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Behavior Matters

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Abstract

Behavior has a broad and central role in health. Behavioral interventions can be effectively used to prevent disease, improve management of existing disease, increase quality of life, and reduce healthcare costs. A summary is presented of evidence for these conclusions in cardiovascular disease/diabetes, cancer, and HIV/AIDS as well as with key risk factors: tobacco use, poor diet, physical inactivity, and excessive alcohol consumption. For each, documentation is made of (1) moderation of genetic and other fundamental biological influences by behaviors and social–environmental factors, (2) impacts of behaviors on health, (3) success of behavioral interventions in prevention, (4) disease management, (5) and quality of life, and (6) improvements in the health of populations through behavioral health promotion programs. Evidence indicates the cost effectiveness and value of behavioral interventions, especially relative to other common health services, as well as the value they add in terms of quality of life. Pertinent to clinicians and their patients as well as to health policy and population health, the benefits of behavioral interventions extend beyond impacts on a particular disease or risk factor. Rather, they include broad effects and benefits on prevention, disease management, and well-being across the life span. Among priorities for dissemination research, the application of behavioral approaches is challenged by diverse barriers, including socioeconomic barriers linked to health disparities. However, behavioral approaches including those emphasizing community and social influences appear to be useful in addressing such challenges. In sum, behavioral approaches should have a central place in prevention and health care of the 21st century.

Behavior is central to the development, prevention, treatment and management of the preventable manifestations of diseases and health conditions (heart disease, cancer, stroke,

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chronic obstructive pulmonary diseases, unintentional injuries, pneumonia and influenza, diabetes, suicide, kidney diseases, chronic liver disease and cirrhosis, HIV/AIDS) on which the U.S. spends about \$1.5 trillion, 75% of our annual healthcare costs.

The breadth of connections between behavior and health is formidable. These include risk factors like smoking, the influence of stress on the course of many diseases, stress management, chronic disease management, psychological and behavioral interventions addressing quality of life, and gene X behavior interactions, including major roles of behaviors in moderation of gene expression.

Sampling of Research on Behavior in Health

This paper documents the role of behavior in four risk factors (tobacco use, poor diet, physical inactivity, and excessive alcohol consumption) that are, collectively, responsible for an estimated 36.8% of all deaths in the U.S.,^{1,2} as well as within three major disease areas (cardiovascular disease/diabetes, cancer, and HIV/AIDS). For each of these seven risk factors and diseases, Table 1 provides examples of six types of behavioral influence. The first entails how behavioral, environmental, and genetic influences moderate one another. The remaining five types of influence entail the roles of behavior in the development of health problems, prevention, disease management, quality of life, and population approaches to health promotion.

Each of the four risk factors and three major diseases was assigned to members of the writing team with expertise in the area, all senior members of the Society of Behavioral Medicine. Based on their knowledge of the area assigned, they identified seminal papers illustrating each of the six types of behavior influence for each of the risk factors/diseases. The resulting sampling of key publications illustrates the importance of behavior in each area rather than constituting a systematic review of the research in each of the 42 combinations of seven areas of health and six types of behavior influence.

Summarize the Evidence

As Table 1 makes clear, published research provides examples of each of the six types of behavioral influence for each of the three major diseases (cardiovascular disease/diabetes, cancer, and HIV/AIDS) as well as the four risk factors, tobacco use, poor diet, physical inactivity, and excessive alcohol consumption. The next paragraphs summarize these influences along with the role of behavioral interventions in a key example of chronic disease prevention and management, diabetes.

Cardiovascular Disease/Diabetes

The roles of behavior in cardiovascular disease are well established, from the effects of stress on expression of the serotonin transporter gene¹¹ through documentation of the roles of diet, physical activity, smoking, and stress in development,²⁷ prevention,^{46, 107} and management of disease,^{108,109} and including demonstration of reduced risk¹⁰² and mortality¹⁰³ through comprehensive, multi-sector community approaches to cardiovascular risk reduction.

Cancer

The role of behavior in cancer includes moderation of gene expression and tumorigenesis¹² and a list of lifestyle risk factors that, since the recognition of cigarette smoking, has grown to include diet, physical inactivity, stress, and social involvements and networks.²⁸⁻³³ With this substantial interface between behavior and cancer, the range of effective interventions is great, including prevention through smoking cessation and increasing physical activity,^{49,50}

as well as interventions improving responses to cancer treatments,^{69–71} quality of life,^{88–91} and perhaps survival¹¹⁰ among those with cancer.

HIV/AIDS

Gene X behavior interactions are also apparent in the progression of HIV, with animal models reflecting interactions among stable versus unstable rearing conditions, sociability, and variants of the serotonin transporter gene.¹³ Additionally, psychological factors affect disease progression in humans.^{34,35} Behavioral interventions that focus on high-risk behaviors contribute to prevention⁵¹ while those focused on adherence, coping and stress management can improve disease management and quality of life.^{28, 92,93}

Alcohol Use

The health effects of excessive alcohol use are substantial, ranging from birth defects to accidents and injuries to alcohol-related liver disease and pancreatitis.²⁶ Genetic predispositions to excessive use are moderated by psychosocial factors such as childhood maltreatment.¹⁰ Although often difficult to treat, brief interventions can reduce drinking^{55,56, 111} and problems associated with alcohol⁴⁵ while more intensive psychological treatments can improve quality of life among those recovering from excessive use.⁸⁰ Along with tobacco use and physical inactivity, excessive alcohol use stands as a behavior for which environmental modifications, such as reducing density of retail outlets, can be effective.¹⁰¹

Cigarette Smoking

From 46% to 84% of the variance in initiation and persistence of smoking is attributable to genetic influence.¹¹² However, multiple environmental, social, familial, marketing, and policy influences set the path from genetic factors to nicotine addiction and chronic smoking.^{113–116}

Parallel to the broad determinants in the development and maintenance of smoking, a broad portfolio of behavioral and environmental changes has brought about a reduction in the adult prevalence of smoking from 42% in 1965 to 20.6% in 2009.¹¹⁷ These include prevention programs and regulations aimed at smoking among youth, cessation activities for adults,^{36, 52, 118} social marketing of nonsmoking, and key environmental policies.¹¹⁵ Of the “estimated 94 million adults who had smoked at least 100 cigarettes during their lifetime” 51.1% had quit by 2008.¹¹⁹

The changes in smoking prevalence are manifest in mortality. In California, reduced cardiovascular mortality was attributed to a comprehensive campaign to promote nonsmoking⁹⁴ and death rates from lung cancer fell at more than double the rate seen in states that have been less effective in promoting smoking cessation.⁹⁵ Considering that cigarettes are addictive, conveniently purchased, and promoted by the most heavily financed marketing campaign in our culture,¹¹⁵ these changes constitute what C. Everett Koop, then Surgeon General, called “a revolution in behavior...a major public health success.”¹²⁰

Diet and Physical Activity

Unhealthy eating and lack of physical activity play substantial roles in the causation and progression of disease.^{2, 121,122} Physical activity and a healthful diet reduce risk for coronary artery disease.¹²³ The majority of cases of prostate cancer are attributable to lifestyle factors such as inactivity and high-fat diets.^{124,125} Physical activity^{126,127} and fiber intake¹²⁸ are also associated with lower risks of breast and colon cancer and vegetable intake is associated with reduced risk of colon cancer.¹²⁹

The critical roles of diet, inactivity, and energy balance as key determinants of weight have been widely recognized.^{130–133} Unfortunately, the prevalence of obesity in the U.S. is moving away from, not toward, the Healthy People 2010 goals of 15% in adults and 5% in children.^{134,135} In contrast to tobacco control¹¹⁵ in which broad public attention evolved in the decades following the 1964 Surgeon General's Report on Smoking and Health,¹³⁶ the first Surgeon General's Reports on physical activity and on nutrition were published less than 15 years ago, in 1996¹³⁷ and 1998.¹³⁸ The examples of successful, broadly focused and multilevel campaigns to reduce smoking,¹¹⁵ are now being recognized as models for understanding a similarly broad array of forces determining diet and physical activity that will require interventions addressing multiple layers of influence.^{139–143}

Prevention and Management of Diabetes

Diabetes entails virtually all the tasks and challenges of any chronic disease, a progressive course, disability, physical as well as psychological comorbidities, and treatment that includes both medication management and lifestyle modification. It is an excellent model for the group of chronic diseases of growing importance as the population ages and as medical advances convert diseases like many cancers and HIV/AIDS into chronic conditions.

The landmark Diabetes Prevention Program (DPP)⁴⁶ showed that the combination of modest weight loss (7% of body weight) and modest physical activity (150 minutes per week) could reduce the incidence of type 2 diabetes by 58% relative to placebo. The common diabetes drug, metformin, reduced incidence by 31%. Moreover, group differences were sustained over a total of 10 years of observation.¹⁴⁴ Worth noting, risk reduction in the DPP lifestyle intervention was similar across all ethnic groups, in contrast to the metformin condition. Reflecting their efficacy in the DPP, lifestyle approaches are also the preferred approach for preventing and managing type 2 diabetes among youth,^{145,146} the rise of which is clearly a result of a parallel epidemic of childhood obesity.^{147–151}

Turning from prevention to management, behavioral diabetes self-management programs have strong and wide-ranging benefits including improvements in self-management patterns, metabolic control, patient satisfaction, and quality of life.^{59, 152–155} Relative to the benchmark of a 0.5-point reduction in hemoglobin A1c (HbA1c) that is generally considered clinically meaningful,¹⁵⁶ meta-analysis of 31 studies published through 1999⁵⁸ showed a 0.76-point difference in HbA1c between self-management and control conditions. A PubMed search of studies of diabetes self-management published between 2003 and July, 2009 identified a total of 10 studies^{152–155, 157–164} among which the average change in HbA1c was 0.82 points. The Look AHEAD Program¹⁶⁵ focusing on weight loss and physical activity achieved reductions in HbA1c from 7.3% to 6.6% over a 1-year period. A recent report indicates advantages in weight loss, fitness, metabolic control, and CVD risk factors sustained relative to controls over 4 years.¹⁰⁸

Diabetes also illustrates a kind of complication by psychological and emotional factors that cuts across many of the behavioral influences described here. An estimated 25% of those with diabetes exhibit depressive symptoms.¹⁶⁶ Coexisting depression is associated with poorly controlled diabetes, subsequent complications, mortality, and increased healthcare expenditures.^{167–169} The relationship appears also bidirectional with increased incidence of diabetes among those with a primary diagnosis of depression.^{170–172} Thus, self-management of diabetes, difficult in itself, is complicated by depression. As much as these observations illustrate problems in adherence to behavioral interventions, they also point to the further role of behavioral approaches in addressing them. For example, a recent review of interventions for those with diabetes and depression¹⁷³ found large effects (average of 0.581 standard units) for psychotherapy, with the greatest improvements in depression noted for Cognitive Behavior Therapy.¹⁷⁴ All five studies of psychotherapy (often combined with

diabetes self-management education) identified in the review reported benefits for glycemic control.

Discussion

The role of behavior in health is substantial and broad, extending across leading causes of death: cardiovascular disease/diabetes, cancer, HIV/AIDS, tobacco use, poor diet, physical inactivity, and excessive alcohol use. It encompasses development and prevention of disease, enhancement of health, treatment of chronic diseases, quality of life and mortality. This central role of behavior in health, health care, and prevention has recently been recognized in the 2010 Annual Status Report of the National Prevention, Health Promotion, and Public Health Council.¹⁷⁵ It noted that “The most effective approach to address the leading causes of death is to reduce and prevent underlying risk factors, including physical inactivity, poor nutrition, tobacco use, and underage and excessive alcohol use” (p. 7).

The influences of behavior and environment are closely linked. Some environmental influences are achieved through their influences on behaviors (e.g., the walkability of neighborhoods or the availability of healthy foods). To complicate things, some environmental influences are themselves made up of the behaviors of others (e.g., community norms or family climate or hostility). Direct influences on health of other environmental factors (e.g., air pollution) are quite independent of behavior, although behavior may be very pertinent to altering them. Additionally, some environmental influences, such as income inequality, may achieve their effects through both behaviors as well as other paths. The focus of this paper is on behavior as it is guided by multiple influences in the individual, social, and broader environments. However, it is not intended to characterize or summarize the influence of the environment, especially those environmental influences that do not achieve their effects through behavior, or to compare those influences to the influence of behavior.

Barriers to Behavior Change and Health Disparities

Given the overwhelming weight of evidence favoring health behaviors (e.g., smoking cessation) and widespread awareness of the importance of health behaviors, at least among middle class audiences and in developed countries, the failure of these behaviors to be more widely adopted is striking. A short list of barriers includes health literacy, emotional distress, social and economic factors, and system and policy factors.

Barriers to behavior change are especially prominent amidst the many disadvantages that contribute to health disparities among low-income and ethnic minority groups. However, as much as many of these disadvantages concern behaviors, behavioral approaches stressing social modeling, coaching on specific approaches to adopting healthy behaviors, and so on are central to many public health- and community-based efforts to address these burdens.^{100, 176–183} Indeed, counter to expectations that low-income or otherwise disadvantaged groups may be “poor bets” to respond to health promotion interventions, behavioral interventions focused on smoking^{184–186} or type 2 diabetes¹⁸⁷ have been especially effective amidst high-risk groups.

Behavior in the Era of Genomics

It has sometimes been thought that genes trump or obviate behavior and environment in development of disease. In fact, there are very few genetic influences that are not dependent on environmental and behavioral factors for their expression.¹⁸⁸ Diabetes among Pima Indians provides a clear example. Those living in the U.S. have “the highest prevalence of type 2 diabetes mellitus ... of any population in the world.”¹⁸⁹ Ample evidence links

genetics to diabetes *within* the Pima population.¹⁸⁹ Yet, Pimas living in Mexico have relatively low levels of diabetes, demonstrating environmental moderation of expression of genes related to diabetes.

Given behavioral and environmental modification of gene expression,¹⁹⁰ the vast majority of polymorphisms have little or no effect if not in combination with unhealthy behaviors.^{191–193} Accordingly, reduction of genetic risks can be accomplished through changing behaviors that moderate those risks.¹⁹⁴ Additionally, genetic testing and related preventive and clinical interventions^{195–196} all entail needs for behavioral approaches for promoting and deciding on the appropriateness of specific tests, coping with stress that test results may entail, and adhering to whatever interventions may follow.

The Goals of Health Care

A focus on behavior is especially pertinent to the USDHHS overall health objectives for the year 2020, to extend the years of *healthy* life, defined by the combination of extended life expectancy and improved life quality. Although considering years of healthy life may often lead to the same decisions as reached by more conventional paths, it may also lead to different conclusions. For example, primary prevention programs focused on healthy behaviors may increase life expectancy as well as improving quality of life, but often receive low priority in health policies.

Can We Afford Behavioral Interventions?

A 2007 review of the economics of behavioral interventions targeting smoking, physical inactivity, poor diet and alcohol misuse¹⁸⁴ singled out smoking-cessation programs as excellent and economically attractive and characterized interventions addressing alcohol, physical activity, and diet as likely cost effective.¹⁸⁴ For example, among 15 independent analyses, the incremental cost effectiveness of smoking-control programs never exceeded 15,000 Euros/QALY. The cost effectiveness of treating tobacco-related diseases is many times higher, \$133,000 to \$216,000/QALY for lung transplantation, \$190,000/QALY for lung volume reduction for emphysema.

Mounting evidence indicates that the greatest return on investment will come from interventions targeting multiple risk behaviors and high-risk populations. These offer better value because of synergy gained among changes in several behaviors.¹⁸⁴ Similarly, interventions targeted to high-risk groups may achieve efficiency through greater available risk to be reduced. For example, interventions to change diet were especially cost effective when applied to groups with three or four risk factors such as smoking, hypertension and elevated LDL cholesterol.^{197,198}

The most compelling evidence for the cost effectiveness of behavioral prevention comes from the Diabetes Prevention Program (DPP),⁴⁶ previously described. Cost per case prevented was \$13,200 for the lifestyle, behavioral approach but \$14,300 for metformin.^{199,200} Further, from a health systems perspective, the lifestyle intervention offers substantially better value for money.¹⁹⁹ Using the Quality Adjusted Life Year (QALY) as a combined index of morbidity and mortality, the cost/QALY for the lifestyle intervention was \$1,100 in comparison to \$31,000 in the metformin condition.²⁰¹ More generally, most estimates suggest that behavioral interventions produce a QALY at about half the cost of other widely accepted treatments.²⁰² In some cases, such as smoking cessation, behavioral intervention offers benefits to smokers at about one tenth the cost of surgical rescue for those unable to quit.²⁰³ Application of state of the art methods in future cost-effectiveness evaluations will enhance direct comparisons of investments in behavior interventions with those in other approaches to health care.²⁰⁴

Population-level behavioral interventions also offer great value for money. For example, a tobacco excise tax increase of \$0.50 per pack of cigarettes for California residents estimated from 1999 would result in about 8,389 QALYs saved the first year with accrued benefits reaching a plateau in about 75 years of 52,136 QALYs.²⁰⁵ From a global perspective, estimates from a study involving 23 countries show that over 10 years (2006–2015), 13.8 million deaths could be averted by implementation of tobacco cessation and salt reduction interventions.²⁰⁶ The costs of implementing these two behavior-focused interventions would be less than \$0.40 per person per year in low-income and lower middle-income countries, and \$0.50–1.00 per person per year in upper middle-income countries (2005 U.S. dollars).

Key objectives of policies, such as reducing health disparities, may be accomplished by varied paths. Behavioral intervention is one among several options (e.g., increasing access to primary care). Continuing assessment of the relative value of these options may help shape the package of services most likely to achieve the goal of improved population health.

Dissemination of Behavioral Interventions

Although the benefit of a well defined pharmacologic treatment may be robust across various settings and populations, dissemination of behavioral interventions is dependent on multiple contextual factors that vary considerably across settings and populations. One comprehensive approach to dissemination and dissemination research is the RE-AIM model of Glasgow and colleagues,^{207,208} that addresses the reach, effectiveness, adoption, implementation and maintenance of interventions. These are gaining emphasis in standards for dissemination research such as the CONSORT Work Group on Pragmatic Trials,²⁰⁹ similar to the CONSORT guidelines in randomized trials.

As daunting as dissemination challenges may be, diabetes provides examples of apparently successful extension of findings from research settings. The benchmark of a 0.5 point reduction in HbA1c in diabetes management was achieved in self-management programs implemented in Federally Qualified Health Centers and other “real world settings” through the Diabetes Initiative of the Robert Wood Johnson Foundation.²¹⁰ Further, cost effectiveness of these interventions was estimated at \$39,573 per QALY,²¹¹ well below the benchmark for acceptable cost of \$50,000–\$75,000 per QALY.²⁰²

The lifestyle prevention strategies of the DPP⁴⁶ offer another example of potential dissemination. Key is recognition that the DPP was an efficacy trial, not validating any particular intervention but rather the combination of modest weight loss (7% of body weight) and modest physical activity (150 minutes per week). Thus, diverse approaches to these changes are worthy of investigation. In one, classes based on procedures from the DPP are taught by local YMCA instructors and offered to overweight individuals.²¹² Initial results indicate promising weight loss and cholesterol lowering during the 6-month intervention, sustained to 12 months.²¹³

Inclusion of behavioral interventions in health care will take more than convincing evidence about reach, effectiveness and cost effectiveness. Replication of major interventions is needed. Other important topics for dissemination research include linkage to primary care, attention to individuals with multiple morbidities and complex psychological and social barriers to change, approaches to those with multiple risk factors, and interactions of behavioral interventions with health and general public policy.

Implications for Clinical Care—Population and Multilevel Perspectives

As with much of prevention and chronic disease management, behavior change in any individual case is often uncertain. Because of this, behavior change interventions in clinical settings are best guided by a *population* as opposed to an individual treatment perspective.

With an individual patient, the probability of success in (e.g., smoking cessation may be modest). However, across a practice that includes several hundred smokers, systematic inclusion of brief reminders to quit and offers of help in doing so may achieve success in 3%–10% of smokers per year. Even within the population of a single practice, the morbidity, mortality and cost burdens of smoking and the potential aggregation of such impacts if repeated over multiple years make the benefits appreciable. Such brief interventions have been documented for smoking cessation,^{214,215} alcohol use among pregnant women,⁴⁵ and are the focus of considerable research in primary care and chronic disease management.^{216,217} Additionally, the broad impact on multiple aspects of health of behaviors such as healthy diet and physical activity make investment in them worth the time of the clinician.

In addition to brief clinician-delivered interventions, behavior change can be promoted through innovations in clinical care, such as group medical visits.²¹⁸ Community oriented primary care and the patient-centered medical home^{219–221} also offer opportunities for linking the primary care setting to health promotion resources in the community. A variety of behaviors such as smoking cessation as well as more varied tasks such as chronic disease management^{221,222} are likely to benefit from the complementary and coordinated efforts of clinical and community-based interventions to take full advantage of the opportunities for prevention and treatment.²²³

One promising strategy for linking community and clinical settings is peer-support programs. These can provide links to the community by recruiting peer supporters from the communities they serve. At the same time peer supporters can implement community-based activities and classes while also providing individual support for prevention and chronic disease management.^{224,225} *Peers for Progress*,²²⁶ a program of the American Academy of Family Physicians Foundation, emphasizes this linkage of peer support with primary care in promoting peer-support programs around the world.

The IOM has articulated the need to address major health threats and concerns from a multilevel perspective, building partnerships across health systems, communities, academia, business, and the media.²²⁷ Several models and frameworks have been developed to demonstrate these kinds of multilevel approaches, such as the Expanded Chronic Care Model.²²⁸ However, there is not a consistent body of evidence showing how well the models work or which ones work best. Continued effort in these areas is needed.

Policy Implications

With the bulk of healthcare costs attributable to disease care, prevention currently accounts for only 2%–3%.²²⁹ In discussion of healthcare reform, mechanisms for reimbursing for clinical services typically receive priority. Given the evidence, our healthcare system would do well to allocate greater resources to behavior and prevention.

Health insurance is clearly an important mechanism for enhancing health. However, attempts to enhance population health need to consider a wider array of investments. The National Action Plan for the Prevention of Cardiovascular Disease and Stroke, developed by the CDC and the NIH, noted that many of the most expensive options for addressing cardiovascular disease (e.g., cardiac surgery for severely impaired ventricular function, resuscitation for multiple system failure) apply only to individuals who have established heart disease. In contrast, interventions to prevent cardiovascular risk factors (e.g., preventing youth from smoking, community-based programs to enhance physical activity) influence multiple disease trajectories and outcomes over time²⁰² and at much lower cost.²⁰²

The goal of enhancing population health is best addressed through systems and policies that integrate a range of investments in health. Within this context, a key feature of behavioral approaches is their parallel breadth, from population approaches for prevention to clinical and disease management interventions of established efficacy.

Individual Responsibility and Contextual Influence

The concept of individual responsibility has been used to denote the importance of individual behavior in health and health care, for example, in Knowles' influential 1977 editorial in *Science*, "Responsibility for Health."²³⁰ However, the appeal to individual responsibility can be used as an argument to minimize attention to behavior. In the clinical setting, we often hear "...there's nothing I can do if the patient doesn't want to help himself." At the policy level, the parallel argument suggests that investment in programs to help individuals improve health behaviors is wasted because those behaviors will ultimately be decided by the individuals themselves.

"Responsibility" is shaped by the contexts of people's lives. SES status, social isolation, associated stress,^{231–235} and cultural characteristics^{233, 236,237} have great influence on health behaviors. Skepticism that encourages unhealthy practices²³⁸ is heightened in communities marginalized from mainstream culture²³⁹ and amidst inconsistent and changing health recommendations. Heavy marketing of unhealthy foods,²⁴⁰ alcohol,²⁴¹ and cigarettes²⁴² especially targeting children is commonplace. Such marketing is disproportionate in low-income neighborhoods,^{243–245} along with limited access to stores selling healthy foods.^{246,247} These influences are substantial (e.g., a 1.46 OR of being obese associated with living in a neighborhood with fast-food outlets but without supermarkets *after controlling* for education, income and other individual characteristics).²⁴⁸

Striking a balance between individuals and their environment is critical.²⁴⁹ This paper documents that behavioral interventions are effective. Clearly, healthcare reform needs to incorporate a "national culture of wellness,"²⁵⁰ balancing individual, community, environmental, and policy influences and an emphasis on behavior as an essential base for all preventive and clinical services. Responding to current concerns about obesity, Brownell and his colleagues have eloquently described the rationale for environmental approaches as well as the ways in which "personal responsibility" can be an excuse for inaction.²⁵¹

Health, health care and the healthcare "system" – or chaos – are enormously complicated.. Widescale implementation of behavioral interventions will not proceed without great political will to address substantial political, economic, and communication challenges. However, 'business as usual' will only exacerbate poor, expensive, and inequitable care. With the advent of healthcare reform, the opportune moment may be upon us.

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Table 1

Behavior–health linkages among major “actual causes” of death and major diseases

Cause of death/disease	Behavior–health linkage
Linkage 1 – Behavioral, environmental, and genetic influences moderate one another	
Tobacco use	Both environmental and genetic factors influence onset and persistence of smoking. ^{3–6}
Poor diet	Environmental factors are more important than genetic influences in food preferences among older adults. ^{7,8}
Physical activity	In a large population-based study of adult men and women, physical activity attenuated the genetic predisposition to obesity. Living a physically active lifestyle was associated with a 40% reduction in the genetic predisposition to obesity as estimated by the number of risk alleles carried for any of the 12 recently GWAS-identified loci. ⁹
Alcohol use	Childhood maltreatment exacerbates genetic influences on adult alcohol use and antisocial personality among women and men. ¹⁰
Cardiovascular disease and diabetes	Influence of serotonin transporter gene on cardiovascular risk is moderated by stress and environmental factors. ¹¹
Cancer	Nutrition and lifestyle intervention reduces prostate gene expression and tumorigenesis in men. ¹²
HIV/AIDS	In monkey models of HIV, individual characteristics (sociability), stable versus unstable social conditions, and genotype for the serotonin transporter gene interact in their effects on disease progression. ¹³
Linkage 2 – Behavior influences health	
Tobacco use	Numerous Surgeon General’s reports have concluded that smoking is a leading cause of cancer, cardiovascular, and pulmonary disease and premature death. ¹⁴
Poor diet	Systematic reviews conclude that obesity contributes to hypertension, hyperlipidemia, diabetes, CVD and some cancers. ^{15–21}
Physical activity	Randomized trials and systematic reviews conclude that physical activity is associated with decreased all-cause mortality, ²² reduced risk for chronic diseases, reduced risk of breast cancer. ^{23–25}
Alcohol use	“Alcohol abuse alone is associated with motor vehicle crashes, homicides, suicides, and drowning... Long-term heavy drinking can lead to heart disease, cancer, alcohol-related liver disease, and pancreatitis. Alcohol use during pregnancy is known to cause fetal alcohol syndrome, a leading cause of preventable mental retardation.” ²⁶
Cardiovascular disease and diabetes	Adverse patterns of dietary intake and obesity are risk factors for diabetes and cardiovascular disease. ²⁷
Cancer	Findings from systematic reviews, meta-analyses, large prospective studies and randomized trials link risk for cancer with poor diet, physical inactivity, smoking, stress, and social involvement. ^{2829–33}
HIV/AIDS	There is “substantial and consistent evidence that chronic depression, stressful events, and trauma may negatively affect HIV disease progression.” ³⁴³⁵
Linkage 3 – Behavior change interventions prevent disease	
Tobacco use	A major multi-site trial demonstrated that smoking-cessation programs substantially reduce mortality even when only a minority of patients stop smoking. ³⁶
Poor diet	Systematic reviews and randomized trials of interventions for childhood obesity show positive impacts on diet, weight gain trajectory, and weight loss maintenance, ^{37–42} and on insulin resistance. ⁴³
Physical activity	Among overweight, previously inactive women at risk for type 2 diabetes, accumulating 10,000 steps/day for 8 weeks improved glucose tolerance and reduced both systolic and diastolic blood pressure. ⁴⁴
Alcohol use	15-minute counseling for pregnant women increased abstinence from drinking 5X relative to controls and resulted in higher birth weights, birth lengths, and 3X reduction in fetal mortality (0.9% vs 2.9%.) ⁴⁵
Cardiovascular disease and diabetes	Lifestyle interventions focusing on diet, weight loss, and exercise can reduce the incidence of diabetes in people at risk for the disease. ^{46–48}

Cause of death/disease	Behavior–health linkage
Cancer	In a number of large prospective longitudinal studies and meta-analyses, physical activity has been linked to reduced risk of colon cancer. ^{49–50}
HIV/AIDS	The U.S. Preventive Services Task Force recommends high-intensity behavioral counseling to prevent sexually transmitted infections for all sexually active adolescents and for adults at heightened risk. ⁵¹
Linkage 4 – Behavior change interventions improve disease management	
Tobacco use	Self-management skills (e.g., setting quit date, planning for coping with temptations to relapse) help individuals quit smoking. ⁵²
Poor diet	Randomized behavioral interventions show that peer nutrition education positively influences diabetes self-management in Latinos. ⁵³
Physical activity	Randomized clinical trials show that exercise training reduces HbA1c among those with diabetes. ⁵⁴
Alcohol use	Brief behavioral counseling interventions with follow-up produce small to moderate reductions in alcohol consumption that are sustained over 6- to 12-month periods or longer. ^{55,56}
Cardiovascular disease and diabetes	Diabetes self-management programs improve disease management ⁵⁷ and metabolic control ^{58–60} including among older adults and ethnic minorities, ^{61–63} and reduce complications ^{64,65} as well as myocardial infarction, stroke, or death from cardiovascular disease. ⁶⁶ Interventions promoting comprehensive lifestyle changes for patients with coronary artery disease can reduce progression of coronary atherosclerosis and cardiac events ⁶⁷ and increase smoking cessation, improve functional capacity, lower LDL cholesterol and reduce all-cause mortality. ⁶⁸
Cancer	Randomized trials of patients with cancer indicate that physical activity increases functional capacity during chemotherapy, ⁶⁹ improves marrow recovery and decreases complications during peripheral blood stem transplantation, ⁷⁰ and decreases fatigue and other symptoms associated with radiation therapy and chemotherapy. ⁷¹
HIV/AIDS	Behavioral medicine interventions have improved adherence and helped individuals cope with the disease and its impacts, in turn improving their general disease management and quality of life. ²⁸
Linkage 5 – Psychosocial and behavioral interventions improve quality of life (QOL)	
Tobacco use	Improved health-related QOL is a significant health outcome for ex-smokers compared to current smokers. ^{72–74}
Poor diet	In randomized trials, lifestyle interventions show improved nutritional status and quality of life and less depressive symptoms and improved physical functioning. ^{75–77}
Physical activity	Randomized trials show physical activity improves quality of life in older adults. ^{75, 78} and improves QOL and fatigue in breast cancer survivors. ⁷⁹
Alcohol use	Cognitive–behavioral treatment of insomnia among those recovering from excessive alcohol use improved measures of sleep as well as depression, anxiety, and QOL. ⁸⁰
Cardiovascular disease and diabetes	Comprehensive behavioral disease management interventions among patients with cardiovascular disease or diabetes show benefits for a variety of clinical indicators as well as reduced general distress and depressive symptoms, ⁸¹ emotional and social functioning, ⁸² reduced anxiety and depressed mood, ⁸³ general QOL. ^{84,85,86,87}
Cancer	Randomized psychosocial interventions show decreased psychological distress, pain and nausea secondary to treatment, and improve QOL and immune system modulation. ^{88–91}
HIV/AIDS	Stress management interventions enhance emotional status and QOL. ^{92,93}
Linkage 6 – Health-promotion programs improve health of population	
Tobacco use	Anti-smoking campaign in California that includes counter-media, youth prevention programs, cessation services, and tax increases reduced smoking and accompanying rates of cardiovascular disease ⁹⁴ and death rates from lung cancer. ⁹⁵
Poor diet	Mass-media health education campaigns ⁹⁶ and policy and environmental supports ^{97,98} can lead to substantial improvements in fruit, vegetable and fat consumption in general populations.

Cause of death/disease	Behavior–health linkage
Physical activity	Community-wide walk-to-school programs increase walking and biking to school ⁹⁹ and walking and fitness trails increased physical activity in a rural African-American population. ¹⁰⁰
Alcohol use	Guide to Community Preventive Services reports that regulating density of outlets for alcohol reduces consumption and that enforcing laws prohibiting the sale of alcohol to minors reduces underage consumption. ¹⁰¹
Cardiovascular disease and diabetes	Working with mass media, food producers, community-level campaigns, diverse professionals, informal opinion leaders, and the health system, a regional program in North Karelia, Finland reduced cardiovascular risk factors ¹⁰² and mortality ¹⁰³ as well as cancer risk factors. ¹⁰⁴
Cancer	In 2006, overall cancer death rates declined because of a 50% reduction in male smoking from 47% in the 1960s to less than 23%. ¹⁰⁵
HIV/AIDS	Behavioral medicine programs have made major contributions to slowing the spread of HIV/AIDS; from 150,000 cases per year in the early 1980s to approximately 40,000 today. ¹⁰⁶