City Cycling

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Health Benefits of Cycling

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Cycling has multiple health benefits, particularly as a form of moderate to vigorous physical activity. Rapid increases in mechanization in the last half of the twentieth century in the industrialized world have engineered physical activity out of daily life for many people. Changes in modes of personal travel have been dramatic, with private motor vehicle trips replacing walking and cycling in many developed and developing countries.

Transportation cycling provides an excellent opportunity for individuals to incorporate physical activity into daily life. Furthermore, cycling for transportation is accessible and appealing to population groups that often have low levels of participation in sport and other forms of leisure-time physical activity. In pro-cycling countries and cities, transportation cycling is undertaken by considerable numbers of children, adolescents, women, older adults, people with low incomes, and nonathletic people in general. Consequently, transportation cycling can make a substantial contribution to improved health through increased physical activity levels across diverse population groups (Buehler et al. 2011). Health benefits also flow from reduced car use, including improved air quality, reduced noise pollution, and reduced greenhouse gas emissions. Improved social capital and community livability enhances quality of life, and "living streets" increase social interaction and reduce crime.

This chapter examines the health benefits of cycling as a form of moderate to vigorous physical activity and the multiple health benefits that flow from human-scale rather than car-dominated urban environments. We use a broad definition of health as incorporating "physical, mental, and social well-being" (World Health Organization 1948). We do not address the injury risks associated with cycling, as this topic is covered in chapter 7.

Physical Health Benefits of Cycling

This section focuses on the epidemiological evidence for the physical health benefits of increased cycling in populations.

Potential for Physical Activity to Improve Health

Regular moderate-intensity physical activity is an important contributor to population health. Epidemiological evidence suggests that accumulating at least thirty minutes each day of moderate-intensity physical activity can contribute to a range of health benefits, with recent recommendations noting that additional benefits can be achieved with up to an hour per day of total physical activity (U.S. Department of Health and Human Services 2008). Health benefits include chronic disease prevention and favorable impacts on antecedent risk factors such as elevated blood pressure and obesity. In addition, physical activity has mental health and social benefits, discussed later in the chapter.

Achieving the recommendations of thirty or sixty minutes per day will generally require adding to leisure-time physical activity other elements of active living, including active transportation, and increasing energy expended in domestic or occupational settings. Utilitarian cycling provides a practical means for inactive people to be active for thirty minutes per day. Most populations have high rates of bike ownership, people generally know how to cycle, and cycling for short trips can contribute to reaching the minimal daily recommendation of thirty minutes of activity. In car-reliant countries, a high proportion of short trips (less than 5 km) are car trips that could be replaced with cycling (Australian Bureau of Statistics 2009a). The energy expenditure of almost all commuting cycling places it at least in the "moderate intensity" category of activity of around 5–8 METs (metabolic equivalent of task, or 5–8 times the energy expenditure at rest) (Ainsworth et al. 2000). This level is around twice as intense as walking and provides an activity that is continuous, expends sufficient energy, and can be performed by most adults and children.

Types of Cycling to Improve Population Health

There are three settings for cycling that could contribute to population levels of physical activity. First is indoor cycling, in gyms or in domestic settings using stationary bicycles. These involve some cost and, above all, personal commitment to use them, and they may be used by individuals who are already active. Second is cycling as a form of recreational physical activity. Most recreational cycling achieves health enhancing levels but is more likely to be a "weekend" or intermittent choice of activity.

Third—and most likely to be of population health benefit—is cycling to get to and from places, including riding to work, to shops, to visit friends locally, or for other regular short trips. Utilitarian cycling is likely to be a more regular or habitual form of physical activity than gym-based or recreational cycling. In the Netherlands, cycling is the activity that contributes most to the total time spent by adults on moderate-to-vigorous physical activity (van Kempen et al. 2010).

Health Benefits: Findings from Epidemiological Studies

Numerous research studies have examined the health benefits of cycling in clinical settings, with special populations, and usually on stationary bicycles. These small-scale or clinical studies show that laboratory-based cycling improves fitness, cardiovascular risk factor levels, and postprandial blood sugar uptake (Oja et al. 2011). The primary focus of this chapter, however, is not on clinical settings but on population-based evidence of the relationship between cycling and improved health.

Cross-sectional studies have shown inverse associations between active commuting and body mass index, lipid levels, and blood pressure (Hu et al. 2002; Wen and Rissel 2008); one study was conducted in a Chinese city where most active commuting was by bicycle (Hu et al. 2002). European studies have shown similar results (von Huth Smith, Borch-Johnsen, and Jørgensen 2007). Japanese workers who commuted using active modes showed a better general health profile (General Health Questionnaire scores) than those using inactive travel modes (Ohta et al. 2007). A German cross-sectional study reported an association between general health and less chronic disease among regular cyclists aged fifty to seventy years (Huy et al. 2008). Further, ecological associations across countries, cities, and US states have noted that obesity rates are inversely related to walking and cycling rates (Pucher et al.

2010; Bassett et al. 2008). These data do not demonstrate a causal relationship but indicate the potential for improved health in active cycling populations.

Population-based studies, usually based on longitudinal cohort designs, have contributed to evidence for the health benefits of cycling. The Copenhagen cohort study identified that cycling to work reduced the risk of all-cause mortality by 28 percent, independent of other types of physical activity (Andersen et al. 2000). Many studies have identified "active commuting" as protective against all-cause or cardiovascular deaths (Hu et al. 2007; Hamer and Chida 2008) but most of these studies asked about "walking or cycling" to work, so the relative protective effects cannot be separated out and distinguished between walking and cycling. For cardiovascular events, active commuting was protective in Finnish adults, though more so for women than men (Hu et al. 2007). In the Zutphen study of elderly Dutch men, physical activity reduced risk and improved metabolic health; in this sample, the most frequent physical activity was cycling, again providing more direct evidence of cycling-specific prevention benefits (Caspersen et al. 1991). Women in the United States who increased their cycling, even by a small amount, significantly reduced their likelihood of weight gain (Lusk et al. 2010). Finally, a meta-analysis of active commuting (walking *and* cycling) and coronary heart disease reported data from eight studies with an 11 percent average risk reduction for developing heart disease and slightly stronger protective relationships in women than men (Hamer and Chida 2008).

Active commuting is inversely related to diabetes incidence (Pucher et al. 2010; Hu et al. 2003). With respect to cancer risk, bicycling alone was not protective for ovarian cancer (Biesma et al. 2006), and there have been inconsistent findings for breast cancer, with no association shown in a study of Chinese women (Matthews et al. 2001), but a German study reporting lower risk among women with high levels of cycling (Steindorf et al. 2003). For colon cancer, a case-control study in older adults reported a 40 percent decreased risk among active commuting men and women (Hou et al. 2004). In this Chinese sample, commuting was mostly cycling, hence conferring most of this observed benefit. Similar results were seen in the Shanghai women's health cohort, in

which cycling more than forty minutes a day significantly reduced all-cause and cancer mortality risk (Matthews et al. 2007).

Among children, walking or cycling to school is associated with higher levels of overall physical activity, but most associations are from cross-sectional studies (Lee, Orenstein, and Richardson 2008). A Danish study showed similar cycling-specific findings using objectively assessed physical activity (Oja et al. 2011). Active commuting to school was also associated with increased aerobic fitness in a study of 6,085 English schoolchildren (Voss and Sandercock 2010). Although active commuting to school is associated with increased physical activity, most studies report no association with body mass index or obesity rates (Lee, Orenstein, and Richardson 2008). As is the case for adults, however, ecological associations across countries indicate that obesity rates are inversely related to rates of active travel to school (usually involving high levels of cycling) (Garrard 2009).

The Potential Impact of Increases in Cycling on Physical Activity Prevalence

As shown in chapter 2, rates of cycling at the population level are much higher in many European countries than in the United States, Canada, Australia and the United Kingdom. The potential public health benefits of cycling promotion are therefore high in countries where the population at risk (i.e., noncyclists) is very large. The challenge is to get those with bicycles to use them on a regular basis in order to make a public health impact on the prevalence of "sufficient activity."

In this section, we analyze data adapted from an Australian population data set in which 57 percent of adults met the recommendation for 150 minutes per week of at least moderate-intensity physical activity and 43 percent were "insufficiently active." The data were modeled to assess what difference it would make to the population prevalence of "sufficiently active" adults if a conservatively estimated 20 percent of people cycled more often. The modeling estimated the prevalence of "sufficient activity" if this subgroup of people cycled once, twice, or three times a week for twenty minutes. Then, the analysis was confined to only those who were "insufficiently active" and 20 percent of them adopted these amounts of cycling activity (see figure 3.1). Given a baseline of 57 percent

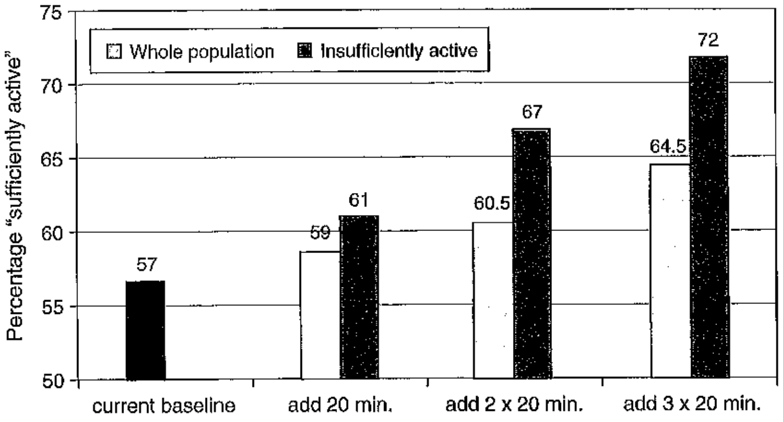

Figure 3.1
Effect of adding episodes of cycling/week on population level (percentage) of "sufficiently active" for (1) 20 percent of the adult population and (2) 20 percent of adult population who are "insufficiently active." *Source:* Data modeled from National Physical Activity Survey, Australia 2000.

"sufficiently active," if 20 percent of Australian adults cycled twenty minutes once, twice, and three times per week, the prevalence of adequately active would increase to 59.0 percent, 60.5 percent, and 64.5 percent, respectively. If only inactive adults were targeted, the prevalence increases would be even larger, to 61.0 percent, 67.0 percent, and 72 percent. Because few population interventions have achieved anywhere near a 5 percent absolute increase in sufficient physical activity, the public health potential for cycling is large, even at modest amounts and frequency of bicycle usage, especially if currently inactive people start cycling. These estimates would be similar for other developed countries with low rates of cycling in which around half the adult population is "insufficiently active." These hypothetical data are compelling, and cycling is accessible, affordable, and achievable by people of all ages. The challenge, therefore, is to establish effective ways to increase cycling in the population.

Psychosocial Health Benefits

The psychosocial benefits of cycling include (1) mental health benefits, (2) social health benefits, and (3) utilitarian cycling as a possible means

of reducing health inequalities. These benefits are discussed in the following three sections.

Mental Health and Well-Being

The psychological health benefits of cycling range from preventing and treating anxiety and depression to improving cognitive functioning and increasing subjective well-being. In some cases, the link has been demonstrated for moderate intensity physical activity in general; other studies have looked specifically at cycling. This section focuses on cycling-specific research but also draws on other forms of moderate-intensity physical activity if cycling-specific research is unavailable.

Treatment and Prevention of Mental Health Conditions

A recent systematic review of the relationship between physical activity and depression concluded that exercise improves depressive symptoms in people with depression (Mead et al. 2009). Based on this evidence, UK guidelines for depression management recommend the inclusion of regular exercise in the treatment of mild to moderate depression (NICE 2009). There is also some evidence that regular physical activity may prevent the development of depressive symptoms in older adults (Lindwall, Larsman, and Hagger 2011).

Cognitive Functioning

A number of studies report improved cognitive functioning and educational attainment among young people who are physically active, though none have focused specifically on cycling (Åberg et al. 2009; Sibley and Etnier 2003). Several recent studies have reported significantly higher cardiovascular fitness among young people who cycle to school (Cooper et al. 2008; Andersen et al. 2009), including, in one study, after controlling for nontravel physical activity (Voss and Sandercock 2010). These data provide some indirect evidence that cycling to school may have educational benefits for young people, in addition to the direct health benefits.

These findings are consistent with research into cognitive functioning among older adults. Several US studies have reported that long-term regular physical activity, including walking, was associated with significantly better cognitive function, less cognitive decline, improved motor function, improved memory, and a decreased risk of Alzheimer's disease (Scarmeas et al. 2009; Angevaren et al. 2008).

The prevention of dementia through physical activity has the potential to help mitigate an important and growing global health problem. As shown in chapter 2, countries such as the Netherlands, Denmark, and Germany have established a culture of everyday utility cycling, with bike trips constituting a high proportion of trips by older adults (e.g., 25% of trips by people aged 65 and older in the Netherlands; Pucher and Buehler 2008). However, the impact of cycling rates on dementia in these countries has not been assessed.

Emotional Well-Being

Cross-sectional surveys consistently report that psychological factors such as relaxation, stress reduction, fun, enjoyment, and social interaction are among the key self-reported motivations for commencing and continuing cycling. In an online survey of 2,403 members and contacts of the Australian cycling advocacy organization Bicycle Victoria, key reasons for commencing and continuing cycling included "fun and enjoyment," "getting outside in the fresh air," "relaxation and stress reduction," and "time out for myself" (Garrard, Crawford, and Hakman 2006). Survey participants bicycled for recreation (91%), transportation (58%), and competition (13%).

Cycling usually occurs outdoors, and "green exercise" carried out "in the presence of nature" may improve self-esteem and mood, with a synergistic effect for exercise and exposure to nature (Barton and Pretty 2010). In a detailed qualitative study of the personal and cultural meanings of cycling among twenty-two mainly elderly male cyclists in north-central Italy, participants talked about cycling making them feel healthier, happier, and more youthful, and of the fun and enjoyment of being out and about in the natural environment (Whitaker 2005). In the words of the men, "The bicycle makes the eyes smile" (19), and "I do it because it is my passion, because it is a habit; it is a habit that attached itself affectionately to me" (25).

Enhanced well-being is frequently associated with recreational cycling but is rarely considered in research into travel mode choice, which is predominantly concerned with utility factors such as cost, convenience, and travel time. A study in the United Kingdom reported that compared

with other commuter modes, cyclists were more likely to report that their journey to work was pleasant, interesting, and exciting (Gatersleben and Uzzell 2007). However, the context may influence perceptions of stress associated with the cycling commute, with a Belgian study reporting that commuter cycling was associated with increased stress among men in blue-collar jobs (though not among other population subgroups in the study sample; Asztalos et al. 2009).

Young people consistently report a preference for active travel to school, including cycling. Evaluation of the Ride2School program in Victoria, Australia, found that cycling was the most popular mode of travel to school among students in fourth through sixth grades participating in the program; 81 percent "liked" cycling or "really liked [it] a lot" (Garrard, Crawford, and Godbold 2009). "Enjoyment," "Exercise and fitness," and "Quick travel time" were the most frequently cited reasons for preferring cycling to school, indicating that—as for adults—cycling is often perceived to be enjoyable as well as having utilitarian value. As shown in chapter 11, despite young people's preferences for cycling (and walking) to school, in countries such as the United States, the United Kingdom, Canada, Australia, and New Zealand, most children are driven to school, and rates of cycling and walking to school have fallen dramatically over recent decades (van der Ploeg et al. 2008). This disconnection between preferences and behavior indicates high latent demand for cycling but also major barriers to acting on preferred travel modes.

The flip side of the enjoyment of cycling is the psychological distress associated with the actual and perceived risks of cycling in traffic. These are frequently reported barriers to cycling (Horton 2007). The social discrimination and victimization of cyclists as minority road users can also lead to harassment of cyclists (Basford et al. 2002; Garrard, Crawford, and Hakman 2006; Gatersleben and Haddad 2010; Heesch, Sahlqvist, and Garrard 2011; Pucher, Garrard, and Greaves 2011). These factors can contribute to what Horton (2007, 133) refers to as the "fear of cycling."

Social norms and values about being a "good mother" can also label parents (usually mothers) who allow their children to cycle to school as "irresponsible" (Skenazy 2009; Horton 2007). The road safety response to fatalities and serious injuries among motor vehicle occupants is to improve road safety (a societal response) rather than to recommend that people drive less (i.e., take individual responsibility to avoid exposure to risk). As noted in chapter 7, a key aspect of motor vehicle domination is to remove cyclists and pedestrians from the road environment by holding them responsible for the harm caused to them by cars (Jacobsen, Racioppi, and Rutter 2009; Horton 2007).

The research cited previously suggests that for people who choose to cycle, even in adverse conditions, the benefits (including enjoyment) outweigh the concerns. However, negative psychological and social factors can act as major barriers to the promotion of cycling among noncyclists. These particular barriers are likely to decline if cycling becomes more prevalent and safer, and sheds its "minority road user" status.

Social Health Benefits

Human-scale urban environments that support cycling and walking and discourage car use can improve social interactions and increase community attachment, livability, and amenity (Litman and Doherty 2009). The provision of road space to enable high-volume, high-speed car travel comes at a cost to other road users and local residents in terms of community disruption, noise pollution, social isolation, urban sprawl, restrictions on children's independent mobility and opportunities for outdoor play and social interactions (Carver, Timperio, and Crawford 2008; Handy, Cao, and Mokhtarian 2005; Dora and Phillips 2000; Ewing et al. 2003). Appleyard and Lintell's original research, which found that heavy traffic is associated with reduced street-based activities and social interactions between neighbors (Appleyard and Lintell 1980), has been replicated in other settings (Bosselmann and Macdonald 1999; Hart 2008). In response to these findings, and to their widespread omission in transportation planning, Litman has developed a comprehensive framework for transportation planning that includes valuing community cohesion and social connectedness (2009).

There is also evidence that the more compact, permeable urban designs that support cycling and walking lead to crime reduction through increased street activity and "natural surveillance" (Hillier and Sahbaz 2006; Cozens, Saville, and Hillier 2005).

The social interactions that occur as part of recreational and transportation cycling have also been documented (de Geus et al. 2008). In the study of elderly Italian cyclists mentioned earlier, Whitaker (2005) reported that the social connectedness associated with cycling was highly valued among the study sample of older male cyclists.

Cycling also contributes to social inclusion because it provides an affordable and convenient form of personal mobility that is accessible to people who do not own or have access to a motor vehicle. Transportation costs (principally motor vehicle related) account for a high proportion (16%) of household expenditure on goods and services in Australia—second only to expenditure on food and nonalcoholic beverages (17%), and similar to housing costs (16%) (Australian Bureau of Statistics 2006). In the United States, transportation is taking up increasing amounts of household budgets. Although study methodologies have changed over time, the available estimates indicate steady increases in transportation costs from 3.1 percent in 1917–1919 to 15.9 percent in 1984 and 19 percent in 2002 (Australian Bicycle Council 2010).

Psychological and social health also affect physical health. Social isolation, lack of social support, and depression are important risk factors for cardiovascular disease. The increased risk contributed by these psychosocial factors is of similar order to the more conventional coronary heart disease risk factors such as smoking, dyslipidemia, and hypertension (Bunker et al. 2003).

Cycling as a Means of Reducing Health Inequalities

Social gradients in health status exist in most countries, with the poor experiencing substantially higher mortality and morbidity than the rich (Marmot 2001). Many factors contribute to health inequalities, including inequalities in health-enhancing behaviors such as physical activity. However, physical activity through active travel is usually more equitably distributed in populations than leisure-time physical activity. Socioeconomically advantaged population groups are about twice as likely as disadvantaged groups to participate in leisure-time physical activity or sports (Australian Bureau of Statistics 2009b), but this is not the case for transportation cycling and walking (Matthews et al. 2007; Andersen et al. 2000; Berrigan et al. 2006).

In addition to socioeconomically disadvantaged population groups, other priority groups for the promotion of physical activity include women, adolescent girls, and older adults. As shown in chapters 2, 10, and 11, in countries such as Germany, Denmark, the Netherlands, and Japan, a high proportion of young people cycle to school (Garrard 2009), women cycle as frequently as men, and in some cases, the majority of trips taken by seniors (aged 65 and older) are active trips such as cycling and walking (Pucher and Buehler 2008, 2010). These diverse population groups frequently achieve adequate levels of physical activity incidentally, at low cost, and without having to find the time and money to participate in organized sports or fitness programs. The socially inclusive, population-wide participation associated with active travel may help to explain the inverse relationship observed between walking and cycling rates and obesity levels internationally (Pucher et al. 2010; Bassett et al. 2008).

Health in general is better and more equitably distributed when all people have access to the conditions and environments that support health and health enhancing behaviors. Accordingly, improved social integration could be achieved by adopting transportation and road use policies that prioritize public good over private interest by providing more equitable public access to space and mobility, thereby "turning an urban nightmare into a fairer society" (Peñalosa 2010). As Peñalosa states, "A bicycle path is a social statement that a person with a $40 bicycle is as important as anyone with a $40,000 car."

Health Benefits of Reduced Motor Vehicle Use

Although motor vehicle use has a number of positive features, such as the abilities to transport large or bulky heavy items and to cover long distances relatively quickly, these benefits are accompanied by health and social costs. At a personal level, the very sedentary nature of driving or sitting in a motor vehicle is a health hazard. A study of Chinese men found that those who reported riding in a car (as driver or passenger) for more than ten hours a week had an 82 percent greater risk of dying from cardiovascular disease than those who reported less than four hours a week, and similar findings have been reported in the United States (Warren et al. 2010).

Driving to work has been associated with a 13 percent increased risk of being overweight or obese (Wen et al. 2006) after controlling for leisure-time physical activity. Similar associations between time spent driving and obesity have been found in other parts of the world, including the United States (Frank, Andresen, and Schmid 2004), China (Bell, Ge, and Popkin 2002), and Latin America. An Australian study found that men who cycle to work are less likely to be overweight or obese than men who drive to work (Wen and Rissel 2008).

An increase in cycling, when it is associated with a decrease in motor vehicle use, also generates a number of indirect health benefits in the form of reductions in air and noise pollution, road traffic injuries, congestion, and greenhouse gas emissions.

Improved Air Quality

Motor vehicles are a major source of air pollution in most major cities (Bureau of Transport and Regional Economics 2005). In Australia, with a population of about 20 million people, between 900 and 4,500 cases of cardiovascular and respiratory disease occurred due to motor vehicle related air pollution in 2000, costing between AUD$0.4 billion and AUD$1.2 billion (about US$0.4 billion–US$1.3 billion). In addition, air pollution caused by motor vehicles accounted for between 900 and 2,000 premature deaths, with an estimated cost of between AUD$1.1 billion and AUD$2.6 billion (about US$1.2 billion–US$2.7 billion) (Bureau of Transport and Regional Economics 2005). These premature deaths, which are comparable to the number of people killed in road crashes (1,464 in Australia in 2008), have been labeled "the silent road toll." The impact of air and noise pollution is greatest in dense urban centers. Cycling therefore offers significant potential to reduce this cost, as these areas are also the most amenable to cycling because trip distance is likely to be shorter than in outer areas.

Comparative Exposure to Air Pollutants: Cyclists Compared to Motor Vehicle Occupants

One reason motorists sometimes give for not riding a bicycle is that they do not want to be exposed to air pollutants in the road carriageway. Motor vehicles emit a variety of air pollutants that are known to be associated with adverse health effects including fine particles, nitrogen dioxide and volatile organic compounds (VOCs) (WHO 2005). It is well established that the motor vehicle is a principal source of air pollution in medium and large cities. Less well established is the extent to which cyclists are at higher or lower risk of harmful exposure to air pollutants than other road users. When comparing cyclists' exposures to those of motor vehicle occupants, it is important to consider not only roadway exposure but also the flow rate of pollutants from outdoors to the car interior and vice versa (Knibbs, de Dear, and Atkinson 2009). For car occupants, interior concentrations of pollutants are affected by interior and exterior sources of pollution and the air exchange rate in the vehicle cabin, which in turn is affected by factors such as vehicle speed, ventilation settings, and window positions (Knibbs, de Dear, and Atkinson 2009).

For cyclists, exposure depends on cycling route, location on the roadway, weather, traffic intensity, vehicle and fuel type, speed, and driving style. In addition, the higher respiration rates for cyclists compared with motor vehicle occupants (estimates range from 2.3 to 4.3 times higher) can result in cyclists experiencing greater inhaled quantities of some pollutants than car passengers (Panis et al. 2010). This area of study is complex, with a recent study concluding that further research is required to enable the development of an appropriate model for assessing the relative health impacts attributable to air pollution for cyclists compared with car drivers (van Kempen et al. 2010). What is certain, however, is that reduced motor vehicle use will reduce the health risks of air pollution for all people in urban areas and that choosing low traffic cycling routes can reduce cyclists' exposure to air pollution.

Reduced Noise Pollution

In most urban areas, traffic is the most important source of noise nuisance, which can contribute to insomnia, stress, and hearing damage (Dora and Phillips 2000; Buis and Wittink 2000). There is also emerging evidence of an association between high levels of noise and heart disease (Coghlan 2007). Motor vehicle noise also contributes to reduced community livability (as mentioned previously). In a population survey of crime victimization in Australia, dangerous/noisy driving was the most frequently reported perceived neighborhood problem with crime or nuisance (ahead of vandalism/graffiti, housebreakings, drunkenness, louts/gangs, car theft, and illegal drugs) (Australian Bureau of Statistics 2010).

Greenhouse Gas Emissions and Climate Change

Transportation is a significant and growing source of the greenhouse gas emissions that contribute to climate change. For example, road transportation is responsible for 22 percent of the United Kingdom's total greenhouse gas emissions (UK Department for Transport 2009). In Australia, transportation emissions rose 30 percent between 1990 and 2005; this level is expected to rise by 67 percent above 1990 levels by 2020 (Department of Climate Change and Energy Efficiency 2008). Cycling, as a zero-emission form of transportation, offers a currently untapped potential to lower emissions in the passenger transportation sector. Unlike a number of high-tech options, bicycles are an equitable, off-the-shelf option that can be deployed immediately. Even with the current limited bicycle infrastructure in Australian cities, cycling to work in 2006 accounted for an estimated 189,392,000 km traveled per year in Australian capital cities, which amounts to a greenhouse gas saving of about 45,000 tons per year relative to single-occupant car travel (Bauman et al. 2008).

The environmental consequences of climate change, which include sea-level rise, degraded air quality, and extreme weather events affect human health both directly and indirectly. Direct health effects include heat-related mortality and morbidity, increased injuries and violence, drowning, vector-, food- and water-borne diseases, food and water shortages and malnutrition, exacerbation of respiratory diseases, and mental health and stress-related disorders (USA Interagency Working Group on Climate Change and Health 2010).

Economic Appraisal of the Health Benefits of Cycling

Transportation services and infrastructure often undergo comprehensive economic appraisals as a basis for investment decision making. However, because many of the benefits of cycling are difficult to measure and are distributed across several sectors, cycling projects tend to be undervalued and consequently underfunded.

Valuing the health benefits of cycling is particularly challenging. As outlined previously, there are multiple health benefits (and some health risks) of cycling that vary across population groups (e.g., men/women, children/adults), time, and place. These benefits can be difficult to quantify and even more difficult to monetize. Nevertheless, some comprehensive benefit-cost analyses (BCAs) of cycling projects that include health benefits have been conducted (ABW 2012). Other studies provide a more general valuation of the health benefits of cycling—for example, estimates of the health cost savings associated with a 10 percent increase in cycling rates.

The World Health Organization's Health Economic Assessment Tool for Cycling (HEAT for cycling) is an example of the latter approach (Rutter et al. 2008). This method has become the standard UK government method for incorporating physical activity benefits into transportation appraisals. It produces an estimate of the mean annual benefit (per cyclist, per trip, and total annual benefit) due to reduced mortality as a result of cycling. The tool consists of a User Guide and Microsoft Excel spreadsheet or direct online system for calculating the health benefit based on parameters entered by the user. The tool uses the "value of statistical life" approach, which estimates reductions in mortality (http://www.heatwalkingcycling.org), and demonstrates health and cost savings for even small increases in population levels of cycling.

A recent report to Cycling England, *Planning for Cycling*, valued the health benefits of a regular commuting cyclist (three times a week for a year) at £679.67 (approximately US$1,070) (SQW Consulting 2008). In the UK Cycling Demonstration Towns project, on average, cycling rates increased by 27 percent in the Cycling Demonstration Towns, and the health benefits (from reduced mortality) were estimated to be around £2.50 for every £1 spent (Cycling England 2010).

Sixteen studies that presented the findings of an economic valuation of an aspect of transportation infrastructure or policy, and included data on walking and/or cycling and health effects in the valuation, were reviewed by Cavill et al. (2008). The benefit-cost ratios (BCRs) were of an impressive magnitude: the median BCR was 5:1, which is far higher than BCRs that are routinely used in transportation infrastructure planning. In the United Kingdom, for example, a BCR of greater than 2 is counted as "high value for money" (Cavill et al. 2008). Health benefits make a sizeable contribution to these BCRs, with a BCA of cycling networks in three cities in Norway reporting that reduced health costs accounted for between two-thirds and one-half of the total benefits (Nordic Council of Ministers 2005).

Few economic appraisals of the health benefits of replacing car trips with cycling trips have included the health benefits of reduced air pollution, noise pollution, and greenhouse gas emissions, although the health benefits of air pollution reduction were included in a study of the impact on walking of the provision of sidewalks (Guo and Gandavarapu 2010).

Summaries of studies that estimate the health value of cycling indicate large variations in health values, reflecting different study types, population groups, appraisal methods, and assumptions (Victoria Transport Policy Institute 2010; Nordic Council of Ministers 2005).

In summary, economic appraisals of the benefits and costs of cycling provision are limited, and few have included the multiple health benefits of cycling (ABW 2012). Nonetheless, the public health benefits of cycling are substantial and make the greatest contribution to overall cycling benefits. These findings indicate that BCAs of transportation infrastructure should routinely include health benefits. There are also indications that BCRs are greatest for cities with low levels of cycling where increases in cycling are easier to achieve than in cities that already have high rates of cycling (Interface for Cycling Expertise 2000).

Conclusions

Cycling has enormous potential to improve public health, particularly in cities and countries that currently have low levels of transportation cycling. Active transportation is consistently associated with meeting recommended levels of physical activity for health (Berrigan et al. 2006) and may flatten out the commonly seen socioeconomic gradient in leisure-time physical activity participation. The potential for active travel to be one of the key solutions to the problem of physical inactivity is well recognized (Shephard 2008) and deserves substantial advocacy and policy focus.

Reduced motor vehicle use also contributes to additional benefits in the form of improved air quality, lower noise levels, reduced greenhouse gas emissions, and improved community livability. When the multiple health and social benefits of a mode shift from private motor vehicle use to cycling are monetized, the economic argument for investing in increased cycling is powerful, with BCRs substantially higher than for investments in alternative forms of transportation infrastructure.

The goal of increased cycling rates in urban areas is achievable, with a number of both developed and developing countries successfully stalling or reversing unhealthy and unsustainable increases in single-occupant car travel for relatively short distances in urban areas. For clean, green, and healthy cities of the future, the road ahead is looking increasingly like a bicycle lane.

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