Journal of Urban Health: Bulletin of the New York Academy of Medicine, Vol. 89, No. 1
doi:10.1007/s11524-011-9628-8

Do Health Benefits Outweigh the Costs of Mass Recreational Programs? An Economic Analysis of Four Ciclovía Programs

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ABSTRACT *One promising public health intervention for promoting physical activity is the Ciclovía program. The Ciclovía is a regular multisectorial community-based program in which streets are temporarily closed for motorized transport, allowing exclusive access to individuals for recreational activities and physical activity. The objective of this study was to conduct an analysis of the cost–benefit ratios of physical activity of the Ciclovía programs of Bogotá and Medellín in Colombia, Guadalajara in México, and San Francisco in the USA. The data of the four programs were obtained from program directors and local surveys. The annual cost per capita of the programs was: US $6.0 for Bogotá, US $23.4 for Medellín, US $6.5 for Guadalajara, and US $70.5 for San Francisco. The cost–benefit ratio for health benefit from physical activity was 3.23–4.26 for Bogotá, 1.83 for Medellín, 1.02–1.23 for Guadalajara, and 2.32 for San Francisco. For the program of Bogotá, the cost–benefit ratio was more sensitive to the prevalence of physically active bicyclists; for Guadalajara, the cost–benefit ratio was more sensitive to user costs; and for the programs of Medellín and San Francisco, the*

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cost–benefit ratios were more sensitive to operational costs. From a public health perspective for promoting physical activity, these Ciclovía programs are cost beneficial.

KEYWORDS *Ciclovía program, Complex system, Urban organization, Physical activity, Economic assessment, Cost–benefit ratio, Nonmotorized transport, Human behavior, Dynamics of large cities*

INTRODUCTION

Over the last decade, the global public health focus has shifted toward the increasing burden of chronic diseases. The World Health Organization (WHO) estimated that 60% of global deaths in 2005 were due to chronic diseases, and 80% of these occurred in low and middle income countries whose governments are least capable of responding to the high direct (health care expenditure) and indirect (lost economic productivity) costs associated with these diseases.[1] In addition WHO estimated that physical inactivity ranked fourth of 19 mortality risks factors globally.[2]

In this context, the recreational opportunities provided by the Ciclovía program make it a promising public health program.[3] The Ciclovía recreativa[4] is a multisectorial, community-based mass program in which streets are temporarily closed to motorized transport allowing exclusive access to individuals for leisure activities and physical activity (PA).[5] The Ciclovía contributes to social capital development, improvement in the population's quality of life by encouraging the use of public space for recreation, and chronic disease prevention through PA promotion.[5] Since the first Ciclovías began in the 1960s,[5] the initiative has gradually spread across America with the greatest growth taking place after 2000. Currently, Ciclovía programs exist in at least 16 countries in the Americas and the Caribbean.[5,6] Furthermore, as part of the World Health Day 2010 campaign "1,000 cities, 1,000 lives", more than 1,500 cities around the world reported programs similar to the Ciclovía.[7]

The economic benefits from programs that promote PA are relevant for the policy makers who allocate financial and infrastructure resources.[8,9] Despite the global expansion of the Ciclovías and the importance of cost–benefit analyses, there are no studies that assess the economic costs and benefits of these programs. Thus, the current study aims at answering the following research question: What are the average economic benefits derived from physically active adult users of the Ciclovía programs of Bogotá, Medellín, Guadalajara, and San Francisco compared to the programs' average costs?

METHODS

Program Description

Bogotá's Ciclovía—whose participating sectors include education, environment, health, security, sports, culture and recreation, transport, and urban planning— was inaugurated in 1974 and is currently managed by Bogotá's Institute of Sports and Recreation (IDRD, Spanish acronym for "Instituto Distrital de Recreación y Deporte"). The Ciclovía program is mainly funded through a tax added to all citizens' phone bills and also by private sponsors. By 2009 the program was offering

72 events, each one occurring on every Sunday and holiday in the year, on the same 97-km circuit of closed streets.

The Guadalajara program called the Vía RecreActiva, whose sectors include transport, education, public security, and health, was inaugurated in 2004 and is managed by the municipal council of sports, which funds it from the municipal government budget. By 2009 this program was offering 52 events per year, each one occurring once per week on every Sunday, on the same 25-km circuit of closed streets.

The Medellín Ciclovía, managed by Medellín's Institute of Sports and Recreation (INDER, Spanish acronym for "Instituto de Recreación y Deporte"), was inaugurated in 1984 and is funded by the city budget for sports and recreation. By 2009, it was offering 158 events per year occurring each one per day, 3 days per week (every Tuesday, Thursday, Sunday, and holiday) on the same 48.7-km circuit of closed streets.

San Francisco's Sunday Streets program is a collaborative effort between the San Francisco Municipal Transportation Agency, Mayor Gavin Newsom's office, and Livable City, the grassroots arm of the sustainable transportation movement in San Francisco. Sunday Streets was inaugurated in 2008, offering two events that year, six events in 2009, and nine events in 2010. The program's circuit consists of six different routes that vary in length from 7.3 to 9.7 km. For the cost–benefit analysis, we assumed that the program had 52 events per year and has the same circuit of closed streets. This assumption permits to project the program costs and benefits per year.

Data Collection

We obtained data on the characteristics of the programs from the directors and managers of the four programs. An estimation of the number of users was obtained from different local surveys conducted in each of the programs between 2005 and 2010. The number of adult users per event (Table 1) in each of the four programs was stratified by sex, age, and type and frequency of the activities conducted per event (e.g., bicycling, walking, or "other" [skating, skate boarding, or riding in a wheel chair]).

For the Bogotá Ciclovía, we determined the number of users based on data from two surveys conducted in 2005[10] and 2009 and regular counts from every event during 2009. According to the 2005 survey, 46.2% of the total adult users were bicyclists, 47.9% were pedestrians, and 5.9% engaged in other activities. In the 2005 survey, 40.5% of the users reported that they spent at least 3 h at the Ciclovía. Additionally, in the 2009 survey, adults were asked about the frequency and intensity of the activities during the Ciclovía. According to this survey, 41.6% of adult users reported moderate to vigorous activities for at least 3 hours. Because we recognized that some of the participants in the Ciclovía would be physically active whether the Ciclovía was held or not, we included the following question: "What activities would you do if Bogotá did not have the Ciclovía program?" Among participants, 11.8% of them reported that they would exercise or do other sports in other settings. We used this estimate to account, in part, for activity substitution and to adjust the prevalence of physically active adults (adults meeting the WHO and US government's recommendations for weekly PA [$\geq$150 minutes of moderate intensity or $\geq$75 minutes of vigorous intensity aerobic physical activity per week]).[11,12] As a result, for the Bogotá Ciclovía program, the prevalence of physically active adult users was estimated to be 35.7%.

TABLE 1 Characteristics, number, and percentage of adults who meet physical activity recommendations (adults meet physical activity recommendations if they report at least 150 minutes of moderate physical activity per week) per type of activity for the Bogotá, Guadalajara, Medellín, and San Francisco Ciclovía programs

	Bogotá			Guadalajara			Medellín			San Francisco		
Number of events per year (2009)	72			52			158			52*		
Number of total users per event (2009, 2005)	600,000–1,400,273			140,000			78,358			25,000		
Percentage of adults (>18 years old; 2005)	86.10			36.97			69.55			60.00		
Number of adults (>18 years old; 2009, 2005)	516,600–1,205,635			51,761			54,498			15,000		
Number of kilometers (2009)	97			25			48.7			7.9		
	Bicyclists	Pedestrians	Skaters/other	Bicyclists	Pedestrians	Skaters/other	Bicyclists	Pedestrians	Skaters/other	Bicyclists	Pedestrians	Skaters/other
Number of adult users	238,669–557,003	247,451–577,499	30,479-71,132	43,479	6,729	1,553	31,227	21,854	1,417	7,247	5,568	2,859
Percentage of total adult users	46.2	47.9	5.9	84.0	13.0	3.0	57.3	40.1	2.6	46.2	35.5	18.2
Number of physically active adult users[a]	102,317–238,787	72,033–168,110	10,296–24,029	17,356	416	22	19,570	13,696	888	3,004	2,308	1,185
Percentage of physically active adult users[a]	19.8	13.9	2.0	33.5	0.8	0.04	35.9	25.1	1.6	20.0	15.4	7.9

"Other" refers to other type of activities: skating, skate boarding, or riding in a wheel chair

[a]Adults meet physical activity recommendations if they report at least 150 minutes of moderate physical activity per week

TABLE 2 Costs of the Bogotá, Guadalajara, Medellín, and San Francisco Ciclovía programs

	Bogotá[a]		Guadalajara		Medellín		San Francisco	
Costs (USD)	Event	Annual	Event	Annual	Event	Annual	Event	Annual
Operational costs								
Variable costs[b]	8,568	616,906	3,280	170,575	5,341	843,999	28,073	1,459,813
Fixed costs[c]	15,245	1,097,684	3,011	156,592	865	136,709	3,322	172,750
Total costs	23,813	1,714,591	6,291	327,168	6,207	980,708	31,395	1,632,563
Cost per user	0.04–0.05	1.71–3.32	0.04	2.34	0.11	18.00	1.26	65.30
Cost per km	245	17,676	251	13,086	127	20,137	3,974	206,653
User costs								
Total costs	32,545–75,947	2,343,059–5,468,205	11,181	581,414	1,863	294,401	2,515	130,805
Cost per user	0.05–0.06	3.91–4.54	0.08	4.15	0.03	5.40	0.10	5.23
Cost per km	335–782	24,255–56,373	447	23,256	38	6,045	318	16,557
Total costs (User costs + Operational costs)								
Total costs	56,536–99,761	4,057,651–7,182,797	17,472	908,582	8,070	1,275,110	33,910	1,763,368
Cost per user	0.08–0.09	5.96–6.76	0.12	6.49	0.15	23.40	1.36	70.53
Cost per km	580–1,028	74,049–41,831	698	36,343	165	26,182	4,292	223,211

The Sunday Street program only occurs once per month during 9 months. Therefore, we assumed that the program occurred once per week during the year in order to attribute the yearly DHB to the physical active that are expected to meet the PA weekly recommendations. Thus, the DHB in this case should be interpreted as the projected DHB for a regularly weekly program

[a]For Bogotá, the results are presented as a range because the number of users is estimated to be between 600,000 and 1,400,273

[b]Variable costs: Bogotá—traffic signals, cones, security tape, lane dividers, bags, loops, modules, batteries, first aid kits, and field employee (hourly) salaries and equipment (helmets, strings, caps, bikes, bags, and uniforms); Guadalajara—food for staff, equipment and logistic supplies, maintenance equipment, medicines and medical equipment, vehicle maintenance, field employee salaries and equipment (helmets, strings, caps, bikes, bags, and uniforms), and training costs; Medellín—field employees (hourly) salaries and equipment (helmets, strings, caps, bikes, bags, and uniforms), guides' salaries, trucks, rental (hourly) of ambulances, and mobile bathrooms; San Francisco—San Francisco Police Department, Department of Parking and Transportation, Department of Public Works Staff, Department of Public Works Equipment, Municipal Transportation Authority Department Support, Interdepartmental Staff Committee on Traffic and Transportation permits, other permits, Dept. of Public Health, San Francisco Fire Dept. (emergency medical technicians), event insurance, portables, equipment rental, and volunteer lunches

[c]Fixed costs: Bogotá—office employee salaries, logistical support, technical support, support modules, radio frequency, and truck rental; Guadalajara—office employee salaries, assemblers, office materials, and communication costs; Medellín—office employee salaries, office materials, and communication costs; San Francisco—graphic design, marketing, web consultant, billboard production, collateral material printing, organizer salary, benefits, payroll costs, rent, volunteer coordination, event staff supervisors, incidental expenses, bookkeeping, fiscal sponsorship, and SF MTA/City

For the Guadalajara and Medellín programs, we determined the number of users based on regular counts conducted during every event in 2009. For the San Francisco program, the number of users is based on counts from three events in 2010. The percentage of activity substitution was assumed to be the same as in Bogotá as data from these three programs was not available. According to these data, 34.3% of adult users in the Vía RecreActiva, 62.6% in the Ciclovía of Medellín, and 43.3% in the Sunday Streets of San Francisco were considered physically active users (Table 1).

We obtained data on the costs of constructing and maintaining the four programs in 2009 and 2010 from their directors and managers (see Table 2). The operational costs included fixed costs—including permanent employee salaries, logistical and technical support, intercoms frequency service, and truck rental costs—and variable costs for modifying streets into pedestrian/bike/skate circuits—for example, traffic signals, cones, security tape, lane dividers, bags, batteries, first aid kits, and salaries for field employees (Ciclovía guardians) and their equipment (helmets, strings, caps, bikes, bags, uniforms). We calculated the user costs (the cost of the equipment that each user in each city must buy to engage in Ciclovía leisure activities) as the cost of bicycles, skates, and helmets (assumed to have a product life of 10 years) weighted by the percentage of bicyclists, pedestrians, and skaters at each event for each of the four programs.

This economic analysis corresponds to an average cost–benefit approach. We did not use an incremental approach because data on adjusted supply prices and opportunity costs of public expenditure were not available. In addition, the costs of road construction, development, and maintenance were not considered for this analysis as Ciclovía programs use existing infrastructure for motorized transport.

Direct Health Benefit

We defined the direct health benefit (DHB) as the amount of money that a physically active adult saves in annual direct health and medical costs for preventing chronic diseases.[13,14] Calculating DHB for a city requires knowledge of the number of both active and inactive persons in the program and the average direct medical costs per person. For San Francisco, the direct health benefit was estimated using the difference in the direct medical cost for active persons and their inactive counterparts in the USA.[13] However, because data on average medical costs for active and inactive persons in Bogotá, Medellín, and Guadalajara were unavailable, we estimated the DHB using a methodology—given by Eqs. 1, 2, and 3—based on the DHB in the USA:[13]

$$\alpha_i = \frac{\text{average annual total medical cost city}_i}{\text{average annual total medical cost USA}} \tag{1}$$

$$\begin{aligned}\mathrm{DHB_{USA}} = {} & \text{direct medical costs of physically active person} \\ & - \text{direct medical costs of physically inactive person}\end{aligned} \tag{2}$$

$$\mathrm{DHB}_i = \mathrm{DHB_{USA}} \times \alpha_i \tag{3}$$

where i refers to Bogotá, Guadalajara, and Medellín and DHB stands for direct health benefit.

We estimated the DHB_{USA} based on the difference in the direct medical cost for active persons and their inactive counterparts. However, because the available data were from a 1987 National Medical Expenditure Survey, we calculated an adjusted figure for 2009 based on the inflation figure from January 1987 to January 2009 (89.9%).[13,15] Following this adjustment, the DHB_{USA} was US $626.6 per person per year and the average annual direct medical cost was US $2,272.

Because the health care system in Colombia includes universal health insurance coverage,[16] in both Bogotá and Medellín, we calculated the annual average medical cost for the city as the per capita payment unit (UPC) weighted by age and gender. The UPC is calculated each year based on all the direct medical costs reported annually for each city divided by the number of health care system users in that city. We assumed that the DHB in each city represented the same percentage (α) of the DHB_{USA} that the direct medical cost in the city represented of the direct medical cost in the USA. Thus, we derived the percentage (α) of the direct medical cost in the USA that represented the direct medical cost in each city.

For Bogotá, the annual direct medical cost for 2009 was US $258, meaning that, according to Eq. 1, α=258/2,272=11.3%. Likewise, based on Eqs. 2 and 3, for DHB_{USA}=US $626.6, then the DHB in Bogotá was $DHB_{Bogotá}$=US $626.6×11.3%= US $71.1 per person per year.

For Medellín, the average annual direct medical cost was US $248, meaning α= 248/2,272=10.9%. Thus, given DHB_{USA}=US $626.6, the DHB for Medellín was $DHB_{Medellín}$=US $626.6×10.9%=US $68.4 per person per year.

Direct medical cost information for Guadalajara was unavailable. Therefore, we estimated a range of the DHB equivalent to 8% to 10% of the DHB_{USA}. Thus, given DHB_{USA}=US $626.6, $DHB_{Guadalajara}$=US $51.1–US $62.7.

For San Francisco, we used the DHB calculated for the USA equal to US $626.6 per person per year as the DHB value for the city. However, the Sunday Streets program only occurs once per month during 9 months. We assumed that the program occurred once per week during the year in order to attribute the yearly DHB to the physical active that are expected to meet the PA weekly recommendations. Thus, the DHB in this case should be interpreted as the projected DHB for a weekly program.

Cost–Benefit Ratio

We calculated the cost–benefit ratio for the Bogotá, Medellín, Guadalajara, and San Francisco programs by dividing the total direct health benefit derived from each Ciclovía program by the total costs of each program, namely:[14]

$$\mathrm{Benefit/Cost}_i = \frac{(\mathrm{PAP}_i + \mathrm{PAB}_i + \mathrm{PAO}_i) \times \mathrm{DHB}_i}{\mathrm{Ciclovía\,Total\,Cost}_i}$$

where *i* is Bogotá, Guadalajara, Medellín, and San Francisco; PAB is the number of physically active bicyclists; PAP is the number of physically active pedestrians; PAO is the number of other physically active users; and DHB is the direct health benefit.

If the cost–benefit ratio, which measures the saving on direct medical costs for every dollar invested in the Ciclovía program, is lower than 1, the investment in the program is higher than the benefit obtained. Otherwise, the program is cost beneficial.

We conducted the following sensitivity analysis. First we tested several scenarios in which the DHB for the different cities was varied (Table 3). For this analysis, the lower limit value for the DHB is such as the cost–benefit ratio is equal to 1 and the

TABLE 3 Sensitivity analysis for the direct health benefit user/year (USD) of the Ciclovía programs in Bogotá, Guadalajara, Medellín, and San Francisco

Percentage of the US direct health benefit (α)	DHB (user/year, USD)	Total benefit (USD)	Benefit/operational costs	Benefit/user costs	Cost–benefit ratio
Bogotá/Ciclovía					
11.34	71.06	13,120,409–30,620,257	7.65–17.86	5.60	3.23–4.26
10.00	62.66	11,570,025–27,001,990	6.75–15.75	4.94	2.85–3.76
7.00	43.86	8,099,018–18,901,393	4.72–11.02	3.46	2.00–2.63
5.00	31.33	5,785,013–13,500,995	3.37–7.87	2.47	1.43–1.88
2.65	21.93	4,049,509–7,155,527	1.79–4.17	1.31	0.76–1.00
Guadalajara/Vía RecreActiva					
20.00	125.32	2,229,978	6.82	3.84	2.45
15.00	93.99	1,672,483	5.11	2.88	1.84
10.00	62.66	1,114,989	3.41	1.92	1.23
8.15	51.07	908,716	2.78	1.56	1.00
Medellín/Ciclovía					
10.91	68.39	2,335,898	2.38	7.93	1.83
9.00	56.39	1,926,087	1.96	6.54	1.51
8.00	50.13	1,712,077	1.75	5.82	1.34
7.00	43.86	1,498,067	1.53	5.09	1.17
5.95	37.28	1,273,357	1.30	4.33	1.00
San Francisco/Sunday Streets					
100.00	626.60	4,070,967	2.49	32.52	2.32
90.00	563.94	3,663,870	2.24	29.27	2.08
80.00	501.28	3,256,773	1.99	26.02	1.85
70.00	438.62	2,849,677	1.75	22.76	1.62
43.00	269.44	1,750,516	1.07	13.98	1.00

The Sunday Street program only occurs once per month during 9 months. Therefore, we assumed that the program occurred once per week during the year in order to attribute the yearly DHB to the physical active that are expected to meet the PA weekly recommendations. Thus, the DHB in this case should be interpreted as the projected DHB for a regularly weekly program

upper limit value for the DHB represents 10% of the DHB_{USA} (except for the Sunday Streets case). Thus, the ranges for the DHB sensitivity analysis for Bogotá, Guadalajara, Medellín, and San Francisco were US $21.9 to US $62.7, from US $51.1 to US $62.7, from US $37.3 to US $62.7, and from US $269.4 to US $626.6 per person per year, respectively. Second, in order to assess the minimum number of program users needed for the cost–benefit ratio to fall below 1, we also calculated the range of number of users in each program and estimated the cost–benefit ratios based on type of physical activity (specifically, bicycling and walking). Third, we tested the sensitivity of the type of costs (operational costs and user costs) associated with the programs. For the Bogotá program, we conducted a combined Monte Carlo sensitivity analysis using Oracle Crystal Ball. The simulation included the following parameters: (1) number of users (the lower bound was the lowest number of users reported by the 2009 survey and the upper bound corresponds to the number reported by 2005 survey), (2) the prevalence of meeting PA recommendations (the lower bound corresponds to the city prevalence of meeting PA recommendations from the 2010 Nutrition survey and the upper bound corresponds to the unadjusted prevalence from the intercept 2009 survey [i.e., not taking into account activity substitution percentage]), and (3) the user costs (varying according to market prices of bikes, helmets, and skates).

Health Economic Assessment Tool for Bicycling

To estimate the mean annual benefit per mortality prevention of bicycling in the Bogotá, Guadalajara, Medellín, and San Francisco's Ciclovía programs, we used the

TABLE 4 Input parameters for HEAT model and mortality benefits obtained for the Ciclovía programs of Bogotá, Guadalajara, Medellín, and San Francisco

City	Annual mortality rate (2009)	Value of statistical life[a] (USD)	Relative risk	Trips per day	Mean number of days cycled per year	Mean trip distance (km)	Mean annual benefit (USD)	Present value of mean annual benefit (USD)
Bogotá	0.00439	102,568–685,370	0.72	238,669-	72	7.9	4,389,765–28,019,740	3,196,956–21,292,660
		102,568–685,370	0.72	557,003	72	7.9	10,245633–68,240,700	7,461,462–49,691,820
Guadalajara	0.00504	102,568–1,572,501	0.72	43,479	52	7.9	664,727–10,146,740	483,956–7,389,540
Medellín	0.00718	102,568–685,370	0.72	31,227	158	7.9	2,061,083–18,700,160	1,501,687–10,144,130
San Francisco	0.00340[b]	7,000,000–8,000,000	0.72	7,247	52[c]	7.9	5,107,159–5,837,363	3,719,344–4,250,272

[a]This value represents the value of statistical life at the country level. For the Bogotá, Medellín, and Guadalajara programs, the lower bound corresponds to the lowest value reported for Latin America countries and the higher bound corresponds to the value reported for Colombia and Mexico respectively.[21] For the San Francisco program, the value is ranged based on estimations for the USA by Kniesner et.al.[20]

[b]This value corresponds to the US annual mortality rate for 2009

[c]The Sunday Streets program had nine events in 2010. We considered 52 events per year to project the cost–benefit estimates therefore assuming a weekly regularity of the program

Health Economic Assessment Tool (HEAT) model.[8,17,18] The HEAT model estimates the benefit based on mortality prevention per bicycling. The calculations considered only adult bicyclists. The HEAT estimations are based on the relative risk of mortality among bicyclists, the number of trips per day, the number of bicycling days per year, the annual mortality rate of the city, the number of hours cycled per week, a 5-year timeframe for benefits to build up, a 10-year timeframe for mean annual benefit calculation, and the value of statistical life (VSL).[18–20] For the Bogotá, Medellín, and Guadalajara programs, the VSL lower bound corresponds to the lowest VSL value reported for Latin America countries and the higher bound corresponds to the VSL value reported for Colombia and Mexico, respectively.[21] For the San Francisco program, the VSL is ranged based on estimations for the USA by Kniesner et al.[20] (Table 4).

Simulation Model for the Bogotá Ciclovía Program

To predict the 5-year cost–benefit ratio pattern for Bogotá's Ciclovía program, a 5-year simulation based on data on the program's historical growth in circuit length and users per year was conducted. First, we performed a linear regression in order to estimate a differential equation in which the variation in length (variation of kilometers, y') was a function of the number of kilometers (y, number of kilometers) along the years (time, t) obtaining function $y'(t)=0.1018y(t)+6.3239$. We also used linear regression to estimate the number of users, z, as a function of the number of kilometers, y. Here, function $z(t)=11404y(t)-95671$ where the reduced error is $R^2=0.97$, which indicates that the historical variation in users and kilometers has maintained similar proportions. We then used these functions to construct a differential equations model [22–24] (using Mathematica 7 software) that incorporated the historical growth of the Ciclovía, the DHB, and the variable and fixed program costs. Medellín, Guadalajara, and San Francisco were excluded from the analysis because historical information for these programs was unavailable.

RESULTS

The four programs differed in costs and in the number of users (Tables 1 and 2). Adult users in Bogotá's Ciclovía ranged from 516,600 to 1,205,635 users per event, of which 102,317 to 238,787 were PAB, 72,033 to 168,110 were PAP, and 10,296 to 24,029 were PAO. In Guadalajara's program the average number of adult users was 51,761 per event, of which 17,356 were PAB, 416 were PAP, and 22 were PAO. In Medellín's program the average number of adult users was 54,498 per event, of which 19,570 were PAB, 13,696 were PAP, and 888 were PAO. In San Francisco's program, the average number of adult users was 15,000 users per event, of which 3,004 were PAB, 2,308 PAP, and 1,185 PAO.

Bogotá's Ciclovía Program

For Bogotá, the results are presented as a range because the number of adult users ranged from 516,600 to 1,205,635. The total annual costs ranged from US $4,057,651 to US $7,182,797. The annual cost per capita of the programs was US $6.0 (Table 1).

The cost–benefit ratio ranged from 3.23 to 4.26 (Table 3). Thus, the savings in direct medical costs ranged from US $3.2 to US $4.3 for every dollar invested in the Ciclovía program. These calculations also accounted for gender differences because

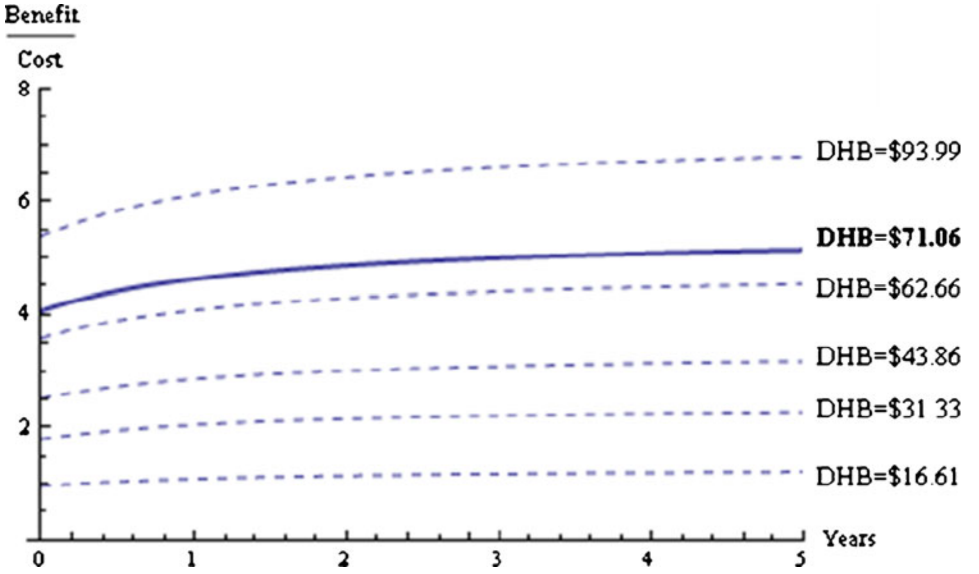

FIGURE 1. Cost–benefit ratio of Bogotá's Ciclovía program in a 5-year simulation using different values (USD) for the Direct Health Benefit in Bogotá.

men participated approximately three times more often than women. Therefore, the cost–benefit ratio for men ranged from 2.12 to 2.80 versus 1.11 to 1.46 for women.

The sensitivity analysis showed that the cost–benefit ratio was more sensitive to the DHB, and the number of users than to the type of activity and the kilometers of the circuit. The cost–benefit ratio was larger than 1 for a DHB over US $16.6 to US $21.9 per year per person (i.e., 2.7% to 3.5% of the DHB_{USA}). However, if the DHB is lower than US $21.9 per person per year, the total program cost is higher than the DHB obtained. If the number of users is smaller than 95,000, the cost–benefit ratio is smaller than 1.

The cost–benefit ratio also differed when we stratified by type of activity. Considering only bicyclists, the cost–benefit ratio ranged from 1.79 to 2.36. Considering only pedestrians, the cost–benefit ratio ranged from 1.26 to 1.66.

The combined Monte Carlo sensitivity analysis showed that the prevalence of physically active bicyclists followed by the total number of users of the program and the prevalence of physically active pedestrians were the main parameters contributing to the cost–benefit estimate variance. The analysis also showed that the user costs did not contribute significantly to the cost–benefit estimate variance.

The output for the simulation model, which indicated the exponential behavior of the cost–benefit ratio over 5 years, showed that the total DHB grew more than the total Ciclovía costs (Figure 1). In fact, increasing the number of users also increased the probability of more physically active users and thus a larger DHB. In contrast, increasing the number of kilometers produced a growth of US $4.4 per user per year in operational and user costs. Thus, even if only about 17.5% of the Ciclovía users meet PA recommendations, each would represent a cost that is approximately 16% of the benefit produced. The HEAT model for Bogotá's Ciclovía program showed that the mean annual benefit for mortality prevention ranged from US $4,389,765 to US $68,240,700, and the present value of the annual benefit for mortality prevention ranged from US $3,196,956 to US $49,691,820 (Table 4).

Guadalajara's Vía RecreActiva Program

The total annual costs were US $908,582, and the annual cost per capita of the program was US $6.5 (Table 2). According to the sensitivity analysis, the cost–benefit ratio was larger than 1 for a DHB greater than US $51.1 per year per person (8.2% of the DHB_{USA}; see Table 3). However, if the DHB falls below US $51.1 per person per year, the total cost for the program is higher than the DHB obtained. The HEAT model for Guadalajara's program showed that the mean annual benefit for mortality prevention ranged from US $664,727 to US $10,146,740, and the present value of the annual benefit for mortality prevention ranged from US $483,956 to US $7,389,540 (Table 4).

Medellín's Ciclovía Program

The total annual costs were US $1,275,110, and the annual cost per capita of the program was US $23.4 (Table 2). The cost–benefit ratio was 1.83. This indicated savings in direct medical costs of US $1.8 for every dollar invested in the program. The sensitivity analysis showed that the cost–benefit ratio was more sensitive to the DHB and the number of users than to the type of activity distribution and the kilometers of the circuit. The sensitivity analysis showed that the cost–benefit ratio was larger than 1 for a DHB greater than US $37.3 per year per person (6% of the DHB_{USA}; see Table 3). However, if the DHB is lower than US $37.3 per person per year, the total cost of the program is higher than the DHB obtained, and if users number fewer than 37,500, the cost–benefit is smaller than 1. When the analysis took into account only bicyclists, the cost–benefit ratio was 1.05. When it included only pedestrians, the cost–benefit ratio was 0.73. The HEAT model for Medellín's program showed that the mean annual benefit for mortality prevention ranged from US $2,061,083 to US $18,700,160, and the present value of the annual benefit for mortality prevention ranged from US $1,501,687 to US $10,144,130 (Table 4).

San Francisco's Sunday Streets Program

The total annual projected costs were US $1,763,368 and the annual cost per capita of the programs was US $70.5 (Table 2). The projected cost–benefit ratio was 2.32. This indicated savings in direct medical costs of US $2.3 for every dollar invested in the program if the program occurs regularly every week. The sensitivity analysis showed that the cost–benefit ratio was more sensitive to the DHB and the number of users than to the type of activity distribution and the kilometers of the circuit.

The sensitivity analysis showed that the cost–benefit ratio was larger than 1 for a projected DHB greater than US $269.4 per year per person (43% of the DHB_{USA}; see Table 3). However, if the DHB is lower than US $269.4 per person per year, the total projected cost of the program is higher than the DHB obtained, and if users number fewer than 11,200, the cost–benefit is smaller than 1. When the analysis took into account only bicyclists, the cost–benefit ratio was 1.07. When it included only pedestrians, the cost–benefit ratio was 0.82. The HEAT model for San Francisco's program showed a projected mean annual benefit for mortality prevention ranged from US $5,107,159 to US $5,837,363, and the present value of the annual benefit for mortality prevention ranged from US $3,719,344 to US $4,250,272 (Table 4).

DISCUSSION

This study is the first to provide evidence, from a public health perspective, of the cost–benefit assessment of Ciclovía programs. Our analysis found that the Ciclovía programs were cost beneficial for an annual transversal assessment. In addition, in the case of Bogotá, the simulation results suggest that if the program increases in the number of users following its historical trend, increasing the number of kilometers will keep the program's cost–benefit ratio greater than 1. In addition, the economic appraisal using the HEAT model illustrates that substantial savings in reduced mortality that results from bicycling can be expected from these programs. These results support, in part, the implementation of this type of programs as part of public health efforts to promote PA in urban settings from developed and developing countries.

Other cost–benefit analyses of public health interventions to promote PA provide a context for the comparison of the Ciclovía programs economic analysis. However, these comparisons should be undertaken with caution due to differences in the analysis. A cost–benefit assessment of five pedestrian trails in Nebraska was conducted in 2005, showing a cost–benefit ratio of 2.94 (17.6 km).[13,14,25] However, the Ciclovía programs have more kilometers (7.9–97 km), and contrary to the Nebraska trails, the Ciclovía programs did not require an infrastructure investment. Furthermore, workplace bicycling programs provided a benefit of US $1.3–US $6.5 for each US $1 spent in cycle promotion due to increased productivity.[26] Concerning the HEAT model analysis, European studies for bicyclists show greater benefits for mortality prevention in UK and lower benefits for mortality prevention

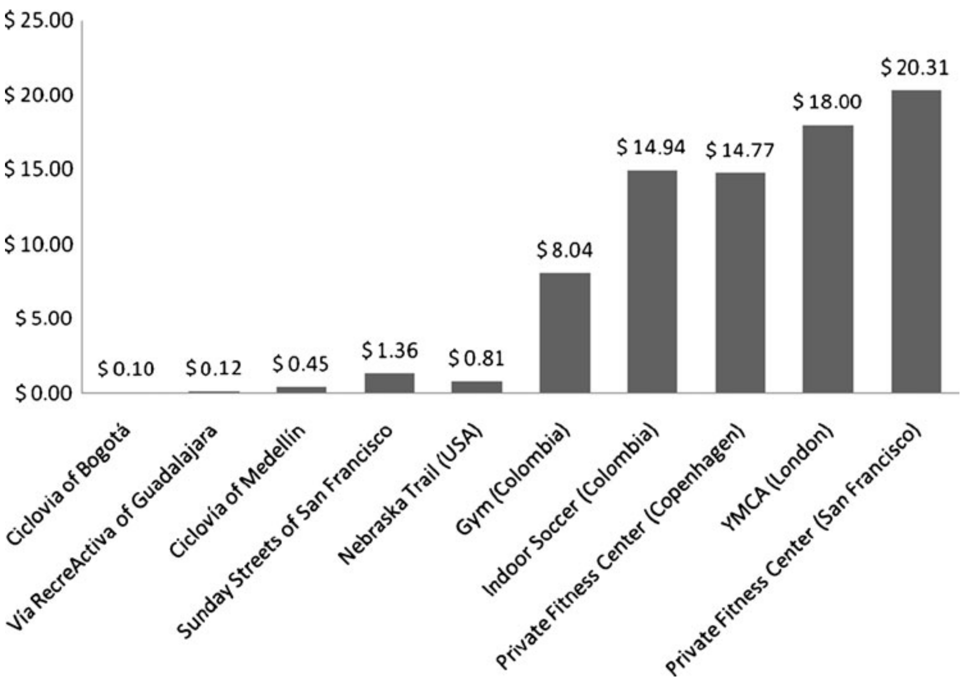

FIGURE 2. Average cost per user per week (USD) of different physical activity programs (2009).

in Czech Republic and New Zealand compared to the mortality benefits estimated for the Ciclovía programs.[8]

In addition, compared to other PA programs in Colombia, the Ciclovía program has the lowest cost per user per week (Figure 2). Although these comparisons should be undertaken with caution due to differences in program's regularity and opportunity, Figure 2 shows that a weekly gym admission fee per user costs US $8.04 [27] and a soccer field rental fee for 3 hours costs US $14.94 per user.[28] In the case of San Francisco, a similar comparison provides comparable results. In fact, private fitness center memberships in San Francisco cost US $20.31 per user per week for a midrange facility. Likewise, European examples provide similar comparisons. Specifically, in Copenhagen, Denmark, a typical facility costs US $14.77 per user per week, and in London, England, fees range from US $18.00 per user per week at a YMCA to US $25.35 per user per week at a luxury facility (Figure 2).

Moreover, in the cases of Bogotá and Guadalajara, the cost–benefit ratios were less sensitive to operational costs than to user costs, which represented 57.7% to 76.1% and 64%, respectively, of total costs. Because the Ciclovía operates on existing streets and requires no investment in new infrastructure, the initial investment and operation of the program involved only operational, management, and equipment costs (the Ciclovía program budget does not include street maintenance costs, so we excluded them also). In the case of Medellín and San Francisco, the cost–benefit ratio was more sensitive to operational costs than to user costs, which in fact represented only 23.1% and 7.4%, respectively, of total costs. These differences resulted from a lower density of adult users per kilometer in Medellín and San Francisco's programs compared to that in the other two programs (Bogotá, 5.3 to 12.4 users/km; Guadalajara, 2.1 users/km; Medellín, 1.1 users/km, San Francisco, 1.9 users/km). In addition, the Ciclovía of Medellín has a lower cost–benefit ratio than the Sunday Streets of San Francisco although the Medellín's program has lower costs per user and a higher number of adults reaching recommendations. This is because the DHB per person in Medellín represents only 10.9% of the DHB in San Francisco, i.e., the total benefit generated by a single active adult in Sunday Streets of San Francisco is equivalent to the total benefit generated by 10–11 active adults in Medellín.

Several limitations should be taken into account to interpret these findings accurately:

1. The methods for counting physically active users differed between programs and the number of surveyed days differed between programs. Depending on the number of days and climate, the counting could be overestimated or underestimated. To assess the variability in the Bogotá program, we used a range of users in the year 2005 and 2009. In the case of Sundays Streets of San Francisco, we assumed that the circuit is taking place weekly on the same circuit of closed streets because data concerning the number of participants according to each route were not available. Future studies should include standardized counting methods during a representative sample of days per year while accounting for changes on the route.
2. The prevalence of physically active users is based on a questionnaire. For Bogotá, we calculated a conservative estimate of physically active adult users taking into account the prevalence of physically active adult users who spent at least 180 minutes during the Ciclovía. In addition, we did not include in the analysis the adults for

whom participating in the Ciclovía program is complementing PA in order to meet recommendations, which is likely to underestimate the calculated cost–benefit ratios.[5] Future studies should include objective measurements of PA.

3. The number of physically active users is assumed to be constant along the year. In the cases of Bogotá, Guadalajara, and Medellín, the event count of physically active users is the average count of users per event along the year. The weekly regularity of the events permits assuming that users meet PA recommendations along the year. In the case of San Francisco, we assumed that the program occurs once per week in order to use the same assessment methodology for the DHB estimation.
4. The direct medical cost for a physically inactive person in the USA was used to estimate the DHB for the other programs. In order to evaluate the robustness of the methodology, a sensitivity analysis was conducted. We focused on simulated scenarios where the programs of Bogotá, Guadalajara, Medellín, and San Francisco are not cost beneficial, concluding that these scenarios are not plausible. For example, in Colombia, the cost per person with a diagnosis of type-2 diabetes attributed to physical inactivity was calculated to be US $210.0 in 2009,[29,30] representing 6 to 13 times the DHB assumed in the simulated scenarios in which the Ciclovía programs of Bogotá and Medellín were not cost beneficial. Future studies of Colombia and Mexico should calculate the direct medical costs of physically inactive adults.
5. The total benefit of the Ciclovías could be underestimated. Specifically the DHB was only a part of the total benefits derived from the Ciclovías: their implementation had the potential of additional benefits including recreation, social capital development, improvements in the population's quality of life, promotion of efficient and sustainable modes of transportation like bicycling, and a decrease of exposure to air and noise pollution.[5,31] Additionally, a Scandinavian study estimates that a physically inactive person who shifts from automobile to bicycle produces a health and fitness economic benefit to the community of approximately 3,000–4,000 euro per year.[31,32] Under this scenario, the cost–benefit ratio would have been 3 to 69 times greater depending on the program (three times in the case of San Francisco and 69 times in the case of Bogotá). However, we could be overestimating the cost–benefit ratios because we did not consider the cost of the leisure time and the indirect costs concerning public transport, vehicle congestion, and alternative routes of main streets that are closed to vehicles during the programs.
6. Our study is an average cost–benefit analysis with a societal perspective. Our results could only be used as references for policy makers in making resource allocations decisions, but not to assess the benefit and effectiveness of a social policy. In fact, more data concerning opportunity costs and adjusted supply prices of public expenditure and cost-effectiveness analysis are needed for future studies.
7. Our historical data for the Bogotá's Ciclovía program is based on eight points in time since 1975. Therefore, we could not fit probability functions to the program's historical growth behavior. Nonetheless, the linear regressions used in the simulation model were an approximation of the historical growth assuming a linear behavior of growth over time.
8. Finally, other educational information is available at the Ciclovía events regarding healthy lifestyles (e.g., nutrition information and health-risk screenings) that provide additional, indirect health benefits. These outcomes would be

difficult to measure without further investigation of a consistent population. Free bicycle rentals and exercise classes provide additional motivation for participants to adopt positive physical activity behavior. Increased exposure to physical activity opportunities may also serve to motivate physically inactive individuals.

The very low per user costs of the Ciclovías in comparison with other programs for physical activity promotion are striking. Clearly using existing infrastructure built and maintained for motorized transport contributes substantially to the positive cost–benefit ratio. The large number of users, and the potential for an even greater proportion of urban populations to participate in Ciclovías due to the ubiquitous presence of road networks and their relative underutilization during certain hours suggests that with appropriate multisectoral partnerships, political support, and effective management and promotion, many more cities can support Ciclovías on the scale of Bogotá.

Considering that Ciclovía programs are not exclusive to Bogotá, Guadalajara, Medellín, and San Francisco, we anticipate that the methodology presented could serve a framework to assess other Ciclovía programs available worldwide. Extending analyses such as this one to include additional beneficial outcomes such as improving air quality, increasing social capital, and reducing carbon emissions might result in even more positive cost–benefit ratios. Economic analyses will be crucial to determine the public health and overall public benefits of Ciclovías and other complex multisectoral programs which impact health and quality of life. These studies may also serve as advocacy tools to promote expansion and creation of Ciclovías in different cities around the world.

ACKNOWLEDGEMENTS

The authors of the research would like to acknowledge the Center for Interdisciplinary Studies in Basic and Applied Complexity, CeiBA (Bogotá, Colombia), Colciencias grant 519 2010, and the grant from sustainable mobility research projects by La Universidad de los Andes in Bogotá. We also would like to acknowledge Pablo Lemoine and Gina Rojas from El Centro Nacional de Consultoria (Bogotá, Colombia); Rocío Gámez of the IDRD of Bogotá; Claudia Arango, Claudia Garzón, Fabián Higuita, and Andrés Felipe García of the INDER of Medellín, the Municipal Council of Sports of Guadalajara, Livable City of San Francisco for providing the data of the Ciclovía programs; and Claudia Guedes, Mi-Sook Kim, Patrick Tierney, and Jackson Wilson of the Active Living Across the Lifespan Research Group of San Francisco State University, California, for the data collection. We would like to thank Maria Luis Latorre, Juan Carlos Mendieta, and Candace Rutt who provided valuable comments on earlier versions of the manuscript. The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention or the Pan American Health Organization.

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