The Cost-Effectiveness of Exercise Training for the Primary and Secondary Prevention of Cardiovascular Disease

Ilka Lowensteyn, PhD,*‡ Louis Coupal, MSc,*‡
Hanna Zowall, MSc,*‡ and Steven A. Grover, MD, MPA, FRCPC*†‡§

Background. *Although exercise training improves cardiovascular disease (CVD) risk factors, few studies have evaluated its potential long-term cost-effectiveness.*

Methods. *Using the Cardiovascular Disease Life Expectancy Model, a validated disease simulation model, we calculated the life expectancy of average 35- to 74-year-old Canadians found in the 1992 Canadian Heart Health Survey. The impacts of exercise training on cardiovascular risk factors were estimated as a 4% decrease in low-density lipoprotein (LDL) cholesterol, a 5% increase in high-density lipoprotein (HDL) cholesterol, and a 6 mm Hg decrease in both systolic and diastolic blood pressure. Exercise adherence was estimated at 50% for the first year and 30% for all additional years. Costs for a supervised exercise program determined from Canadian sources and converted to US dollars were estimated at $605 for the first year (medical evaluation, stress test, exercise prescription, and program costs) and $367 for all additional years (program costs). For an unsupervised program, the costs were estimated at $311 for the first year and $73 for all additional years.*

Results. *The cost-effectiveness (CE) of an unsupervised exercise program (1996 U.S. dollars) was less than $12,000 per year of life saved (YOLS) for all individuals. The CE of a supervised exercise program was less than $15,000/YOLS for men with CVD, and between $12,000 and $43,000 for women with CVD and men without CVD.*

Conclusions. *Given the relatively few risks, substantial long-term benefits, and modest costs, an unsupervised exercise training program represents good value for all. A more expensive supervised exercise program is also cost-effective for most individuals with CVD.*

Key words: cardiovascular diseases, cost–benefit analyses, coronary disease, exercise, prevention.

Cardiovascular disease (CVD) remains a primary cause of death and disability in most Western societies and therefore a major target for healthcare spending. However, increasingly constrained healthcare budgets have made it necessary to evaluate the cost-effectiveness of the various treatments competing for these limited funds. Clinical studies have shown that exercise training improves cardiovascular disease risk factors[1–5] and decreases the clinical morbidity and mortality of this disease.[6] However, very few studies have evaluated the potential long-term cost-effectiveness of exercise as a CVD prevention strategy.

One randomized controlled trial found that an 8-week cardiac rehabilitation program with exercise, risk factor management, and group behavioral counseling had a cost-effectiveness ratio of $21,800 per life year gained in 1991 US dollars.[7] Two nonrandomized trials found that supervised exercise training and health education sessions had a direct cost savings per rehabilitation patient and resulted in significantly lower cardiac hospitalization charges during the 3-year follow-up period.[8,9]

A nonrandomized study found that exercise training and a series of lectures on risk factor management resulted in $900 lower hospital and physician expenses per patient in the first 6 months and $2,600 lower expenses in the second 6-month period.[10] Finally, one study, using various data sources, estimated the cost-effectiveness of cardiac rehabilitation with exercise at $4,950 per year of life saved in 1995 US dollars.[11]

Hatziandreu et al.[12] has calculated the cost-effectiveness of exercise in preventing coronary heart disease using hypothetical cohorts of men 35 years of age. Nonexercisers were assumed to have a relative risk of 2.0 for a coronary event. They calculated the direct and indirect costs of jogging, incorporating injury rates, adherence, and the value of time spent and found that jogging had a cost utility of $11,313 per quality-adjusted life year saved. Benefits other than coronary mortality were not considered.

*From the *Centre for the Analysis of Cost-Effective Care and the †Divisions of General Internal Medicine and ‡Clinical Epidemiology, The Montreal General Hospital; and the §Departments of Medicine and Epidemiology and Biostatistics, McGill University, Montreal, Quebec.*

Address for correspondence: Steven A. Grover, MD, MPA, FRCPC, Centre for the Analysis of Cost-Effective Care, The Montreal General Hospital, 1650 Cedar Avenue, Montreal, Quebec H3G 1A4, Canada.

The Cardiovascular Disease Life Expectancy Model has been developed to estimate the benefits and costs associated with cardiovascular risk factor modification.[13] This validated disease simulation model is used herein to estimate the benefits and cost-effectiveness of long-term aerobic exercise training among patients with and without symptomatic cardiovascular disease.

Methods

Model

Estimates of increased life expectancy attributable to exercise training were derived using the Cardiovascular Disease Life Expectancy Model.[13] This model calculates the annual probability of death of coronary disease, stroke, and other causes using multivariate logistic regression models developed from the Lipid Research Clinics Program Prevalence and Follow-up Studies data.[14,15] The risk of CVD death is based on the levels of independent risk factors that include age, gender, the natural log of the low-density lipoprotein (LDL) cholesterol/high density lipoprotein (HDL) cholesterol ratio, mean blood pressure, and the presence of CVD, glucose intolerance, and cigarette smoking. This model has been shown to predict accurately the results of prospective randomized clinical trials using summary data characterizing the treatment and control cohorts.[13]

The model forecasts the long-term risk of developing cardiovascular endpoints such as myocardial infarction, congestive heart failure, transient ischemic attacks, arrhythmias, and strokes, as well as the need for surgical procedures (coronary artery bypass graft surgery, catheterization, angioplasty, and pacemaker insertion).

Patient Characteristics

Risk factor data representative of the Canadian population with and without diagnosed cardiovascular disease was obtained from the Canadian Heart Health Survey.[16] This survey combines information from 10 provincial surveys conducted between 1986 and 1992 that recorded anthropometric measurements, blood pressure, plasma cholesterol, and lipoproteins at clinic visits.

The average risk profiles of Canadian men and women with and without CVD were generated for the age groups 35 to 54, 55 to 64, and 65 to 74 years, and were used for the simulations. The presence of CVD was defined as a self-report of previous heart attack, stroke, or other heart disease. Subjects were excluded if they had not fasted for at least 8 hours or if they had any missing information on risk factors required by the model. The mean values of cardiovascular risk factors among 35- to 74-year-old Canadian men and women with and without CVD are presented in Table 1.

The Effects of Exercise Training on Cardiovascular Risk Factors

We estimated the benefits of exercise training on blood lipid levels using the results of randomized controlled trials lasting between 3 and 12 months that were published in English between 1980 and 1999. Exercise training was defined as aerobic exercise performed at least 3 times per week for 30 minutes per session within 65% to 85% of an individual's maximum heart rate. Table 2 lists studies fulfilling these criteria.[2–4,17–29] For the current analysis, the impacts of exercise training on LDL and HDL cholesterol were taken to be the weighted averages (using the sample size of the exercise group) of the observed percent changes in the exercise group compared with the con-

Table 1. *Average Risk Factors Among 35- to 74-Year-Old Canadian Men and Women With and Without Previous Cardiovascular Disease*

Sample Size (n)	*Men without CVD 3426*	*Men with CVD 815*	*Women without CVD 3592*	*Women with CVD 671*
Smokers (%)	22.9%	18.7%	21.1%	18.7%
Total cholesterol (mmol/L)	5.43	5.38	5.39	5.70
LDL cholesterol (mmol/L)	3.44	3.39	3.26	3.59
HDL cholesterol (mmol/L)	1.21	1.13	1.47	1.37
Systolic blood pressure (mmHg)	128.4	135.1	123.7	130.7
Diastolic blood pressure (mmHg)	81.2	81.1	76.7	77.9
Diabetes (%)	4.9%	12.1%	4.1%	11.9%

CVD: cardiovascular disease; LDL: low-density lipoprotein; HDL: high-density lipoprotein.

Table 2. *Effect of Exercise on Lipids in Men and Women*

Author	N (n)*	*CVD*	*Gender*	*HDL-C*	*LDL-C*
Anderson et al., 1995	219 (54)	No	Male and female	+3%	+2%
Baker et al., 1986	34 (20)	No	Male	+24%†	−11%
Binder et al., 1996	71 (23)	No	Female	+2%	−12%†
Blumenthal et al., 1991	101 (33)	No	Male	−3%	−3%
Blumenthal et al., 1997	107 (34)	Yes	Male and female	+5%	−8%†
Duncan et al., 1991	102 (55)	No	Female	+4%	−6%
Hellenius et al., 1993	157 (39)	No	Male	+2%	+2%
Katzel et al., 1995	170 (71)	No	Male	+4%	−8%
LaRosa et al., 1982	223 (110)	Yes	Male	+2%	−4%
Lindheim et al., 1994	101 (25)	No	Female	−3%	−15%†
Marti et al., 1990	61 (39)	No	Male	+9%	+2%
Stefanick et al., 1998	177 (43)	No	Female	+3%	−1%
Stefanick et al., 1998	190 (47)	No	Male	+4%	+1%
Stein et al., 1990	49 (38)	No	Male	+9%	−10%
Williams et al., 1994	130 (46)	No	Male	+8%†	N/A
Wood et al., 1983	81 (48)	No	Male	+3%	−5%
Wood et al., 1988	131 (47)	No	Male	+12%†	−2%

CVD: cardiovascular disease; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol.
**N* = entire sample (*n* = exercise group).
†Exercise group different from control, $P < 0.05$.

trol group. The weighted changes were calculated as a 4% decrease in LDL and a 5% increase in HDL.

Associated decreases in blood pressure were taken from a critical review by Arroll and Beaglehole[1] of 22 articles evaluating physical activity as a means of reducing blood pressure. The average reduction in the better-designed studies was 6 to 7 mm Hg for both systolic and diastolic blood pressure; therefore, we conservatively chose a 6 mm Hg decrease in both systolic and diastolic blood pressure. Although many studies show other benefits associated with exercise on cardiovascular risk factors, we did not include changes such as decreases in plasma glucose values and reductions in glucose intolerance in this study.[3,30]

Adherence

Studies have shown that adherence with exercise training is approximately 50% 1 year after the initiation of a supervised program.[31,32] With long-term exercise, the adherence drops to approximately 30% to 40% at 5 years.[33,34]

Estimating the Benefits of Exercise Training on Cardiovascular Risk

The long-term benefits of exercise training are estimated using the Cardiovascular Disease Life Expectancy Model by forecasting the life expectancy of subjects under two scenarios (with and without exercise training).

For each of these scenarios, the model enters a cohort of patients (n = 1,000) with a given set of risk factors. Each year, subjects can either die of CVD, die of other causes, or survive with or without experiencing a CVD event. Subjects surviving are aged 1 year and reenter the model the following year. This process continues until all subjects have died or have reached 102 years of age. At this point, the remaining subjects are assumed to die, and mean life expectancy can be calculated by summing across the total person-years of life enjoyed by the cohort and dividing by the cohort size at entry into the model (i.e., 1,000).

The benefits of exercise training on cardiovascular risk are calculated as the years of life saved (YOLS) by exercise training versus no exercise.

Economic Evaluation

The Cardiovascular Disease Life Expectancy Model assigns treatment costs to acute, nonsurgical manifestations of coronary disease. Treatment costs for each CVD medical event include the costs for hospitalization, physician fees, as well as outpatient and emergency services when applicable. Determination of these costs were from Canadian sources and have been described previously.[35] All costs were calculated on the basis of 1996 Canadian dollars and converted to US dollars at the 1996 exchange rate (US $1 = Canadian $1.364).

A physician visit with a blood test as well as an exercise stress test were included as first-year costs for all individuals as per the American College of Sports Medicine recommendations.[36] These costs are based on an average of Ontario and Quebec health insurance plan fees from 1996. The cost for a physician visit was calculated at $37.50 ($51.15 Canadian dollars), and the cost of an exercise stress test, including both the professional and technical fees, was $56.21. The cost of the blood tests, including a full lipid profile and glucose level, was $18.23. The cost of an exercise prescription by an exercise professional was also included as a direct cost for all individuals in their first year. The cost of the exercise prescription was estimated at $125 for a 90-minute initial evaluation and three 30-minute follow-up visits. Overall, we estimated that the average evaluation would cost $238.00.

We evaluated the cost of two different types of exercise programs that an individual might follow. The first option consisted of a group supervised exercise class, which we estimated in Canada would cost approximately $367/year ($500 Canadian dollars/year), including suitable clothing and footwear. The second exercise option was an unsupervised walking program performed outdoors or in a local shopping mall. The only cost associated with this second option was the cost of proper clothing and footwear, which was estimated at approximately $73/year.

The supervised program consists of first-year costs of $605 (for the initial assessment as well as the supervised group exercise class) and an additional cost of $367 for each additional year (program cost only). Adherence was estimated at 50% for the first year, dropping to 30% for all remaining years. After the first year, only the 50% of individuals who continue to exercise paid the $367/year program cost.

The unsupervised program has first-year costs of $311 (for the initial evaluation and an unsupervised walking program) and additional yearly costs of $73 from the second year on (program costs only). Adherence was once again estimated at 50% for the first year, dropping to 30% for all remaining years. We conservatively assumed that subjects who stopped exercise training stopped accruing benefits and that their risk factors reverted back to their original values.

Given the absence of clinical trial data proving mortality benefits by treating cholesterol and blood pressure in the very elderly, we conservatively assumed that benefits would stop at age 75 years, whereas the cost of the exercise program would continue until death.[13] Because costs and benefits in the future are not valued as highly as costs or benefits that may be realized immediately, all future costs and years of life saved were discounted at an annual rate of 3% to determine their current value.[37]

The incremental cost-effectiveness (CE) of an exercise training program was calculated as the difference in costs between the exercise program and no exercise, divided by the difference in effectiveness, defined as years of life saved (YOLS):

$$CE_{\text{exercise} - \text{no exercise}} = (\text{Cost}_{\text{exercise}} - \text{Cost}_{\text{no exercise}}) / (\text{Life expectancy}_{\text{exercise}} - \text{Life expectancy}_{\text{no exercise}})$$

To put the CE values in perspective, we used categorizations summarized by the American College of Cardiology Bethesda Conference. They classified CE values less than $20,000/YOLS as highly cost-effective, between $20,000 and $40,000/YOLS as relatively cost-effective, between $40,000 and $60,000 as borderline, and greater than $60,000 as expensive.[37]

Sensitivity Analysis

To handle the uncertainty of CE analyses, we performed numerous sensitivity analyses. We performed analyses using 100% and 20% adherence rates, a 5% discount rate, double and half the yearly cost of the supervised exercise program, and the assumption that the impact of exercise training on CVD risk would continue until death.

Results

Assuming 100% lifetime adherence, the benefits of exercise training on blood lipids and blood pressure are forecasted to result in 0.70 year of life saved (YOLS) for men without CVD between 35 and 54 years of age. The YOLS are less for older men and all women without CVD but greater for those with CVD compared with their age- and sex-matched counterparts without CVD. The YOLS are greatest for younger men with CVD, with 1.18 year of life saved for men 35 to 54 years of age.

Lifetime costs broken down by source of expenditure are represented in Table 3, using an unsupervised exercise program for 35- to 54-year-old men without CVD as an example. These costs vary depending on age-group, gender, disease status, and type of exercise program. The discounted net cost (or cost saving) is divided by the discounted average life expectancy to determine the cost-effectiveness ratio.

An unsupervised exercise program with 100% compliance results in an increased life expectancy and a net savings in healthcare costs for most men with and without CVD as well as older women with and without CVD (Table 4). Even for younger women with

Table 3. *Estimated Lifetime Average Costs for an Average 35 to 54 Year Old Man Without Cardiovascular Disease (CVD) Participating in an Unsupervised Exercise Program**

	No Exercise	*Unsupervised Exercise (100% Adherence)*
Cost of exercise program†	$0	$2,999.73
Cost of fatal CVD events‡	$1,476.91	$1,386.11
Cost of non-fatal CVD events§	$5,815.21	$5,312.32
Cost of medical procedures‖	$5,483.53	$4,622.82
Cost of medical follow-up#	$21,733.92	$19,159.85
Total costs (undiscounted)	$34,509.57	$33,480.81
Total costs (discounted at 3%/year)	$13,416.97	$13,234.27
Net cost (savings)		($182.70)

*All costs are in 1996 US dollars.
†Cost of $311 for the first year and $73/year for the reminder of the average LE.
‡Sudden death, fatal MI, stroke death, and non-cardiovascular death.
§Angina, coronary insufficiency, non-fatal MI, TIA, etc.
‖Angioplasty, bypass surgery, etc.
#Physician fees, tests, etc.

and without CVD, the cost/YOLS (in 1996 US dollars) is highly cost-effective at less than $5,000/YOLS. This represents an ideal scenario in which patients are medically cleared to exercise, taught how to do so safely, and are sufficiently motivated to continue on their own.

A more expensive supervised program is highly cost-effective (< $20,000/YOLS) for all men and older women (55–74 years) with CVD, as well as men without CVD between 55 and 64 years of age (Table 4). It is relatively cost-effective (between $20,000 and $40,000/YOLS) for the remaining men without CVD and younger women with CVD. Given our conservative underlying assumptions, a supervised program for women without CVD appears to be borderline cost-effective or expensive (> $40,000/YOLS) even with 100% adherence.

We determined more realistic adherence rates of 50% for the first year and 30% for all remaining years.[31–34] In Table 5, we show the results of both unsupervised and supervised exercise programs using these adherence rates. Unsupervised exercise is highly cost-effective (< $12,000/YOLS) for all individuals with and without CVD (Table 5). Supervised exercise is highly cost-effective (< $20,000/YOLS) for all men with CVD and women with CVD between 55 and 64 years of age. It is relatively cost-effective ($20,000-$40,000/YOLS) for younger men without CVD and

Table 4. *Cost-Effectiveness of Exercise Training (100% Adherence)*

		Men		*Women*	
	Age (years)	*Unsupervised Cost/YOLS**	*Supervised Cost/YOLS*	*Unsupervised Cost/YOLS*	*Supervised Cost/YOLS*
Without CVD	35–54	($645)	$22,566	$4,915	$42,296
	55–64	($2,517)	$15,015	($1,583)	$49,353
	65–74	($1,237)	$20,544	($1,367)	$60,283
With CVD	35–54	$356	$10,783	$3,154	$34,677
	55–64	($912)	$5,871	($2,464)	$8,084
	65–74	($777)	$9,034	($2,484)	$12,839

YOLS: year of life saved; CVD: cardiovascular disease.
*All cost/YOLS values are in 1996 US dollars.
Values in parenthesis represent net cost savings per YOLS.

older women with CVD and is borderline or expensive (> $40,000/YOLS) for all others.

The results of our sensitivity analyses for men with CVD participating in supervised exercise are shown in Figure 1. When the discount rate is raised from 3% to 5%, supervised exercise training in men with CVD becomes less cost-effective, increasing by 7% to 30%. The increase is largest in the youngest age-group. Similar but slightly larger increases are seen in women with CVD (9% to 41%), men without CVD (11% to 46%), and women without CVD (12% to 43%). Accordingly, higher discount rates reduce the cost savings of preventing CVD events in the future.

When the benefits of risk factor modification were extended until death, the cost-effectiveness improved substantially (Figure 1). For men with CVD participating in supervised exercise, the cost-effectiveness ratios decreased by 21% to 59%, with the largest decrease occurring in the oldest age-group. Even larger improvements are seen in women with CVD (36% to 75%), men without CVD (38% to 80%), and women without CVD (49% to 92%). In women without CVD, 65 to 74 years of age, the cost-effectiveness drops from an expensive $87,166/YOLS to a highly cost-effective $7,095/YOLS, underscoring the importance of this assumption among older individuals.

Compared with an average adherence rate of 50% for the first year and 30% long-term adherence, when we evaluate an adherence rate of 20%, supervised exercise becomes less cost-effective (Figure 1). In men with CVD, a supervised exercise program will have CE ratios that increase by 10% to 19%, affecting the highest age-group the most. Similar changes are observed for women with CVD, as well as men and women without CVD (between 8% and 18%).

When we doubled the cost of the yearly supervised exercise program, supervised exercise became far less cost-effective, increasing between 109% and 132% (Figure 1). When we halved the cost of the yearly supervised exercise program, the CE became much more favorable, with decreases between 51% and 66%.

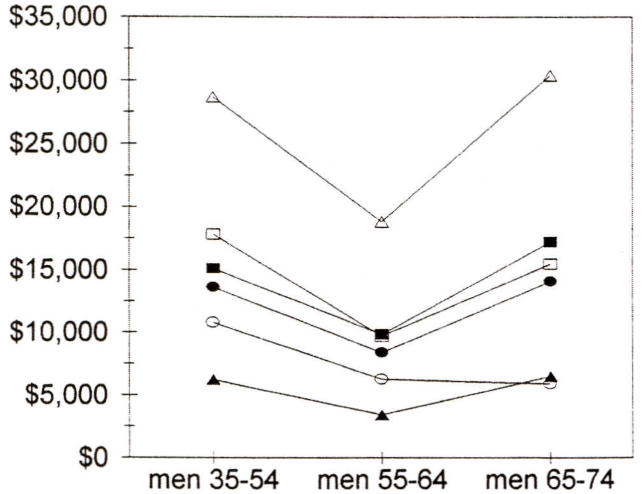

Figure 1. Sensitivity analyses for men with cardiovascular disease in a supervised exercise program. Y axis represents cost/year of life saved in 1996 in 1996 US dollars. Filled circles represent the baseline analysis for supervised exercise (50% first-year adherence, 30% long-term adherence, 3% discounting; benefits stop at age 75, $605 first-year cost, $367 cost for each additional year). Open circles represent benefits continuing until death. Filled squares represent 20% adherence. Open squares represent 5% discounting. Open triangles represent double the exercise program cost. Closed triangles represent half the exercise program cost.

Discussion

These analyses suggest that exercise training as a primary and secondary prevention intervention for cardiovascular disease can be cost-effective providing that adherence is adequate. With optimal adherence of 100%, an unsupervised exercise program can actually save lives and money across a wide range of individuals. A more expensive supervised program is also considered highly cost-effective for most individuals with CVD.

Unfortunately, adherence with exercise, as with most treatment modalities, is not perfect. The literature shows that a realistic adherence rate for exercise training is 50% after 1 year and 30% after 5 years.[31–34] Incorporating these estimates into our analyses, some form of exercise training is still highly cost-effective for all individuals (Table 5). For men with CVD, supervised and unsupervised exercise are both highly cost-effective. For men without CVD, supervised exercise is borderline cost-effective; however, unsupervised exercise remains highly cost-effective. Because of the lower risk of mortality for most men without CVD compared with those with disease, an unsupervised exercise program should be sufficiently safe for most men without CVD who have proper medical clearance.

The benefits of exercise training on life expectancy for women are less than that for their age- and disease-matched male counterparts. This results in CE ratios that are substantially higher. The CE of supervised exercise is only cost-effective for women 55 to 74 years of age with CVD, whereas unsupervised exercise is highly cost-effective for all women with CVD and younger women without CVD (Table 5).

The CE values we estimated for individuals with CVD in a supervised exercise training program are slightly less than what has been reported in the literature for cardiac rehabilitation programs consisting primarily of exercise. In a group of individuals with CVD (88% men; average age, 52.9 years), a CE analysis of a

Table 5. *Cost-Effectiveness of Exercise Training**

	Age (years)	Men: Unsupervised Cost/YOLS*	Men: Supervised Cost/YOLS	Women: Unsupervised Cost/YOLS	Women: Supervised Cost/YOLS
Without CVD	35–54	$2,083	$28,377	$9,135	$51,281
	55–64	$345	$21,131	$6,112	$65,765
	65–74	$3,493	$30,704	$11,191	$87,166
With CVD	35–54	$1,734	$13,719	$6,765	$42,367
	55–64	$341	$8,562	($634)	$12,015
	65–74	$1,723	$14,464	$965	$20,307

YOLS: year of life saved; CVD: cardiovascular disease.
*First year: 50% adherence; all other years: 30% adherence.
†All cost/YOLS values are in 1996 US dollars.
Values in parentheses represent net cost savings per YOLS.

cardiac rehabilitation program using primary data was found to be $21,800/YOLS.[7] Our results for men without CVD in an unsupervised exercise program were also slightly less than what has been published previously. A CE analysis using primarily calculations found that the direct costs of a jogging program for 30-year-old men who had a 50% decrease in CHD death attributable to the jogging were estimated at $3,433/YOLS.[12]

The forecasted benefits of exercise training occur despite the use of conservative assumptions. We made four assumptions that could potentially affect benefits and costs. First, we considered only the effect of exercise on lipids and blood pressure and did not consider the other benefits such as managing and preventing noninsulin-dependent diabetes mellitus,[5,38,39] reducing body fat,[40] or the 50% reduction in coronary mortality that is observed even after adjusting for all other risk factors.[6] These are all factors that would improve the YOLS and in turn improve the cost-effectiveness values.

Second, the higher cost-effectiveness values for older individuals reflect the assumption that the benefits of exercise stop at age 75 years, whereas the costs continue until death. In one sensitivity analysis, we extended the benefits until death and showed that the cost-effectiveness values improved by at least 21% and by as much as 92% for older women. When benefits continued until death, the CE values for the older age-groups are similar or better than those for younger individuals.

Third, we did not consider the benefits of exercise training on quality of life. This is an important issue because for many individuals, exercise improves quality of life,[41] whereas other treatment modalities such as diet or medications are neutral or sometimes even associated with a decrease in quality of life.[42–44] For example, Hatziandreu et al.[12] estimated the direct cost/YOLS of a jogging program at $3,433, whereas the cost-effectiveness in terms of quality-adjusted years of life saved was only $1,395.

Finally, we did not consider potential cost savings associated with non-CVD events that would result from exercise training. Nor did we consider the indirect costs of exercise training (e.g., earlier return to work).[8] These cost savings would further improve the cost-effectiveness ratios.

Another important issue is that we did not adjust for differences in US versus Canadian healthcare costs. Given the Canadian/American exchange rate (1 US dollar = 1.364 Canadian dollars in 1996) and generally lower costs for health services in Canada, one would expect that the costs of health screening tests for exercise training (stress test, physician visit, and blood tests) and the cost savings of reducing cardiovascular events would both be higher in the United States than in Canada. Whether this substantially alters the results presented herein remains to be determined. Nonetheless, other studies using exclusively US costs for prevention and treatment of CVD with exercise have shown similar results.[7,12]

The CE of exercise training is comparable to that for other prevention strategies. The most consistent and cost-effective CVD prevention strategies are smoking cessation programs. A program consisting of physician counseling for male and female smokers 40 to 45 years of age had a 2.7% success rate and a 10% relapse. It cost approximately $1,300 to $1,850 /YOLS in men and $2,300 to $3,900/YOLS in women.[45] In a study evaluating smoking cessation in individuals after an acute myocardial infarction, a nurse-managed program had a cost-effectiveness of $220/YOLS based on a quit rate of 26/100 more than controls. Even with a quit rate of 3/1,000, the cost-effectiveness was still less than $20,000/YOLS.[46]

Exercise training is at least as cost-effective as lipid-lowering and hypertension medications. The cost-effectiveness of simvastatin for men and women 35 to 70 years of age at various cholesterol levels before treatment ranged from $3,800/YOLS for 70-year-old men with 8 mmol/L cholesterol to $27,400/YOLS for 35-year-old women with 5.5 mmol/L cholesterol (1995 US dollars).[47] Edelson et al.[48] estimated the antihypertensive and total cholesterol effects of various antihypertensive regimens for individuals 35 to 64 years of age without CVD and found the cost per YOLS in 1987 US dollars to be $10,900 for propranolol hydrochloride; $16,400 for hydrochlorothiazide; $31,600 for nifedipine; $61,900 for prazosin hydrochloride; and $72,100 for captopril.[48] These analyses also assumed 100% compliance with medication.

In conclusion, unsupervised exercise training appears to be an extremely efficient use of resources. A basic unsupervised walking program is highly cost-effective across all age-groups and for both genders, even with a long-term compliance rate of only 30%. Supervised exercise is highly cost-effective for all men with CVD and women with CVD between 55 and 64 years of age. It is relatively cost-effective for men without CVD and older women with CVD. It is either borderline or expensive for women without CVD and younger women with CVD. Given the relatively few risks and the many benefits, some form of exercise training (either supervised or unsupervised) can be cost-effective for everyone. If long-term compliance can be improved, we may even save lives and money.

Acknowledgment

Dr. Grover is a senior research scientist (chercheur-boursier) supported by the Fonds de la Recherche en Santé du Québec, Montréal.

References

1. Arroll B, Beaglehole R: Does physical activity lower blood pressure: A critical review of the clinical trials. *J Clin Epidemiol* 1992;45:439–447.
2. Baker TT, Allen D, Lei KY, Willcox KK: Alterations in lipid and protein profiles of plasma lipoproteins in middle-aged men consequent to an aerobic exercise program. *Metabolism* 1986;35:1037–1043.
3. Blumenthal JA, Jiang W, Babyak MA, et al: Stress management and exercise training in cardiac patients with myocardial ischemia: Effects on prognosis and evaluation of mechanisms. *Arch Intern Med* 1997;157:2213–2223.
4. Duncan JJ, Gordon NF, Scott CB: Women walking for health and fitness: How much is enough? *JAMA* 1991;266:3295–3299.
5. Holloszy JO, Schultz J, Kusnierkiewicz J, Hagberg JM, Ehsani AA: Effects of exercise on glucose tolerance and insulin resistance. *Acta Med Scand* 1986;711:55–65.
6. Blair SN, Kohl HW, Barlow CE, Paffenbarger RS, Gibbons LW, Macera CA: Changes in physical fitness and all-cause mortality: A prospective study of healthy and unhealthy men. *JAMA* 1995;273:1093–1098.
7. Oldridge N, Furlong W, Feeny D, et al: Economic evaluation of cardiac rehabilitation soon after myocardial infarction. *Am J Cardiol* 1993;72:154–161.
8. Levin LA, Perk J, Hedback B: Cardiac rehabilitation: A cost analysis. *J Intern Med* 1991;230:427–434.
9. Ades PA, Huang D, Weaver SO: Cardiac rehabilitation participation predicts lower rehospitalization costs. *Am Heart J* 1992;123:916–921.
10. Edwards WW, Glickman-Weiss E, Franks BD, Iyriboz Y, Dodd SL, Quaid TP: Percutaneous transluminal coronary angiography rehabilitation: A cost-effectiveness analysis. *J Cardiopulmonary Rehabil* 1993;13:172–181.
11. Ades PA, Pashkow FJ, Nestor JR: Cost-effectiveness of cardiac rehabilitation after myocardial infarction. *J Cardiopulmonary Rehabil* 1997;17:222–231.
12. Hatziandreu EI, Koplan JP, Weinstein MC, Caspersen CJ, Warner KE: A cost-effectiveness analysis of exercise as a health promotion activity. *Am J Public Health* 1988;78:1417–1421.
13. Grover SA, Paquet S, Levinton C, Coupal L, Zowall H: Estimating the benefits of modifying cardiovascular risk factors: A comparison of primary versus secondary prevention. *Arch Intern Med* 1998;158:655–662.
14. Central Patient Registry and Coordinating Centre for the Lipid Research Clinics: *Reference Manual for the Lipid Research Clinics Prevalence Study.* Vols. 1 and 2. Chapel Hill: University of North Carolina; 1974.
15. The Lipid Research Clinics Program Epidemiology Committee: Plasma lipid distributions in selected North American populations: The Lipid Research Clinics Prevalence Study. *Circulation* 1980;61:302–315.
16. The Canadian Heart Health Database 1986-92. Canadian Heart Health Database Centre, Memorial University of Newfoundland, St. John's, 1998.
17. Anderssen SA, Haaland A, Hjermann I, Urdal P, Gjesdal K, Holme I: Oslo Diet and Exercise Study: A one-year randomized intervention trial. Effects on hemostatic variables and other coronary risk factors. *Nutr Metab Cardiovasc Dis* 1995;5:189–200.
18. Binder EF, Birge SJ, Kohrt WM: Effects of endurance exercise and hormone replacement therapy on serum lipids in older women. *J Am Geriatr Soc* 1996;44:231–236.
19. Blumenthal JA, Emery CF, Madden DJ, et al: Effects of exercise training on cardiorespiratory function in men and women >60 years of age. *Am J Cardiol* 1991;67:633–639.
20. Hellénius ML, de Faire U, Berglund B, Hamsten A, Krakau I: Diet and exercise are equally effective in reducing risk for cardiovascular disease: Results of a randomized controlled study in men with slightly to moderately raised cardiovascular risk factors. *Atherosclerosis* 1993;103:81–91.
21. Katzel LI, Bleecker ER, Colman EG, Rogus EM, Sorkin JD, Goldberg AP: Effects of weight loss vs aerobic exercise training on risk factors for coronary disease in healthy, obese, middle-aged and older men: A randomized controlled trial. *JAMA* 1995;274:1915–1921.
22. LaRosa JC, Cleary P, Muesing RA, Gorman P, Hellerstein HK, Naughton J: Effect of long-term moderate physical exercise on plasma lipoproteins. *Arch Intern Med* 1982;142:2269–2274.
23. Lindheim SR, Notelovitz M, Feldman EB, Larsen S, Khan FY, Lobo RA: The independent effects of exercise and estrogen on

lipids and lipoproteins in postmenopausal women. *Obstet Gynecol* 1994;83:167–172.
24. Marti B, Suter E, Riesen FW, Tschopp A, Wanner HU, Gutzwiller F: Effects of long-term, self-monitored exercise on the serum lipoprotein and apolipoprotein profile in middle-aged men. *Atherosclerosis* 1990;81:19–31.
25. Stefanick ML, Mackey S, Sheenan M, Ellsworth N, Haskell WL, Wood PD: Effects of diet and exercise in men and post-menopausal women with low levels of HDL cholesterol and high levels of LDL cholesterol. *N Engl J Med* 1998;339:12–20.
26. Stein RA, Michielli DW, Glantz MD, Sardy H, Cohen A, Goldberg N, Brown CD: Effects of different exercise training intensities on lipoprotein cholesterol fractions in healthy middle-aged men. *Am Heart J* 1990;119:277–282.
27. Williams PT, Stefanick ML, Vranizan KM, Wood PD: The effects of weight loss by exercise or by dieting on plasma high-density lipoprotein (HDL) levels in men with low, intermediate, and normal-to-high HDL at baseline. *Metabolism* 1994;43:917–924.
28. Wood PD, Haskell WL, Blair SN, et al: Increased exercise level and plasma lipoprotein concentrations: A one-year, randomized, controlled study in sedentary, middle-aged men. *Metabolism* 1983;32:31–39.
29. Wood PD, Stefanick ML, Dreon DM, et al: Changes in plasma lipids and lipoproteins in overweight men during weight loss through dieting as compared with exercise. *N Engl J Med* 1988;319:1173—1179.
30. Reitman JS, Vasquez B, Klimes I, Nagulesparan M: Improvement of glucose homeostasis after exercise training in non-insulin-dependent diabetes. *Diabetes Care* 1984;7:434–441.
31. Oldridge NB: Cardiac rehabilitation exercise programme. Compliance and compliance-enhancing strategies. *Sports Med* 1988;6:42–55.
32. Oldridge NB: Compliance with cardiac rehabilitation services. *J Cardiopulmonary Rehabil* 1991;11:115–127.
33. Erdman RAM, Duivenvoorden HJ, Verhage F, Kazemier M, Hugenholtz PG: Predictability of beneficial effects in cardiac rehabilitation: A randomized clinical trial of psychosocial variables. *J Cardiopulmonary Rehabil* 1986;6:206–213.
34. Kinsey MG, Fletcher BJ, Rice CR, Watson PH, Fletcher GF: Coronary risk factor modification followed by home-monitored exercise in coronary bypass surgery patients: A four-year follow-up study. *J Cardiopulmonary Rehabil* 1989;9:207–212.
35. Grover SA, Coupal L, Paquet S, Zowall H: The cost-effectiveness of HMG-CoA reductase inhibitors in the secondary prevention of cardiovascular disease: Forecasting the long-term benefits of the 4S study. *Arch Intern Med* 1999;159:593–600.
36. American College of Sports Medicine: *ACSM's Guidelines for Exercise Testing and Prescription*. Media, PA: Williams & Wilkins; 1995:25.
37. Goldman L, Garber AM, Grover SA, Hlatky MA: Task Force 6: Cost effectiveness of assessment and management of risk factors. *J Am Coll Cardiol* 1996;27:1020–1030.
38. Helmrich SP, Raglan DR, Leung RW, Paffenbarger RS: Physical activity and reduced occurrence of non-insulin-dependent diabetes mellitus. *N Engl J Med* 1991;325:147–152.
39. Manson JE, Nathan DM, Krolewski AS, Stampfer MJ, Willett WC, Hennekens CH: A prospective study of exercise and incidence of diabetes among U.S. male physicians. *JAMA* 1992;268:63–67.
40. Ballor DL, Keesey RE: A meta-analysis of the factors affecting exercise-induced changes in body mass, fat mass, and fat-free mass in males and females. *Int J Obesity* 1991;15:717–726.
41. Maines TY, Lavie CJ, Milani RV, Cassidy MM, Gilliland YE, Murgo JP: Effects of cardiac rehabilitation and exercise programs on exercise capacity, coronary risk factors, behavior, and quality of life in patients with coronary artery disease. *Southern Med J* 1997;90:43–49.
42. Cox ID, Hann CM, Kaski JC: Low dose imipramine improves chest pain but not quality of life in patients with angina and normal coronary angiograms. *Eur Heart J* 1998;19:250–254.
43. Santanello NC, Barber BL, Applegate WB, Elam J, Hunninghake DB, Gordon DJ: Effect of pharmacologic lipid lowering on health-related quality of life in older persons: Results from the Cholesterol Reduction in Seniors Program (CRISP) Pilot Study. *J Am Geriatr Soc* 1997;45:8–14.
44. Weir MR, Berger ML, Weeks ML, Liss CL, Santanello NC: Comparison of the effects on quality of life and of the efficacy and tolerability of lovastatin versus pravastatin: The Quality of Life Multicenter Group. *Am J Cardiol* 1996;77:475–479.
45. Cummings SR, Rubin SM, Oster G: The cost-effectiveness of counselling smokers to quit. *JAMA* 1989;261:75–79.
46. Krumholz HM, Cohen BJ, Tsevat J, Pasternak RC, Weinstein MC: Cost-effectiveness of a smoking cessation program after myocardial infarction. *J Am Coll Cardiol* 1993;22:1697–1702.
47. Johannesson M, Jonsson B, Kjekshus J, Olsson AG, Pedersen TR, Wedel H: Cost effectiveness of Simvastatin treatment to lower cholesterol levels in patients with coronary heart disease. *N Engl J Med* 1997;336:332–336.
48. Edelson JT, Weinstein MC, Tosteson ANA, Williams L, Lee TH, Goldman L: Long-term cost-effectiveness of various initial monotherapies for mild to moderate hypertension. *JAMA* 1990;263:408–413.