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# Exercise-based transportation reduces oil dependence, carbon emissions and obesity

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## SUMMARY

**Societal dependence on oil leads to increasingly negative social consequences throughout the world, including climate change, air pollution, political and economic instability, and habitat degradation. Reliance on the automobile for transportation also contributes to a sedentary lifestyle, an obesity epidemic and poor health. These problems are particularly pronounced in the USA, which currently consumes *c.* 27% of global oil production and produces *c.* 25% of global carbon emissions, and where *c.* 65% of adults are overweight or obese. Other countries throughout the world that replicate or hope to replicate the automobile-based lifestyle of the USA face similar problems now or in the near future. This paper develops and applies calculations relating the distances that could be travelled through recommended daily walking or cycling with weight loss, oil consumption and carbon emissions. These straightforward calculations demonstrate that widespread substitution of driving with distances travelled during recommended daily exercise could reduce the USA's oil consumption by up to 38%. This saving far exceeds the amount of oil recoverable from the Arctic National Wildlife Refuge, suggesting that exercise can reduce foreign oil dependence and provide an alternative to oil extraction from environmentally sensitive habitat. At the same time, an average individual who substitutes this amount of exercise for transportation would burn respectively *c.* 12.2 and 26.0 kg of fat per year for walking and cycling. This is sufficient to eliminate obese and overweight conditions in a few years without dangerous or draconian diet plans. Furthermore, a reduction in carbon dioxide emissions of *c.* 35% is possible if the revenue saved through decreased health care spending on obesity is redirected toward carbon abatement. As a result, exercise-based transportation may constitute a favourable alternative to the energy and diet plans that are currently being implemented in the USA and may offer better development choices for developing countries.**

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## INTRODUCTION

Use of the automobile for personal transportation confers considerable individual benefits, such as the ability to travel quickly, easily and independently over long distances. However, car travel also causes substantial societal costs in the form of air pollution, climate change, habitat degradation, political instability and economic insecurity. In addition, reliance on the automobile contributes to a sedentary lifestyle and resulting poor health (USDHHS [USA Department of Health and Human Services] 1996; NIH [USA National Institute of Health] 1998; Must *et al.* 1999; Sothern *et al.* 1999; Brown *et al.* 2000). Most notably, low rates of physical activity in the USA partly explain why *c.* 65% of Americans are obese or overweight (Flegal *et al.* 2002) because weight gain or loss is determined by the balance of energy intake (eating) and energy expenditure (exercise) (Pi-Sunyer 2003). The resulting health care expenditures are substantial with *c.* US$ 117 billion spent annually in the USA on health care for obesity and overweight alone (Colditz 1999; CDC [Centers for Disease Control and Prevention] 2003). Including other health care costs associated with physical inactivity leads to even higher estimates: *c.* US$ 28.7 billion annually for the state of California (Chenoweth 2005) and *c.* US$ 8.9 billion annually for the state of Michigan (Chenoweth *et al.* 2003).

Therefore, substitution of recommended daily exercise (Institutes of Medicine of the National Academies 2002), such as walking or cycling, for driving could improve health while reducing oil consumption and carbon dioxide emissions (Higgins & Higgins 2005). I demonstrate here that adopting previously recommended levels of daily exercise by substituting the distances covered during one hour of walking or cycling for car travel could help alleviate three of the most pressing problems that all countries currently face: oil dependence, climate change and health care. In the case of the USA, adoption of recommended exercise guidelines could save more oil than is contained in the Arctic National Wildlife Refuge (ANWR), reduce carbon emissions far below the reduction required by the Kyoto Protocol at no net cost and greatly improve the health of the citizens of the USA.

## METHODS

I determined the potential annual oil saved (barrels) and $CO_2$ emissions foregone (kg) if the population of the USA in the age range 10–74 years substituted recommended daily walking or cycling for car travel based on the following equations (adapted from Higgins & Higgins 2005).

$$\text{Oil saved} = \frac{G}{g_{bar}} \tag{1}$$

$$CO_2 \text{ not emitted} = G \times C_{gas} \tag{2}$$

Where $G$ is the gasoline saved (litres) by substituting exercise for driving, $g_{bar}$ is the average gasoline content of a barrel of oil (73.3 litres; EIA [Energy Information Administration] 2000*b*), and $C_{gas}$ is the $CO_2$ emitted by burning gasoline (2.34 kg $l^{-1}$).

$$G = \frac{D}{v_{eff}} \tag{3}$$

Where $D$ is the distance travelled during exercise and substituted for driving, and $v_{eff}$ is the average vehicle fuel efficiency (8.3 km $l^{-1}$; EIA 2001).

$$D = R_{ex} \times T_{ex} \times Y \times N \tag{4}$$

Where $R_{ex}$ is the rate of exercise (5 km $h^{-1}$ for walking and 20 km $h^{-1}$ cycling), $T_{ex}$ is the recommended daily exercise time, $Y$ is the number of days per year, and $N$ is the size of the USA's population aged 10–74 (225 095 836 people; US Census Bureau 2002). In these calculations I use the most recent recommendation, which is one hour of exercise per day (Institutes of Medicine of the National Academies 2002), but 30 minutes per day is also still recommended (Pate *et al.* 1995). Using the lower recommendation cuts reported values in half. For stepwise calculations and results see electronic addenda (supplement 1, URL http://nature.berkeley.edu/∼phiggins/supplement_EBT.htm).

Next I calculated the annual per person energy expenditure of exercise in joules ($E_{xp}$) and the resulting weight loss (kg) as follows:

$$E_{xp} = R_{ex} \times E_{ex} \times T_{ex} \times Y \tag{5}$$

$$\text{Weight loss} = \frac{E_{xp}}{E_{fat}} \tag{6}$$

Where $R_{ex}$ is the rate of exercise (5 km $h^{-1}$ for walking and 20 km $h^{-1}$ cycling), $T_{ex}$ is the recommended daily exercise time (1 h; Institutes of Medicine of the National Academies 2002), $Y$ is the number of days per year, $E_{ex}$ is the rate of energy expenditure of exercise (I used central estimates of 115 J $m^{-1}$ for cycling and 215 J $m^{-1}$ for walking; Ainsworth *et al.* 1998) and $E_{fat}$ is the energy content of fat (32290.0 kJ $kg^{-1}$).

Finally, I calculated the total cost of $CO_2$ emissions abatement by assuming a marginal cost of emissions abatement that increased linearly at a rate of US$ 50 per tonne per 5% emission reduction, and integrated the marginal cost function to calculate the total cost. This marginal cost function is at the upper end of marginal cost estimates for the USA throughout the range shown (Weyant & Hill 1999; Goulder & Nadreau 2002).

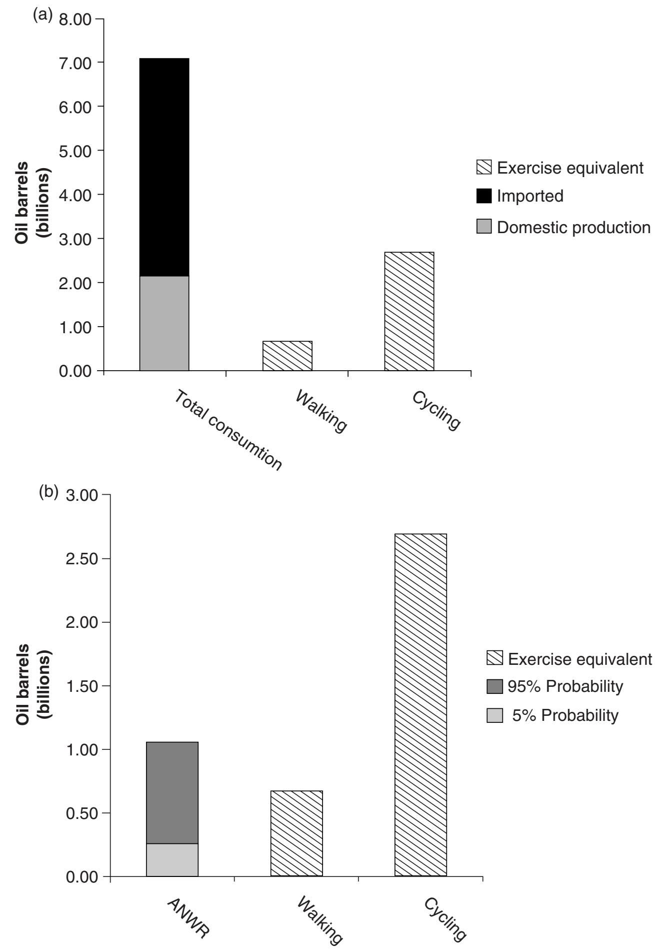


**Figure 1** Potential oil saved by substituting exercise for car travel relative to (*a*) total annual domestic oil consumption (EIA 2000*b*) and (*b*) upper and lower estimates (EIA 2000*a*) of peak annual oil production from the Arctic National Wildlife Refuge (ANWR).

## RESULTS

### Oil consumption and carbon emissions

The distances travelled if everyone in the USA aged 10–74 years cycled the recommended daily amount, would equal the distances driven using 38.0% of USA oil consumption and 126.4% of USA oil production (EIA 2000*b*) (Fig. 1*a*; Eq. 1). For comparison, the reduction in gasoline

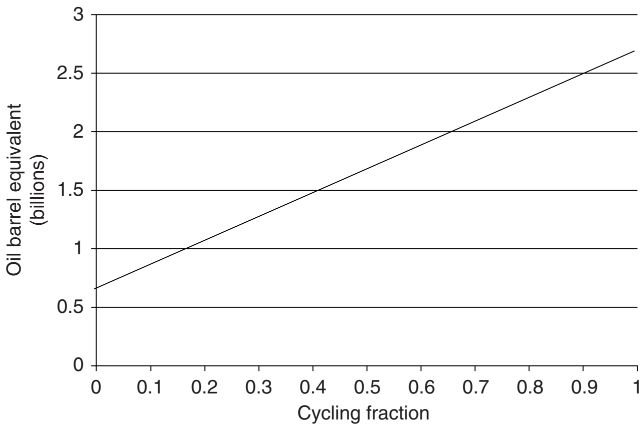


**Figure 2** Potential oil saved annually as a function of the relative contribution of walking and cycling as sources of physical activity. Cycling fraction is shown, but cycling and walking sum to 1.0.

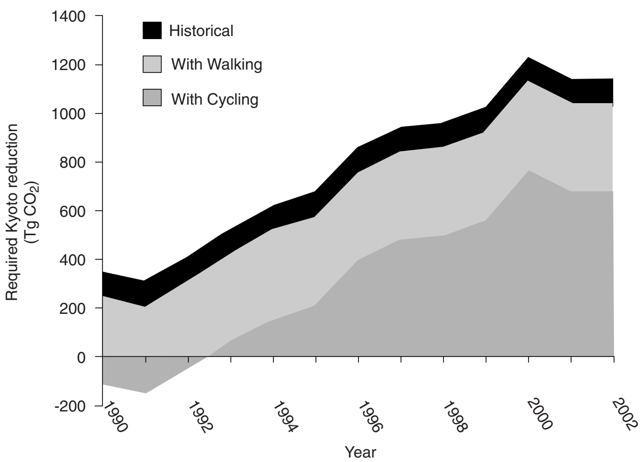


**Figure 3** USA's $CO_2$ emissions 1990–2002, relative to the USA's Kyoto target, historically and with potential walking or cycling distances substituted for driving. The 11.9% reduction with cycling initially exceeds that required by Kyoto. However, substantial emission increases have occurred since 1990.

demand from walking is approximately equivalent to the gasoline that could be produced from median estimates of peak oil production from the ANWR (EIA 2000*a*) (Fig. 1*b*). The reduction in gasoline demand from cycling far exceeds the gasoline that could be produced even from the upper estimates of peak oil production from ANWR (EIA 2000*a*) (Fig. 1*b*). Not surprisingly, the larger the fraction of exercise achieved through cycling, the greater the reduction in distances travelled by car and the larger the gasoline savings (Fig. 2).

The reduction in driving that could be possible with the substitution of exercise distances would also reduce $CO_2$ emissions. For example, the direct reduction in $CO_2$ emissions associated with substituting regular daily cycling for driving equals up to 11.9% of the USA's 1990 net emissions (EPA [US Environmental Protection Agency] 2002) (Eq. 2). This constitutes a substantial step toward satisfying the USA's target specified by the Kyoto Protocol (Fig. 3). However,

**Table 1** Annual per person energy expenditure (J) and weight loss (kg) with adoption of recommended daily exercise.

| *Exercise* | *Energy expenditure (J)* | *Potential weight loss (kg)* |
|---|---|---|
| Walking | $3.9 \times 10^8$ | 12.2 |
| Cycling | $8.4 \times 10^8$ | 26.0 |

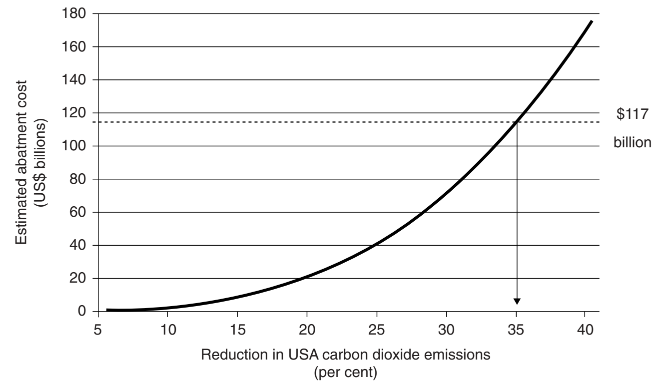


**Figure 4** Estimated cost of the USA's $CO_2$ emissions abatement. Approximately 35% of $CO_2$ emissions could be eliminated with the US$ 117 billion currently spent on heath care for obesity and overweight.

the reduction in $CO_2$ emissions possible due to walking is only a small fraction of that required by the Kyoto Protocol.

## Individual weight loss potential

Assuming constant food intake, the energy expenditure associated with walking or cycling is sufficient to burn *c*. 12.2 or 26.0 kg of fat per person annually, respectively (Table 1; Eq. 6). At this rate of weight loss obese and overweight conditions would be eliminated in a few years for all but the most extreme cases without reducing food intake or engaging in expensive or dangerous diet plans.

## Reduction in $CO_2$ emission from revenue recycling

Huge financial savings would accompany the health benefits associated with the adoption of exercise-based transportation as a result of a reduction in health care expenditures and productivity losses associated with poor health. How that money would be redirected is a complex question for society, policy makers and individuals. One illustrative option, however, would be to channel the savings toward dealing with the closely related and increasingly evident threat posed by climate change. I estimate that nearly 35% of $CO_2$ emissions could be eliminated if the US$ 117 billion spent annually on obesity and overweight (Colditz 1999; CDC 2003) were instead redirected toward further $CO_2$ abatement (Fig. 4). Thus, the substantial health care savings associated with the adoption of exercise-based transportation could allow significant progress on climate change at no net cost. Furthermore, this emissions abatement does not include the direct $CO_2$ emissions reduction from the substitution of exercise distances for driving, calculated earlier. Though the results from each calculation may overlap and therefore cannot be summed, they are also not completely redundant, suggesting that an even larger reduction in $CO_2$ emissions is possible or that a given emissions reduction could be achieved more cheaply.

## DISCUSSION

Recent research demonstrates that meeting projected future energy demand while also decarbonizing that energy supply will require massive investment in technology and research (Hoffert *et al.* 2002). An exclusive focus on supply, however, overlooks the potential to reduce demand without sacrificing the benefits of energy consumption. The rough calculations shown here, for example, demonstrate that exercise-based transportation has tremendous potential to reduce energy demand and carbon emissions, while conferring huge health benefits to individuals and society. Thus, widespread adoption of exercise may constitute an alternative to the energy policies currently being implemented by developed and developing countries alike. In particular, exercise-based transportation may constitute a substantial improvement over oil exploration.

The calculations presented here are highly simplified and incorporate assumptions that overestimate and, in some cases, underestimate factors that affect the substitutability of exercise for driving. For example, driving distances are unequally distributed throughout the population, whereas the distances calculated for walking and cycling assume an equal distribution and thereby complete substitutability of exercise distances. Under real world conditions, many individuals do not drive sufficiently far (or even at all), which makes the complete substitution of exercise distances impossible. Furthermore, the average vehicle in the USA is driven further than the distances that can be covered even by cycling (54.6 km $day^{-1}$), which implies a need for potentially cumbersome combinations of exercise with auto travel or other long-distance transport. Similarly, the average load factor for cars in the USA is 1.5 individuals (i.e., car trips are often taken with multiple occupants), which implies that only 0.67 of the exercise distances and gasoline savings could be substituted for current driving.

There are also significant barriers to the implementation of exercise-based transportation. Given the option to drive, humans are often reluctant to walk or cycle even short distances under ideal conditions. Poor health, disability, weather, time of travel and previously developed infrastructure all pose additional obstacles to the substitution of exercise for driving. Even relatively trivial obstacles such as the need for ready access to showers following exercise could limit widespread adoption over the short term. Similarly, factors such as genetics (Friedman 2003), culture, economics and politics (Nestle 2003) do predispose some individuals to obesity and overweight.

Although each of these factors suggests that real world conditions constrain the potential to substitute exercise for current driving patterns, those limitations depend critically on specific policy choices for promoting exercise-based transportation, the timescale over which those policies are implemented, and existing local, regional, or national infrastructural characteristics that create both impediments and opportunities alike. For example, existing development patterns, particularly in the USA, create substantial short-term obstacles to the widespread adoption of exercise as a means of transportation since most development patterns originally assumed the ubiquitous use of automobiles and the resulting potential for rapid, long-distance private transportation. A complete societal transition to exercise-based transportation, if possible, would require sufficiently long-term planning to remould existing infrastructure.

Alternatively, long-term urban planning could facilitate a transportation approach that combines public transportation with exercise. Such a combination could easily permit trips that exceed distances reasonably travelled through exercise alone and therefore amplify the calculated reductions in oil dependence and carbon emissions. For example, individuals could walk or bike to bus or train stops, and then take mass transit to within a short walk or bike of their final destination. Critically, the exercise component of these longer trips could improve the viability of public transportation by converting apparently inefficient and slow journeys to and from buses and trains into beneficial daily exercise. Viewed this way, even larger reductions in oil consumption and carbon emissions are possible when carefully combined with more comprehensive urban planning, transportation and health policy.

Given the ambiguity of long-term policy and planning, the calculations shown here do not account for all factors that may limit or amplify the potential gains of exercise-based transportation, but strive instead to be general and straightforward. While this makes some elements of the calculations described above somewhat unrealistic, this approach nevertheless constitutes a preliminary step to quantifying the potential benefits of exercise-based transportation to individuals and society through improved health, decreased energy dependence and climate protection. Perhaps more importantly, these calculations provide a template for future development choices by revealing the limits on the distances that can be regularly travelled using exercise as a primary source of transportation and demonstrating the vast personal and societal benefits that can be achieved by remaining within these limits. This is consistent with existing research that demonstrates how different urban planning approaches lead to more or less exercise and driving (Ewing *et al.* 2003), but goes further to demonstrate that wise planning can also greatly influence oil dependence and carbon emissions. Therefore, informed policy approaches that help overcome obstacles and encourage the widespread adoption of exercise-based transportation can contribute to major progress on complex social problems.

The relationships identified and explored here may provide even more valuable insights to countries still making preliminary choices about future development pathways. Those countries that emulate the USA's lifestyle and emphasize automobile-based transportation will face the same health and social problems discussed here. Development pathways that stress exercise-based transportation, however, can improve health and reduce future oil dependence, urban sprawl and the threat of climate change.

The ecological and environmental benefits of exercise-based transportation and the resulting reduction in oil consumption come in at least three forms. The first compelling benefit would be to ease the conflict between habitat conservation and energy consumption, which currently requires environmentally damaging and politically contentious proposals. In the USA, this conflict is most apparent with the proposal to extract oil from ANWR, which is widely viewed as exchanging oil production for habitat in one of the world's least disturbed areas. But this trade-off affects all countries or regions that produce oil. Shifts to exercise-based transportation also have the potential to reduce and discourage urban sprawl and the direct habitat damage that accompanies the diffuse living patterns established in the USA and being replicated throughout the world. Ecological systems and the environment would also benefit from the reduction in greenhouse gas emissions by helping to protect the climate system. Along with these direct environmental benefits, exercise-based transportation would reduce the dangers posed by the interactions between climate change and urban sprawl since factories, farms, roads and other buildings all impose migratory barriers on species that will have to move in order to adapt to climate change.

Finally, individuals seeking to lose weight can benefit from the knowledge that (1) integrating exercise into daily life can lead to substantial and rapid weight loss and (2) exercise can not only improve individual health but can also help solve several of today's most pressing and challenging social problems. Given the crushing burden of obesity on individuals and society, all potential sources of motivation need to be stressed.

## CONCLUSIONS

Simply walking or cycling to the extent recommended for a healthy lifestyle could drastically reduce current and future oil dependence and carbon emissions while simultaneously improving health. For the USA, widespread substitution of driving with distances travelled during recommended daily exercise could (1) save more oil than is contained in the ANWR, (2) reduce carbon emissions far below that required by the Kyoto Protocol at no net cost, and (3) greatly improve the health of the population by quickly eliminating obese and overweight conditions.

These conclusions directly contradict the widely-held views that (1) meeting current and future energy needs requires either extraction or technological development, (2) addressing the threat posed by climate change requires social and economic sacrifice, and (3) dieting constitutes the most effective weight-loss strategy. As a result, exercise-based transportation may constitute a favourable alternative to the energy and diet plans that are currently being implemented in developed countries like the USA and may offer better development choices for developing countries. Realizing the potential benefits explored here is likely to require the combined efforts of policy makers, urban planners, physicians and the general population, but oil dependence, climate change and physical inactivity constitute three of the most pressing problems currently faced by developed and developing countries alike.

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## References

Ainsworth, B.E., Haskell, W.L., Leon, A.S., Jacobs, D.R., Montoye, H.J., Sallis, J.F. & Paffenbarger Jr, R.S. (1998) Compendium of physical activities: classification of energy costs of human physical activities. In: *ACSM's Resource Manual for Guidelines for Exercise Testing and Prescription* (Third edition), ed. J.L. Roitman, M. Kelsey, T.P. LaFontaine, D.R. Southard, M.A. Williams & T. York, pp. 656–669. Baltimore, MD, USA: Williams & Wilkins.

Brown, C.D., Higgins, M., Donato, K.A., Rohde, F.C., Garrison, R., Obarzanek, E., Ernst, N.D. & Horan, M. (2000) Body mass index and the prevalence of hypertension and dyslipidemia. *Obesity Research* **8**(9): 605–619.

CDC (2003) *Physical Activity and Good Nutrition: Essential Elements to Prevent Chronic Diseases and Obesity 2003*. Washington, DC, USA: Department of Health and Human Services.

Chenoweth, D. (2005) The economic costs of physical inactivity, obesity, and overweight in California adults during the year 2000: a technical analysis. Cancer Prevention and Nutrition Section, California Department of Health Services, Sacramento, CA, USA.

Chenoweth, D., DeJong, G., Sheppard, L. & Lieber, M. (2003) The economic cost of physical inactivity in Michigan. Michigan Fitness Foundation, Michigan, USA.

Colditz, G.A. (1999) Economic costs of obesity and inactivity. *Medicine and Science in Sports and Exercise* **31** (11 Supplement): S663–S667.

EIA (2000*a*) Potential oil production from the coastal plain of the Arctic National Wildlife Refuge: updated assessment.United States Department of Energy, Office of Oil and Gas, Washington, DC, USA.

EIA (2000*b*) Petroleum supply annual 2000.United States Department of Energy, Office of Oil and Gas, Washington, DC, USA.

EIA (2001) Annual energy review 2000.US Department of Energy, Office of Energy Markets and End Use, Washington, DC, USA.

EPA (2002) Inventory of US greenhouse gas emissions and sinks: 1990–2000.United States Environmental Protection Agency, Washington, DC, USA.

Ewing, R., Schmid, T., Killingsworth, R., Zlot, A. & Raudenbush, S. (2003) Relationship between urban sprawl and physical activity, obesity, and morbidity. *American Journal of Health Promotion* **18**(1): 47–57.

Flegal, K.M., Carroll, M.D., Ogden, C. L. & Johnson, C.L. (2002) Prevalence and trends in obesity among US adults, 1999–2000. *Jama* **288**(14): 1723–1727.

Friedman, J. (2003) A war on obesity, not the obese. *Science* **299**(5608): 856–858.

Goulder, L.H. & Nadreau, B.M. (2002) International approaches to reducing greenhouse gas emissions. In: *Climate Change Policy*, ed. S.H. Schneider, A. Rosencranz & J.O. Niles, pp. 115–149. Washington, DC, USA: Island Press.

Higgins, P.A.T. & Higgins, M. (2005) A healthy reduction in oil consumption and carbon emissions. *Energy Policy* **33**(1): 1–4.

Hoffert, M., Caldeira, K., Benford, G., Criswell, D., Green, C., Herzog, H., Jain, A., Kheshgi, H., Lackner, K., Lewis, J., Lightfoot, H., Manheimer, W., Mankins, J., Mauel, M., Perkins, L., Schlesinger, M., Volk, T. & Wigley, T. (2002) Advanced technology paths to global climate stability: energy for a greenhouse planet. *Science* **298**(5595): 981–987.

Institutes of Medicine of the National Academies (2002) *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids.* Washington, DC, USA: The National Academies Press.

Must, A., Spadano, J., Coakley, E.H., Field, A.E., Colditz, G. & Dietz, W.H. (1999) The disease burden associated with overweight and obesity. *Jama* **27**(282): 1523–1529.

Nestle, M. (2003) The ironic politics of obesity. *Science* **299**(5608): 781.

NIH (1998) Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults.National Heart Lung and Blood Institute, Bethesda, MD, USA.

Pate, R., Pratt, M., Blair, S., Haskell, W.L., Macera, C., Bouchard, C., Buchner, D., Ettinger, W., Heath, G. & King, A.C. (1995) Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *Jama* **273**(5): 402–407.

Pi-Sunyer, X. (2003) A clinical view of the obesity problem. *Science* **299**(5608): 859–860.

Sothern, M.S., Loftin, M., Suskind, R.M., Udall, J.N. & Blecker, U. (1999) The health benefits of physical activity in children and adolescents: implications for chronic disease prevention. *European Journal of Pediatrics* **158**(4): 271–274.

US Census Bureau (2002) United States Census 2000. US Department of Commerce Economics and Statistics Administration, Washington, DC, USA.

USDHHS (1996) Physical activity and health: a report of the Surgeon General. US Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Atlanta, GA, USA.

Weyant, J.P. & Hill, J.N. (1999) Introduction and overview. *The Energy Journal* **20**: 1–24.