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New Forecasting Methodology Indicates More Disease And Earlier Mortality Ahead For Today's Younger Americans

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ABSTRACT Traditional methods of projecting population health statistics, such as estimating future death rates, can give inaccurate results and lead to inferior or even poor policy decisions. A new "three-dimensional" method of forecasting vital health statistics is more accurate because it takes into account the delayed effects of the health risks being accumulated by today's younger generations. Applying this forecasting technique to the US obesity epidemic suggests that future death rates and health care expenditures could be far worse than currently anticipated. We suggest that public policy makers adopt this more robust forecasting tool and redouble efforts to develop and implement effective obesity-related prevention programs and interventions.

Most Americans enjoy better health today than at any other time in our nation's history,[1] despite the persistent burden of cardiovascular disease and cancer. Fueling recent improvements in the health status of adults are notable declines in death rates from the top three causes of death: heart disease, cancer, and stroke.[2–4] Although this is exceedingly good news, many researchers have made a potentially serious error in extrapolating this trend forward in time, thereby arriving at the conclusion that the nation's health will continue to improve and that life expectancy gains will persist unabated.[5–8]

The underlying assumption that the future will be like the past is always problematic. Commonly used metrics of population health, such as trends in period life expectancy, can lead to misguided health forecasts. They fail to account for the time lag between behavioral risk factors now present among groups of younger people and those risk factors' likely influence on the health status of these cohorts as they age.

Put differently, death rates observed today provide an accurate reflection of the lifetime of risk factors—both behavioral and epigenetic—accumulated by the recently deceased. Epigenetic risk factors are acquired but inheritable nongenetic changes that alter the expression of genes and can thus trigger disease processes in subsequent generations (for example, exposure to tobacco smoke by young people in the twentieth century could trigger disease in their offspring in the twenty-first century).

But death rates provide only a limited, "two-dimensional" vision of the future by failing to take into account the potentially different risk factors accumulated by people who are still alive. A more accurate gauge of the future of health and longevity requires a "three-dimensional" view—that is, a vision that accounts for the time lag (latency period) between the accumulation of risk factors and their eventual manifestation in health outcomes, such as cardiovascular disease or premature mortality.

To illustrate and reinforce this point, we compare how accurately two-dimensional and three-dimensional forecasting methods would have predicted the US cardiovascular disease mortality rates actually observed in 2000 and 2007. Our results—along with a number of recent studies—suggest that some subgroups within the United States, and by implication, other developed nations, are headed toward worsening health and a shorter lifespan at a time when traditionally reported national vital statistics indicate otherwise. We conclude that traditional, two-dimensional health indicators must be supplemented with three-dimensional methods of forecasting health and longevity, so that policy makers can take targeted actions to improve the health and well-being of the population.

Two-Dimensional Forecasting

Two-dimensional forecasts are derived from age-specific health statistics, such as life expectancy at birth. The data are then plotted over various periods of observation. These sequential plots are often extended into the future via statistical methods, the most popular of which is linear extrapolation.

The implicit assumption underlying current two-dimensional forecasting is that younger generations will experience better health and lower mortality than their predecessors as they age. It is further assumed that past improvements in health and longevity, already experienced by older cohorts and expressed in national vital statistics, will continue at an identical or accelerated pace for younger cohorts for the remainder of their lives. This approach is appealing to many because it simplifies computations and leads to some pleasantly optimistic conclusions about future longevity prospects.

However, history has proved that two-dimensional forecasts can be inaccurate, sometimes with dire consequences for policy. For example, many company pension plans have become strained or bankrupt because they failed to account for declines in smoking and improvements in lifestyles and medical technologies that led to greater-than-expected longevity among employees covered in the plans.[9] These trends were not captured in forecasts that were based on past trends in health and mortality among the recently deceased. Similarly, inaccurate assumptions about future life expectancy have contributed to a one-trillion-dollar gap in state pension funds between resources promised and those that states need to cover retiree benefits.[10]

More recently, the Social Security Administration used past trends to predict that mortality rates from diabetes will decline steadily in the coming decades,[11] despite the increasing prevalence of diabetes and obesity among adults and children. Also, recent studies based on a series of national health surveys[12] and a group of older Americans[13,14] have concluded that the US obesity epidemic is not sufficient to reverse long-term trends in rising life expectancy. If such predictions are used as the basis for public policy, they could undermine efforts to prevent childhood and adult-onset obesity and its escalating negative effects on health and longevity.

If environmental and health conditions were always improving or declining on a steady and predictable course, the underlying assumption of constant change in two-dimensional forecasts would be plausible. However, as declines in smoking and the adult and childhood obesity epidemics already documented in the population demonstrate, health conditions among generations can change quite rapidly and dramatically, and sometimes for the worse.

Three-Dimensional Forecasting: An Example

As noted, the two-dimensional perspective can account for variation in health status across age groups and periods of observation. The three-dimensional perspective incorporates these factors, but it also accounts for variation in health status across groups of people born during a particular period or year. As we will show, this is a crucial difference when considering the future health implications of the US obesity epidemic.

In one analysis that adopted a three-dimensional perspective by accounting for the latent health effects of the US obesity epidemic, the current life-shortening effect of adult obesity was shown to be about three-quarters of a year—an amount larger than from all sources of accidental death combined. But the life-shortening effect of obesity could increase to two to five years, perhaps more, once the cohort effects of childhood obesity on subsequently observed adult mortality are taken into account.[15] Although that study accounted for the third dimension, it was criticized by scholars who argued that the obesity epidemic is unlikely to counter the complex array of medical, social, and behavioral factors that have resulted in recent improvements in US life expectancy.[16,17]

Nevertheless, a number of recent studies show that the US obesity epidemic, which began in the early 1980s,[18,19] could erode hard-won gains in health and longevity and is already doing so. For instance, data from the National Health and Nutrition Examination Surveys show that cardiovascular risk-profiles have worsened since the late 1980s as the result of unfavorable trends in type 2 diabetes, blood pressure, and body mass index.[20] Autopsy findings for people ages 16–64 who died of external causes show that declines in the severity of coronary heart disease among younger people ended in the mid-1990s and may have reversed after 2000.[21,22]

Consistent with this evidence, trends in coronary heart disease mortality between 1980 and 2002 showed substantial improvement among Americans age fifty-five or older, but much less improvement among Americans ages 35–54.[23] In fact, the most recent period of observation (2000–02) showed a decline of only 0.5 percent in coronary heart disease mortality among younger adult males and an increase of 1.5 percent among females in this age range.

An analysis of nearly one million participants in fifty-seven prospective studies in North America and Western Europe has shown that elevated body mass index increases the risk of premature mortality.[24] This study found that the optimal body mass index is 22.5–25.0 and that median survival was two to four years less among participants with an index of 30–35 and eight to ten years less among those with an index of 40–45. Similarly, an analysis of 1.46 million white participants in nineteen prospective studies from the National Cancer Institute Cohort Consortium has shown that overweight and obesity are associated with mortality from all causes.[25]

In accord with findings from these prospective studies, statistically significant declines in life expectancy occurred between 1983 and 1999 for a substantial number of US counties.[26] These declines were most pronounced among females who lived in disadvantaged counties in the Southeast—precisely where the obesity epidemic has struck the hardest. In the period of observation just before the onset of the obesity epidemic (1961–83), no significant declines in life expectancy at birth were observed in any US county. The authors attribute worsening life expectancy in these counties to chronic diseases related to smoking, hypertension, and obesity—risk factors that tend to be concentrated in those areas.

Studies published within the past two years have shown that recent cohorts of younger Americans (born since 1960) are at increased risk of obesity, compared to cohorts born prior to 1960.[19,27,28] For instance, Joyce Lee and colleagues used data from the National Health and Nutrition Examination Surveys to show that although at least 20 percent of Americans born after 1965 were obese by ages 20–29, this threshold was not reached until ages 30–39 for Americans born between 1946 and 1965, until ages 40–49 for Americans born between 1936 and 1945, and until ages 50–59 for Americans born between 1926 and 1935.[28]

Using data from twenty-seven National Health Interview Surveys, Eric Reither and colleagues found that the predicted probability of obesity at age twenty-five increased by 30 percent for cohorts born between 1955 and 1975.[19] These studies indicate that recent cohorts of Americans are heavier than their predecessors and have become obese earlier in life. This implies that an increasing share of young Americans are about to carry excess weight—and the elevated morbidity and mortality risks associated with it—for a larger proportion of their lives.

Although these trends were observed in the general US population, they were consistently stronger among blacks, particularly black females.[19,27,28] John Komlos and colleagues found that body mass index increased by 5.6 units among black females ages 2–19 between 1941 and 2004, compared to just 1.5 units among white females.[27] This finding was reinforced by evidence demonstrating that the predicted probability of obesity for a twenty-five-year-old black female from the 1980–84 birth cohort was 0.27—more than twice the probability for a white female from the same cohort.[19]

Substantial racial/ethnic disparities in obesity have been documented elsewhere.[29] This emerging body of three-dimensional research goes further by suggesting that the observed disparities are deeply rooted in the past and therefore likely to persist into the future.

Three-Dimensional Mortality Projection: A Demonstration

Here we provide a concrete illustration of the greater utility of three-dimensional projections that account for the latent effects of the health status of younger cohorts. This example uses data from the decades before 2000 to predict mortality at two points in the following decade, for which actual data are already available.

STUDY DATA AND METHODS Using observed age-specific death rates from coronary heart disease among males published by the National Center for Health Statistics during 1960–99, we first projected mortality forward to 2002 and 2007 with the commonly used two-dimensional approach of linear extrapolation. Next, using an established method for three-dimensional projection,[30] we drew on age-period-cohort model coefficients for coronary heart disease mortality reported by a recent investigation of cause-specific mortality trends in the United States.[31] We projected the period and cohort effect estimates forward to two points in time (2002 and 2007) and for two birth cohorts (males born in 1980 and 1985), respectively.

A well-known model-identification problem arises with the conventional age-period-cohort model. Because the three variables are mathematically related to each other (period equals age plus cohort), their separate effects cannot be identified without additional constraints. And different constraints produce different estimates of these effects.

But the model-based projection is not subject to this problem because it does not concern individual effects—only fitted/predicted values from the model combining all these effects, which are invariant to the choice of identifying constraints. In other words, even though various ways of addressing the identification problem yield different coefficient estimates (for example, the effect that belonging to a particular birth cohort has on the death rate), they all result in equivalent projections. Finally, with these additional estimates, we obtained predicted coronary heart disease mortality rates for the corresponding time periods and birth cohorts, which we compared to the observed rates and linearly extrapolated rates of coronary heart disease mortality for males in 2002 and 2007.

Given that obesity increased for US cohorts born after 1950,[19,27] and that coronary heart disease risk profiles and health outcomes have recently worsened for younger Americans,[20–23] we hypothesized that two-dimensional projections would systematically underestimate observed coronary heart disease mortality rates for males age fifty and younger. We also hypothesized that because the three-dimensional approach takes into account the additional source of variation in mortality rates attributed to birth cohort, it would be less susceptible to errors in prediction.

RESULTS The results confirm that the two-dimensional projection method underestimated observed rates of coronary heart disease mortality among US males for cohorts born after 1950. As shown in Exhibits 1 and 2, the decline in observed coronary heart disease mortality slowed among men ages 45–49 and reversed among men ages 25–29 after 2000. However, the decline in predicted coronary heart disease mortality from linear extrapolation modeling showed no such abatement. By contrast, three-dimensional projections more closely approximated observed mortality.

Discussion

The future of health and longevity will be driven by the accumulated life experiences of people now alive, not by the past life, health, and mortality experiences of the recently deceased. Using the childhood and adolescent obesity epidemic in the United States as an example, it is suggested here that the future health and longevity of an entire generation of young Americans may be in jeopardy. The magnitude and severity of the problem is as yet unknown. Public health interventions now being developed could attenuate some or all of the concern,[32] or the problem could grow worse, as suggested by a recent exercise in network modeling.[33]

Although we provide one illustration of a three-dimensional method, the key point here is not to indicate how three-dimensional metrics should be constructed, but rather to suggest that they routinely be used for policy making purposes. As our example illustrates, they reveal a more reliable picture of the future of health and longevity based on the observed health status of younger cohorts alive today.

We have shown that a reversal in US life expectancy rates is a distinct possibility in the long term, and a high probability in the short term for subgroups of the population most affected by obesity. Indeed, period life expectancy has already begun to decline in some US counties,[26] highlighting the need for disaggregated analyses capable of detecting deviations from overall national trends in subsets of the population.

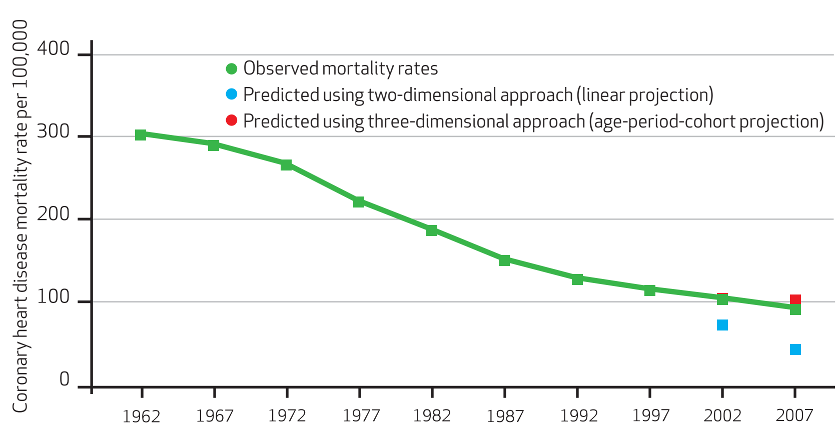
Some may disagree by asserting that advances in pharmacological and other interventions, which have improved cardiovascular risk profiles and mortality rates in the past,[34,35] are likely to keep pace with future health challenges posed by the latent effects of obesity acquired by younger cohorts in recent decades. Recent studies cast doubt on this argument.[20,26]

IMPLICATIONS FOR MORBIDITY PROJECTIONS It is important not to lose sight of the fact that despite the difference of opinion on how the high prevalence of obesity and other adverse health conditions among US children today will affect longevity, scientists generally agree that these liabilities will increase the burden of various chronic diseases that children will face in the future.[36,37] That fact alone should engender quick action in the public health arena.

By way of example, research has shown that

EXHIBIT 1

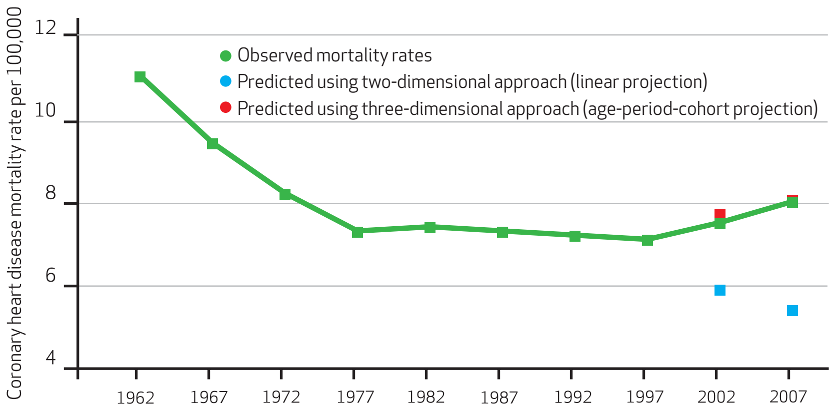
Two- Versus Three-Dimensional Projections For Coronary Heart Disease Mortality Among US Males Ages 45–49, 1962–2007



SOURCE Authors' analysis.

EXHIBIT 2

Two- Versus Three-Dimensional Projections For Coronary Heart Disease Mortality Among US Males Ages 25–29, 1962–2007



SOURCE Authors' analysis.

obese children and adolescents are susceptible to metabolic syndrome—a cluster of risk factors such as hypertension, insulin resistance, and lipid disorders that predict the development of diabetes and cardiovascular disease.[38–40] Excess weight gain in childhood and adolescence is also strongly related to the presence of these risk factors in young adulthood.[41]

Furthermore, the degree and duration of obesity influence the latency period for type 2 diabetes.[42–44] This suggests that younger US cohorts will develop diabetes at earlier ages relative to previous generations. Acquiring type 2 diabetes earlier in life accelerates subsequent negative health outcomes, including end-stage renal disease.[45] Particularly disturbing are the indications of damage to the heart and blood vessels that have been observed in obese children.[46–48]

Two-dimensional projections are likely to underestimate the future prevalence and severity of morbidity because they do not account for the fact that recent cohorts are, as a rule, becoming obese at earlier ages than their predecessors. This point was alluded to recently by Rob van Dam and Walter Willett, who note that although recent trends in cardiovascular disease are disturbing, they "do not yet reflect the effects of the current epidemic of childhood obesity, which causes an early onset of type 2 diabetes, hypertension, and dyslipidemia."[49] The authors proceed to argue that obese children with early onset diabetes will, by midlife, accumulate "several decades of exposure that will greatly elevate risks of not just coronary heart disease and stroke but also microvascular [small blood vessel] complications that can eventually lead to amputations, blindness, and kidney failure."[49]

Because this three-dimensional perspective anticipates substantial increases in morbidity and related health care expenditures, it suggests that the appropriate public policy response is to redouble efforts to develop and implement effective obesity prevention programs and other targeted interventions.

INTERGENERATIONAL PROCESSES Concerns about latent effects of harmful conditions acquired early in life are amplified by accumulating evidence that obesity risks may be determined before birth. This may occur through fetal programming (developmental changes in a fetus during gestation caused by environmental conditions of the mother that lead to harmful health effects for the child later in life)[50] and by transgenerational epigenetic inheritance (the inheritance of acquired factors from one's forebears that alter genetic expression).[51–53]

For example, fetal overnutrition has been shown to permanently increase appetite and shift preferences toward junk food among offspring,[50] increasing the risk of obesity. Both human and animal studies indicate that maternal and paternal health behaviors—such as diet and smoking—affect the probability of obesity and related conditions among offspring through metabolic programming. In other words, a child's metabolism and risk for certain diseases later in life can be "programmed" by conditions that existed during gestation.[54–56]

Once obesity actually develops, it may be transferred across generations through epigenetic inheritance.[51] The implications of this body of science are profound: the high prevalence of obesity observed among younger people today is likely to be transmitted to future generations—regardless of the health behaviors of children yet to be born. The detrimental health effects of epigenetic inheritance are not accounted for by two-dimensional forecasting models.

SUGGESTIONS FOR POLICY MAKERS There are important public policy implications associated with continuing to rely exclusively on two-dimensional metrics. The US obesity epidemic provides a perfect illustration of this point. Whereas national vital statistics and analyses of older cohorts suggest that the rise of obesity does not represent a major health hazard for the US population, three-dimensional models and health assessments of younger cohorts strongly suggest otherwise.

Public policy makers need to be aware of the fact that currently reported statistics on the health and well-being of the population are based on vital statistics data drawn from the ages of individuals and the period in which their health (or mortality) is observed. These measures are easy to calculate and invaluable for comparing health statistics across nations or following trends from the past to the present. However, they overlook the third dimension of time (or what we refer to here as cohort effects). To reiterate, forecasts of health and longevity must take into account all three dimensions of time—age, period, and birth cohort—to generate appropriately targeted public policies to improve the health and well-being of the population.

Because the three-dimensional perspective warns of potential declines in US children's health and longevity, it provides strong support for policies and programs that attempt to reverse trends in childhood obesity and that are consistent with existing legislation and initiatives. The Affordable Care Act of 2010 tackles childhood obesity through several provisions, including the Childhood Obesity Demonstration Project.[57] First Lady Michelle Obama's "Let's Move" campaign, and childhood obesity research and intervention initiatives supported by private and public agencies (such as the Robert Wood Johnson Foundation and Department of Agriculture), promise to yield tremendous health benefits for the population by reducing the burden of obesity in the coming decades.

Conclusions

The future of health and longevity will be determined by the behaviors and characteristics of people alive now—not by the attributes of the recently deceased, who were born and lived under different circumstances. Our examination of the US obesity epidemic suggests that projected trends in national vital statistics may be misleading because they fail to account for recently observed declines in the health and mortality prospects of younger generations. On the other hand, declines in smoking and improved health status among certain subsets of the population could yield, for them, improved health and more accelerated increases in longevity than currently anticipated.

Unfortunately, possible changes in future health and longevity of this magnitude and importance—both positive and negative—cannot be foreseen using the two-dimensional metrics currently used to report on our nation's health. We suggest that traditionally reported national vital statistics be supplemented with three-dimensional models that, by focusing on living rather than extinguishing cohorts, more reliably predict the future of health and longevity. ■

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