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Health and Economic Benefits of Reducing the Number of Students per Classroom in US Primary Schools

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Objectives. We estimated the costs associated with reducing class sizes in kindergarten through grade 3 as well as the effects of small class sizes on selected outcomes such as quality-adjusted life-years and future earnings.

Methods. We used multiple data sets to predict changes in the outcomes assessed according to level of educational attainment. We then used a Markov model to estimate future costs and benefits incurred and quality-adjusted life-years gained per additional high school graduate produced over time.

Results. From a societal perspective (incorporating earnings and health outcomes), class-size reductions would generate a net cost savings of approximately $168 000 and a net gain of 1.7 quality-adjusted life-years for each high school graduate produced by small classes. When targeted to low-income students, the estimated savings would increase to $196 000 per additional graduate. From a governmental perspective (incorporating public expenditures and revenues), the results of reducing class sizes ranged from savings in costs to an additional cost of $15 000 per quality-adjusted life-year gained.

Conclusions. Reducing class sizes may be more cost-effective than most public health and medical interventions. (*Am J Public Health.* 2007;97:XXX–XXX. doi:10.2105/AJPH.2006.105478)

With health costs soaring and student performance falling, the United States is in jeopardy of losing its economic dominance. As low-skilled jobs are outsourced, the availability of highly skilled workers is increasingly a determinant of global competitiveness.[1,2] At the same time, government and corporate budgets are struggling under the weight of soaring health costs.[3,4] One partial solution to both problems resides in America's schools.

In recent years, the performance of students in the United States has been declining relative to the performance of students in competing countries; however, a variety of innovative school-based interventions and programs are beginning to show promise.[5–7] In the case of 1 intervention, implementation of small class sizes, long-term follow-up data are now available from a large, multischool randomized controlled trial.[7] This trial, Project STAR (Student Teacher Achievement Ratio), is the highest quality long-term experiment to date in the field of education. If Project STAR is proven to be reproducible on a national scale, it could markedly improve the human capital of the United States.[8,9]

Reducing class sizes may also represent an effective health intervention. Improvements in educational attainment have long been linked to increases in both health status and longevity. Potential mechanisms include improved cognitive abilities, higher earnings, and better job quality.[10] Improved cognition and knowledge enable people to make better lifestyle and health care choices, conferring a range of skills[11] allowing them to better survive in their environmental niche. Higher earnings and better job quality enhance access to health insurance coverage, reduce exposure to hazardous work conditions, and provide individuals and families with the necessary resources to move out of unfavorable neighborhood environments (where exposure to crime and pollution, and inadequate access to health care are heightened) and to purchase goods and services, ranging from healthful foods to prescription drugs and good housing, that contribute to improved health.[9,12]

Beyond the intuitive mechanisms just described, there is growing evidence that the overall link between educational achievement and health is causal in nature.[5,10,13–16] If so, it would be informative to explore whether the potential net economic benefits would offset the massive societal investment that would be required for widespread adoption of an effective educational intervention, such as reducing class sizes, on a national scale.

We estimated the health and economic effects of reducing class sizes from 22–25 students to 13–17 students in kindergarten through grade 3 nationwide, the intervention tested in Project STAR. We acknowledge that some uncertainty remains regarding whether the effect size observed in that trial is reproducible or will produce substantive health benefits. However, we used its findings as a starting point for constructing a model exploring how those uncertainties define the boundaries of the potential costs and benefits of educational interventions designed to improve high school graduation rates. Because we focused on a relatively expensive intervention (one that included limited estimates of future cost savings) and examined outcomes over a range of efficacy values, our results should provide a conservative framework for evaluating this and other interventions as long-term data on educational interventions become more plentiful.

METHODS

Study Design

We used data from Project STAR to conduct 2 separate analyses of (1) all students and (2) low-income students eligible for school free-lunch programs. In each analysis, we examined costs from a societal perspective (incorporating the individuals' earnings and health outcomes only) and from a governmental perspective (incorporating public expenditures and revenues only). We adhered to the standards recommended by the Panel on Cost-Effectiveness in Health and Medicine.[17] However, rather than adhering to the panel's recommendation that all costs be included in all calculations, we included crime and various other sources of cost savings only in the sensitivity analysis to ensure that our estimates were as conservative as possible.

Project STAR

We used efficacy data from Project STAR to generate effectiveness estimates—i.e., a 12% increase in the high school graduation rate among the general population of students and an 18% increase in the high school graduation rate among free-lunch students—and tested these estimates in a broad sensitivity analysis.[7,8] Project STAR, a randomized trial of 12 000 students that began in 1985, was conducted in 329 classrooms across 46 school districts in Tennessee. Both students and teachers were randomly assigned to classes containing either 22 to 25 students or 13 to 17 students.

Some of the more than 100 studies of small class sizes conducted before Project STAR showed little or no effect on graduation rates of reducing class sizes; taken as a whole, however, these investigations indicated that small class sizes increase high school graduation rates, especially among low-income students.[18] Because none of these earlier studies had involved randomized designs, Project STAR helped solidify the conclusion that small class sizes are effective. Although a single randomized trial—albeit a large, multicenter trial—cannot guarantee reproducibility, Project STAR provides the best available estimate of the efficacy of small classes in producing additional high school graduates.

Project STAR provides high-quality data on differences in educational attainment according to class size, but information was not collected on relevant health or economic outcomes. We used regression analyses to estimate the extent to which educational level influences earnings, health, and longevity. There is good evidence from a variety of studies differing in design that regression analyses produce valid estimates of the effects of educational attainment on earnings.[9,19] There is also evidence that by using regression analyses, it is possible to conservatively predict causal effects of educational attainment on health status.[14,15] However, regression analyses may underestimate effect sizes for low-income populations and overestimate effect sizes for high-income populations.[20]

Medical Expenditure Panel Survey

We used data from the 2003 Medical Expenditure Panel Survey (MEPS), which focused on a nationally representative sample of 34 215 noninstitutionalized individuals, to quantify the effects of smaller class sizes on health-related quality of life, Medicare and Medicaid enrollment, and health care expenditures.[21] We eliminated respondents younger than 25 years-old and older than 65 years, foreign-born respondents, proxy respondents, and those with missing values, which resulted in a final sample size of 12 229.

MEPS participants completed the EuroQol-5D,[22] a health-related quality of life measure that captures data in the areas of mobility, self-care, typical activities, pain or discomfort, and anxiety or depression. Health-related quality of life scores were scaled from 0 to 1.0, with 0 representing death and 1.0 representing perfect health. Thus, 10 years lived at a health-related quality of life rating of 0.7 is equal to 7 (10×0.7) quality-adjusted life years. A quality-adjusted life-year is a year of perfect health. We used point-in-time data for Medicare and Medicaid enrollment rather than enrollment throughout the year.

Other Data Sources

We used combined data from the March 2003 and March 2004 versions of the Current Population Survey to generate earnings and welfare inputs.[23] We used the TAXSIM program version 5.1 (National Bureau of Economic Research, Cambridge, Mass) to calculate federal tax returns according to different levels of educational attainment. The welfare programs examined included Temporary Assistance for Needy Families, housing assistance, and food stamps. We obtained crime data from the Federal Bureau of Investigation's Uniform Crime Report.[24] Crime costs included costs associated with violent crime, property crime, and drug offenses. We excluded crime data from the primary analysis to ensure conservative estimates; however, we included the data in our sensitivity analyses.[5,13,16]

Statistical Analyses

Our model calculations focused on a hypothetical cohort of children aged 5 years who were exposed to small classes and who were then followed until the age of 65 years. To calculate quality-adjusted life-years gained when the hypothetical cohort members graduated from high school or college, we examined the effects of reducing class sizes on health-related quality of life scores and age-specific mortality.[25] We obtained data on risk of death according to different levels of educational attainment from an analysis of the National Longitudinal Mortality Survey; in that study, Backlund et al. examined educational attainment–specific mortality patterns among 400 000 persons aged 25 to 64 years.[26]

Individuals with a higher level of education are less likely than are those with lower levels to qualify either for Medicaid or for Medicare before the age of 65 years. To estimate enrollment rates in these programs according to highest degree completed, we constructed 2 logistic regression models, 1 with Medicaid enrollment as the dependent variable and 1 with Medicare enrollment as the dependent variable. We then multiplied these enrollment rates by the mean cost per enrollee to estimate per capita costs.

Because educational attainment influences an array of modifiable covariates, ranging from marriage rates to occupations, in our regression models, we controlled only for nonmodifiable covariates: age (25 to 65 years), gender, race (White, Black, Asian, American Indian, Hawaiian, or membership in more than 1 racial group), ethnicity (Hispanic or non-Hispanic), and highest level of education completed (no high school, high school or general equivalency diploma, or college).

Consistent with the income-specific variations in medical expenditures observed in a randomized trial focusing on health insurance coverage,[27] we found that educational attainment exerts little influence on health expenditures; thus, we did not include health expenditures in our societal analysis. Expenditure levels according to educational attainment (or its correlate, income) appear similar in part because less-educated people are less likely than are more highly educated people to be insured (and therefore consume care at lower rates when they are not ill) but are in worse health (and therefore more likely to need costly treatment).

Using the more complete National Health Accounts data,[10,28] we derived data on

Medicare and Medicaid per enrollee costs from the 2003 MEPS and adjusted these data for costs not included in the MEPS, such as disproportionate share hospital payments, which support hospitals in poor neighborhoods. We estimated that mean costs for adult Medicaid enrollees and Medicare beneficiaries (i.e., those aged 25–64 years) were $7695 and $11 894, respectively.

Using the methods of Levin and Belfield, we based mean national costs of classroom size reductions on data derived from the education literature and on general salary and school construction costs (at a 5% amortization rate over 30 years).[29,30] Construction and salary costs average $8076 per student in smaller (12–17 students) kindergarten through grade 3 classes. We then applied our discount rate of 3% over 12.5 years, because the benefits of these expenditures would not be realized until students graduate from high school. This procedure yielded an estimated cost of $13 555 per student in present terms.

We estimated that students in small classes would complete an average of 1.5 additional years of high school (dropouts complete less schooling and thus incur lower costs), at an average national cost of $14 394 (Table 1).[32] Also, we estimated that students who went on to college would incur additional expenses of $49 081 to the government and $65 860 to society as a whole[33] and that they would delay entering the labor force for 4 years. Thus, we calculated the total cost of small classes per each additional graduate as follows:

$$C = c_p + c_h \times p_g + c_c \times p_c \qquad (1)$$

where C is the overall per student cost of small classes, c_p is the per student cost of reducing class sizes (the cost of the program itself), p_g is the probability that small classes will produce an additional high school graduate, c_h is the cost of additional high school attended by students in small classes (as a result of fewer dropouts), c_c is the cost of additional college attended, and p_c is the probability of students attending college. The overall costs of producing an additional graduate are $79 211 from a societal perspective and $78 876 from a governmental perspective.

We used a Markov model to compare life expectancy, health-related quality of life scores, costs, and earnings over the lifetime

TABLE 1—Major Modeling Assumptions and Supporting Evidence Used to Justify the Assumptions

Assumption	Supporting Evidence
A higher level of education produces an increase in wages consistent with that predicted by linear regression	Data from randomized controlled trials, natural experiments, and instrumental variable analyses[9]
A higher level of education leads to better health outcomes and thus results in a reduction in Medicare enrollment and an increase in quality-adjusted life expectancy	Data from instrumental variable analyses and randomized educational trials[5,14,15]
A higher level of education produces improvements in health-related quality of life and mortality consistent with those predicted by linear regression	The literature suggests that regression analyses may underestimate the real-world differences in mortality associated with compulsory schooling[14]
Benefits will accrue only among those students who actually graduate from high school as a result of small class sizes	There is some evidence that nongraduates also benefit from early schooling interventions, but this is difficult to quantify and mostly takes the form of reduced social pathology (a cost excluded from the present analyses)[5]
A generic class size intervention modeled after Project STAR will produce increases in high school graduation rates similar to those observed in Project STAR[7,8]	Project STAR was a large multischool trial; this critical assumption was tested in a broad sensitivity analysis ranging from no additional graduates produced up to the number observed in Project STAR
Project STAR will increase college graduation rates by 4%	Although Project STAR did not examine college completion rates, it did report that students randomized to small class sizes were 4% more likely to take college entrance examinations[31]; most students probably enter via 2-year colleges that do not require entrance examinations
Students who graduate from high school rather than drop out will incur costs associated with 1.5 years of additional schooling	Students who do not drop out of high school as a result of exposure to smaller class sizes incur costs associated with 2 additional years of schooling, on average[23]; these costs may be offset by decreased demand for special education programs and reduced chances of being held back from advancing 1 grade while still in school (grade retention)
Medical expenditures are constant across levels of educational attainment, and thus medical expenditures should not be included in societal analyses	There is little difference in medical expenditures according to educational attainment or income[10,27]; whereas health status improves with increasing education, so too do rates of health insurance coverage and use of medical care
Approximately 11% of low-income high school graduates produced by smaller class sizes will go on to complete college	In Project STAR, roughly 22% of the additional low-income high school graduates produced by small class sizes took college preparatory examinations[31]
The governmental costs of violent crime and drug offenses should not be included in baseline analyses	This conservative assumption was made to simplify the overall analysis; these costs were included in the sensitivity analyses, however
Students who drop out of college or earn an associate degree experience no additional benefit beyond the health effects associated with earning a high school diploma	This assumption was made to simplify the overall analysis

TABLE 2—Selected Values Used in the Analyses, Along With High and Low Estimates of These Values Used in the Monte Carlo Simulation

Parameter	Overall Sample	High Value	Low Value
High school graduates, %			
All students			
Full-sized classroom	76.3	78.0	74.0
Reduced-sized classroom	87.8	90.0	82.0
Free-lunch students			
Full-sized classroom	70.2	74.0	66.0
Reduced-sized classroom	88.2	92.0	84.0
Increase in college attendance, %			
All students	3.7	5.0	2.0
Free-lunch students	4.0	5.0	2.0
Health-related quality of life score[a]			
High school dropouts	0.74	0.75	0.74
High school graduates	0.78	0.79	0.78
College graduates	0.87	0.88	0.87
Medicaid enrollment, %			
High school dropouts	24.8	25.4	24.8
High school graduates	8.2	8.8	8.2
College graduates	4.8	5.3	4.8
Medicare enrollment, %			
High school dropouts	7.6	7.9	7.2
High school graduates	3.7	4.1	3.3
College graduates	3.4	3.8	3.0
Earnings, $[b]			
High school dropouts	12 349	12 871	11 827
High school graduates	23 007	23 427	22 587
College graduates	33 701	34 105	33 297
Tax payments, $			
High school dropouts	1 302	1 360	1 244
High school graduates	3 085	3 139	3 031
College graduates	5 954	6 012	5 896
General costs, $<<AU: Okay?>>			
Per student cost of small class sizes	13 555	16 266	10 844
Cost of additional time in high school[c]	14 394	15 834	12 955
Cost of additional time in college[c]			
Public	49 083	53 991	44 175
Private	65 860	72 446	59 274
Total cost, Project STAR[d]			
Public	78 876	...[e]	...[e]
Private	79 211	...[e]	...[e]
Medicaid cost per enrollee	7 695	8 521	6 869
Medicare cost per enrollee	11 894	13 842	9 946

[a]Range = 0 to 1.0, with 0 representing death and 1.0 representing perfect health.
[b]Obtained from the March 2003 and 2004 versions of the Current Population Survey. Figures reflect the high and low estimates that are because of random error, which was used to generate confidence intervals in the Monte Carlo simulation. Effects were also tested using plausible ranges of nonrandom error in 1-way sensitivity analyses.
[c]Students exposed to small class sizes are less likely to drop out and more likely to complete additional schooling, which is associated with additional costs.
[d]Per additional high school graduate. Includes cost of high school and college attendance.
[e]High and low values used in the model varied according to (1) number of additional high school graduates produced, (2) number of additional college graduates produced, and (3) error in each cost input.

of our hypothetical cohort of high school dropouts, high school graduates, and college graduates. To obtain life expectancy for each education category, we multiplied mortality among high school dropouts[34] by educational attainment–specific risk ratios.[26] The model considered the costs associated with reducing class sizes for students aged 5 through 9 years, but it was assumed that benefits would not begin accruing until cohort members were aged 20 years. Calculations were discontinued after the age of 65 years, when all of the cohort members become eligible for Medicare and other retirement benefits irrespective of their educational attainment. Model inputs are listed in Table 2.

We conducted 1-way sensitivity analyses to isolate the most influential variables in our model. In addition, we used Monte Carlo simulations, based on the values shown in Table 2, to generate confidence intervals around the estimates derived.[17] We used DATApro 2006 (TreeAge Software, Morristown, Mass) in constructing the model.

RESULTS

Health Effects

Our regression analyses showed that students enrolled in small classes would achieve improved health status. The mean health-related quality of life scores were 0.74 for high school dropouts, 0.78 for high school graduates, and 0.87 for college graduates (Table 2). The health status of the average college graduate aged 45 years was comparable to that of the average high school dropout aged 25 years, with both having a health-related quality of life score of approximately 0.89.

Future Earnings and Tax Revenues

Results showed that the earnings of high school graduates would be almost twice those of high school dropouts ($23 000 and $12 000, respectively; Table 2). Because the tax curve is progressive, taxes paid by high school graduates would be approximately 2.5 times as great as those paid by high school dropouts ($3000 and $1300, respectively), and those graduating from college would pay about 4.5 times more in taxes than would high school dropouts ($6000).

TABLE 3—Cost-Effectiveness Values From Societal and Governmental Perspectives for All Students and for Students Receiving Free Lunches

Strategy	Total Lifetime Costs,[a] $	Incremental Cost,[a] $	Total Quality-Adjusted Life-Years[b] (SE)	Incremental Quality-Adjusted Life-Years[b] Gained	Incremental Cost-Effectiveness, $
All students					
Societal perspective[c]					
Small classes	−454 294	−168 431	19.7 (0.09)	1.7	
Regular classes	−285 863		18.0 (0.06)		. . .[d]
Governmental perspective[e]					
Small classes	60 038	25 685	19.7 (0.09)	1.7	15 415
Regular classes	34 353		18.0 (0.06)		
Free-lunch students					
Societal perspective[c]					
Small classes	−482 129	−196 266	19.7 (0.10)	1.5[f]	
Regular classes	−285 863		18.0 (0.06)		. . .[d]
Governmental perspective[e]					
Small classes	24 615	−9 738	19.7 (0.10)	1.5[f]	
Regular classes	34 353		18.0 (0.06)		. . .[d]

Note. Incremental values represent the cost or effectiveness of small class sizes minus the cost or effectiveness of regular-sized classes.
[a]Lifetime earnings of students are greater than costs of schooling; thus, societal values are negative.
[b]A quality-adjusted life-year is calculated from the health-related quality of life scores. These scores were scaled from 0 to 1.0, with 0 representing death and 1.0 representing perfect health. Ten years lived at a health-related quality of life rating of 0.7 is equal to 7 (10×0.7) quality-adjusted life years. A quality-adjusted life-year is a year of perfect health.
[c]The societal perspective incorporated individual income earnings and quality-adjusted life-years.
[d]Both more expensive and less effective than small classes.
[e]The governmental perspective incorporated public expenditures and revenues only.
[f]Differences here were because of rounding. Free-lunch students were assumed to have lower rates of college attendance, thus resulting in slightly lower predicted gains in quality-adjusted life-years.

Medicare and Medicaid Enrollment

Medicaid enrollments and costs among high school graduates would be about one third those of high school dropouts (8.2% and 24.8%, respectively). The effect of educational attainment on Medicare enrollment among individuals aged 25 to 65 years would not be as steep, with 3.4% of high school graduates enrolled in Medicare relative to 7.6% of high school dropouts.

Cost-Effectiveness

Class-size reductions are cost saving from a societal perspective (Table 3). According to our model, a student graduating from high school after attending smaller-sized classes gains an average of 1.7 quality-adjusted life-years and generates a net $168 431 in lifetime net revenue (increase in wages minus intervention cost) relative to a high school dropout who attended regular-sized classes. In addition, greater savings accrue when reductions in class sizes are targeted toward free-lunch students, among whom the lifetime net gain is $196 266 per additional graduate (again, after accounting for the cost of the intervention). The total gain in quality-adjusted life-years was slightly lower (1.5) in this group because fewer of these students were assumed to enter college.

From a governmental perspective, reducing class sizes for all students would generate an additional governmental cost of $25 686 over each student's lifetime but would add 1.7 quality-adjusted life-years to a given student's life expectancy, resulting in an incremental cost-effectiveness ratio of $15 415 per quality-adjusted life-year gained.

Small class sizes targeted toward all students became cost saving from a governmental perspective once the economic effects of smaller classes on other welfare programs and crime were included in the calculations. From a governmental perspective, small class sizes would save at least $2700 for each student by reducing demand for welfare programs, and $31 000 by lowering the costs of crime over the lifetime of the average high school graduate.

These additional savings render small classes cost saving for all students. However, when targeted toward free-lunch students, small classes result in cost savings whether or not crime and welfare costs are considered. Were the government to target this low-income group alone, it would save $9738 over each additional graduate's lifetime.

Sensitivity Analyses

The standard deviations for costs and quality-adjusted life-years gained are presented in Table 4. The Monte Carlo simulations were not affected by random and nonrandom error in the parameter estimate; all interventions remained cost saving with the exception of the analysis that focused on all students from a governmental perspective, which was associated with a confidence interval of $19 000 to $33 000 per quality-adjusted life-year gained.

The variable to which cost savings were most sensitive in 1-way sensitivity analyses was the efficacy of small classes in producing additional numbers of high school graduates. From a societal perspective, small classes must produce at least 5 additional graduates per 100 students to remain cost saving. When crime and welfare costs are considered, this number falls to 4 per 100.

The cost of reducing class sizes was another important variable. From a societal perspective, any educational intervention that produces 12 additional high school graduates per 100 must cost less than $49 000 per graduate produced in net present terms to remain cost-effective. Excluding the benefits associated with college attendance had little effect on outcomes, with total savings dropping to $141 000 and total quality-adjusted life-years to 1.3.

Removing discounting greatly increased the predicted benefits and rendered all 4 scenarios cost saving. From a societal perspective, small class sizes targeted toward either all students or free-lunch students would remain

TABLE 4—Standard Deviations of Values in Monte Carlo Simulation

	Incremental Cost-Effectiveness Ratio, $	Quality-Adjusted Life-Years[a] Gained
All students		
Societal perspective[b]		
Small classes	6 898	0.09
Regular classes	6 101	0.058
Incremental cost	8 000	
Governmental perspective[c]		
Small classes	4 923	0.09
Regular classes	555	0.058
Incremental ratio	3 300	
Free-lunch students		
Societal perspective[b]		
Small classes	5 685	0.10
Regular classes	6 085	0.058
Incremental cost	11 000	
Governmental perspective[c]		
Small classes	2 347	0.10
Regular classes	551	0.058
Incremental cost	1 700	

[a]A quality-adjusted life-year is calculated from the health-related quality of life scores. These scores were scaled from 0 to 1.0, with 0 representing death and 1.0 representing perfect health. Ten years lived at a health-related quality of life rating of 0.7 is equal to 7 (10 × 0.7) quality-adjusted life years. A quality-adjusted life-year is a year of perfect health.
[b]The societal perspective incorporated individual income earnings and quality-adjusted life-years only.
[c]The governmental perspective incorporated public expenditures and revenues only.

cost saving were the discount rate to increase to 5%. However, from a governmental perspective, small classes targeted toward all students and free-lunch students would be associated with incremental cost-effectiveness ratios of $43 000 per quality-adjusted life-year gained and $14 000 per quality-adjusted life-year gained, respectively.

DISCUSSION

We found that reducing class sizes would, in all likelihood, be cost saving from a societal perspective. Although educational interventions occur outside the ambit of medicine, our analysis suggests that class-size reductions would generate more quality-adjusted life-year gains per dollar invested than the majority of medical interventions[34] and would compare favorably with childhood vaccinations in terms of the quality of life years gained per dollar invested.[36,37]

Policy Implications

The national implications of these savings are considerable, given that approximately 600 000 to 800 000 American students do not complete high school by their 20th birthday.[38–40] Reducing class sizes would increase graduation rates, producing 72 000 to 140 000 additional graduates each year. These additional graduates would in turn produce a net savings totaling $14 to $24 billion and 111 000 to 240 000 quality-adjusted life-years over their lifetimes. Although these national estimates rely on data from a single trial (Project STAR) and similar results may not be achievable in all settings, our sensitivity analyses indicate that cost savings from a societal perspective will be realized even if small class sizes are half as effective as shown here.

Whether reducing class sizes is cost saving from a governmental perspective is less clear. Our sensitivity analysis showed that savings accrued by the government were contingent on reductions in crime or targeting reductions in class sizes toward low-income children. However, whether or not it is cost saving our estimate of the cost-effectiveness of reducing class sizes far exceeds the incremental cost-effectiveness ratio for most health care services currently funded by the government.[35,41]

Limitations

Even if educational attainment is causally linked to health,[5,14,15] we cannot be certain of the magnitude of the effect of educational attainment on health or earnings. Although the effect sizes in experimental studies examining the impact of education on health tend to be large and there is some evidence that simple correlations might underestimate the effects of educational attainment on mortality and earnings,[9,14] a variety of confounders could influence the accuracy of the health-related quality of life score, life expectancy, and future earnings effect sizes we predicted using linear regression.[42]

One such factor is innate intelligence: children who drop out of high school may be less genetically endowed, on average, than high school graduates. Other potential confounding variables include family structure, social support, and parenting skills; health habits (e.g., nutrition and physical activity); presence of infectious diseases; environmental exposures at home (e.g., exposure to lead and environmental tobacco smoke) and in the community (e.g., exposure to air pollution); exposure to stress, family dysfunction, substance abuse, violence, and abuse or neglect; and neighborhood conditions such as access to health care and opportunities to engage in physical activity.

Whereas not accounting for these genetic and environmental covariates could produce overestimates of the effects of class-size reductions, other factors could lead to underestimations. For example, the 12% to 18% of students who would otherwise have dropped out of high school but graduate as a result of their enrollment in small classes[7] are likely to be the healthiest, brightest, and least exposed to adverse environmental conditions unrelated to schooling among students at risk for dropping out. Because we considered only the marginal health gains in this advantaged subset of the dropout cohort, effect sizes predicted by our regression analyses (in which we controlled for race, gender, and ethnicity) may have been conservative. Moreover, the select few additional high school graduates produced by small class sizes are often from low-income families, and studies suggest that low-income students are at a considerably increased likelihood of being held back as a result of rectifiable environmental variables (e.g., school quality) as opposed to genetic factors.[20]

Our study involved other limitations as well. First and foremost, we based our effect-size estimates on a single trial. Although the sample size in Project STAR was large—12 000 students spread over 46 school districts—the project's findings may not be generalizable to other settings. Although the STAR findings are corroborated by many, but not all, earlier studies of small class sizes, these earlier studies involved weaker designs,[18] and a national program might not meet with similar success. For example, the intervention discussed here involved kindergarten through grade 3 classes only, and it would be expected to confer less benefit in communities overrepresented by children who are more likely to enter the school system at later ages or whose greatest setbacks occur after grade 3. Nonetheless, our sensitivity analysis demonstrated that a program roughly one third as effective as Project STAR would still lead to cost savings.

Interventions other than class-size reduction merit study because they could be less expensive and more effective than class-size reductions. Prekindergarten interventions, high school tutorial and college preparatory programs, and some charter school models are examples of educational interventions that may hold promise. We examined class-size reduction because this is the only intervention to have been evaluated in a multicenter randomized controlled trial.[5,13]

Second, we did not examine the feasibility of nationwide implementation of the class-size reduction tested in Project STAR. Determining whether the potential costs and benefits of an intervention are favorable, the focus of our study, is a necessary first step in determining whether the feasibility of an intervention deserves closer scrutiny. Third, our analysis excluded potentially relevant costs. For example, an expansion in teaching positions would probably foster competition among schools for qualified teachers, which in turn could increase teacher salaries.

Finally, our college progression rates were based on increases in rates of students taking college preparatory examinations rather than actual college attendance. However, incremental cost savings and quality-adjusted life-years gained would be little changed even if no students went on to college, with savings dropping from $168 000 to $141 000 and quality-adjusted life-years gained falling from 1.7 to 1.3.

Conclusions

Despite these limitations, our findings raise the intriguing question of whether investments in social determinants of health can be more cost-effective than investments in conventional medical care. More intriguing still, each dollar invested in education could potentially produce long-term returns. Further research is needed to refine models and produce more-precise estimates, but our findings point to the importance of looking more broadly at the options available for improving health outcomes—including those outside the boundaries of clinical medicine—and of the fallacy of assuming, without evidence, that investments in medical care contribute more to health than do investments elsewhere. In short, it is more appropriate to address underlying conditions than it is to treat the victims of social deprivation only to return them to the conditions that brought about their situation in the first place. ■

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Contributors

P. Muennig originated the study, conducted the data analyses, and contributed to development of the article. S.H. Woolf contributed to the origination of the study and to development of the article.

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Human Participant Protection

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