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Cost-effectiveness of the primary prevention of non-insulin dependent diabetes mellitus

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SUMMARY

Non-insulin dependent diabetes mellitus (NIDDM) is a chronic disease, with increasing prevalence widely reported. NIDDM is associated with high rates of morbidity and premature mortality and is the cause of high health service use. There is clinical, epidemiological and scientific evidence that NIDDM is potentially preventable through weight loss, enhanced fitness and nutrition modification. The research question addressed in this article is whether the prevention of NIDDM is cost-effective compared with other possible uses of our health care resources and whether some approaches to NIDDM prevention are more cost-effective than others. Program types analysed are surgery, group behavioural program, media campaign, general practitioner (family physician) lifestyle advice, and intensive diet and behavioural programs. Target groups include seriously obese persons, women with previous gestational diabetes, overweight men and all adults. Expected diabetes years and life years were modelled for hypothetical intervention and control cohorts and used, with information on program cost, to derive estimates of cost-effectiveness, expressed as cost per diabetes year avoided and cost per life year gained. Markov modelling was used to track states of normal glucose tolerance, impaired glucose tolerance (IGT) and NIDDM for intervention and control cohorts. Expected life years were calculated through application of age and gender specific mortality vectors, adjusted for diabetic state and weight loss. Expected savings in health care costs from NIDDM prevention were based on estimated annual cost of NIDDM management and were used to derive net cost-effectiveness ratios. The group program for overweight men and media programs were identified as extremely worthwhile, generating estimated net savings in health care resources, while reducing diabetes incidence and extending life expectancy. The behavioural/diet programs for high risk groups were found to be highly cost-effective relative to other health care programs, at an estimated net cost per life year saved of between A$1000 (US$720) and A$2600 (US$1900). Surgery performed poorest, but still well at A$4600 (US$3300) net cost per life year saved, if targeted at persons with IGT. We conclude that the primary prevention of NIDDM can be highly cost-effective. The development and funding of pilot programs for NIDDM prevention is recommended to test these findings and address the increasing incidence of NIDDM.

Key words: cost-effectiveness; non-insulin dependant diabetes mellitus; primary prevention

AIMS

The prevalence and incidence of non-insulin dependent diabetes mellitus (NIDDM) is high and increasing in Western and developing countries. In Australia, in 1990, prevalence of diabetes, diagnosed and undiagnosed, was estimated at 3.8% of the population and 6% of adults, a 50% increase since 1981 (McCarty *et al.*, 1996). In the USA prevalence of diagnosed cases is 2.6% of the population and 9.5% of persons over 65 (American Diabetes Association, 1994). In some South Pacific countries and particular subpopulations prevalence can exceed 20% (King *et al.*, 1993; McCarty *et al.*, 1994). NIDDM accounts for at least 85% of cases of diabetes.

The burden of diabetes to society, in terms of excess morbidity, premature mortality and health service use is high. Excess mortality rates are estimated at 100% for persons with diabetes with reduction in life expectancy of up to 10 years reported (Panzram, 1987; Knuiman *et al.*, 1992; Stengard *et al.*, 1992; Balkau *et al.*, 1993; Simons *et al.*, 1996). High health service costs have also been documented (Huse *et al.*, 1989; American Diabetes Association, 1994; Stuart, 1994; McCarty *et al.*, 1996).

Persons with diabetes have an excess risk of cardiovascular disease, vision-threatening diabetic retinopathy and cataracts, renal failure and neuropathy, resulting in high rates of foot ulcer and lower limb amputation (Pirart, 1978; Keen *et al.*, 1982; Knuiman *et al.*, 1986; American Diabetes Association, 1993; Phillips *et al.*, 1995; Simons *et al.*, 1996). Morbidity and mortality are primarily related to age of onset, duration of disease, glycemic control and intensity of management [Pirart, 1978; World Health Organization (WHO), 1985; Panzram, 1987; Stengard *et al.*, 1992; Schneider *et al.*, 1993; Helman *et al.*, 1997].

There is substantial evidence that NIDDM is predominantly a lifestyle disease, with incidence and disease progression exacerbated by overnutrition and a sedentary lifestyle. Prevalence of NIDDM is substantially higher in obese and overweight persons, especially those displaying abdominal obesity and weight gain (O'Sullivan, 1982; O'Dea *et al.*, 1988; Lean *et al.*, 1990; Tuomilehto *et al.*, 1992). Relative risk for NIDDM for a woman with a body mass index (BMI) of 35+ was found to be 61 times that for a woman with a BMI <22 (Colditz *et al.*, 1990).

There is also evidence that interventions to address obesity and sedentary lifestyle can reduce the incidence of NIDDM. For behavioural interventions, reduction in incidence of NIDDM of 31– 50% is reported (Eriksson and Lindgarde, 1992; Pan *et al.*, 1997). For surgical interventions, incidence of NIDDM is reduced dramatically, by >90% in those undergoing surgery (Pories *et al.*, 1992; Long *et al.*, 1994; Sjostrom, 1995). In overweight persons with NIDDM, diet and exercise reduces blood glucose levels (Kanders *et al.*, 1989; Helmrich *et al.*, 1991; Wing *et al.*, 1991; Eriksson and Lindgarde, 1992).

Despite policy statements from health authorities, working parties and professional meetings, recognising the risks associated with a sedentary lifestyle and obesity [*Journal of the American Medical Association* (*JAMA*), 1993; NIH National Taskforce, 1993; Australian Department of Human Services and Health, 1994; Australian Society for the Study of Obesity, 1995], obesity is still increasing (National Heart Foundation, 1980, 1983, 1989; McCarty *et al.*, 1996).

Our research used cost-effectiveness analysis to determine the role for NIDDM prevention, to ascertain whether programs for the primary prevention of NIDDM are cost-effective relative to other health programs, warranting greater resourcing by health agencies, and whether particular types of programs for the prevention of NIDDM are more cost-effective than others.

METHODS

Cost-effectiveness analysis is a common economic evaluation technique for comparing programs directed at the same objective. Performance is expressed in terms of cost per unit of outcome, where the lower the cost per unit of outcome the better. (For those unfamiliar with cost-effectiveness analysis see, for instance, Drummond *et al.*, 1987).

Performance measures

Two outcome measures were selected for the cost-effectiveness analyses: (i) reduction in diabetes years, most suitable for comparing alternative programs for NIDDM prevention; and (ii) life years saved, to facilitate comparison with other programs, for NIDDM management or addressed to other disease areas. The effect of risk factor modification on all-cause mortality, not just the incidence of NIDDM, can be incorporated in the estimated life years saved.

Diabetes years avoided and life years gained are simply the difference in total diabetes years and total life years of the intervention and control cohorts. Gross cost-effectivness is the quotient of program cost and diabetes years avoided or life years saved. Net cost is calculated by subtracting the discounted future health service costs avoided through the prevention of NIDDM, from the cost of program implementation.

The quality adjusted life year (QALY) is a potentially powerful outcome measure, combining life expectancy and quality of life. There is limited descriptive material on quality of life of persons with diabetes and isolated reports of the application of quality of life instruments in conjunction with interventions (Sjostrom, 1995). To develop QALYs, utility scores would be required for diabetes (preferably by disease stage), for obesity and associated with successful and failed weight loss. This type of evidence is not available and could not be incorporated into the analysis (see Drummond *et al*., 1987, for a description of QALYs and cost–utility analysis).

Selection of programs

A systematic analysis was carried out to determine the range of possible intervention options for the prevention of NIDDM (both existing and those that might be established), reflecting a knowledge of the preventable risk factors for NIDDM. To assist in this identification process, a three-dimensional classification system was used covering health delivery setting, target group and program philosophy/program elements. Program types (existing and possible) were listed to cover all realistic combinations. Programs were selected for evaluation to cover a wide range of options, specifically to cover: (i) all health delivery settings (hospital in-patient and outpatient, community based, primary care physician, the work place and the media); (ii) selected target groups [persons with impaired glucose tolerance (IGT), overweight/obese men, seriously obese persons, women with previous gestational diabetes and the general Australian population]; and (iii) possible program elements (behavioural, information, surgical, and individual and group format).

The final selection was also influenced by the availability of reports of trials from which to draw inferences about program outcomes. A list of program types included in the analysis is provided in Table 1. Information on the key trials from which program effectiveness and cost were derived or inferred has been summarised in an Appendix, which is available from the authors on request. Intervention studies that employed a (preferably randomised) control study design, incorporated at least 5 years of follow-up and recorded impact on weight and diabetes status, were favoured for inclusion. This proved too restrictive. While a small number of studies meet those criteria (Wadden *et al*., 1989, 1993; Farquhar *et al*., 1990; Eriksson and Lindgarde, 1992; Karvetti and Hakala, 1992; Long *et al*., 1994; Pan *et al*., 1997), the source material also includes observational epidemiological and intervention studies (Bjorvall and Rossner, 1985, 1992; Helmrich *et al*., 1991; Henry *et al*., 1991; Pories *et al*., 1992; Sugarman *et al*., 1992; Food and Nutrition Program, 1993; Peters *et al*., 1996) and studies with <5 years of follow up (Kanders *et al*., 1989; Fitzwater *et al*., 1991; Family Heart Study Group, 1994; Reid and Jennings, 1995; Sjostrom, 1995; Egger *et al*., 1996).

Despite evidence that ethnicity is a risk factor for NIDDM, programs targeted at high risk ethnic groups were not included in the analysis due to a lack of evidence from which estimates of costs and outcomes could be developed. The use of anti-diabetic drugs for the management of persons with IGT and newly diagnosed NIDDM is an effective means of reducing blood glucose levels and incidence of NIDDM (Melander *et al*., 1988). However, this strategy may be regarded as early management rather than primary prevention and was considered outside the scope of our research design.

Program costs

The resource use or costs of implementing programs are rarely reported in the literature and in any case are rarely transferable. Program descriptions were used to derive program elements, to which published unit costs were applied. Unit costs for inpatient services were taken from an Australian survey of hospital costs (Jackson *et al*., 1994). Medical costs were based upon the Commonwealth Medical Benefits Schedule, of rates of reimbursement for medical services under Australia's universal health insurance scheme (Australian Department of Human Services and Health, 1995a). For the group program for overweight men, cost reflects the price of a commercial program.

In theory, cost-effectiveness analysis should reflect the marginal costs and benefits associated with possible program expansion or contraction. As a simplification it was assumed that marginal cost would approximate average cost within the program range likely to be relevant, except for the media program which presumes no pre-existing program and is costed for a region of ~4 million persons. The program costs used in the model are reported in Table 4 together with other program parameter values.

Outcomes—the model/cohort analysis

A model was developed, consisting of several Markov sub-models, to explore diabetic state and survival in an intervention and control cohort for each program type. The model was developed using a spreadsheet format (Microsoft Excel v.5). Five-yearly progression between states of NIDDM, IGT and normal glucose tolerance

Table 1: Program types analysed

Program type	
I	**Intensive diet and behavioural modification** Low/very low energy diet, combined with counselling, nutrition advice, delivered by multi-disciplinary team, with 2–3 year follow-up Target: all seriously obese, and seriously obese with IGT
II	**Intensive diet and behavioural modification** Target: women with previous gestational diabetes—mixed group, IGT only
III	**Surgery for severe obesity** Gastric bypass surgery plus prior counselling and 12 months active follow-up Target: seriously obese BMI > 40 or >45 kg excess weight, seriously obese IGT
IV	**Group behavioural modification for men** 5–6 group sessions: aim reduction in waist size through change in diet and increased activity; empowerment philosophy, predominantly at the workplace Target: overweight and obese men—mixed and IGT only
V	**General practitioner advice** Healthy life style advice, by specially recruited primary care physicians, supported by printed material, ~ 8 visits in 12 months Target: high risk adults, BMI > 27, other CVD risk factor, mixed group, IGT
VI	**Media campaign with community support** Across a region of ~4 million people, through radio, television, print media, supported by community-based activities, such as phoneline, written materials, school/shopping centre based activities, etc. Target: general population, overweight adults

(NGT) were described by separate 3×3 transition matrices for control and intervention cohorts for each program type. The intervention group was classified into two streams: (a) those who successfully completed the program and (b) those who failed to maintain weight reduction or failed to complete the program. It was conservatively assumed that the outcomes of the unsuccessful intervention group would be identical to the control cohort. The model also incorporated age-specific column vectors for mortality (see below). The cohorts were subject to an annual mortality, yielding a progressive tally of the number of survivors for control and intervention cohorts and expected life years. Accumulated diabetic years were calculated for 25 years post-intervention. The difference in total diabetes years and life years between the intervention and control cohorts provided the estimate of diabetes years avoided and of life years gained.

Transition matrices were based on the literature and judgements of the research team and their clinical advisers. Transition matrices used in the cost-effectiveness analysis of the Group Behavioural Program for men are reproduced as Tables 2A and 2B. These matrices were derived, from the Swedish study reported by Eriksson and Lindgarde (1992) of an intensive weight loss and fitness enhancement program for overweight persons with IGT or NIDDM, and of a standard care group with IGT or normal glucose tolerance. At the 5–6 year follow-up, persons in the IGT intervention group had less than half the rate of progression to NIDDM of the IGT control (standard care group), 10.6% compared with 21.4% (or 28.6%). The intervention group achieved a mean weight loss of 3.3 kg and an improvement in fitness, compared with a small weight gain in the IGT control group and reduction in oxygen uptake. The result is similar to the Chinese study (Pan *et al.*, 1997), which reported a 42% reduction in the incidence of NIDDM in a diet plus exercise group, compared with standard care controls.

With the behavioural program for seriously obese persons, the matrices applied to the intervention group were adjusted to reflect an expected weight regain over time and consequent reduction in effect on incidence of NIDDM. With the gestational diabetic group, 18 years of data reflecting ‘standard care’ have been used in the development of the transition matrices (Henry *et al.*, 1991).

Two sets of 3×1 mortality vectors were derived for each program type, reflecting expected average annual mortality for persons with NIDDM, IGT and NGT at each age group. One set of vectors represents expected mortality of the intervention cohort who maintain weight loss and the other for the control cohort and unsuccessful intervention participants. The mortality vectors were derived from the Australian

Table 2: Five year transition matrix—Group Program for Overweight Men. Probability of transition between states in successive five year periods

A: Successful intervention group

State at time *t*	State at time *t* + 5 years		
	NIDDM	IGT	NGT
NIDDM	**0.462**	**0.307**	**0.231**
IGT	**0.106**	**0.373**	**0.522**
NGT[a]	0.01	0.04	0.95

B: Control group and unsuccessful intervention group

State at time *t*	State at time *t* + 5 years		
	NIDDM	IGT	NGT
NIDDM	0.95	0.04	0.01
IGT	**0.214**	**0.428**	**0.358**
NGT[a]	0.01	**0.07**	**0.92**

[a]NGT is glucose tolerance within the normal range.
Source: entries in bold from Eriksson and Lindgarde (1992), other entries derived by research team.

all-cause, age and gender specific mortality rates (Australian Bureau of Statistics, 1995) adjusted for the relative risk of diabetes and IGT (Panzram *et al.*, 1987; Balkau *et al.*, 1993; Simons *et al.*, 1996), and for weight loss (Drenick *et al.*, 1980; Manson *et al.*, 1987; Rissanen *et al.*, 1990; Lee *et al.*, 1993). The mortality rate in the successful intervention group is assumed to revert to that for the general population, except for programs for the seriously obese, for which all-cause mortality for the successful intervention group is set midway between the control cohort (incorporating full excess risk) and the population average. To illustrate the methodology, the mortality rates used in the group program for overweight males are shown in Table 3.

Mortality vectors were applied to the cohorts for 25 years post-intervention. Beyond this, the remaining life expectancy for survivors was calculated by adjusting the population life expectancy, for diabetic state and whether weight loss was achieved. Reduction in life expectancy for persons with NIDDM is taken to be 2–3 years relative to persons with normal glucose tolerance, and 0.5–3 years for excess weight, depending on the program (Drenick *et al.*, 1980; Panzram, 1987; Knuiman *et al.*, 1992; Schneider *et al.*, 1993). Values used in the model are reported in Table 4.

Potential downstream cost savings

It has been established that NIDDM is responsible for excessive health service use. Stuart (1994) reported that in Maryland, USA, Medicaid recipients with diabetes experienced three times the average health service cost of all Medicaid clients. The prevention of NIDDM is presumed to reduce diabetes-related health care costs. The average annual cost for the management of NIDDM in Australia was calculated by the authors and used to estimate savings in downstream health care costs. The cost of diabetes was based on several data sources. Medical and allied health services was based on a National Health Survey (Australian Bureau of Statistics, 1990). Pharmaceutical use and cost was derived from the pharmaceutical database of the Department of Health and Family Services. Hospital costs were based on data from the Department of Human Services, Victoria and nursing home costs from a study attributing nursing home expenditure to disease groups. The cost of managing NIDDM in Australia, was estimated at >A$1600/diabetic/year (McCarty *et al.*, 1996). A figure of A$1800/year has been used in the model, reflecting an update of the analysis by the authors, which required an upward revision of the hospital cost estimate.

Other program impacts

A range of program impacts have not been incorporated in our model, including the time involved in participation. Benefits have been restricted to effects on the incidence of NIDDM and life years. Quality of life impacts have been

Table 3: Illustration of all-cause mortality rate calculation: Group program, males

Age group (yr)	All-cause mortality male[a] (deaths/100)		Annual mortality adjusted for metabolic state[b] (deaths/100)[d]	Annual mortality adjusted for over-weight[c] (deaths/100)[e]
45–49	0.311	NIDDM	0.55	0.66
		IGT	0.44	0.53
		NGT	0.28	0.33
50–54	0.534	NIDDM	0.94	1.13
		IGT	0.75	0.90
		NGT	0.47	0.56
55–59	0.955	NIDDM	1.60	1.92
		IGT	1.28	1.54
		NGT	1.80	0.96
60–64	1.61	NIDDM	2.82	3.38
		IGT	2.26	2.71
		NGT	1.41	1.69
65–69	2.61	NIDDM	4.64	5.57
		IGT	3.71	4.45
		NGT	2.32	2.78

[a] Australian Bureau of Statistics (1995).
[b] Relative risk for NIDDM = 2.0, Simons (1996), Balkau (1993); relative risk for IGT = 1.6 Balkau (1993).
[c] Relative risk of overweight derived from Lee (1993), Rissanen(1990), Manson(1987), and excess annual mortality risk of overweight = 0.2.
[d] Annual mortality rates for successful intervention cohort.
[e] Annual mortality rates for control cohort and unsuccessful intervention cohort.

ignored, even though different disease or health states (NIDDM, IGT, NGT, obesity) and successful or failed program participation would be expected to be associated with a differential quality of life. Any effects on production have also been ignored. These wider effects have been excluded due to a lack of evidence concerning their value, but also because most cost-effectiveness studies, with which comparisons may be made, tend to adopt narrow definitions of costs and outcomes, similar to those adopted here.

Discounting/sensitivity analysis

Where impacts occur over time, discounting of future streams of costs and outcomes is appropriate, to reflect the greater value attached to more immediate gains and the lesser value of distant costs. A commonly accepted rate for discounting, of 5% per annum, has been used to discount future benefits and costs (Australian Department of Human Services and Health, 1995b).

The effect of changes in key parameter values on the cost-effectiveness result has been determined through a sensitivity analysis, incorporating a range of assumed values.

RESULTS

Life years gained and reduction in diabetes years for each of six program types, for a general and all-IGT participant group were estimated with the results shown in Table 5. (Cost-effectivness of the media program is reported in Table 6.) Programs were estimated to yield between 43 and 423 life years gained per 100 persons and a reduction of between 10 and 927 diabetes years. No consistent relationship between reduction in diabetes years and life years gained is observed. This is because life years gained reflects all-cause mortality as a function of obesity as well as diabetic state and average excess weight of participants varies across programs, as does program success (from 20% for GP-based advice to 87% for surgery). The program yielding the largest reduction in diabetes years is surgery, which is also the most expensive program. The general practitioner program is least effective, avoiding 10–35 diabetes years and gaining an estimated 43–64 life years, per 100 participants.

Gross and net cost per diabetes year deferred and life years gained were calculated for all program types, with estimated life years gained reported in Table 6. The behavioural based programs exhibit gross cost per life year saved of between A$500 and A$5900 (US $360–4300). Net

Table 4: Key program parameters

Program type[a]	Program cost(A$)[b]	% successful	Reduced incidence of NIDDM	Mortality rel. risk[d]	Mortality life expectancy 25 yr post-program[e]		
					NIDDM	IGT	NGT
I	2500	33[c]	70% reducing to 30%	C: 2.5–1.5 I: 1.75–1.2 over 25 yr	8 8	9 9	11 11
II	2500	33[c]	50%	Control: 1.75 Interval: 1.0	10 19	11 21	12 23
III	15 580	87% > 50%[h] redn in excess weight	85%	C: 2.5–1.5 I:1.75–1.2 over 25 yr	8 11	9 12	11 13
IV	195 577[f]	33[c]	50%	Control: 1.20 Interval: 1.0	9 10	10 11	11 12
V	420/patient 473[g]	20[c]	12.5%	Control = 1.2 Interval = 1.1	11 11.5	12 12.5	13 13.5
VI	2 million for community of ~4.5million persons	1[c]	50%	Interval = 1.0	10	11	12

[a] Programs as described in Table 1; cohort age at commencement of program 40–45 yr all programs, except gestational diabetic women (program II), where age at commencement was 30–35 years.
[b] Program cost per participant.
[c] Success taken as any sustained weight loss, defined as 1 kg or more. Average weight loss expected to be achieved is not identical across all programs and is expected to be least with the GP style program.
[d] Average relative risk for the control and intervention group compared with population all-cause mortality with further adjustment for diabetic state.
[e] Given state of NIDDM, IGT or NGT at 25 yr post-program.
[f] Including screening cost at $382 per case found (Eastman and Segal, 1997).
[g] Including additional screening cost at $53 (basic program already assumes blood test, additional cost for oral glucose tolerance test to confirm diagnosis in persons testing positive on the initial test).
[h] Success defined as a > 50% reduction in excess weight.
C: control cohort and unsuccessful intervention group.
I: intervention cohort.

of expected savings in downstream costs for diabetes management, two programs—the behavioural group program for overweight men and the media campaign with community support—are expected to generate net savings in health care resources, savings in downstream health care costs exceeding initial program cost. The least cost-effective program is surgery for a mixed participant group at A$12 300 (US$8900) net cost per life year saved, or A$4600 if targeted at seriously obese persons with IGT. Efficiency of targeting at persons with IGT depends on whether screening and case finding is already occurring, and screening cost relative to program cost.

Net cost per life year saved is sensitive to program success as demonstrated in Table 7. But even assuming a 20% success rate for behavioural programs and 10% for GP advice, program performance is still good (see Discussion below). The implication of making adjustments to a wider range of parameter values is illustrated by reference to the behavioural modification program for seriously obese persons (see Table 8).

These cost-effectiveness ratios compare favourably with those reported in the literature for other program types. George *et al.* (1997) reporting on drugs for which a listing on the Australian Government Pharmaceutical Benefits Schedule was sought, found that listing was generally recommended where incremental cost per life year was below A$70 000, with most drugs in the range of A$16 000 to A$35 000. Cost-effectiveness ratios of 500 life-saving interventions reported by Tengs and colleagues (1995) demonstrate an extremely wide range, from cost saving (for some drug and alcohol treatment programs and prenatal care, etc.), to over US$100 000 (~A$140 000) for poorly targeted intensive care services and screening programs. For the purpose of evaluating road safety initiatives in Australia, a value of life of $631 000 has been adopted, which is approximately equivalent to $60 000/life

Table 5: Undiscounted diabetes years prevented and life years gained per 100 program participants

Program type[a]	Participant group	Diabetes years			Life years		
		Control	Interv.	**Difference**	Control	Interv.	Gained
I Intensive diet and behavioural for seriously obese	mixed	715	571	**144**	2582	2737	**155**
	IGT	1148	889	**259**	2361	2574	**213**
II Intensive diet/ behavioural women with previous GDM	mixed	583	442	**141**	4430	4654	**224**
	IGT	827	624	**203**	4379	4611	**232**
III Surgery for seriously obese	mixed	715	144	**571**	2582	2833	**251**
	IGT	1148	221	**927**	361	2784	**423**
IV Group behavioural for overweight men	mixed	172	135	**37**	2905	3016	**111**
	IGT	639	484	**155**	2888	2750	**138**
V General Practitioner advice	mixed	182	172	**10**	3211	3264	**43**
	IGT	669	634	**35**	3056	3120	**64**

[a] Results for media program not reported, as the analysis is based on population of 4 million citizens, not 100 participants.
GDM: gestational diabetes mellitus.

Table 6: Cost per life year saved

Program type and target	Participant group[a]	Cost per life year gained[b]			
		Gross cost		Net cost	
		$A	$US[c]	$A	$US[c]
I Intensive diet and behavioural seriously obese	IGT only	4200	3000	net saving	
	10%IGT 90%NGT	5900	4300	2600	1900
II Intensive diet/ behavioural women with previous GDM	IGT only	4400	3200	1200	900
	25%IGT 75%NGT	4600	3300	2400	1700
III Surgery for the seriously obese	IGT only	12 100	8700	4600	3300
	10%IGT 90%NGT	19 100	13 800	12 300	8900
IV Group behavioural overweight men	IGT only	500	400	net saving	
	IGT only[d]	1600	1200	net saving	
	10%IGT 90%NGT	700	500	net saving	
V Media campaign plus community support	mixed population	500	400	net saving	
VI General Practitioner (family physician), CVD risks + BMI > 27	IGT only	3000	2200	1000	700
	10%IGT 90%NGT	3200	2300	2400	1700

Source: calculations of research team.
[a] For programs targeted at persons with IGT, testing for diabetes not included in cost, assumed to be part of standard management, except for the group program for overweight men, which includes cost of screening.
[b] Program costs and life year saved discounted at 5% per annum, rounded to nearest $100. US dollar ($US) figure based on simple conversion of $A (Australian dollar) estimate using median exchange rate for Aug/Sept/Oct 1997 of A$1 = US$0.72.
[d] Based on cost per new case of diabetes found through screening program of $382.67 'net cost saving'.
Expected downstream savings in health service costs (discounted at 5%) are greater than program cost.

year (Bureau of Transport and Communication Economics, 1992). Laupacis and colleagues (1992, p. 475) argue, based on a review of available economic evaluations and suggested guidelines, that 'technologies that cost less than US$20,000 [~A$27 500] per QALY are almost universally acceptable as being appropriate ways of using society's and the health care systems's resources.'

Programs for the prevention of NIDDM,

Table 7: Sensitivity analysis: effect of change in program success (on mixed participant group)

	Program type and target	Assumed percent success (%)	Net cost per life year saved ($)A
I	Intensive diet and behavioural seriously obese	20	2700
		33	saving
		45	saving
II	Intensive diet/ behavioural women with previous GDM	20	3830
		33	2400
		45	1400
III	Surgery for the seriously obese	60	19 100
		87	12 300
IV	Group behavioural overweight men	20	100
		33	net saving
		45	net saving
V	General practitioner	10	3280
		20	2600
VI	Media	0.1	2270
		1	net saving
		2	net saving

Note: parameter value used in the primary calculation shown in bold.

which are potentially cost saving in some circumstances, or involve a net cost of up to an estimated A$12 300/life year saved (for surgery), fall well within community expectations of what constitutes reasonable cost to gain a year of life.

DISCUSSION

The economic analysis reported here demonstrates that under a range of plausible parameter values, programs for the prevention of NIDDM are highly cost-effective relative to other funded health programs and indicated community standards. This suggests that programs for the prevention of NIDDM which incorporate similar characteristics to those studied would, therefore, represent a highly desirable use of the community's scarce health care resources. Provision of a range of program types for the prevention of NIDDM seems justified on efficiency grounds. This is also consistent with equity and access objectives. Subgroups of the population who are at high risk of NIDDM and the associated morbidity and mortality currently have very limited access to publicly funded programs for NIDDM prevention.

Prior to full-scale introduction of public sector prevention programs, research support for their pilot introduction is recommended. In recognition of the limited number and nature of the intervention studies on which the analysis is

Table 8: Sensitivity analysis—the behavioural program seriously obese

Assumptions		Net cost per life year saved [a] ($A)
Baseline assumptions see Table 6		3000
Discount rate. Change from 5% to:	zero	1100
	10%	11 500
Program cost. Change from $2500 to:	$5000	8900[b]
	$1250	100[b]
Savings in downstream health costs. Change from $1600 to:	$3200	200
	$1200	3700
Program success. Change from 33% to:	50%	1300
	10%	7200
Effect of success on incidence of NIDDM. Change from 70% reducing to 30% to:	70%	2100
	30%	4400
Life expectancy at age 70–75. Change from control 8 (NIDDM), 9 (IGT), 11 (NGT) and intervention 10, 11, 12, to:	intervention 11, 13, 15	2200
	intervention 9, 10, 11	4400
Higher-risk group of participants. Change from 90% NGT, 10% IGT to:	100% IGT	400

[a] Rounded to nearest $100.
[b] Gross cost/life year saved is directly proportional to change in program cost.

based, gaining further evidence on costs and long-term effectiveness is highly desirable. This would ideally cover a range of program types, targeted at high risk groups (persons with IGT, women with previous gestational diabetes, the seriously obese, high risk ethnic groups), as well as broader population-based programs.

Another reason for caution relates to simplifications incorporated into the model. For most programs a single transition matrix has been used to progress each cohort between diabetic states. A more dynamic model could possibly be developed if better information on rates of progression between diabetic states for population subgroups became available. The sensitivity analysis suggests this simplification may not have had a major effect on program performance, in part because the cost-effectiveness analysis depends on differences between the control and intervention cohort.

A further simplification of the analysis is the selection of a single target age group for each program. We have not explored the effect of targeting different age groups at point of program entry. The calculated downstream health care saving is an underestimate. The cost of managing diabetes used in the calculation excludes some items for which the costs attributable to diabetes could not be obtained, and it also excludes any savings in the costs of managing other diseases, such as cardiovascular, for which weight and physical activity are also risk factors.

Costs have been limited to the direct costs of program implementation and potential savings in health service costs for the management of diabetes. Benefits have been limited to effect on the incidence of diabetes and on mortality. No account is taken of other program costs, such as time commitment of participants. Inferring time allocations from program descriptions would be uncertain and the appropriate unit value to assign to time is contentious. Further, as incorporation of patient time is not common in health evaluations, comparisons with other health programs would be less, rather than more valid.

A desirable advancement to the approach would be incorporation of quality of life impacts. Differential quality of life will be associated with the onset and progression of NIDDM, with levels of overweight and obesity and program participation and program outcome. For instance, participation in group programs may be viewed favourably, while surgery generally imposes a temporary reduction in quality of life, due to post-operative morbidity and pain. But with the high success rates for surgery, improved sense of well-being in the medium to longer term is reported (see Sjostrom, 1995).

More robust cost-effectiveness estimates require the establishment of pilot or demonstration programs, which can provide evidence on whether the changes to risk factors and health end points incorporated in our model can be achieved and if so, at what cost. Pilot introduction of programs would also provide an opportunity for a more comprehensive range of costs and impacts to be studied, including quality of life impacts.

While our analysis has been conducted in an Australian context, much of the data on program effectiveness are derived from the international literature. The rise in NIDDM is occurring across many countries, for instance in Singapore increasing from 2.5% of adults in 1975 to 8.4% in 1992 (Caterson, 1997). Application of the study to other countries would be most interesting.

A focus on NIDDM prevention has some urgency. If the incidence of NIDDM is not contained, the cost to the community in terms of illness, loss in quality of life, premature death and allocation of scarce health care resources will be an ever-increasing burden. This research suggests that there are alternatives—that NIDDM is a disease for which prevention options exist and that interventions may be cost-saving or highly cost-effective relative to other possible uses of health care resources.

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