J-Shaped Curves and Public Health

Interventions that alter population-level risk exposure have yielded a number of improvements in public health. Tobacco taxes are an example of such population-based approaches to disease prevention. In the case of tobacco, the harms of shifting total population exposure through taxation are minimal, because there is no safe level of consumption. However, other risk factors do not exhibit the same linear relationship between exposure and mortality—and therefore may introduce new complexities in communicating with individuals and the public. In particular, many risk factors, such as alcohol consumption, exhibit a J-shaped association when plotting health effects like mortality on the vertical axis against the magnitude of the risk factor on the horizontal axis (Figure).

Setting aside population risk, any clinician who has tried to counsel a patient about alcohol use has encountered the question: “But I thought a couple of drinks a night is good for my health?” In this way, the strategies of preventive medicine—both individual and population based—that have proven quite successful for tobacco control may be less effective when confronting the epidemiologic and perceptional challenges presented by the J-shaped curve.

Real-World Examples

Three examples—alcohol consumption, body mass index (BMI), and blood pressure—help elucidate the challenges posed by J-shaped curves. With respect to alcohol consumption, a meta-analysis of 34 prospective studies, pooling findings from more than 1 million individuals and almost 100,000 deaths, showed a J-shaped relationship between alcohol intake and total mortality.1 Consumption of up to 2 drinks per day in women and 4 drinks per day in men was associated with lower mortality than zero consumption, with about one-half drink per day associated with the lowest mortality risk.

BMI and blood pressure are more complex risk factors not solely based on consumption, as with alcohol. BMI is a simple, if imperfect, proxy for energy metabolism—and therefore the current standard for representing healthy weight. A prospective study of 1.46 million white adults demonstrated a J-shaped association between BMI and all-cause mortality after adjusting for potential confounders, including smoking and alcohol intake.2 All-cause mortality was generally lowest among those with BMI of 20.0 to 24.9 and higher on either side of that interval.

Blood pressure is another complex modifiable risk factor because of its multiple determinants—but also because it is a commonly treated condition. A large meta-analysis of 61 prospective studies including 1 million patients without cardiovascular disease revealed a linear relationship between blood pressure and mortality risk from a blood pressure level of 115/75 mm Hg and greater.3 Yet treating hypertension may transform the linear relationship into a J-curve. A retrospective cohort study involving 400,000 treated patients with hypertension demonstrated a J-shaped relationship between both achieved systolic and achieved diastolic blood pressure and all-cause mortality.4 Although the evidence for this relationship remains disputed, this study raised questions about potential negative effects of population-based approaches to lower blood pressure in the setting of widespread hypertension treatment.

Methodological issues further limit understanding of these fundamental epidemiologic relationships. Reverse causality can result in J-shaped associations in observational studies. For example, one possibility is that the lip of the J-shaped curve for BMI may result from premortality cachectia in individuals with chronic disease. Complex risk factors such as blood pressure and BMI raise questions around how to meaningfully interpret associations with disease. As illustrated by the case of blood pressure, the nature of interventions may matter as much as risk factor distributions. In the face of these uncertainties, public health policy makers must act and communicate in a way that is understandable and resonant with individuals.

Framing and Public Health Communication

Traditional messaging oriented around “reduce, restrict, limit, ban” may make sense for determinants that have a linear relationship with health outcomes, as with tobacco and mortality. But in the case of J-shaped associations, such unequivocal framing is problematic. The J-shaped curve complicates matters in 2 principal ways: (1) the potential for real, unintended adverse consequences for certain subpopulations and (2) magnification of potential adverse consequences by opponents of public health interventions.

For instance, a primary determinant of BMI is caloric intake, which also has a J-shaped association with mortality—with the left lip of the curve representing caloric malnutrition. In countries with concurrent epidemics of malnutrition and obesity, efforts to curb either could result in harmful unintended consequences. For example, some evidence suggests that supplementary feeding programs in Chile intended to treat malnutrition may have contributed to an increase in overweight and obesity among children of higher socioeconomic position.5

Meanwhile, theoretical perceived harms to subpopulations may make any population-based approach considerably more difficult to implement. For example, the overall prevalence of alcohol use in the United States has not changed substantially between 2005 and 2012—but the prevalence of heavy drinking and binge drinking has increased in 2012–2013. Indeed, 12-month and lifetime prevalences of alcohol use disorder in the United States were 13.9% and 29.1%, respectively.6 General public support for a leftward shift in the alcohol consumption distribution might follow, particularly given links between alcohol and violence and motor vehicle crashes. However, restrictive initiatives are vulnerable to politically powerful interests who leverage the J-shaped curve—“good for you when...
joyed responsibly”—to discredit any limitation at all. Indeed, while tobacco excise taxes have steadily increased over the past 2 decades, alcohol tax rates have not been increased since 1991 and are far lower than historical levels when adjusted for inflation.7

**Health Policy and J-Shaped Curves**

Three public health strategies may help make the challenges surrounding J-shaped curves more soluble. First, health communication should emphasize the nadir of a J-shaped curve as a healthy range for the general population. Presentation of the risk curve could be paired with information about what proportion of the population lies an unhealthy distance away from the nadir. Then conversations might focus more on what is epidemiologically important, such as curbing excessive intake, rather than on theoretical risks to small subpopulations.

Second, “linearizing” elements of a given J-shaped curve enables less controversial application of traditional population-based approaches. Linearization refers to the idea that certain subcomponents of complex risk factors like BMI may be characterized by a more straightforward relationship between exposures and health effects. For example, while overall fat intake likely follows a J-shaped curve, there is no safe level of trans fat consumption; therefore, more aggressive regulation of trans fats may be justified and more feasible. Taxes and regulations on sugar-sweetened beverages can be interpreted in a similar way. Importantly, even for exposures that follow a J-shaped curve, there may be situations in which similar public health tactics are warranted.

Powdered alcohol, for instance—or very sugary alcoholic beverages appealing to adolescents—are cases for which regulation would address a specific health harm that does not have a countervailing benefit. Third, when a population is variably distributed across a J-shaped risk curve, “funnelling” subpopulations from either side toward a curve’s nadir could in some cases help focus on a shared objective of lower risk. For example, in low- and middle-income countries, a multifaceted approach could include addressing micronutrient deficiency and substituting empty (nutrition-poor) calories across the entire population—while also tailoring more local interventions to subpopulations that are malnourished or obese. When the evidence is clear, public health leaders should embrace the left side of the J-shaped curve to counter perception as “nannies” or prohibitionists and point out pursuit of the nadir as the goal.

Ultimately, successful approaches will depend on more robust and precise mapping of the inflections of epidemiologically important J-shaped relationships as well as understanding how many people actually are distributed along different points on the curve. Further characterization should include the causal mechanisms underlying the J-shaped trajectory. Recent controversies around sodium intake thresholds, for instance, revealed the missed opportunities for clear public health strategies when the true contours of the exposure-outcome curve are not firmly established. When the existence of a J-shaped curve remains controversial, fundamental research is even more vital to formulating sound policy.

**ARTICLE INFORMATION**

**Published Online:** September 21, 2015. doi:10.1001/jama.2015.9566.

**Conflict of Interest Disclosures:** All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest and none were reported.

**Disclaimer:** The views in this article are those of the authors and do not necessarily reflect the policies or views of the New York City Health and Hospitals Corporation.

**Additional Contributions:** We thank Thomas Farley, MD, MPH (Public Good Projects), Joshua Sharfstein, MD (Johns Hopkins University), Marc Gourevitch, MD, MPH (New York University Langone Medical Center), and Sandro Galea, MD, DrPH (Boston University School of Public Health), for their insightful comments on an earlier draft of the manuscript. None of these individuals were compensated for their contributions.

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