Association of Temporal Trends in Risk Factors and Treatment Uptake With Coronary Heart Disease Mortality, 1994-2005

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eAppendix and eTables  
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Association of Temporal Trends in Risk Factors and Treatment Uptake With Coronary Heart Disease Mortality, 1994-2005

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CORONARY HEART DISEASE (CHD) remains the most common cause of death worldwide and generates a large economic burden. Rates of CHD mortality have decreased substantially over the last 3 decades. Identifying the underlying factors associated with this decline is critical for planning future health policy, and prioritizing strategies for primary and secondary prevention.

Previous studies have shown that the largest portion of this reduction in CHD burden can be attributed to improvements in modifiable lifestyle and dietary risk factors. For example, from a population perspective, a reduction of 1 mmol/L in mean plasma cholesterol levels is associated with a 40% reduction in CHD mortality. Treatment strategies have also played a pivotal role, with 25% to 55% of the decreases in CHD mortality worldwide being attributed to the improved uptake of evidence-based pharmacological therapies.

Context Coronary heart disease (CHD) mortality has declined substantially in Canada since 1994.

Objective To determine what proportion of this decline was associated with temporal trends in CHD risk factors and advancements in medical treatments.

Design, Setting, and Patients Prospective analytic study of the Ontario, Canada, population aged 25 to 84 years between 1994 and 2005, using an updated version of the validated IMPACT model, which integrates data on population size, CHD mortality, risk factors, and treatment uptake changes. Relative risks and regression coefficients from the published literature quantified the relationship between CHD mortality and (1) evidence-based therapies in 8 distinct CHD subpopulations (acute myocardial infarction [AMI], acute coronary syndromes, secondary prevention post-AMI, chronic coronary artery disease, heart failure in the hospital vs in the community, and primary prevention for hyperlipidemia or hypertension) and (2) population trends in 6 risk factors (smoking, diabetes mellitus, systolic blood pressure, plasma cholesterol level, exercise, and obesity).

Main Outcome Measures The number of deaths prevented or delayed in 2005; secondary outcome measures were improvements in medical treatments and trends in risk factors.

Results Between 1994 and 2005, the age-adjusted CHD mortality rate in Ontario decreased by 35% from 191 to 125 deaths per 100,000 inhabitants, translating to an estimated 7585 fewer CHD deaths in 2005. Improvements in medical and surgical treatments were associated with 43% (range, 11% to 124%) of the total mortality decrease, most notably in AMI (8%; range, −5% to 40%), chronic stable coronary artery disease (17%; range, 7% to 35%), and heart failure occurring while in the community (10%; range, 6% to 31%). Trends in risk factors accounted for 3660 fewer CHD deaths prevented or delayed (48% of total; range, 28% to 64%), specifically, reductions in total cholesterol (23%; range, 10% to 33%) and systolic blood pressure (20%; range, 13% to 26%). Increasing diabetes prevalence and body mass index had an inverse relationship associated with higher CHD mortality of 6% (range, 4% to 8%) and 2% (range, 1% to 4%), respectively.

Conclusion Between 1994 and 2005, there was a decrease in CHD mortality rates in Ontario that was associated primarily with trends in risk factors and improvements in medical treatments, each explaining about half of the decrease.
RISK FACTORS, TREATMENT, AND TRENDS IN CHD MORTALITY

The most recent study evaluated trends in the United States up to 2000, since then, many new treatments have been introduced into contemporary practice, questioning the applicability of these previous observations. Moreover, the underlying factors associated with trends in CHD mortality in Canada have not been evaluated. Accordingly, our objective was to model CHD deaths between 1994 and 2005 in the province of Ontario to determine the contribution of prevention and treatment strategies to the Canadian decline in CHD mortality.

METHODS

The Ontario population, aged 25 to 84 years between 1994 and 2005, was evaluated using an updated version of the IMPACT model. This is a cell-based model, constructed using Microsoft Excel (Microsoft Corporation, Redmond, Washington), which integrates available country-specific epidemiological data to explain an observed decrease in CHD mortality. Specifically, the IMPACT model (1) incorporates temporal trends in major CHD risk factors including smoking, diabetes, systolic blood pressure, total cholesterol level, exercise, and obesity, in addition to the uptake of evidence-based medical and surgical treatments for CHD at 2 cross-sectional time points, and (2) estimates the relative reduction in CHD mortality associated with each. The IMPACT model has been validated in the United States, New Zealand, China, and Europe.

Whenever possible, Ontario-specific data sources were used. The 2 time points for the Ontario model were 1994 and 2005, based on the availability of high-quality data. Data used to construct the Ontario IMPACT model are described in detail in the eAppendix (see http://www.jama.com). Briefly, data on the Ontario population and age distribution and specific CHD death counts based on the International Classification of Diseases, Ninth Revision, and the International Statistical Classification of Diseases, Tenth Revision, were obtained from Statistics Canada, while the prevalence of major cardiovascular risk factors came from Ontario-specific self-reported population health surveys, such as the National Population Health Survey, the Canadian Heart Health Database, and the Canadian Community Health Survey. To determine the number of eligible patients and their 1-year mortality for specific medical and surgical treatments, linked administrative databases at the Institute for Clinical Evaluative Sciences were used. These databases included the Canadian Institute for Health Information discharge abstract database, which has records on the frequency and type of all acute and chronic care hospitalizations in the province; the Ontario Health Insurance Plan database, which includes fee-for-service claims submitted by physicians and other licensed health professionals; and the Ontario Drug Database, which has comprehensive drug use information on patients older than 65 years. All individual patients were identified by a unique, encrypted identifier, thereby allowing linkage between all administrative databases. The use of linked administrative databases represented a substantial methodological improvement in data acquisition compared with previous models because it allowed accurate accounting for potential overlaps between patient groups. This data was supplemented with use data on specific medical and surgical treatments from Ontario-specific clinical registries, including the Southwestern Ontario database for outpatient information, the Global Registry of Acute Coronary Events, and the Enhanced Feedback for Effective Cardiac Treatment (EFFECT) 2 trial for inpatient therapies, and others (see eTable 1 at http://www.jama.com).

The primary output of the IMPACT model was the number of deaths prevented or delayed in 2005 due to the reduction in CHD mortality rates. This was calculated as the difference between the observed 2005 CHD deaths and the expected CHD deaths in 2005 had 1994 mortality rates remained constant. Change in population size and age was considered using indirect standardization. The expected number of CHD deaths was calculated by multiplying age- and sex-specific mortality rates in 1994 by the population size for each 10-year age-sex stratum in 2005. Having calculated the total number of deaths prevented or delayed in 2005, the proportion associated with either trends in risk factors or treatment uptakes between 1994 and 2005 was determined.

The treatment group of the model consisted of 8 mutually exclusive CHD subgroups. These included patients hospitalized for an acute myocardial infarction (AMI), an acute coronary syndrome, or heart failure due to ischemic cardiomyopathy within the last year. In addition, the model evaluated community-dwelling patients who were AMI survivors, patients with stable coronary artery disease (with and without percutaneous or surgical revascularization), and patients with heart failure. Finally, individuals with hypertension and hypercholesterolemia eligible for primary prevention with pharmacological therapy were examined. Within each of these groups, a total of 42 medical and surgical therapies were assessed (Table 1). These included aspirin, thrombolytic therapy, and primary angioplasty for AMI; β-blockers, angiotensin-converting enzyme inhibitors, and spironolactone for heart failure; and statin therapy for chronic stable coronary artery disease.

The deaths prevented or delayed attributable to a specific CHD treatment within a disease subgroup were estimated by taking the product of the number of individuals in the subgroup, the proportion of those patients who received a particular treatment (see eTable 2 at http://www.jama.com), the 1-year mortality rate (eTable 3), and the relative risk reduction attributed to that specific treatment based on the published literature (eTable 4). For
<table>
<thead>
<tr>
<th>Treatment Uptake</th>
<th>1-Year Case Fatality</th>
<th>RR Reduction</th>
<th>No. of Patients</th>
<th>%</th>
<th>1-Year Case Fatality</th>
<th>RR Reduction</th>
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<td>AMI</td>
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<td>16,640</td>
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<td>(−5.1 to 39.9)</td>
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<td>78</td>
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<td>82</td>
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<td>31</td>
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<td>4</td>
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<td>88</td>
<td>9</td>
<td>22</td>
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<td>80</td>
<td>72</td>
<td>33</td>
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<td>150 (2.0)</td>
<td>(0.7 to 2.4)</td>
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<td>11</td>
<td>9</td>
<td>15</td>
<td>0</td>
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<td></td>
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<td>Glycoprotein IIb/IIIa receptor blocker</td>
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<td>0</td>
<td>9</td>
<td>0</td>
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<td></td>
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<tr>
<td>ACE inhibitor or ARB</td>
<td>55</td>
<td>23</td>
<td>7</td>
<td>10</td>
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<td>0.01</td>
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<td>50</td>
<td>0</td>
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<td>15</td>
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<td>32</td>
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<td>0.01</td>
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<tr>
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<td>78</td>
<td>8</td>
<td>22</td>
<td>60</td>
<td></td>
<td>0.01</td>
</tr>
<tr>
<td>2 Previous AMIs</td>
<td>37,500</td>
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<td></td>
<td>0.026</td>
<td>170 (2.3)</td>
<td>(2.0 to 10.0)</td>
</tr>
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<td>Aspirin</td>
<td>91</td>
<td>74</td>
<td>15</td>
<td>10</td>
<td></td>
<td>0.026</td>
</tr>
<tr>
<td>β-Blocker</td>
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<td>51</td>
<td>23</td>
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<td>0.026</td>
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<td>20</td>
<td>40</td>
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<td>0.026</td>
</tr>
<tr>
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<td>9</td>
<td>22</td>
<td>55</td>
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<td>26</td>
<td>15</td>
<td></td>
<td>0.026</td>
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<td>Chronic stable CAD</td>
<td>292,210</td>
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<td></td>
<td>0.030</td>
<td>1305 (17.2)</td>
<td>(7.0 to 35.4)</td>
</tr>
<tr>
<td>Aspirin in community</td>
<td>78</td>
<td>64</td>
<td>15</td>
<td>0.030</td>
<td>130 (1.7)</td>
<td>(0.7 to 3.6)</td>
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<tr>
<td>Statins in community</td>
<td>78</td>
<td>8</td>
<td>23</td>
<td>725</td>
<td></td>
<td>0.030</td>
</tr>
<tr>
<td>ACE inhibitor</td>
<td>55</td>
<td>20</td>
<td>17</td>
<td>375</td>
<td></td>
<td>0.030</td>
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<td>CABG surgery</td>
<td>5680^a</td>
<td>3470^a</td>
<td>21</td>
<td>60</td>
<td></td>
<td>0.030</td>
</tr>
<tr>
<td>Angioplasty</td>
<td>5260^a</td>
<td>1440^a</td>
<td>13</td>
<td>15</td>
<td></td>
<td>0.030</td>
</tr>
<tr>
<td>Heart failure</td>
<td>3365</td>
<td></td>
<td></td>
<td>0.036</td>
<td>80 (1.0)</td>
<td>(0.4 to 2.2)</td>
</tr>
<tr>
<td>In the hospital</td>
<td>3365</td>
<td></td>
<td></td>
<td>0.036</td>
<td>80 (1.0)</td>
<td>(0.4 to 2.2)</td>
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<tr>
<td>ACE inhibitor</td>
<td>62</td>
<td>89</td>
<td>20</td>
<td>−45</td>
<td></td>
<td>−0.6</td>
</tr>
<tr>
<td>β-Blocker</td>
<td>55</td>
<td>29</td>
<td>35</td>
<td>70</td>
<td></td>
<td>0.4</td>
</tr>
<tr>
<td>Spironolactone</td>
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<td>3</td>
<td>30</td>
<td>40</td>
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<td>0.5</td>
</tr>
<tr>
<td>Aspirin</td>
<td>52</td>
<td>42</td>
<td>15</td>
<td>10</td>
<td></td>
<td>0.1</td>
</tr>
<tr>
<td>In the community</td>
<td>50,440</td>
<td></td>
<td></td>
<td>0.112</td>
<td>750 (9.9)</td>
<td>(6.1 to 31.1)</td>
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<tr>
<td>ACE inhibitor/ARB</td>
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<td>89</td>
<td>20</td>
<td>−125</td>
<td></td>
<td>−1.7</td>
</tr>
<tr>
<td>β-Blocker</td>
<td>67</td>
<td>29</td>
<td>35</td>
<td>760</td>
<td></td>
<td>10.0</td>
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<td>3</td>
<td>30</td>
<td>35</td>
<td></td>
<td>0.4</td>
</tr>
<tr>
<td>Aspirin</td>
<td>52</td>
<td>42</td>
<td>15</td>
<td>85</td>
<td></td>
<td>1.1</td>
</tr>
<tr>
<td>Hypertension treatment</td>
<td>459,900</td>
<td>46</td>
<td>28</td>
<td>13</td>
<td>0.005</td>
<td>50 (0.7)</td>
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<td>Hyperlipidemia treatment</td>
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<td></td>
<td>0.004</td>
<td>90 (1.2)</td>
<td>(0.4 to 2.6)</td>
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<tr>
<td>Statins</td>
<td>45</td>
<td>20</td>
<td>35</td>
<td>85</td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>Gemfibrozil</td>
<td>6</td>
<td>0</td>
<td>7</td>
<td>5</td>
<td></td>
<td>0.1</td>
</tr>
<tr>
<td>Niacin</td>
<td>2</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total treatment</td>
<td>3280</td>
<td></td>
<td></td>
<td>0.112</td>
<td>123 (42.6)</td>
<td>(11.2 to 123.6)</td>
</tr>
</tbody>
</table>

Abbreviations: ACE, angiotensin-converting enzyme; AMI, acute myocardial infarction; ARB, angiotensin II receptor blocker; CABG, coronary artery bypass grafting; CAD, coronary artery disease; CPR, cardiopulmonary resuscitation; PCI, percutaneous coronary intervention (with or without stenting); RR, relative risk.

*Instead of percentages, the actual numbers of patients receiving treatment (determined from an administrative database) are presented.
example, in Ontario in 2005, about 2790 men aged 55 to 64 years were hospital-
ized with AMI, of whom, 94% were given aspirin. Aspirin reduces the case-
fatality rate by 15%.17 The underlying 1-year case-fatality rate in these men was
6.4%. The approximate number of deaths prevented or delayed attributable to as-
pirin use in AMI was therefore calculated as:

Patient numbers × treatment uptake × relative mortality reduction × 1-year case-
fatality rate = 2790 × 94% × 15% × 6.4% = 25 deaths prevented or delayed.

There is a paucity of data on the ef-
ficacy of treatment combinations. Sim-
ply assuming that the efficacy of mul-
tiple treatments was additive would overestimate the treatment effect. The Mant and Hicks method18 was used in-
stead to estimate case-fatality reduc-
tion by polypharmacy. This approach
estimates the cumulative relative ben-
et if as follows:

Relative benefit = 1 − (1 − relative redu-
duction in case-fatality rate for treat-
ment A) × (1 − relative reduction in
case-fatality rate for treatment B) . . . ×
(1 − relative reduction in case-fatality
rate for treatment N).

(See the eAppendix for further details
and examples at http://www.jama.
com.) Because many of the therapeu-
tic interventions studied were widely
used in 1994, the net benefit of an in-
tervention was calculated by subtract-
ing the expected number of deaths pre-
vented if the 1994 use rates remained
constant from the observed deaths pre-
vented as calculated in the example
above.

Risk factors included diabetes mel-
itus, total cholesterol level, systolic blood
pressure, body mass index, smoking, and
physical inactivity. Two approaches were
used to estimate the number of deaths prevented or delayed as a conse-
quence of changes in CHD risk factors. The
regression coefficient approach was used
for the risk factors of systolic blood pres-
sure, total cholesterol level, and body
mass index (expressed in continuous
data).4,7,10,16 Three variables were used
for this approach: (1) the expected num-
ber of CHD deaths in 2005, (2) multi-
plied by the absolute change in risk fac-
tor prevalence, (3) multiplied by a
regression coefficient that quantified the
change in CHD mortality expected for
the change in risk factor level (see
eTable 5 at http://www.jama.com).4,7,10,16
For example, in 2005, there were 448
expected CHD deaths among 476 670
women aged 55 to 64 years. The mean
systolic blood pressure in this group de-
creased by 6.9 mm Hg (from 139.3
mm Hg in 1994 to 132.4 mm Hg in
2005). The largest meta-analysis eval-
uating the effect of blood pressure treat-
ment on mortality estimated age- and
sex-specific reduction in mortality to be
50% for every 20-mm Hg reduc-
tion in systolic blood pressure, gener-
ating a logarithmic coefficient of
−0.035.11 The number of deaths pre-
vented or delayed as a result of this
change was estimated as:

\[
(1 − [\text{EXP}(\text{coefficient} × \text{change})] ×
\text{expected deaths in 2005}) = (1 − [\text{EXP}(
−0.035 × 6.88)] × 448) = 96 
\text{deaths prevented or delayed}.
\]

The second approach used was the
population-attributable risk fraction
(PARF).4,7,10,16 This approach was used
to determine the mortality benefit due
to changes in the prevalence of dichoto-

mous risk factors of smoking, diabe-
tes, and physical inactivity.4,7,10,16

\[
\text{PARF} = \frac{P \times (R \text{R} − 1)}{[1 + P \times (R \text{R} − 1)]}
\]

where \(P\) is the prevalence of the risk fac-
tor and \(R\) is the relative risk for CHD
mortality associated with the pres-
ence of that risk factor. Deaths pre-
vented or delayed were then esti-
mated as the expected CHD deaths in
2005 multiplied by the difference in the
PARF between 1994 and 2005. For ex-
ample, the prevalence of diabetes among
men aged 65 to 74 years was
13.5% in 1994 and increased to 18.3%
in 2005. Assuming a relative risk of
1.93,7 the PARF was calculated as
0.112 in 1994 and 0.145 in 2005. The approximate number of deaths attrib-
utable to the increase in diabetes preva-
lence from 1994 to 2005 was calcu-
lated as:

\[
\text{Expected deaths in 2005 × (PARF in} \ 2005 − \text{PARF in 1994)} = (3196) × 
(0.145 − 0.112) = 105 \text{additional deaths}.
\]

Because of the uncertainty surround-
ing many of the values, multiway sen-
sitivity analyses were performed.4 For
each model parameter, minimum and
maximum plausible values were as-
signed using the 95% confidence in-
tervals from the source documentation;
if these were unavailable, these
limits were defined as 20% above and
below the best estimate.4 The mini-
mum and maximum plausible values
were introduced into the model, gen-
erating the minimum and maximum es-
timates for deaths prevented or de-
layed. This represents a conservative
estimation of uncertainty; in selected
simulations, this approach has consis-
tently yielded broader confidence
bounds than those represented by 99%
confidence intervals.

This study was based on secondary
analyses of multiple deidentified cli-
cal, survey, and administrative data-
bases, and was approved by the ethics
review board at Sunnybrook Health Sci-
ence Centre. Where required under pri-

cacy legislation, informed patient con-
sent or a waiver of informed consent has
been obtained by the principal inves-
gigators of these various databases, prior
to the data being made available for
these secondary analyses.

**RESULTS**

Between 1994 and 2005, the age-
adjusted CHD mortality rate in On-
tario decreased by 35% from 191 to 125
deaths per 100 000 inhabitants. Of the
8.4 million Ontario residents between
the ages of 25 and 84 years in 2005,
there were 10 060 CHD deaths. In con-
trast, there were 13 010 CHD deaths in
1994 despite an overall population of
only 7 million residents between the
ages 25 to 84 years. With indirect age
standardization, the IMPACT model es-
timated that there were 7583 deaths
prevented or delayed in 2005; given the
observed mortality rates compared with

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the deaths expected, the 1994 CHD mortality rates remained constant.

Risk factor changes were associated with 48% (range, 28%-64%) of the total mortality decrease, whereas new medical and surgical treatments were associated with 43% (range, 11%-124%) of the decrease. Of the observed reduction in CHF mortality, 9% (range, 0%-61%) was not associated with factors studied in the IMPACT model. The decrease in observed CHD deaths was concentrated in older patients aged 75 to 84 years (Figure).

An estimated 3280 of the total deaths prevented or delayed were associated with improvements in medical and surgical treatments between 1994 and 2005 (Table 1). The most substantial contributions came from the management of patients with chronic stable coronary artery disease (1305 fewer deaths; 17% of total [range, 7%-35%]). In 1994, 8% of patients with chronic stable coronary artery disease were taking statins compared with 78% in 2005. This improvement in use rates was associated with 725 deaths prevented or delayed (9% of total; range, 4%-20%). In contrast, percutaneous and surgical revascularizations were associated with only 1% (range, 0%-2%) of the overall deaths prevented or delayed.

Improvements in the treatment of patients with heart failure in the community were associated with approximately 750 fewer deaths (10% of total; range, 6%-31%). In 1994, 29% of patients were taking β-blockers compared with 67% in 2005. Interestingly, use of angiotension-converting enzyme inhibitors or angiotensin II receptor blockers decreased from 89% in 1994 to 69% in 2005. However, this was outweighed by the improved uptake of other medications including β-blockers and aldactone. An important limitation in this cohort is the inability to distinguish between heart failure from systolic and diastolic dysfunction because many of the evaluated therapies are of proven benefit only for systolic dysfunction.

Deaths prevented or delayed from treatments for the acute hospital-based subgroups were relatively modest (Table 1). Although improvements in the treatment of AMI patients represented 8% (range, −5% to 40%) of the overall deaths prevented or delayed; new acute treatment modalities, such as primary angioplasty, prevented or delayed only 105 deaths. Even in this subgroup of patients, improved secondary prevention with statin therapy represented the most important advance in treatment over the model period, contributing to 320 deaths prevented or delayed.

Overall, risk factor changes accounted for an estimated 3660 fewer CHD deaths prevented or delayed (48% of total; range, 28%-64%). Over the 11-year period of the model from 1994 to 2005, there was an absolute reduction of 0.05 mmol/L in the mean total cholesterol level of the Ontario population (Table 2). After controlling for increased use of lipid-lowering pharmacological treatments, 1730 CHD deaths were prevented or delayed due to reductions in cholesterol level from lifestyle and dietary changes from 1994 to 2005, representing 23% (range, 10%-33%) of the overall reduction in CHD mortality. There was also an absolute decrease of 1.4 mm Hg in mean systolic blood pressure from 1994 to 2005. This was associated with 1545 fewer deaths (20% of total; range, 13%-26%) after subtracting deaths prevented or delayed due to risk factor changes (20% of total; range, 13%-26%).

### Table 2. Deaths Prevented or Delayed Due to Population Risk Factor Changes

<table>
<thead>
<tr>
<th>Risk Factors</th>
<th>Changes in Risk Factors, %a</th>
<th>Deaths Prevented or Delayed, Mean (%) (Range)c</th>
<th>Relative Riskb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoking prevalence</td>
<td>−6</td>
<td>725 (9.5) (7.6 to 11.4)</td>
<td>2.52</td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td></td>
<td>2.14</td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td>2.59</td>
</tr>
<tr>
<td>Diabetes prevalence</td>
<td>−1</td>
<td>−470 (−6.2) (−4.1 to −7.8)</td>
<td>1.93</td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td></td>
<td>2.59</td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td>1.33</td>
</tr>
<tr>
<td>Physical inactivity</td>
<td>−11</td>
<td>310 (4.1) (3.3 to 4.9)</td>
<td>1.27</td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td></td>
<td>2.59</td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td>1.33</td>
</tr>
<tr>
<td>Systolic blood pressure, mm Hg</td>
<td>−1.39</td>
<td>1545 (20.4) (12.7 to 26.0)</td>
<td>β1</td>
</tr>
<tr>
<td>Male</td>
<td>−0.033</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>−0.041</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total cholesterol, mmol/L</td>
<td>−0.05</td>
<td>1730 (22.8) (9.8 to 32.6)</td>
<td>−0.922</td>
</tr>
<tr>
<td>Male</td>
<td>−0.901</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body mass indexd</td>
<td>0.37</td>
<td>−180 (−2.3) (−1.3 to −3.6)</td>
<td>0.029</td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td>0.028</td>
</tr>
<tr>
<td>Total risk factors</td>
<td>3660 (48.3) (28.1 to 63.5)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

©2010 American Medical Association. All rights reserved. **(Reprinted) JAMA, May 12, 2010—Vol 303, No. 18** 1845
ventuated due to advances in pharmacological therapies (Table 2). Reductions in smoking (6%) and physical inactivity (11%) were associated with 725 and 310 fewer CHD deaths, respectively. However, there was an increase in both diabetes prevalence (1%) and body mass index (calculated as weight in kilograms divided by height in meters squared; absolute change of 0.37), both increasing mortality by 470 (6% of total; range, 4%-8%) and 180 (2% of total; range, 1%-4%) more CHD deaths, respectively. Despite the different study period, we observed similar mortality reductions associated with risk factor improvements compared with the United States between 1980 and 2000, particularly total cholesterol level and systolic blood pressure.4 These trends may reflect the general improvement in socioeconomic status at the population level, which in turn may support healthier lifestyles and dietary habits. However, this may also lead to overconsumption, which may partially explain the recent epidemic of obesity and diabetes mellitus. Our results suggest that we have not reached the nadir of population cholesterol or blood pressure levels. Strategies to improve these areas will continue to be of importance. Conversely, policies to address the increasing prevalence of obesity and diabetes mellitus will be crucial if the gains realized over the last decade are not to be lost.

Despite the exponential increase in expenditures on medical technologies and drugs, the Ontario IMPACT model found that less than half of the observed CHD mortality reduction was associated with treatment improvements. Although this overall result appears similar to that seen in the United States from 1980 to 2000, there were substantial differences in the relative importance of disease subgroups.4 While primary pharmacological prevention for hypertension and hyperlipidemia played an important role in the United States (7% and 4.9%, respectively), these accounted for only 2% of the total mortality reduction in Ontario.4 In contrast, improvements in chronic stable coronary artery disease management in Ontario represented 17.3% of the mortality reduction, whereas this subgroup accounted for only 5.4% in the United States.4 We believe several factors are important in understanding these results. First, because the baseline year of our analysis was 1994, many of the treatment strategies evaluated were already in use unlike in the US model, which had a much earlier base year of 1980.4,7,8 Any effect on CHD mortality was due to the incremental change in use between 1994 and 2005. Although use rates improved for most treatments over this period, these were modest in areas such as fibrinolysis and aspirin use. In contrast, there was a marked increase in the use of statins and angiotensin-converting enzyme inhibitors, which in turn had a dramatic reduction in overall mortality. Second, the majority of new treatments developed over the last decade, such as primary angioplasty for AMI, glycoprotein IIb/IIIa receptor inhibitors and clopidogrel for acute coronary syndrome, or automated internal cardiac defibrillators for severe cardiomyopathy, were applicable to only a small proportion of CHD patients. Patients with chronic stable coronary artery disease continued to represent the largest burden of CHD disease; thus, treatment improvements in these patients translated to the greatest overall effect. This highlights an important potential use of models such as IMPACT for strategic planning by identifying the areas in which future gains are likely to be in optimizing treatment uptake from a population perspective. This may be of particular importance in low- and middle-income countries in which health care resources are limited.

Our results must be interpreted within the context of several limitations, most importantly, the use of multiple data sources for populating the mathematical model. Despite the use of linked administrative databases to mitigate this issue, residual double counting of some patients may have occurred despite our best efforts. In addition, efficacy data derived from clinical trials may not be generalizable to real-world practice, and may therefore overestimate the clinical benefits. Our analyses were limited to 2005 because it represented the most contemporary period in which comprehensive data were available; however, we do not believe that the trends in risk factors and medical therapies seen in our study would be qualitatively different in a more updated model. As seen in our sensitivity analyses, there was sub-

COMMENT

Using Ontario-specific epidemiological data, we observed a reduction in the burden of CHD comparable with that reported in other Western countries. From 1994 to 2005, this 35% decrease in CHD mortality translated into 7585 fewer CHD deaths. The bulk of this mortality reduction was associated with improvements in traditional CHD risk factors, particularly total cholesterol levels and systolic blood pressure. These positive trends were offset by adverse trends in the prevalence of obesity and diabetes. The CHD mortality reduction associated with advances in surgical and medical treatments were principally observed in community-dwelling patients with chronic stable coronary artery disease and heart failure.

Understanding the underlying mechanisms for past trends in CHD mortality is critical for strategic planning and prioritization of health policy. The IMPACT model has been applied to a wide range of populations. Past studies have consistently explained 80% to 99% of the observed CHD mortality decline, with more than 50% being attributed to temporal trends in CHD risk factors and less than half to treatment.4,6,13 Our analysis builds on this previous work by assessing a more recent period from 1994 to 2005, thereby incorporating relevant contemporary medical and surgical therapies and recent trends in risk factors, such as the increase in obesity rates.
stantial uncertainty in our estimates, most pronounced in the treatment group of the model. In comparison with the best estimate of 43%, the overall treatment effect ranged from a minimum of 11% to a maximum of 124%. Although, the uncertainty surrounding the risk factor estimates was less, there remained a range from 28% to 63% around the best estimate of 48%. Finally, 91% of the observed CHD mortality decline was associated with factors studied in our model; the residual portion may reflect imprecision around our estimates or failure to quantify other important factors, such as the consumption of fruits and vegetables, psychosocial stress, and abdominal obesity. The INTERHEART study investigators examined the relationship of these factors with the risk of AMI and found a population-attributable risk that ranged from 10% to 25%. This emphasizes the importance of collecting population-level data on these and other known risk factors, such as exposure to secondhand smoke and incorporating them into future studies.

In conclusion, our results suggest that approximately half of the CHD mortality reduction in Ontario between 1994 and 2005 was associated with improvements in major risk factors and approximately 43% to evidence-based treatments. However, obesity and diabetes mellitus both increased substantially. Although our study was not designed to establish a causal relationship between these trends and mortality, these results may inform decision making at all levels with the goal of ensuring that the gains in CHD mortality reduction during the previous decade are not lost in the next decade.

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Critical revision of the manuscript for important intellectual content: Machado, Farahati, Wang, Wittman, Tu, Lee, Goodman, O’Flaherty, Krahn, Capewell.


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Study supervision: O’Flaherty, Krahn, Capewell.

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Online-Only Material: eAppendix and eTables 1-5 are available at http://www.jama.com.

REFERENCES


