The Economics of Better Health:

The Case of Cardiovascular Disease

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February 2001

Note: This paper is a chapter from a book I am writing this year. The book is for a less technical audience, so the paper has the technical detail in an appendix. The seminar will focus on this chapter and the book as a whole.

Franklin Roosevelt died of hypertension.[1] The proximate cause was a massive stroke; the underlying explanation was high blood pressure. Roosevelt was significantly impaired by the disease in the last year of his life. At a time when a world war was being fought and the post-war balance of power negotiated, Roosevelt fatigued easily, had difficulty concentrating, became weak and lost weight, and suffered from headaches.
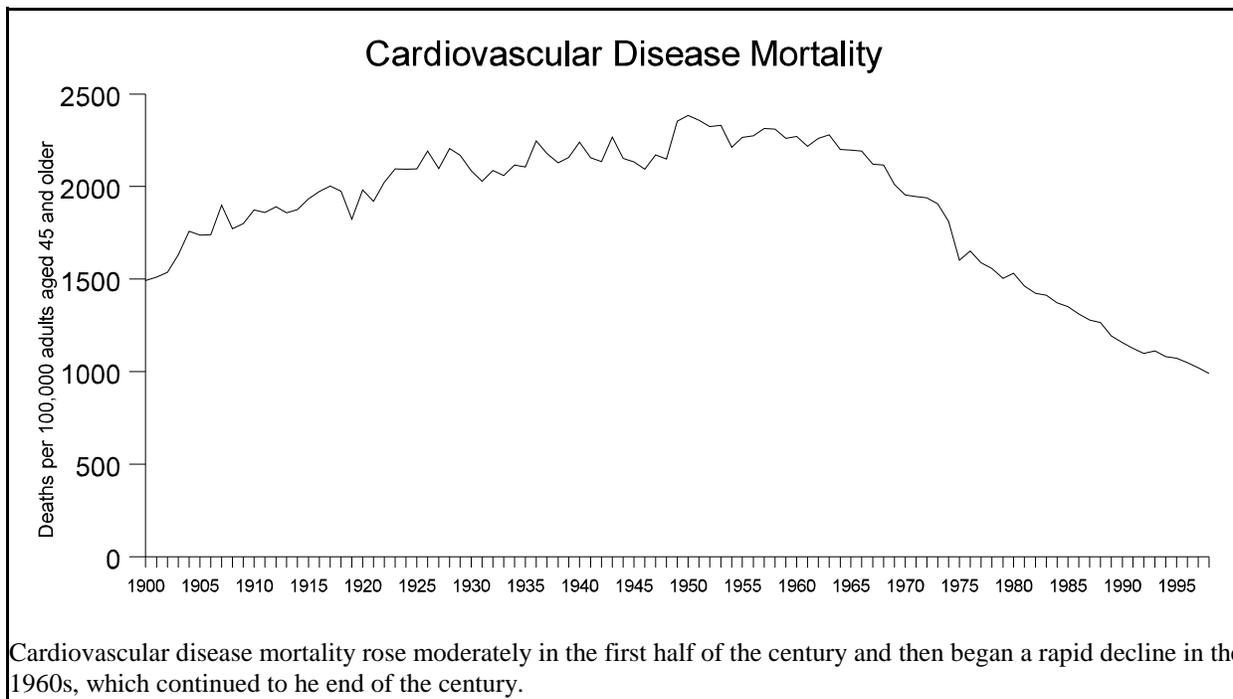
In the mid-1940s, hypertension was essentially untreatable. Roosevelt was given some medication for his condition, but it was late and not very effective. Knowing what we know now, Roosevelt's death was entirely preventable. Indeed, by 2 decades later, hypertension could be managed with minimal risk.

How would history be different if hypertension medication had been available just two decades earlier? Some have argued that a healthy Roosevelt could have convinced Stalin to allow peaceful elections in Eastern Europe, saving millions of people from decades of communist rule. Others have suggested that Roosevelt would have shifted US support from Chiang Kai-shek to Mao's China, perhaps preventing the Korean War. Such parlor games are more than fun speculation. Even Roosevelt's cardiologist confessed, years after his death, "I have often wondered what turn the subsequent course of history might have taken if the modern methods for the control of hypertension had been available."

This chapter considers the modern methods for treating cardiovascular disease. There is no more important issue in understanding recent trends in health. After infant mortality declined in the first half of the 20th century, cardiovascular disease became the nation's leading killer.

Death from cardiovascular disease was high and rising in the first half of the century.

But in the latter few decades of the 20th century, there was a dramatic reversal of this trend. Between 1960 and 1998, cardiovascular disease mortality fell by nearly two-thirds, with no end in sight. Further, health among people who have cardiovascular disease is improving. Cardiovascular disease survivors used to be bedridden for life; today, they are often out golfing in a matter of weeks. Understanding why this change occurred and what caused it is essential to our understanding of the medical system.

Cardiovascular disease mortality rose moderately in the first half of the century and then began a rapid decline in the 1960s, which continued to he end of the century.

Examination of the sources of cardiovascular disease mortality reduction suggests three factors as chief contributors to better health. The first is intensive treatment of acute cardiovascular illness, particularly heart attacks. In 1950, little could be done for a heart attack victim. Today, treatment involves drugs, surgical procedures, and elaborate monitoring. Survival

after a heart attack has increased dramatically. The second factor is non-acute pharmaceuticals to prevent the onset of cardiovascular disease and limit its progression. Anti-hypertensive medication, cholesterol-lowering drugs, anti-coagulants, anti-arrhythmic agents, and other medications all fall in this category. Pharmaceuticals also contribute to acute survival, but the issues of acute and chronic management are very different, so I separate out medical care into these two components. The third factor is behavioral change. People have reduced their fat and salt intake and most importantly quit smoking. Behavioral change reduces the onset of disease and reduces the probability of disease reoccurring. I estimate that these three factors – intensive technologies, non-acute pharmaceuticals, and behavioral change – have had roughly equal effects on cardiovascular disease mortality.

Evaluating the costs and benefits of these changes yields staggering conclusions. For every dollar spent on medical treatment of cardiovascular disease, the gain from people living longer is about $7. For every dollar spent on research on the behavioral inputs to cardiovascular disease – the underlying source of behavioral changes – the return is $100. The cardiovascular disease example shows that medical care and research are among the most productive activities imaginable.
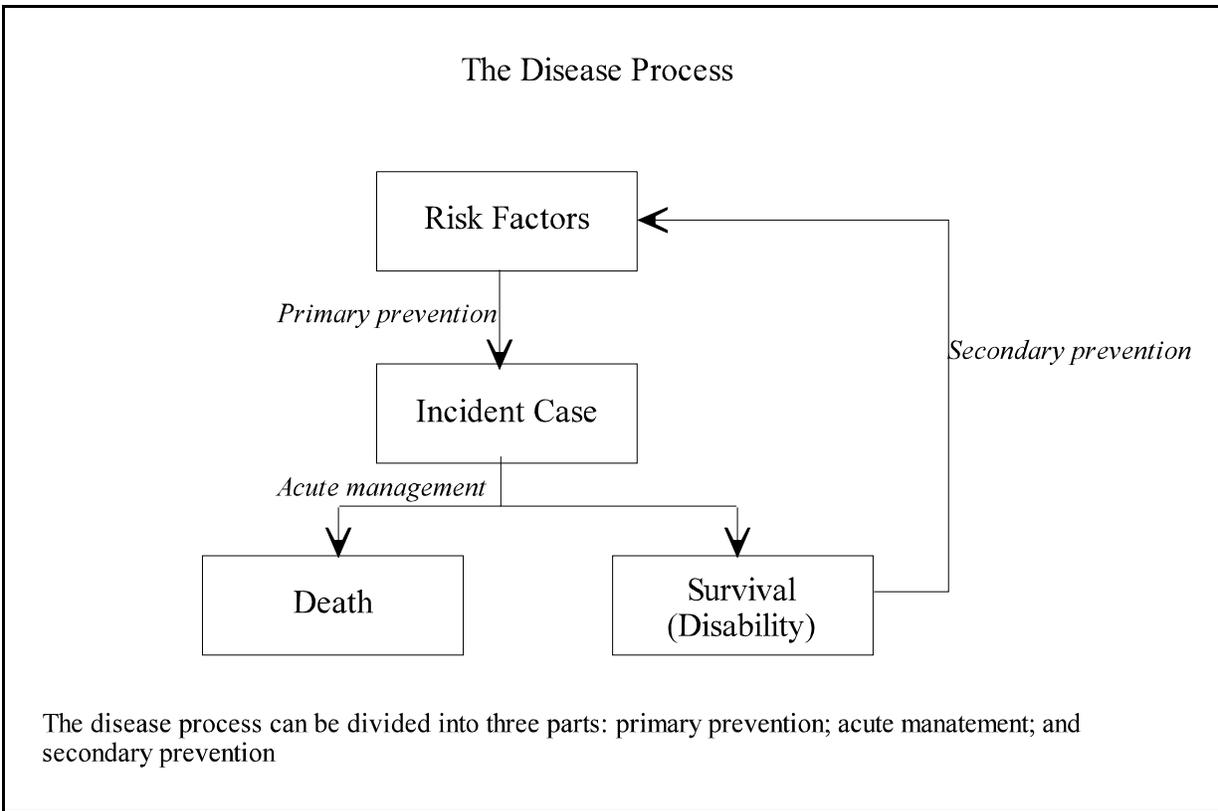
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Cardiovascular diseases are diseases of the heart and blood vessels. The most prominent form of cardiovascular disease is coronary artery disease: arteries that supply oxygen-rich blood to the heart become clogged, reducing or cutting off oxygen supply to the heart. Starved of

oxygen, part of the heart muscle weakens or dies. A complete occlusion of the coronary arteries resulting in death of some of the heart muscle is termed a heart attack. Untreated, heart attacks are often fatal. If blood flow can be restored, death can be averted, but there may be significant long-term complications from weakened or dead heart muscle such as difficulty engaging in normal activities of daily living and recurrent chest pain. There are about 750,000 hospitalizations for heart attacks annually and almost 700,000 deaths from heart disease (including both new and older cases).

Stroke, or cerebrovascular disease, is the second most common form of cardiovascular disease. A stroke occurs when oxygen supply to the brain is disrupted, either because arteries in the brain have become occluded (an ischemic stroke) or because blood vessels in the brain burst (a hemorrhagic stroke). Franklin Roosevelt suffered a cerebral hemorrhage. Strokes are less common, but often more damaging than heart attacks, since it may be difficult to locate and treat the source of the problem. Survivors of a stroke typically experience physical problems such as paralysis or weakness in limbs and cognitive problems such as memory loss and speech difficulty, depending on the location and severity of the stroke. There are 150,000 deaths from strokes annually.

The progression of heart disease and stroke is similar, and can be divided into three phases. Otherwise healthy individuals may have one or more risk factors for cardiovascular disease. Some risk factors,[2] such as genetics, demographics, and family history of heart disease are immutable; older males and postmenopausal women are at greater risk of cardiovascular disease than are other groups. Other risk factors can be modified, including hypertension, high cholesterol, obesity, diabetes, and cigarette smoking. Some of those with elevated risk factors

4

The Disease Process

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                    ┌──────────────┐
                    │ Risk Factors │ ◄──────────────┐
                    └──────────────┘                │
                           │                         │
              Primary prevention                     │  Secondary prevention
                           ▼                         │
                    ┌──────────────┐                 │
                    │ Incident Case│                 │
                    └──────────────┘                 │
                           │                         │
          Acute management ──────┬──────             │
                     ▼                 ▼             │
              ┌──────────┐      ┌──────────────┐     │
              │  Death   │      │   Survival   │ ────┘
              └──────────┘      │ (Disability) │
                                └──────────────┘
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The disease process can be divided into three parts: primary prevention; acute management; and secondary prevention

will suffer an acute event, the most severe of which are heart attacks, heart failure, and strokes. Less severe ailments include congestive heart failure, stable or unstable angina, and intermittent claudication. The process of preventing people with risk factors from developing an acute episode is termed primary prevention.

For those who suffer an episode, there is a period of acute treatment, generally lasting about 90 days. The primary goal of acute management is to prevent death and long-term physical damage. For people who survive the acute episode, secondary prevention is designed to prevent a recurrent event. Secondary prevention involves the same risk factor changes as primary prevention as well as other therapies such as medication to prevent blood clots, stabilize heart rhythm, and reduce the workload of the heart.

5

Primary prevention, acute treatments, and secondary prevention have all been important in reduced cardiovascular disease mortality. The importance of primary prevention is shown by falling incidence of serious disease. The share of people with new heart disease cases has been falling about 1 percent annually since the early 1960s.[3] Mortality among existing cases, in both the acute and post-acute phases, has fallen even more. Thus, acute management and secondary prevention have also contributed to better health. The fact that health is improving at each phase of the process suggests that no single factor is responsible for better health.

This disease process is more general than for just cardiovascular disease. Low birth weight, for example, is an 'incident case' in the progression of infant death. The analysis of neonatal mortality improvements showed that primary prevention to reduce the incidence of low birth weight births had only a small effect on neonatal survival; better acute management was the dominant factor leading to health gains in the past half century. Similarly, in the case of mental health, the incidence of depression has probably not fallen, and may even have increased, but acute management and secondary prevention have led to health improvements. For both of these diseases, post-incident medical technology is the chief factor in better health. Cardiovascular disease is more complex because primary prevention has been important as well.

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Medical care for the treatment of acute cardiovascular incidents has advanced enormously in the past half century. Innovations in acute management have been most prominent in the care of heart attack patients.[4] In the 19th century, heart attacks were thought to

6

be a medical curiosity but not a common condition. It was not until early in the 20th century that physicians recognized the frequency of heart attacks and that fact that they need not be fatal.

It was not initially known how to treat a heart attack. It was thought that heart attacks were fatal because they led to cardiac rupture. Thus, successful treatments were designed to reduce the strain on the heart as much as possible. Heart attack survivors were typically kept in a hospital bed for 6 weeks, and send home for bed rest for at least 6 months. Painkillers were used to help the patient weather the heart attack, but other care was minimal. This treatment recommendation survived until the 1950s. Indeed, it is essentially the method used in treating the msot famous heart attack of the 1950s – President Eisenhower's in 1955.[5]

Bed rest is now known to be ineffective. Cardiac rupture is a rare condition, and bed rest does not seem to prevent it. Further, bed rest can lead to other complications such as blood clots in the veins or lungs. Today, it is not a recognized therapy.

Treatment of heart attacks today is much more intensive. The most common form of acute treatment is the administration of thrombolytic drugs, which work to dissolve the clot blocking the coronary artery. The benefits of thrombolysis were first demonstrated in the 1970s, with newer and mildly more effective drugs developed in the 1980s. Surgical interventions may supplement or replace thrombolytic therapy. Cardiac catheterization, first developed in 1959, is a diagnostic procedure where dye is injected into the coronary arteries to measure the extent of arterial blockage. If the blockage is sufficient severe, the patient might undergo one of two types of revascularization surgeries, which seek to restore blood flow to the heart. Coronary artery bypass graft, developed in 1968, involves grafting a new route for blood flow around the occluded arteries. Percutaneous angioplasty, developed in 1978, involves inflating a balloon

amid the clot to reopen the occluded artery. All of these surgeries have changed over time, as technology has improved and physicians and nursing teams have developed more experience with them. Other medications have also been developed to help treat heart attacks. Aspirin is widely administered to heart attack patients to prevent clotting, and patients may be given other drugs to reduce the workload of the heart and regulate the heart's rhythm.

Beyond these major treatment innovations have been a wealth of other changes. Coronary care units, developed in the 1960s, are specialized units of hospitals with trained personnel to monitor patients with heart attacks and with specialized equipment to treat serious complications. Emergency Medical Service systems developed in the 1970s enable paramedics to reach heart attack patients faster and allow better trained paramedics to get to the scene.

While public attention is often drawn to the dramatic change in acute treatments, much less attention has been focused on the revolution in knowledge and treatments to prevent cardiovascular disease and limit its progression. Changes in preventive knowledge and therapy have been no less impressive than changes in acute treatment.

In 1950, not much was known about the causes of cardiovascular disease.[6] It was clear from animal studies and autopsies that high cholesterol was a factor in heart disease, and there was pretty good evidence that hypertension was related to cardiovascular disease although the case was not airtight. But no values were presented for normal and excessive ranges of cholesterol and blood pressure. Indeed, common medical textbooks stressed that what was acceptable in one population or for one person might be excessive in another.

Treatment of hypertension and high cholesterol was to be guided by the clinical manifestations of coronary artery disease, not the underlying level of risk. Textbooks counseled

that a person with severe chest pain, dizziness, or other obvious symptom of cardiovascular distress should be treated; one without such symptoms probably should not. This was the practice followed with Franklin Roosevelt; his hypertension was not treated until there were severe cardiovascular complications. This is now known to be a very poor strategy; by the time of clinical coronary artery disease, most of the damage has already been done.

Knowledge was not particularly valuable, however, without effective treatments. A few anti-hypertensives were developed around 1950, but these were impractical to use on a regular basis, requiring 3 or 4 injections daily, and having severe side effects. Very severe cases might require sympathectomy, surgery to sever the nerves to blood vessels (a surgery with great risk of complication!) or pyrogen therapy, inducing fever to lower blood pressure. For cases of high cholesterol, there were reports of drugs that would reduce cholesterol, but these were unproven. For both hypertension and cholesterol, the best treatments were lifestyle changes. Hypertensives were counseled to reduce salt intake and obesity, and people with high cholesterol were urged to cut back on fat and cholesterol. These recommendations were still valuable and constitute sound advice even today.

Knowledge and treatments improved steadily over the next few decades. Particularly important for this advance was the Framingham Heart Study. Begun in 1948 to look for 'the' cause of cardiovascular disease, the Framingham study has followed a group of people in Framingham, Massachusetts – and now their children – every other year, gathering information on risk factors, cardiovascular incidents, and outcomes.[7]

By the early 1960s, data from the Framingham Heart Study, along with many other sources linked cigarette smoking to cardiovascular disease.[8] By 1970 obesity or physical

inactivity, and diabetes were also established risk factors. These five risk factors – hypertension, high cholesterol, cigarette smoking, obesity, and diabetes – are still the major identified risks taught to medical students today. But they may not be the final word. Recent work has highlighted several other possible risk factors for cardiovascular disease, including white blood cell count, fibrinogen, homocysteine, and infection and inflammation.[9] It is possible that a decade from now there will be an entirely new understanding of cardiovascular disease, with newer and even better treatments.

Knowledge about cholesterol and blood pressure were also refined. There is no single value where cholesterol and blood pressure go from safe to damaging; rather, the risk increases gradually as cholesterol and arterial pressure climb. There is a broad area of blood pressures and cholesterol where there is little additional damages to small increases in risk. But past some point, additional rises in blood pressure or cholesterol become increasingly more hazardous. The goal of research was to find the point at which risk begins to increase particularly rapidly, and thus where treatment is warranted.

It was difficult for early researchers to pinpoint this value exactly, since the samples of people were relatively small and there is heterogeneity in how people respond to risk. Thus, it was clear that blood pressure above 160/95 conveyed greater risk than blood pressure below 140/90 (the first number is blood pressure when the heart is contracting; the second is blood pressure between beats), but risk at the intermediate values was not well known. Similarly, it was clear that cholesterol above 260 milligrams per deciliter of blood, abbreviated mg/dL, had higher risk than cholesterol below 220 mg/dL, but risk at intermediate values was less certain. Since about 20 to 40 percent of the population fell in these intermediate ranges, this was a

10

significant issue. It was not until the early 1980s that these issues were resolved. Clinical studies showed that blood pressures in the intermediate range should be treated, and the diagnosis of hypertension was changed to its current level, 140/90.[10] Studies of the link between cholesterol and heart disease also showed that more moderate levels of cholesterol were harmful. As a result, cholesterol levels between 200 mg/dL and 240 mg/dL are now considered borderline high, and levels above 240 mg/dL are considered high. Research also showed the predictive power of particular forms of cholesterol (LDL, or bad cholesterol versus HDL or good cholesterol) for cardiovascular disease, and most current treatment guidelines are based on cholesterol composition more than overall numbers.

For both hypertension and high cholesterol, dietary change is recommended for moderate cases of disease and medications for more severe cases, or if lifestyle changes alone are unsuccessful. Dietary change for cholesterol consists of reduced fat and cholesterol intake, along with overall weight reduction. Encouragement to reduce salt intake and lose weight have been mainstays for hypertensives since the 1950s, but have since been joined by other recommendations. In particular, diets rich in fruits, vegetables, lowfat dairy products and nutrients such as potassium and calcium, and low in saturated fat and cholesterol (the DASH diet) have been shown in clinical trials to reduce hypertension.[11] Heavy alcohol use is also associated with hypertension.

Medication is the second avenue of treatment, and here too there have been important advances. The first anti-hypertensives were developed shortly after World War II, but these therapies had substantial drawbacks. More important were diuretics, developed in the late 1950s and 1960s. Diuretics were the first truly effective, easily tolerated drugs for hypertension. They

did not require hospitalization, could be taken orally, and had few side effects. Subsequent years saw the development of beta blockers (largely developed in the 1970s), calcium channel blockers (the 1980s), ACE inhibitors (the 1980s and 1990s), and other medications. All of these medications are in use today, with different prescriptions based largely on the other conditions of the patient.

Clinical trials followed the development of medication. Landmark studies on the effectiveness of anti-hypertension medication were conducted by the Veteran's Administration in the 1960s and reported in the late 1960s and early 1970s. The VA studies showed that successfully treating blood pressure had major health benefits. This finding galvanized the medical profession. The National Institutes of Health created the National High Blood Pressure Education Program to make treatment recommendations and publicize the new results. Other public and private agencies did the same. As shown below, these efforts were extremely successful; hypertension diagnosis and treatment rates rose substantially. Other major clinical trials confirmed the safety and efficacy of new classes of drugs, and demonstrated the benefits of care for moderate hypertension.[12]

Pharmaceutical treatment of high cholesterol was slower to progress. Nicotinic acid was used in the treatment of cholesterol in the 1950s and 1960s, and bile acid sequestrants and fibric acid derivatives were approved by the FDA in the early 1970s. But all of these drugs have unpleasant side effects. The first easy to take and effective cholesterol medications were not developed until the late 1980s. Mevacor (generic name lovastatin), approved by the FDA in 1987, was the first "statin" drug for treating high cholesterol. Statins are the most commonly prescribed anti-cholesterol medication today.

Clinical trials followed the development of medication. The most prominent trial for cholesterol medication was the Lipids Research Clinic Coronary Primary Prevention Trial (CPPT), published in 1984. That trial showed cholesterol medication to be safe and effective, with large health benefits. The CPPT trial was big news, and was treated as such. The results were widely publicized, and led to the formation of the National Cholesterol Education Program, which issued the first treatment guidelines for high cholesterol and publicized the benefits of therapy. These efforts were joined by other public and private groups. In a few years' time, pharmaceutical companies advertized about high cholesterol, to promote use of their new statin medications, and food manufacturers promoted their products as cholesterol-reducing and thus heart healthy. Once again, this information turned out to be very important.

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The key issue is how this new knowledge and treatment change influenced cardiovascular health. Mortality is much easier to analyze than morbidity, so I focus on that. Even limiting the analysis to mortality, the task is not easy, as the vast number of treatment changes alone attests. Indeed, no exact decomposition of better health is available. But some guesses can be made.

I have analyzed this question along with a graduate student colleague of mine, Srikanth Kadiyala. Several other researchers have considered the question as well, including the group that operates the Framingham Heart Study, and a team at the Harvard School of Public Health led by Milt Weinstein.[13] The bulk of research comes to relatively similar conclusions, so I focus on the similarities more than the differences. I just summarize the results here; the technical

appendix contains much more detail.

Almost all of the research analyzes cardiovascular disease mortality through the early 1990s. Data on cardiovascular disease risk and behavior are only available with a lag and more recent information simply is not yet available. While more recent data will be quite valuable, the period through the early 1990s picks up enormous improvements in cardiovascular health. Thus, the conclusions drawn over this time period are still very important.

Cardiovascular disease mortality reduction is a product of three, roughly equal factors. The first factor is intensive treatment of acute conditions, particularly heart attacks. Mortality in the immediate aftermath of a heart attack has declined rapidly over time, with all of the technologies identified above playing a part in this trend.[14] The pace of treatment changes has increased over time, as newer technologies have been developed and older ones have been improved and extended to more people. Thus, most of the studies find a larger role for technological change in explaining mortality reduction in the later time periods than in the earlier time periods. Over the whole time period, technological change in acute treatments explains about one-third of better health.

The second factor is better medical management of risk, largely pharmaceuticals for hypertension and to a lesser extent cholesterol-lowering drugs. As noted above, pharmaceuticals also contribute to the reduced mortality in the acute phase. But it is worth differentiating non-acute use of drugs since the economic issues involved here, including compliance with long-term medication, diagnosing people in outpatient settings, and affordability are very different in the two settings.

Treatment changes for people with hypertension were great. In the early 1970s, about
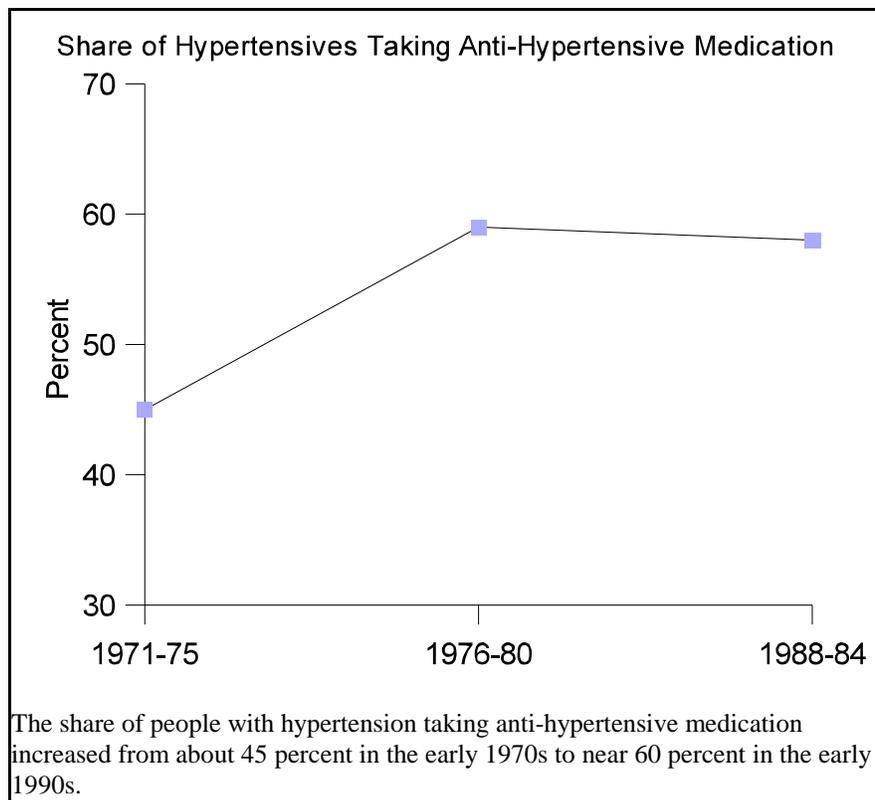
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two in five hypertensives were on medication. By the early 1990s, the share was three in five. Most of this increase was in the 1970s; over the course of the subsequent decade there were no major changes in treatment rates.
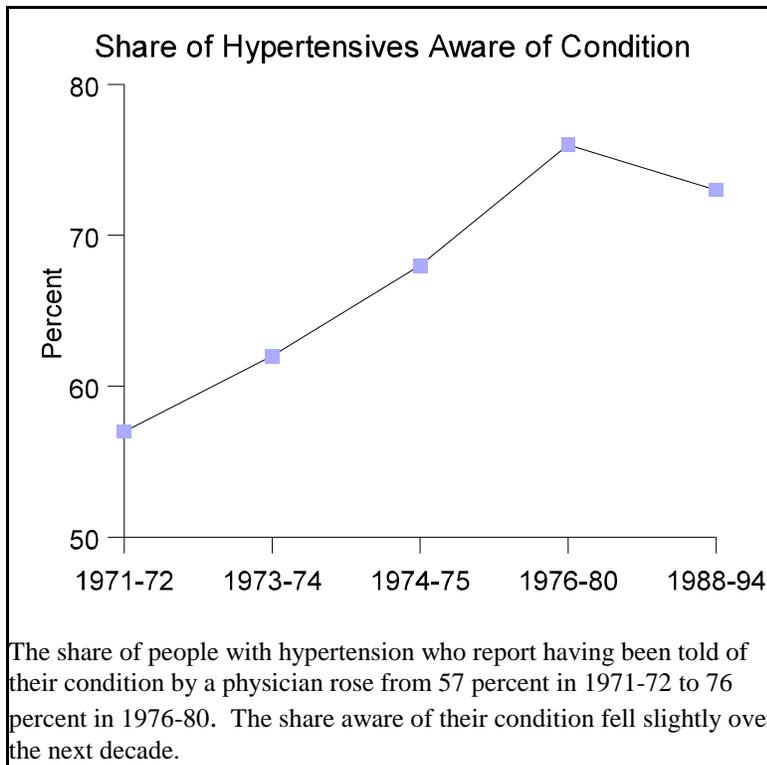
The impetus behind the change in

Share of Hypertensives Taking Anti-Hypertensive Medication

The share of people with hypertension taking anti-hypertensive medication increased from about 45 percent in the early 1970s to near 60 percent in the early 1990s.

treatment rates is not difficult to find. After the VA studies showed that anti-hypertensive medication was effective, significant efforts were made to act on this knowledge. The National High Blood Pressure Education Committee promoted hypertension awareness, as did pharmaceutical companies selling patented anti-hypertensive medication. The language from the era is still in place. Hypertension became known as the "silent killer". People were encouraged to "know your number", and physicians were urged to test for and treat hypertension. Compliance with medication instructions was stressed.

One can see these changes diffusing through the 1970s. In 1971-72, mostly prior to the information dissemination, just over half of hypertensives reported a physician had told them about their hypertension. Within five years, three-quarters reported such knowledge. In each

15

Share of Hypertensives Aware of Condition

The share of people with hypertension who report having been told of their condition by a physician rose from 57 percent in 1971-72 to 76 percent in 1976-80. The share aware of their condition fell slightly over the next decade.

case, the actual shares may be higher, since these percentages are based on patient reports, not direct observations. Patients may not recall or want to reveal what physicians actually told them. But underreporting is more likely to affect the level of awareness in every year rather than the change in awareness over time. Indeed, there may be more underreporting over time, and thus a greater increase in diagnosis than these figures indicate, as some people who do not take their recommended medication may claim they had no knowledge of their condition. [15]

Thus, in hypertension management, treatment changes precede changes in diagnosos. This is similar to what was found in the study of depression. It is a recurring theme about medical progress.
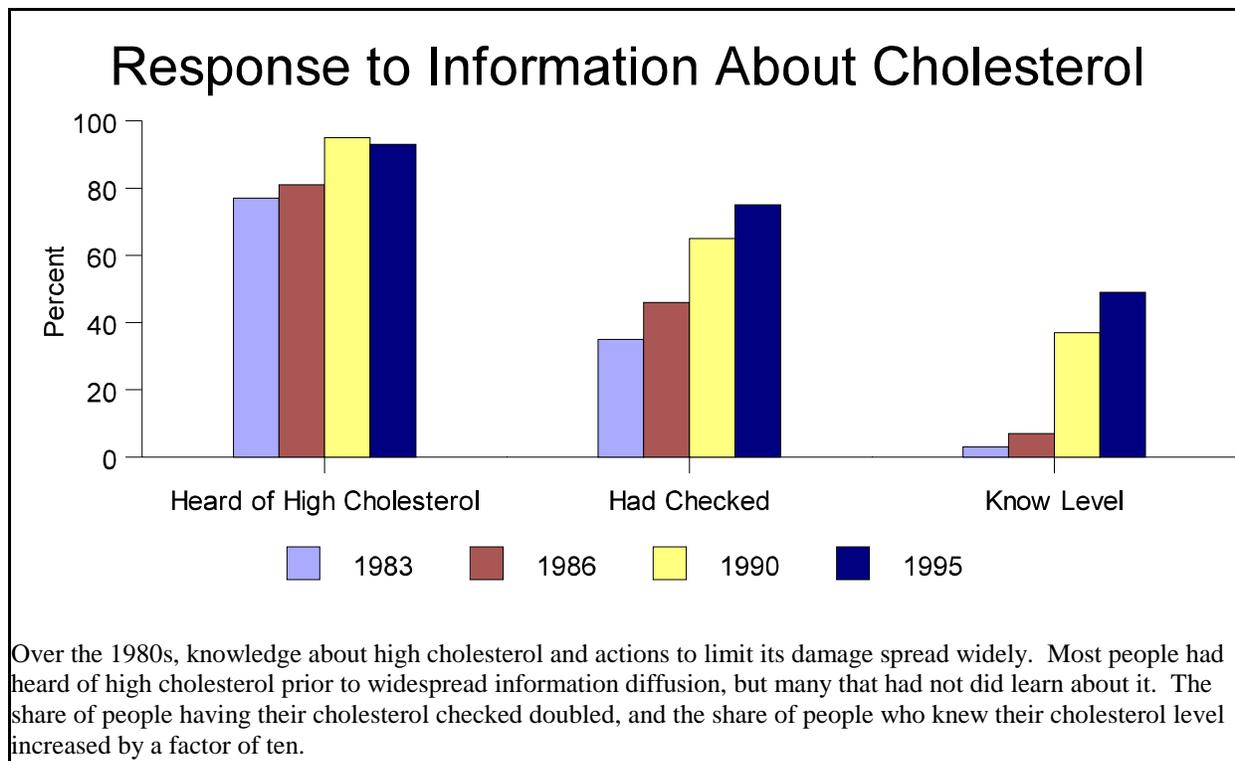
Among those diagnosed with hypertension, compliance with recommended therapies improved. More people took them in later years than in earlier years.[16] Some of this increase is because new medications were easier to take and had fewer side effects than older ones. Greater insurance coverage for outpatient pharmaceuticals is also important, along with increased encouragement by physicians.

16

Even with this effort, about 40 percent of hypertensives are not taking medication. What is happening to these people? The vast majority of this group report not having been told they have hypertension. In some cases, this may be true; many people do not go to a doctor regularly. Others likely were told about hypertension but have forgotten the diagnosis or are too embarrassed to admit they are not taking medication so they claim not to know. The high share of people not well treated in outpatient basis is only too common. It was present in the analysis of depression as well. The medical system has failed to reach everyone it should, and this failure is quite costly.

Treatment of cholesterol improved as well, and the explanation is similar. The CPPT trial in 1984 was reported in all the major newspapers and on television, and brought a wave of public attention to the issue of cholesterol management. The National Cholesterol Education Program encouraged cholesterol diagnosis and treatment. Pharmaceutical companies did as well; by the late 1980s these companies had new, expensive cholesterol-lowering drugs for sale. And food manufacturers were influential as well. Thanks to liberalized rules about food advertizing in the mid-1980s, producers could promote products on the basis of their health benefits. Thus, people were reminded about health risks every time they went to the supermarket (even today, one learns that "Cheerios May Reduce Your Risk of Heart Disease")

A series of Cholesterol Awareness Surveys shows how this information diffused. The first survey was conducted in 1983, the year before the CPPT trial was reported. The survey was repeated in 1985, 1990, and 1995, allowing for various snapshots over time.

Three-quarters of people had heard about high cholesterol prior to the CPPT trial. This is not surprising; public and private agencies had been alerting people to the dangers of high

17

Response to Information About Cholesterol

Over the 1980s, knowledge about high cholesterol and actions to limit its damage spread widely. Most people had heard of high cholesterol prior to widespread information diffusion, but many that had not did learn about it. The share of people having their cholesterol checked doubled, and the share of people who knew their cholesterol level increased by a factor of ten.

cholesterol since at least the 1960s. Some people did learn about cholesterol from the attendant information campaign, though. By 1990, an incredible 95 percent of people had heard about the dangers of high cholesterol.

More impressive is changes in what people and their physicians did about it. In 1983, about a third of the population had had their cholesterol checked. By 1995, the share was well over two-thirds. The share of people who knew their cholesterol increased from 3 percent to nearly half. Physicians also learned about appropriate treatments. In 1983, the typical physician believed that dietary change to reduce cholesterol risk should be initiated at total cholesterol levels of 260 mg/dL, and that pharmaceutical therapy should be initiated at 340 mg/dL, both far above consensus estimates at the time. By 1995, these cutoffs were 200 mg/dL and 240 mg/dL, roughly consistent with current guidelines (although the guidelines stress LDL cholesterol more

18

Physician Responses About Cholesterol Treatment

A bar chart titled "Physician Responses About Cholesterol Treatment" with y-axis from 0 to 350 in increments of 50. Two groups: "Level for Dietary Change" and "Level for Drugs". Legend: 1983, 1986, 1990, 1993.

Physician responses about treating patients with cholesterol changed in the 1980s and 1990s. Physicians indicated a willingness to treat patient with lower levels of cholesterol using both diet and drug therapy. Current practices are roughly at guideline levels.

than total cholesterol).

The overall impact of this knowledge on cholesterol management has been less pronounced than the impact of hypertension medication on rates of hypertension, at least through the early 1990s, since the information and new treatments were still relatively new and had not yet fully diffused. In the 1988-94 national survey, about 20 percent of people with high cholesterol were taking cholesterol-lowering drugs, far below the 60 percent of hypertensives on medication. Over the 1990s, however, prescriptions for anti-cholesterol medications, particularly the new statin drugss, have soared. Data available in a few years will indicate how much treatment change there has been.

Other medications beyond anti-hypertensives and cholesterol-lowering drugs have also improved health, particularly in secondary settings – after people have been diagnosed with cardiovascular disease. These drugs include nitrates to treat angina, beta blockers to reduce heart attack risk, and aspirin to thin the blood. Systematic data on the use of these medications in outpatient settings is difficult to find, although their increase in use in inpatient settings has been dramatic.

Overall, non-acute pharmaceutical use for primary and secondary prevention explains
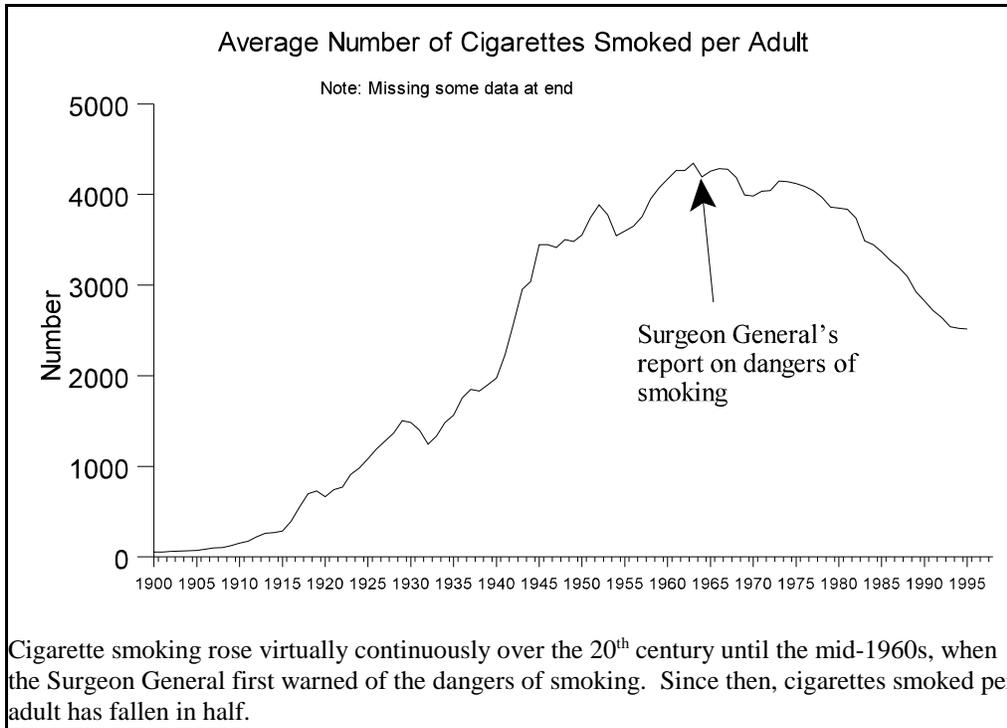
about a third of mortality reduction. Again, the exact magnitude is impossible to determine, but

the conclusions drawn below are not particularly sensitive to the specific share that is explained.

The third factor in reduced cardiovascular disease mortality is behavioral change. Some

behavioral responses have already been noted. Blood pressure and cholesterol screening

increased significantly with information about better treatments, and physician knowledge about

when to prescribe different therapies improved. But there have been changes far beyond these

medical system changes that have been an equally important part of better health.

The single most important behavioral change affecting cardiovascular health is the

reduction in smoking. In the early 1960s, nearly half of adults were regular smokers. Since then,

the share of adults smoking has fallen by third and the number of cigarettes consumed has fallen

by half.

Greater public awareness about the dangers of smoking is the single most important factor

in this change. The dangers of smoking first received widespread attention in the 1964 Surgeon

General's report on the health hazards of smoking. That report drew substantial media attention,

and began a four decade campaign to reduce demand for cigarettes.

People have clearly heard the message. Virtually everyone, including current smokers,

knows about the dangers of smoking.[17] And people have responded to it. The peak in smoking

behavior in the United States was in 1963, the year before the Surgeon General's report. Smoking

has fallen steadily since then. Most of the decline is people quitting the habit. Smoking is among

the most addictive substances known, and yet half of people alive who ever smoked have quit.

People will change their behavior dramatically if the health gains make it worthwhile to do so.

Average Number of Cigarettes Smoked per Adult

Note: Missing some data at end

Number (y-axis): 0, 1000, 2000, 3000, 4000, 5000

Surgeon General's report on dangers of smoking

1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995

Cigarette smoking rose virtually continuously over the 20th century until the mid-1960s, when the Surgeon General first warned of the dangers of smoking. Since then, cigarettes smoked per adult has fallen in half.

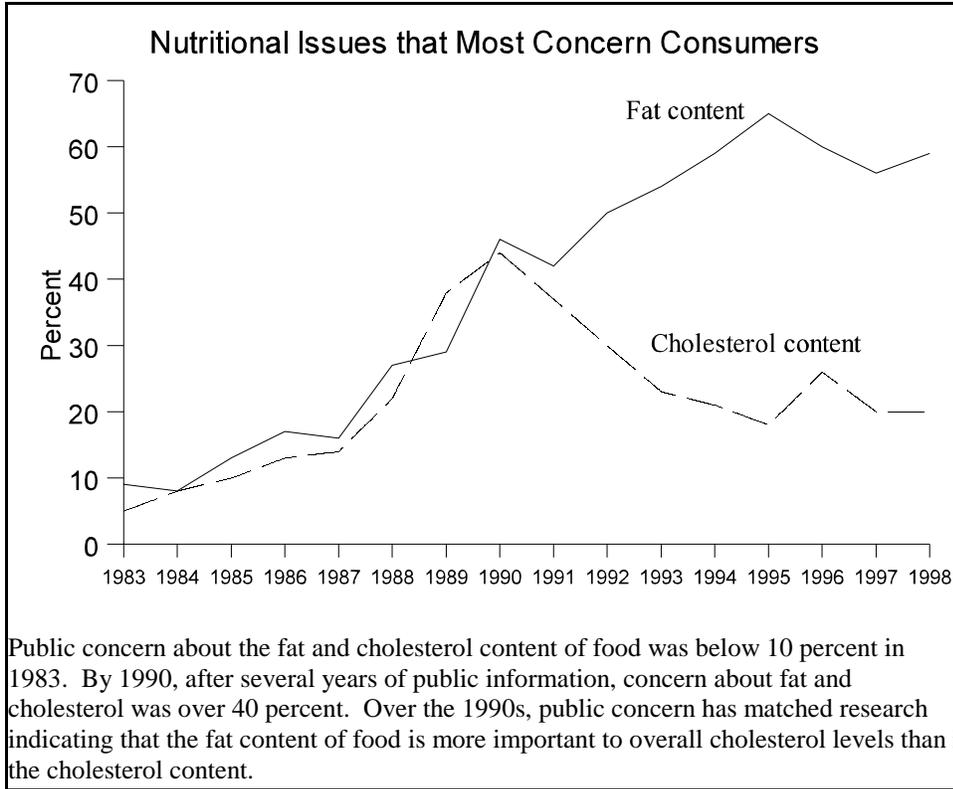In addition to informing people about health risks, the public sector has also make smoking more difficult and costly. Adjusted for inflation, cigarette taxes increased in the 1960s and early 1970s, fell through the mid-1980s, and have since increased again. Taxes are a powerful factor influencing whether people – particularly teens – smoke. More recently, mandating smoke-free workplaces has contributed to the decline in smoking.

Public concern has recently focused on the increase in smoking among youths in the 1990s. If these trends continue and youths do not drop the habit after becoming adults, smoking will ultimately increase. It will be important to follow these trends as the new generation of youth smokers enters maturity and realizes the health consequences of their youthful behavior – and faces the higher cigarette prices brought about by recent tobacco litigation. They may well quit the habit at that point. For the next few decades, though, the decline in smoking in the 1960s through 1990s will continue to dominant the cardiovascular disease scene.

Beyond smoking, changes in diet have also affected cardiovascular disease risk.[18] Dietary

changes have not been in one direction. Obesity has increased since the 1970s. Obesity has

direct effects on cardiovascular disease risk as well as many indirect effects on disease. Other

nutrition trends have been more favorable. Fat consumption has fallen steadily since the 1950s.

Bacon and eggs used to be a healthy breakfast. For many people, it is now a special treat.

Although data are sketchier, salt intake appears to have declined as well. The decline in salt use

was coincident with widely publicized warnings about the impact of salt on blood pressure in the

late 1970s and early 1980s. Finally, fewer people are heavy drinkers now than in the past. The

reduction in heavy drinking was probably not caused by concern about heart disease – liver

failure and drunk driving deaths are much more prominent concerns – but the reduction in

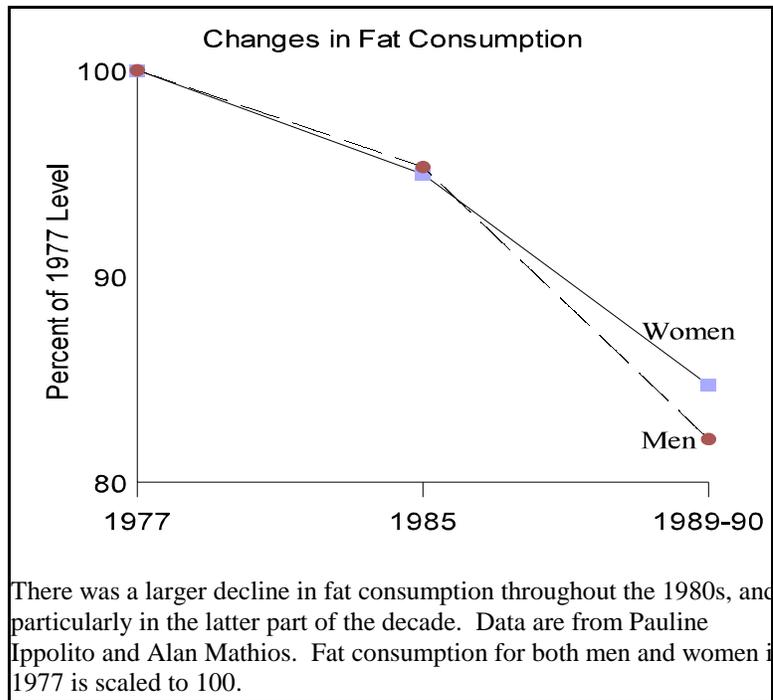excessive alcohol use does have a salutary effect on blood pressure.

The link between behavioral changes and public information is clear, just as it was with

cigarettes. Consider the evolution of fat consumption. Surveys by the Food Marketing Institute

in 1983, before the wave of cholesterol attention, showed that fewer than 10 percent of people

were concerned about the fat and cholesterol content of their food. Over the next few years, as

information about the potential harm from high cholesterol was provided, the share of people

concerned rose to 40 percent. Increasingly, consumer understanding became more refined.

Concern shifted from fat and cholesterol equally to a dominant concern over fat, consistent with

medical understanding that the fat content of food, being so much larger than the cholesterol

content, poses a greater health risk.

People's actions regarding food purchases have tracked their growing concern.

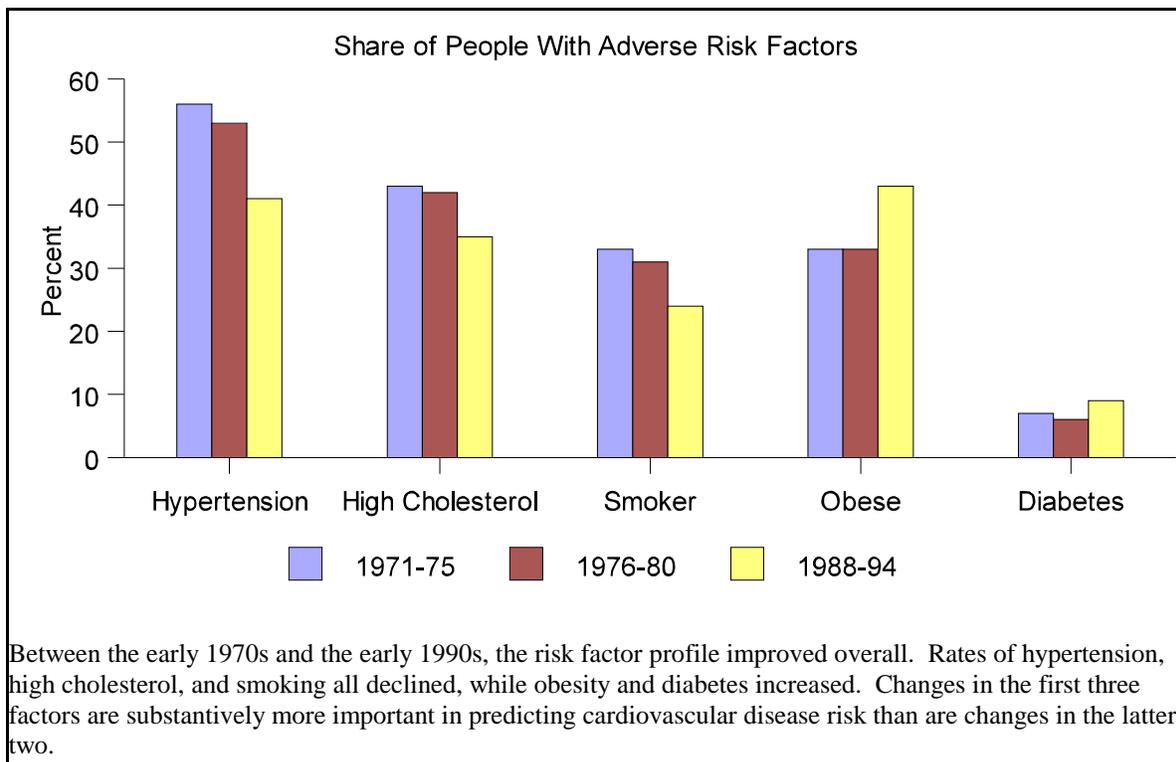Economists Pauline Ippolito of the Federal Trade Commission and Alan Mathios, formerly of the

Nutritional Issues that Most Concern Consumers

Public concern about the fat and cholesterol content of food was below 10 percent in 1983. By 1990, after several years of public information, concern about fat and cholesterol was over 40 percent. Over the 1990s, public concern has matched research indicating that the fat content of food is more important to overall cholesterol levels than is the cholesterol content.

Federal Trade Commission and now at Cornell University, have presented fascinating data on this topic. They examined trends in fat consumption in the 1977 to 1985 period, mostly

before the cholesterol attention, and then between 1985 to 1989-90, when substantial attention was focused on the issue. Fat consumption fell modestly in the 1977-85 period, consistent with the generally high knowledge about high cholesterol and the consequent downward trend in fat consumption over the past few

Changes in Fat Consumption

There was a larger decline in fat consumption throughout the 1980s, and particularly in the latter part of the decade. Data are from Pauline Ippolito and Alan Mathios. Fat consumption for both men and women in 1977 is scaled to 100.

23

decades. After 1985, though, the decline in fat consumption was many times greater.

These changes in dietary composition, combined with the reduction in smoking, more than offset the overall increase in obesity in affecting cardiovascular disease risk – at least through the early 1990s. Between the early 1970s and the early 1990s, the share of people who were hypertensive, or would have been in the absence of medication, fell nearly in half. The share of people who had high cholesterol, or would have without medication, fell by a third. Overall, the risk of cardiovascular disease events fell significantly.

Share of People With Adverse Risk Factors

Between the early 1970s and the early 1990s, the risk factor profile improved overall. Rates of hypertension, high cholesterol, and smoking all declined, while obesity and diabetes increased. Changes in the first three factors are substantively more important in predicting cardiovascular disease risk than are changes in the latter two.

In total, the change in behavior explains about one-third of reduced cardiovascular disease mortality. The fact that behavioral change is of equal importance to improvements in acute treatment may seem surprising but should not be. Acute treatments are only provided to a

share of the population, those suffering a severe cardiovascular disease incident. But preventive

behavior affects everyone. Changing everyone's behavior by a little can have as big an effect as

treating a few people quite intensively.

<p align="center">* * * * *</p>

The important question is whether these technology and behavioral trends have been a

good investment for society. They are, after all, costly. The primary benefit of cardiovascular

treatment is, of course, longer and healthier life. This benefit has been extremely large. As a

consequence of reduced cardiovascular disease mortality, the average American aged 45 could

expect to live nearly four additional years in 1990 over that in 1950.[19] With roughly equal

importance for intensive medical technologies, non-acute pharmaceuticals, and behavioral

change, each factor is estimated to have extended life by just over one year. Since the years

gained are in the future, they must be discounted to the present. Using the $100,000 value for a

year of life, the discounted value of this for a person roughly age 45 is about $150,000 in total, or

about $100,000 from changes in medical treatments and $50,000 from changes in behavior.

The benefits attributable to better medical treatments must be weighted against the

substantial increase in spending on cardiovascular disease over time. About one dollar in every

hundred earned in the economy as a whole is spent on cardiovascular disease. In terms of the

typical 45 year-old considered above, that person can expect now to spend about $15,000 in

present value on cardiovascular disease care over their lifetime. In 1950, there was some

spending on cardiovascular disease, but it was small. In the absence of good data, I assume such

<p align="center">25</p>

spending was very small, and approximate the increase in spending as the full $15,000.

Costs and Benefits of Better Cardiovascular Disease Health			
Benefit		Cost	
Medical			
Intensive technologies (1+ year)	$50,000	Additional spending on medical and pharmaceutical treatments	$15,000
Pharmaceuticals for risk factor prevention (1+ year)	$50,000		
Return	7:1		
Behavioral			
Smoking and diet changes (1+ year)	$50,000	NIH research on heart disease	$500
Return	100:1		
Spending on medical treatments and research have produced gains much larger than their costs.			

Comparing the costs and benefits of medical technology change makes it clear that the innovations in cardiovascular disease treatment are worth it. For every dollar increase in treatment costs over time, the health benefits have been $7, for a rate of return of 600 percent. In making investment decisions, we are typically happy with a return of 10 percent. This is an order of magnitude greater.

Behavioral change has costs as well. One cost is the research effort involved in learning about health and getting that knowledge to individuals. To a significant extent, these costs are publicly financed, through the National Institutes of Health. Compared to the costs of medical treatment, however, these costs are paltry. The NIH spends about $10 per person per year on all

cardiovascular disease research. Even if this entire spending was for the type of behavioral

information noted above (it is not), the total costs over a person's 50-year taxpaying lifetime are

about $500. Compared to the $50,000 benefit, the return is 100:1. If I told you that I had an

investment that would generate $100 in returns for every $1 invested, you wouldn't believe me.

But I just showed you one.

Even this return is understated, since it ignores the benefits to future generations and to

people in other countries from the knowledge generated today. Health information is a public

good. Once discovered, everyone can get it for free. So, the benefits to these other groups ought

to be added in to this calculation. But there is no need to go overboard; the picture is already

clear.

There are other, non-monetary, costs to behavioral change. People must give up

something they like to get better health – smoking or high-fat foods, for example. People

presumably like these goods or they would have given it up earlier. Estimating the costs of

changing behavior is difficult, for the same reasons that estimating the value of better health is

difficult; both are non-monetary values that are not generally expressed in a market. But

economic analysis provides some guidance in valuing these costs. In particular, a benchmark

case is that the costs of changing behavior will be about half the value of the health

improvement.

This paragraph is true economically, but does it make any sense? Why half?

Consider a person who decides to cut back from one candy bar a day to a candy bar only on

weekends, in an effort to lose weight. Giving up the first candy bar has health benefits but low

cost (one hopes!); after all, there is still plenty of candy during the week. Conversely, the last

candy bar given up should have consumption value about equal to the health gains from not consuming it, since if the last piece of candy had health gains that were much greater than the value of consumption, the person would give up even more candy. Thus, the lost consumption has negligible value for the first little bit given up, and value about equal to the health benefits for the last amount given up. The average of these is about half the health benefits.

This calculation clear assumes a degree of foresight people don't normally have – least of all about chocolate. But the model gives a benchmark with which to proceed; costs are somewhat around half of the health gains. Even with this offset, the return to medical research is staggering. The net benefit would be $25,000 on a cost of $500, or a return per dollar invested of 50:1. Again, this value would be greater if one counted future generations or people in other countries.

The returns to cardiovascular disease treatment, and to basic research on cardiovascular health, have been enormous. They are so large that they dwarf any of the uncertainties inherent in the analysis. If medical treatments accounted for only a third of better health, instead of the estimated two-thirds, treatment changes would still be overwhelmingly worth it. If a year of life were worth only a fifth its estimated value, the spending would still be worth it.

* * * * *

While cardiovascular disease health has improved greatly, not all of the potential gains have been realized. As noted above, 40 percent of people with hypertension are still not taking medication. People are still obese, even in the face of widespread medical knowledge about its

28

dangers. Information works, but only so much.

Contrast this with acute care for a heart attack. The medical system isn't perfect here, but it is better. Physicians are involved at all stages, people get valuable treatments, and things don't go too wrong. Very few people die because they don't get any care. There are lots of qualifications there; the system is not perfect. But it works pretty well.

The differences between the relative success of inpatient care and the lower success of outpatient care are directly related to the incentives in the system. The medical system is passive; it pays physicians when patients come to them needing treatment. Such payments have historically been very generous, so physicians were quite willing to provide this care. As a result, when a patient comes to a physician in an emergency setting, he is treated well and the doctor is highly compensated.

In outpatient settings, the situation is different. For conditions like hypertension which are largely asymptomatic, people do have have the imperative to seek care.   Physicians are still paid when patients come to them, but don't receive money for reaching out to people, making sure patients take their medication, or seeing that patients follow through on plans to reduce weight and cut back on salt intake. How many of the hypertensives not being treated would be treated if they got a monthly call from someone reminding them to get help? How many would take medication if prescriptions were refilled for them? How many would play an active role in management of their disease if blood pressure home testing machines were covered by insurance? The medical system doesn't do this because it isn't designed to promote health; it is designed to accept sick people coming in and treat them.

To be sure, some groups have incentives to seek out the untreated sick, but it is harder for

them to act. Pharmaceutical companies receive more when more people use their medications, particularly the ones on patent. Thus, they spend large sums to get doctors to diagnose disease and prescribe their medications. When the big problem is getting people into care, as it is for many outpatient conditions, this spending is valuable. Many in the policy community find pharmaceutical company advertizing distasteful, but the alternative may be even worse.

But the efficacy of this indirect system is limited. Pharmaceutical companies can't do all the things a well-meaning doctor could. They can't, for example, tailor their message to particular people. Pharmaceutical companies are also equally happy to have people switch from older, less expensive drugs to newer, more expensive ones, even with the same efficacy. Spending to do that is wasteful for society. And pharmaceutical company advertizing stops when the patent runs out, since there are few gains to advertizing generics.

One can't help but wonder how different the system would e if financial incentives were better targeted. Why not have a health system where someone is paid for bring in needy patients, for making sure they get and take appropriate medications, and for improving the health of people, not just treating them when they are sick. Moving the system along this road is one of the major challenges in medical care, and is a topic I take up next.

Technical Appendix

This appendix describes the decomposition of cardiovascular disease mortality

improvements into different factors. More detailed analysis can be found in my paper with

Srikanth Kadiyala.[20]

Decomposition of Changes in Mortality

We start by dividing changes in cardiovascular disease mortality into primary prevention,

acute management, and secondary prevention. We use data from the Framingham Heart Study.

The Framingham data beings in 1948a nd ends in 1988. We examines cohorts aged 45-74 in

each of 1948, 1958, 1968, and 1978 and without a previous cardiovascular disease incident.

Primary prevention is measured as the change in the share of people who have an acute incident

within a decade. We then pool everyone who had an acute incident by decade. For example, we

include all cardiovascular disease incidents from the 1948 cohort that occurred within 10 years

into a group of acute incidents occurring in the 1950s. Acute survival is measured by the change

in the share of people dying within 90 days of an acute incident occurring in the 1950s, 1960s,

1970s, and 1980s. Ninety day survival is a common time period in the literature for acute

management.[21] Finally, we measure 10 year survival for those survived the 90 day interval as a

measure of secondary prevention. Note that secondary mortality cannot be determined for the

1978 cohort, since these people had first episodes of cardiovascular disease any time between

1980 and 1988 and thus we do not have 10 years of complete follow-up data.

All of our sample means are weighted to the 1990 age and sex distribution of the US

population as a whole. We measure age in five year increments from 45-49 to 70-74. First

incident rates are weighted by the total population in each age group. Acute survival and
secondary prevention are weighted by the acute incident rate at each age. We form these
weights as the product of the age and sex specific 1990 national population times the age and sex
specific acute incident rate over the entire time period in the Framingham data.

The Framingham data does not have people in all age groups in all years. For example,
the initial sample in 1948 was aged 30 to 62. We form changes in prevention or acute
management across adjacent time periods using all the data that is common to those two time
periods, imposing a minimum of 10 people in an age-sex cell. We then benchmark these chain
weights to the Framingham data in the middle of the time period. The results for the Framingham
data are as given in Table 5.1:

Table 5.1: Prevention and Acute Management in the Framingham Data

	Cohort				Effect of Change:
	1948	1958	1968	1978	
Acute incident in 10 years	20.6%	20.7%	17.3%	15.8%	-2.3%
90 day mortality for acute incident	20.7	18.9	13.0	6.1	-2.0
10 year survival for acute survivors	34.3	28.8	22.2	—	-2.0
10 year cardiovascular mortality	8.9%	7.5%	4.7%	3.0%	-5.9%

Note: Data are age and sex adjusted to the 1990 US population.

The last column shows the change in 10 year mortality assuming the indicated row was
the only factor that changed. For example, the last column in the first row indicates if acute
incident rates had changed but acute and secondary survival had not changed, the expected
change in overall mortality would be -2.3 percentage points. Comparing the first three rows

indicates that primary prevention, acute management, and secondary prevention are of roughly equal importance in explaining mortality changes, each contributing about 2 percentage points. Further, the last row shows that these three factors together add roughly to the total change in 10 year cardiovascular disease mortality over this time period.

These findings from the Framingham data match others in the literature. Pamela Sytkowski, William Kannel, and Ralph D'Agostino, investigators on the Framingham Heart Study, have also analyzed the sources of better health in the Framingham data. Those authors also find that about two-thirds of mortality reductions are a result of better risk factor control, and one-third are a result of acute treatments. Sytkowski, Kannel, and D'Agostino do not decompose the change in risk factor profiles into medical and behavioral factors although they speculate that both are important.

Acute management

The improvement in acute survival may be a result of treatment innovations in the acute period or changes in risk factors that lead to increases in expected survival given an acute episode. An example of the latter phenomenon is that with fewer people smoking over time, more people might survive a first heart attack than previously. To differentiate between these two explanations, we estimated a regression model for acute survival over time, with and without controls for risk factor variables in the period just before the acute incident. We use a linear probability model for ease of interpretation. Table 5.2 shows the results:

Table 5.2: Regression Models Explaining 90-Day Acute Survival

Independent Variable	Coefficient	Standard Error	Coefficient	Standard Error
Year dummies*				
1960s	-.019	(.025)	-.018	(.025)
1970s	-.068	(.027)	-.064	(.027)
1980s	-.153	(.034)	-.142	(.034)
Risk factors:				
Systolic blood pressure	—	—	.00048	(.00035)
Cholesterol	—	—	.000003	(.00018)
Smoker	—	—	.065	(.019)
Diabetes	—	—	.003	(.026)
BMI	—	—	-.011	(.012)
BMI^2	—	—	.00016	(.00020)
N	1,900		1,900	
R^2	.024		.032	

Note: Data are from the Framingham Heart Study. Both regressions include age and sex dummy variables. * omitted group is 1950s.

Risk factors in the pre-episode period do not explain a significant part of the change in acute survival rates. Only the coefficient on the smoking variable is statistically significantly different from zero. Further, the coefficients on the decade dummy variables are very similar with and without the risk factor controls. Thus, we conclude that essentially all of the changes in acute survival over time are due to changes in medical care provided in the acute period. This mirrors other findings in the literature. Mark McClellan and Paul Heidenreich, for example, show that over the 1980s and 1990s, changes in intensive treatment of heart attacks were the dominant factor in improved heart attack survival.[22] Improved risk factor profiles for people with

a heart attack explained at most 10 to 20 percent of lower mortality.

Since acute survival accounts for 32 percent of total changes in survival in the Framingham data, we attribute this share to changes in intensive treatments.

<u>Primary prevention</u>

We next consider the factors associated with primary prevention. While intensive medical treatments are sometimes performed on a preventive basis, that was not the case in most of this time period. Thus, we assign no importance to intensive treatments in primary prevention. Instead, we consider the importance of behavioral change and non-acute medication. We start by understanding which risk factor changes are most important in affecting the incidence of cardiovascular disease. Using the Framingham data, we estimated Cox proportional hazard models for the probability of developing cardiovascular disease among the sample of people without a previous cardiovascular disease incident. After some experimentation, we specified risk factors as: blood pressure (max(0, systolic pressure-140)); cholesterol (max(0, total cholesterol-200)); smoker (yes/no); diabetes (yes/no); obesity (BMI and BMI^2). Blood pressure and cholesterol are both allowed to affect risk non-linearly: at low levels, increasing blood pressure or cholesterol does not affect risk, while at higher levels increases in blood pressure or cholesterol do affect risk. For blood pressure, there is some evidence that both systolic and diastolic pressure influence disease, but the two are highly correlated, so the models fit just as well using systolic pressure only. The estimates from the proportional hazard models are given in Table 5.3:

Table 5.3: Cox Proportional Hazard Models for
Cardiovascular Disease Incidence

Variable	Odds Ratio	Standard error
Systolic blood pressure	1.019	(.001)
Cholesterol	1.004	(.0005)
Smoker	1.284	(.057)
Diabetic	1.767	(.107)
BMI	.965	(.028)
BMI^2	1.001	(.0005)
N	58,041	
ln(Likelihood)	-19,446	

Note: Hazard models include dummy variables for five
year age groups by sex.

All of the risk factors significantly affect cardiovascular disease incidence and do so in

the expected direction. The baseline risk level, the incidence rate holding risk factors constant,

does not change decline over time once the risk factors are included. Thus, changes in these risk

factors account for the vast majority of the reduction in cardiovascular disease incidence over

time.

To measure how and why these risk factors changed over time, we use national data from

the Health and Nutrition Examination Surveys (NHANES) in 1971-75 and 1988-94. The

NHANES are better for this purpose than the Framingham data because of the national

representativeness of the sample.

In each of the NHANES years, we divided the sample into 384 cells: 12 age/sex groups;

and groups for high blood pressure or not (systolic blood pressure above 140); high cholesterol or not (total cholesterol above 240); smoker or not; obese or not (BMI greater than or equal to 27); and diabetic or not. Within each group, we measure average systolic blood pressure, average cholesterol, and average BMI and its square. We also measured the share of people in each cell. Not all cells have people in each year. We form cells of individuals because it is easier in simulating changes in risk factors over time to work with cell averages than to simulate changes directly using individual data.

We then evaluated the cardiovascular disease risk for each cell, using the proportional hazard coefficients from the Framingham data. Finally, we weight the cell means to the 1988-94 age and sex distribution of the population. This gives us average disease risk in 1971-75 and 1988-94 holding age and sex constant but allowing the other risk factors to vary. To evaluate the importance of each risk factor to overall changes in disease incidence, we change each risk factor in turn, holding the other risk factors constant at their 1971-75 level. Table 5.4 shows the results:

Table 5.4: Change in 10 Year Cardiovascular Disease Incidence

	Total	Medication	Behavioral
Probability of no event, 1971-75	83.5%		
Probability of no event, 1988-94	85.4		
Change resulting from:			
Hypertension	1.7%	0.9%	0.8%
Cholesterol	0.5	0.1	0.4
Smoking	0.5		0.5
Obesity	-0.2		-0.2

Diabetes	-0.1		-0.1	
Total	2.4%	1.0%	1.4%	

Data are from the National Health and Nutrition Examination Surveys for 1971-75 and 1988-94. Effects on cardiovascular disease risk are based on proportional hazard models from the Framingham Heart Study data.

The baseline probability of suffering a cardiovascular incident is for males aged 45-49 without any of the risk factors. For this group, 10 year disease incidence rates were 16.5 percent in 1971-75 and 14.6 percent in 1988-94, for a reduction of 1.9 percentage points.[23] As the next rows show, the most important factor in this change is reduced blood pressure. Blood pressure decline explains a reduction of 1.7 percentage points in disease risk. Changes in cholesterol and smoking also explain reduced incidence rates, while changes in obesity and diabetes work in the opposite direction, but are quantitatively much less important.

Reduced rates of hypertension and high cholesterol may result from either increased use of medication or from other behavioral change such as changes in diet. To estimate the share resulting from increased use of medications, we first determined the mean and standard deviation of blood pressure and cholesterol for people receiving medication in 1971-75 and 1988-94. As Table 5.5 shows, medication became vastly more effective, and was used in many more people, in 1988-94 compared to 1971-75.

Table 5.5: Blood Pressure and Cholesterol for People Taking Medication

	1971-75		1988-94	
	Systolic Blood Pressure	Cholesterol	Systolic Blood Pressure	Cholesterol
Mean (standard deviation)	153 (24)	—	141 (19)	232 (46)

| Share taking medication | 26% | — | 55% | 16% |

We then simulate how changes in medication have affected the incidence of disease. In our simulation, we first increase the share of people in 1971-75 taking anti-hypertensive or cholesterol-lowering medication to the rates in 1988-94. The additional people using medication are a random sample of those with untreated hypertension or high cholesterol in the 1971-75 survey. We then draw normal random variables for blood pressure and cholesterol among people who were actually taking medication in 1971-75 or are simulated to take medication. The random variables have the mean and standard deviation shown in Table 5.5. Thus, new levels of blood pressure and cholesterol are obtained for the 55 percent of hypertensives simulated to be on medication (including the 26 percent already on medication) and the 16 percent of people with high cholesterol simulated to be on medication. Finally, we aggregate the simulated population to the same 384 cells as the original population. We can then estimate disease risk for the simulated cohort.

As Table 5.4 shows, about half of reduced hypertension results from increased medication, and about 20 percent from reduced rates of high cholesterol. The greater importance of anti-hypertensive medication than of cholesterol-lowering medication is consistent with the much greater share of people on anti-hypertension drugs in 1988-94.

There are a variety of behavioral changes that would influence trends in hypertension and high cholesterol. Fat intake fell in absolute terms and as a share of total energy intake in the post-World War II period. Salt use declined in the 1980s. Heavy alcohol consumption fell as

well. Unfortunately, it is difficult to determine quantitatively how different lifestyle factors

influenced blood pressure and cholesterol. There are several reasons for this difficulty. First,

medical understanding is not entirely clear. For example, it was only recently shown in clinical

trials that dietary changes such as the DASH diet affect blood pressure. Other nutritional issues

are still undergoing clinical trials. Second, we do not have good estimates of dietary composition

linked to individual risk behavior. The NHANES surveys do have 1 day food recall, but the

correlation between individual intakes of various foods such as salt and fat, and individual blood

pressure and cholesterol readings is not high. Indeed, food intake is known to be under-reported,

as caloric intake in the surveys is far below estimates of food produced and is inconsistent with

the increase in weight observed over time. For these reasons, we do not attempt a decomposition

of the exact behavioral changes leading to lower rates of hypertension and high cholesterol.

The net result is shown in the bottom of Table 5.4. Roughly one-third of primary

prevention is a result of better and more commonly used medication, and the remaining two-

thirds is a result of behavioral change. Since primary prevention in total explains somewhat over

one-third of reduced cardiovascular disease mortality, this suggests that about 15 percent of total

reduced mortality is a result of medication and about 20 percent is a result of behavioral change.

Secondary prevention

We finally turn to reduced mortality for those surviving an acute incident. Changes in

secondary survival may result from more effective technologies used in acute treatment,

medication to lower blood pressure and cholesterol risk after an acute incident, other medications

such as nitrates and beta blockers in post-incident populations, or behavioral changes made after

an acute incident. It is difficult to tell these various factors apart, since the samples of people

surviving acute illnesses is not large, and thus behavioral and medication changes are difficult to

differentiate. For example, our NHANES samples have about 4,000 to 6,000 people without a

prior cardiovascular disease incident in each survey, but only 400 to 700 with a prior incident. In

addition, we do not have detailed information on all the cardiovascular drugs patients may take,

such as anticoagulants (including aspirin), antiarrhythmic drugs, and nitrates.

Several factors suggest that intensive medical treatments were not a significant part of

secondary survival, however. First, most of the medical treatments that would be expected to

promote long-term survival did not diffuse until late in the time period. For example,

revascularization procedures such as bypass surgery and angioplasty were not developed

extensively until the late 1970s or 1980s, well after much of the reduction in secondary mortality

had occurred. Innovations such as emergency response systems and coronary care units did

diffuse in the 1960s, but the greatest impact of these technologies is likely to be on immediate

mortality rather than mortality several years later.

Second, other evidence shows a decline in mortality for survivors of strokes as well as

heart attack.[24] But strokes are much less amenable to medical intervention than is heart disease,

even today. Reductions in stroke mortality are almost certainly due to changes in risk factors

after the acute period, particularly blood pressure.

Third, there is direct evidence of better risk factor control for people who had survived

acute episodes. To the extent the small samples permit analysis, rates of hypertension and high

cholesterol were lower in the 1988-94 period compared to the 1971-75 period, while smoking

was about the same, and obesity and diabetes were greater.

If the bulk of the decline in secondary mortality is not due to intensive treatments, it results from either behavioral change on increased use of medication. Medication is almost certainly more important in secondary prevention than in primary prevention. In addition to pharmaceuticals to control blood pressure and cholesterol, people with pre-existing coronary heart disease might take anticoagulants such as aspirin, anti-arrhythmic agents to control heart rhythm, beta blockers to reduce the work load on the heart, nitroglycerin, and other medications to prevent recurrent episodes. Fewer of these medications will be taken prior to the incidence of coronary heart disease.

To account for this differential, we assume that two-thirds of secondary prevention is a result of medication, and one-third results from behavioral change. This division is based on informed judgment more than evidence, in contrast to the estimates for primary prevention and acute management.

Summary and comparison to other literature

Table 5.6 shows the combined effects of intensive technologies, medication, and behavioral change to better health. As a first approximation, the three factors are of equal importance:

Table 5.6: Summary of Factors Explaining Better Health

| Factor | Explanation | | |
	Intensive Technology	Medication	Behavioral Change
Primary prevention (37%)	—	15%	21%
Acute management (32%)	32%	—	—

Secondary prevention (32%)	—	21%	11%
Total	32%	36%	32%

While there is considerable uncertainty about the specific values in the estimation, particularly for secondary prevention, this uncertainty does not substantially affect the conclusions drawn. As noted in the chapter, the conclusions about the return to intensive technologies and behavioral research are robust to even very large changes in the mix of factors explaining better health.

These results are also consistent with other evidence in the medical literature. Lee Goldman and Fran Cook were the first to analyze changes in cardiovascular disease mortality, considering the period from 1968 to 1976. They concluded that 54 percent of reduced mortality was a result of lifestyle improvements, most importantly reduced serum cholesterol levels and fewer people smoking. An additional 19 percent was due to medical management of patients with heart disease or hypertension, in both cases predominantly through medication, and 20 percent was a result of intensive treatment of patients with disease.

Finally, Maria Hunink, Lee Goldman, Anna Tosteson, Murray Mittleman, Paula Goldman, Lawrence Williams, Joel Tsevat, and Milt Weinstein built a simulation model to examine changes in cardiovascular disease mortality over the 1980s. They concluded that 15 percent of mortality reduction over the 1980s resulted from acute treatment for heart attacks, another 29 percent results from medical and surgical treatment of coronary artery disease, 25 percent resulted from primary prevention of risk, and 29 percent resulted from better risk factor control in people with pre-existing disease. The total role of intensive technologies in better

health is the 15 percent case fatality plus some share of the 29 percent from treating patients with

coronary artery disease. While an exact division of this amount is not available, it is likely to

come close to the 33 percent presented here. The authors do not divide risk factor control into

medication and lifestyle changes.

The NHANES Data

Many of the trends in the chapter rely on data from the NHANES. Our NHANES

samples are people aged 45-74. The sample sizes are 4,067 in 1971-75, 6,609 in 1976-80, and

5,969 in 1988-94. The data are all adjusted to the age, sex, and racial composition of the

population in 1990.

1.   For discussion of Roosevelt's illness and its implications, see Robert H. Ferrell, *The Dying President: Franklin D. Roosevelt, 1944-45*, Columbia, MO: University of Missouri Press 1998; Franz H. Messerli, "Occasional notes: This Day 50 Years Ago", *New England Journal of Medicine*, April 13, 1995: 1038-1039; Ray W. Gifford, "FDR and Hypertension: If We'd Only Known Then What We Know Now", *Geriatrics* 1996; 51(Jan):29-32. The statement of Roosevelt's physician is from Howard G. Bruenn, "Clinical Notes on the Illness and Death of President Franklin D. Roosevelt", *Annals of Internal Medicine*, 72:579-591, 1970, p. 591. For additional speculation about the importance of Roosevelt's illness for world history, see Alvan L. Barach, "Franklin Roosevelt's Illness: Effect on Course of History", *New York State Journal of Medicine*, November 1977, 77(13), 2154-2157; Jeffrey Hart, "While America Slept", *National Review*, September 15, 1989, 32-34.

2.   An introduction to risk factors predicting cardiovascular disease is Donald Lloyd-Jones and William B. Kannel, "Coronary Risk Factors: An Overview", in James T. Willerson and Jay N. Cohn, eds., *Cardiovascular Medicine, 2nd Edition*, New York: Churchill Livingstone, 2000, 2193-2215.

3.   As the Technical Appendix shows, this is true in the Framingham Heart Study data. This is also true in the data from the Minnesota Heart Study. See Lila R. Elvebac, Daniel C. Connolly L. Joseph Melton, "Coronary Heart Disease in Residents of Rochester, Minnesota, VII: Incidence, 1950 through 1982," Mayo Clinical Proceedings, 1986;61:896-900. Overall mortality has been falling even more rapidly, at over 2 percent per year, so mortality among acute incident survivors is falling as well.

4.   For a longer rendition, see Eugene Braumwald, "Evolution of the Management of Acute Myocardial Infarction: A 20th Century Saga", *The Lancet*, 352(9142), November 8, 1998, 1771-1774.

5.   For more discussion of Eisenhower's heart attack, including the claim that Eisenhower's physician mis-diagnosed the heart attack in the crucial first few hours, see Clarence G. Lasby, *Eisenhower's Heart Attack*, Lawrence, KS: University of Kansas Press, 1997.

6.   To understand these changes, I have reviewed every edition of the leading textbook for internal medicine for the past 50 years, Harrison's *Principles of Internal Medicine*. This is the standard reference for students in internal medicine. This discussion is drawn from the chapters on atherosclerosis and hypertension. In addition, I have reviewed national panels that issued guidelines on hypertension and high cholesterol, including the Joint National Committee on Detection, Evaluation, and Treatment of High Blood Pressure (including its predecessor, Task Force I), and the National Cholesterol Education Program (and its predecessor, the Consensus Development conference on Lowering Blood Cholesterol to Prevent Heart Disease). Finally, there have been periodic medical reviews of the state of the field. For discussion of hypertension, see Lot B. Page and James J. Sidd, "Medical Management of Primary Hypertension", *New England Journal of Medicine*, part 1: 287;19, November 9, 1972, 960-967;

part 2: 287;20, November 16, 1972, 1018-1023; and part 3: 287;21, November 23, 1972, 1074-1081; and Harriet P. Dustan, Edward J. Roccella, and Howard H. Garrison, "Controlling Hypertension: A Research Success Story," *Archives of Internal Medicine*, 1996; 156:1926-1935.

7.   The earliest results from the Framingham Heart Study are in Kannel WB, Dawber TR, Kagan A, Revotskie N, Stokes JI, "Factors of risk in the development of coronary heart disease--six year follow-up experience; the Framingham Study". *Annals of Internal Medicine*, 1961;55:33-50.

8.   An historical discussion of the link between cigarette smoking and disease is in United States Department of Health and Human Services, *Reducing Tobacco Use: A Report of the Surgeon General*, Atlanta, GA: US Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, 2000.

9.   Kishore J. Harjai, "Potential New Cardiovascular Disease Risk Factors: Left Ventricular Hypertrophy, Homocysteine, Lipoprotein(a), Triglycerides, Oxidative Stress, and Fibrinogen", *Annals of Internal Medicine*, 131(5), September 7, 1999, 376-386.

10.   The most recent guidelines are: <120/80 is optimal; 120/80 to 130/85 is normal; 130/85 to 140/90 is high normal; 140/90 to 160/100 is stage 1 or mild hypertension; 160/100 to 180/110 is stage 2 or moderate hypertension; and >180/100 is stage 3 or severe hypertension.

11.   Lawrence J. Appel, Thomas J. Moore, Eva Obarzanek, et al., "A Clinical Trial of the Effects of Dietary Patterns on Blood Pressure", *New England Journal of Medicine*, 1997; 336:1117-1124.

12.   Hypertension Detection and Follow-up Program Cooperative Group, "The Effect of Treatment on Mortality in 'Mild' Hypertension", *New England Journal of Medicine*, 1983; 307:976-980.

13.   The research of the Harvard group is summarized in Maria G. M. Hunink, Lee Goldman, Anna N. A. Tosteson, Murray A. Mittleman, Paula A. Goldman, Lawrence W. Williams, Joel Tsevat, and Milton C. Weinstein, "The Recent Decline in Mortality From Coronary Heart Disease, 1980-90", *Journal of the American Medical Association*, 1997 277: 535-542. Analysis from the operators of the Framingham Heart Study is in Pamela A. Sytkowski, William B. Kannel, and Ralph B. D'Agostino, "Changes in Risk Factors and the Decline in Mortality from Cardiovascular Disease", *New England Journal of Medicine*, 1990; 322:1635-1641; and Pamela A. Sytkowski, "Declining Mortality from Cardiovascular Disease", *Comprehensive Therapy*, 1991; 17(5): 39-44. The first look at this question was Lee Goldman and E. Francis Cook, "The Decline in Ischemic Heart Disease Mortality Rates: An Analysis of the Comparative Effects of Medical Interventions and Changes in Lifestyles", *Annals of Internal Medicine*, 1984; 101: 825-836.

14.   Both the Framingham Heart Study and the Minnesota Heart Study reach such findings. There is some confusion about the exact timing of cardiovascular disease events in the Framingham data, but the conclusions are not specific to the particular timing chosen. Results from the Minnesota Heart Study are in Patricia G. McGovern, Aaron R. Folsom, Michael J. Sprafka, et al., "Trends in Survival of Hospitalized Myocardial Infarction Patients Between 1970 and 1985: The Minnesota Heart Survey", *Circulation*, 1992; 85: 172-179.

15.   The increase in diagnosis is also not because blood pressure measurement became any easier, more accurate, or less expensive. The sphygmomanometer, the cuff physicians use to measure blood pressure, has been unchanged since early in the 20th century.

16.   According to the 1971-75 National Health and Nutrition Examination Surveys, 80 percent of people who reported being prescribed anti-hypertensives were taking such medication. In the 1976-80 survey the share was 87 percent, and in the 1988-94 survey the share was 88 percent.

17.   According to survey data, in 1960 bout 60 percent of people thought that smoking was bad for them. Today, the share is over 95 percent.

18.   In addition to what is presented here, trends in risk factors may be found in several articles in the literature. Information on obesity may be found in Robert J. Kuczmarski, Katherine M. Flegal, Stephen M. Campbell, and Clifford L. Johnson, "Increasing Prevalence of Overweight Among US Adults", *Journal of the American Medical Association*, 1994; 272:205-211. Data on diabetes are in Maureen I. Harris, Katherine M. Flegal, Catherine Cowie, Mark S. Eberhardt, David E. Goldstein, Randie R. Little, Hsiao-Mei Wiedmeyer, and Danita D. Byrd-Holt, "Prevalence of Diabetes, Impaired Fasting Glucose, and Impaired Glucose Tolerance in U.S. Adults: The Third National Health and Nutrition Examination Survey, 1988-1994", *Diabetes Care*, 1998; 21(4), April, 518-524.data on hypertension are in Vicki L. Burt, Jeffrey A. Cutler, Millicent Higgins, Michael J. Horan, Darwin Labarthe, Paul Whelton, Clarice Brown, and Edward J. Roccella, "Trends in the Prevalence, Awareness, Treatment, and Control of Hypertension in the Adult US Population", *Hypertension*, 1995; 26: 60-69. Data on high cholesterol are in Christopher T. Sempos, James I. Cleeman, Margaret D. Carroll, Clifford L. Johnson, Paul S. Bachorik, David J. Gordon, Vicki L. Burt, Ronette R. Briefel, Clarice D. Brown, Kenneth Lippel, and Basil M. Rifkind, "Prevalence of High Blood Cholesterol Among US Adults: An Update Based on Guidelines from the Second Report of the National Cholesterol Education Program Adult Treatment Panel", *Journal of the American Medical Association*, 1993; 269: 3009-3014. Data on fat intake are in Alison M. Stephen and Nicholas J. Wald, "Trends in Individual Consumption of Dietary Fat in the United States, 1920-1984, *American Journal of Clinical Nutrition*, 1990; 52: 457-469. Data on salt consumption are in Alta Engstrom, Rosemary C. Tobelmann, and Ann M. Albertson, "Sodium Intake Trends and Food Choices", *American Journal of Clinical Nutrition*, 1997; 65(Suppl): 704S-707S.

19.   The exact increase is 4.7 years. The total increase in longevity for 45 year olds was 4.4 years. The cardiovascular disease share is thus 85 percent.

20.   David Cutler and Srikanth Kadiyala, "The Economics of Better Health: The Case of Cardiovascular Disease", mimeo, 2000.

21.   See Mark McClellan, Barbara J. McNeil, and Joseph P. Newhouse, "Does More Intensive Treatment of Acute Myocardial Infarction In the Elderly Reduce Mortality?: Analysis Using Instrumental Variables." *Journal of the American Medical Association,* 272(11):859-866, September 21, 1994.

22.   Paul Heidenreich and Mark McClellan, "Accounting for Changes in Survival for Heart Attack Patients", in David Cutler and Ernst Berndt, eds., *Medical Care Output and Productivity*, Chicago: University of Chicago Press, 2001.

23.   We can examine how much using cell averages affects our results. Using the individual level data, the probability of an acute incident within 10 years is 17.1 percent in 1971-75 and 15.6 percent in 1988-94. These are very close to the group averages, suggesting that our groups do contain sufficient information.

24.   Per Thorvaldsen, Kari Kuulasmaa, Anna-Maija Rajakangas, Daiva Rastenyte, Cinzia Sarti, and Lars Wilhelmsen, "Stroke Trends in the WHO MONICA Project", *Stroke*, 1997; 28(3): 500-506.