.
24. Diabetes Prevention Program Research Group (2004) Achieving weight and activity goals among Diabetes Prevention Program lifestyle participants. *Obes Res* **12**, 1426–1434.
25. Palmer AJ, Roze S, Valentine WJ *et al.* (2004) Intensive lifestyle changes or metformin in patients with impaired glucose tolerance: modelling the long-term health economic implications of the Diabetes Prevention Program in Australia, France, Germany, Switzerland, and the United Kingdom. *Clin Ther* **26**, 304–321.
26. Hamman RF, Wing RR, Edelstein SL *et al.* (2006) Effect of weight loss with lifestyle intervention on risk of diabetes. *Diabetes Care* **29**, 2102–2107.
27. Pan XR, Li GW, Hu YH *et al.* (1997) Effects of diet and exercise in preventing NIDDM in people with impaired glucose tolerance. The Da Qing IGT and Diabetes Study. *Diabetes Care* **20**, 537–544.
28. Li G, Hu Y, Yang W *et al.* (2002) Effects of insulin resistance and insulin secretion on the efficacy of interventions to retard development of type 2 diabetes mellitus: the Da Qing IGT and Diabetes Study. *Diabetes Res Clin Pract* **58**, 193–200.
29. Eriksson J, Lindstrom J, Valle T *et al.* (1999) Prevention of type II diabetes in subjects with impaired glucose tolerance: the Diabetes Prevention Study (DPS) in Finland. *Diabetologia* **42**, 793–801.
30. Uusitupa M, Louheranta A, Lindstrom J *et al.* (2000) The Finnish Diabetes Prevention Study. *Br J Nutr* **83**, S137–S142.
31. Tuomilehto J, Lindstrom J, Eriksson JG *et al.* (2001) Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. *N Engl J Med* **344**, 1343–1350.
32. Lindstrom J, Eriksson JG, Valle TT *et al.* (2003) Prevention of diabetes mellitus in subjects with impaired glucose tolerance in the Finnish Diabetes Prevention Study: Results from a randomized clinical trial. *J Am Soc Nephrol* **14**, S108–S113.
33. Lindstrom J, Ilanne-Parikka P, Peltonen M *et al.* (2006) Sustained reduction in the incidence of type 2 diabetes by lifestyle intervention: follow-up of the Finnish Diabetes Prevention Study. *Lancet* **368**, 1673–1679.
34. Lindstrom J, Peltonen M, Eriksson JG *et al.* (2006) High-fibre, low-fat diet predicts long-term weight loss and decreased type 2 diabetes risk: Finish Diabetes Prevention Study. *Diabetologia* **49**, 912–920.
35. Eriksson KF & Lingarde F (1991) Prevention of type 2 (non-insulin-dependent) diabetes mellitus by diet and physical exercise. The 6-year Malmo feasibility study. *Diabetologia* **34**, 891–898.
36. Nwobu CO & Johnson CC (2007) Targeting obesity to reduce the risk for type 2 diabetes and other co-morbidities in African American youth: a review of the literature and recommendations for prevention. *Diab Vasc Dis Res* **4**, 311–319.
37. Irons BK, Mazzolini TA & Greene RS (2004) Delaying the onset of type 2 diabetes mellitus in patients with prediabetes. *Pharmacotherapy* **24**, 3662–3371.
38. American Diabetes Association (2007) Nutrition recommendations and interventions for diabetes. *Diabetes Care* **30**, S48–S65.

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39. Smith GD, Bracha Y, Svendsen KH *et al.* (2005) Incidence of type 2 diabetes in the Randomized Multiple Risk Factor Intervention Trial. *Ann Intern Med* **142**, 313–322.
40. Macaulay AC, Paradis G, Potvin L *et al.* (1997) The Kahnawake Schools Diabetes Prevention Project: Intervention evaluation, and baseline results of a diabetes primary prevention program with a native community in Canada. *Prev Med* **26**, 779–790.
41. Jimenez MM, Receveur O, Trifonopoulos M *et al.* (2003) Comparison of the dietary intakes of two different groups of children (grades 4 to 6) before and after the Kahnawake Schools Diabetes Prevention Project. *J Am Diet Assoc* **788**, 1191–1194.
42. Cargo M, Levesque L, Macaulay AC *et al.* (2003) Kahnawake Schools Diabetes Prevention Project (KSDPP) Community Advisory Board. *Health Promot Int* **18**, 177–187.
43. Trevino R, Pugh JA, Hernandez AE *et al.* (1998) A diabetes risk-factor prevention program. *J School Health* **68**, 62–67.
44. Trevino RP, Yin Z, Hernandez A *et al.* (2004) Impact of the Bienestar school-based diabetes mellitus prevention program on fasting capillary glucose levels. *Arch Pediatr Adolesc Med* **158**, 911–917.
45. Teufel NI & Ritenbaugh C (1998) Development of a primary prevention program: insight gained in the Zuni Diabetes Prevention Program. *J Clin Pediatrics* **37**, 131–141.
46. Webber LS, Osganian SK, Feldman HA *et al.* (1996) Cardiovascular risk factors among children after a 2 1/2-year intervention – The CATCH study. *Prev Med* **25**, 432–441.
47. Khunti K, Stone AM, Bankart J *et al.* (2008) Primary prevention of type 2 diabetes and heart disease: action research in secondary schools serving an ethnically diverse UK population. *J Public Health* **30**, 30–37.
48. Holcomb JD, Lira J, Kingery PM *et al.* (1998) Evaluation of Jump Into Action: A program to reduce the risk of non-insulin diabetes mellitus in school children on the Texas-Mexico border. *J School Health* **68**, 282–288.
49. Daniel M, Green LW, Marion SA *et al.* (1999) Effectiveness of community-directed diabetes prevention and control in a rural Aboriginal population in British Columbia, Canada. *Soc Sci Med* **48**, 815–832.
50. Simmons D, Fleming C, Voyle J *et al.* (1998) A pilot urban church-based programme to reduce risk factors for diabetes among Western Samoans in New Zealand. *Diabet Med* **15**, 136–142.
51. Rowley KG, Su Q, Cincotta M *et al.* (2001) Improvements in circulating cholesterol, antioxidants, and homocysteine after dietary intervention in an Australian Aboriginal community. *Am J Clin Nutr* **74**, 442–448.
52. Auslander W, Haire-Joshu D, Houston C *et al.* (2002) A controlled evaluation of staging dietary patterns to reduce the risk of diabetes in African-American Women. *Diabetes Care* **25**, 809–814.
53. Lindahl B, Nilson TK, Jansson JH *et al.* (1999) Improved fibrinolysis by intense lifestyle intervention. A randomized trial in subjects with impaired glucose tolerance. *J Intern Med* **246**, 105–112.
54. Wing RR, Venditti E, Jakicic JM *et al.* (1998) Lifestyle intervention in overweight individuals with a family history of diabetes. *Diabetes Care* **21**, 350–359.
55. Absetz P, Valve R, Oldenburg B *et al.* (2007) Type 2 diabetes prevention in the 'real world', One-year results of the GOAL Implementation Trial. *Diabetes Care* **30**, 2465–2470.
56. Brekke HK, Jansson P-A & Lenner RA (2005) Long-term (1- and 2-year) effects of lifestyle intervention in type 2 diabetes relatives. *Diabetes Res Clin Pract* **70**, 225–234.
57. Mensink M, Blaak EE, Corpeleijn E *et al.* (2003) Lifestyle intervention according to general recommendations improves glucose tolerance. *Obes Res* **11**, 1588–1596.
58. Mensink M, Corpeleijn E, Feskens EJ *et al.* (2003) Study on lifestyle-intervention and impaired glucose tolerance Maastricht (SLIM): design and screening results. *Diabetes Res Clin Pract* **61**, 49–58.
59. Kosaka K, Noda M & Kuzuya T (2005) Prevention of type 2 diabetes by lifestyle intervention: a Japanese trial in IGT males. *Diabetes Res Clin Pract* **67**, 152–162.
60. Watanabe M, Yamaoka K, Yokotsuka M *et al.* (2003) Randomized controlled trial of a new dietary education program to prevent type 2 diabetes in a high-risk group of Japanese male workers. *Diabetes Care* **26**, 3209–3214.
61. Swinburn BA, Metcalf PA & Ley SJ (2001) Long-term (5-year) effects of a reduced-fat diet intervention in individuals with glucose intolerance. *Diabetes Care* **24**, 619–624.
62. Oldroyd JC, Unwin NC, White M *et al.* (2006) Randomised controlled trial evaluating lifestyle interventions in people with impaired glucose tolerance. *Diabetes Res Clin Pract* **72**, 117–127.
63. Liao D, Asberry PJ, Shofer JB *et al.* (2002) Improvement of BMI, body composition, and body fat distribution with lifestyle modification in Japanese Americans with impaired glucose tolerance. *Diabetes Care* **25**, 1504–1510.
64. Wein P, Beischer N, Harris C *et al.* (1999) A trial of simple versus intensified dietary modification for prevention of progression to diabetes mellitus in women with impaired glucose tolerance. *Aust N Z J Obstet Gynaecol* **39**, 162–166.
65. Plotnikoff RC, McCargar LJ, Wilson PM *et al.* (2005) Efficacy of an E-mail intervention for the promotion of physical activity and nutrition behaviour in the workplace context. *Am J Health Promot* **19**, 422–429.
66. Tate DF, Wing RR & Winett RA (2001) Using Internet technology to deliver a behavioural weight loss program. *J Am Med Assoc* **285**, 1172–1177.
67. Tate DF, Jackvony EH & Wing RR (2003) Effects of Internet behavioural counselling on weight loss in adults at risk for type 2 diabetes: a randomized trial. *J Am Med Assoc* **289**, 1833–1836.
68. Harvey-Berino J, Pintuaro SJ & Gold CE (2002) The feasibility of using Internet support for the maintenance of weight loss. *Behav Modif* **26**, 103–116.
69. McCoy MR, Couch D, Duncan ND *et al.* (2005) Evaluating an Internet weight loss program for diabetes prevention. *Health Promot Int* **20**, 221–228.
70. Sonnenberg FA & Beck JR (1993) Markov models in medical decision making: A practical guide. *Med Decis Making* **13**, 322–338.
71. Vijgen SMC, Hoogendoorn M, Baan CA *et al.* (2006) Cost effectiveness of preventive interventions in type 2 diabetes mellitus. A systematic review. *Pharmacoenomics* **24**, 425–441.
72. Dalziel K & Sedal L (2007) Time to give nutrition interventions a higher profile: cost-effectiveness of 10 nutrition interventions. *Health Promot Int* **22**, 271–283.
73. Perry MS, Horner C, Trevino RP *et al.* (2007) NEEMA: a school-based risk prevention program designed for African-American children. *J Natl Med Assoc* **99**, 368–375.

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