ORIGINAL RESEARCH

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The Physical Activity Transition

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Physical activity is important for the prevention of chronic disease morbidity and mortality, and the lack of adequate levels of physical activity represents a growing public health burden around the world. The purpose of this report is to introduce the concept of the "Physical Activity Transition" and to explore the potential effects that declining physical activity levels may play on health and life expectancy as countries undergo economic and demographic changes. Physical activity is related to mortality rates in humans, and the available evidence suggests that the adoption of a lifestyle characterized by lower levels of physical activity will attenuate the expected gains in life expectancy associated with the epidemiological transition. Advances in the measurement of physical activity at work, in the home, for transport, and in leisure time in a wide variety of populations will be integral to advancing the current understanding of how macro-level factors shape physical activity patterns and patterns of morbidity and mortality.

Keywords: nutrition transition, developing countries, life expectancy, mortality rates, urbanization, exercise

Background

The role of physical activity as a health-protective behavior has become more clearly defined in recent years. Individuals who do not attain sufficient levels of physical activity have an increased risk of developing several chronic degenerative diseases as well as premature mortality. Recent estimates from the World Health Organization indicate that 41% of the world's population is insufficiently physically active, and 1.9 million deaths are attributable to physical inactivity annually.[1] These assertions are supported by data that suggest that approximately 60% of mortality (35 million deaths in 2005) worldwide is now from chronic or noncommunicable disease, and 1 billion people are either overweight or obese[2].

Chronic physical inactivity is now manifest in many developed countries. Recent data from the United States indicate that 23% of adults participate in no regular physical activity at all.[3] Further, more direct estimates of physical activity levels based on data from accelerometers indicate that less than 5% of Americans are meeting the current physical activity recommendations of 30 minutes per day, five days a week.[4] Although these data suggest that physical activity levels are currently quite low in the United States, there is very little information available on long-term trends, as robust measures of physical activity have typically not been included in long-term population health surveillance programs.

The epidemiological transition is a model that has been developed to explain long-term shifts in population mortality rates that are tied to economic and demographic changes.[5,6] Within this context, the theory of nutrition transition seeks to explain how changes related to lifestyle, particularly diet, have occurred in parallel with the increasing prevalence of obesity and chronic disease.[7–10] Changes in nutritional patterns have been widely studied within the context of the escalating levels of obesity and chronic disease in countries undergoing rapid economic development; however, the role of shifts in physical activity patterns has been less explored. Thus, the purpose of this report is to introduce the concept of the "Physical Activity Transition" and to explore the potential effects that shifting physical activity levels may play on health and life expectancy in countries experiencing rapid economic development.

The Epidemiological Transition

The epidemiologic transition is described in terms of four stages or ages: (1) pestilence and famine, (2) receding pandemics, (3) degenerative and man-made

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diseases, and (4) delayed degenerative diseases. The age of pestilence and famine is characterized by large swings in mortality rates that follow infectious disease epidemics and famine conditions. Countries in this stage have high mortality rates and low life expectancy. The age of receding pandemics is characterized by increases in life expectancy, largely due to lower mortality rates at young ages. The progression through the age of receding pandemics in many countries has been brought about largely by targeting the spread of infectious disease through improvements in sanitation and public health and by stabilization of the food supply through improvements in agriculture and trade agreements with other regions. The age of degenerative and man-made diseases is characterized by increases in life expectancy brought about by shifting the mortality burden to older ages as cardiovascular disease and cancer become increasingly prevalent in the population. Further increases in life expectancy achieved during the final stage of epidemiological transition, the age of delayed degenerative diseases, are predominantly brought about by improvements in health at older ages, mainly through improved prevention and the treatment of chronic diseases.

Countries around the world are currently experiencing different stages of the epidemiological transition. Some low-income countries (predominantly in Sub-Saharan Africa and regions affected by long-term warfare) remain in the age of pestilence and famine as they fight to control the spread of infectious disease and develop a stable food supply. However, many developing countries would be considered to be in the stage of receding pandemics or that of degenerative and man-made diseases. On the other hand, many Westernized countries such as Canada, the United States, and Switzerland, have progressed into the stage of delayed degenerative diseases as their public health systems focus on combating major chronic disease risk factors.

While the progression through the stages of the epidemiological transition has occurred relatively gradually throughout the 19th and 20th centuries in many European countries, it is now becoming apparent that an accelerated rate of economic, industrial, and social change in many developing countries is contributing a "dual burden of disease" as populations face simultaneously high rates of under-nutrition and infectious disease as well as obesity and chronic disease.[11,12] For example, many developing countries have significant rates of childhood overweight while at the same time they have high rates of wasting (weight-for-height < -2 SD of NCHS/WHO reference) in children.[13]

The Nutrition Transition: Understanding the Role of Lifestyle-related Risk Factors

Within the broader context of the epidemiological transition, the theory of nutrition transition seeks to describe how changes related to lifestyle, particularly diet, have occurred in tandem with the rising global prevalence of overweight and obesity and are contributing to shifting morbidity and mortality profiles around the world.[7–10] Generally speaking, the nutrition transition is characterized by a shift away from traditional diets (based on indigenous staple grains, local legumes, fruits and vegetables, and limited foods of animal origin) in favor of a more "industrialized" diet (comprised of more animal-based food products and processed food high in saturated fats and sugar). The five patterns of the nutrition transition have been characterized as (1) collection of food, (2) famine, (3) receding famine, (4) degenerative disease, and (5) behavioral change.[7,8] The focus of the nutrition transition model is on the energy intake side of the energy balance equation,[7] and in many research reports describing the nutrition transition, physical activity patterns are considered as a contributing factor in shifting health patterns;[10,14] however, until recently, there have been limited attempts to study physical activity patterns or trends within the context of the epidemiologic transition.[15,16]

The Physical Activity Transition

In a similar way that changing dietary patterns are thought to be contributing to the rise in obesity and chronic disease worldwide, shifting patterns of physical activity may also be an important contributor. Over time there has been a major change in the role that physical activity has played in relation to survival.[17] For the majority of our evolutionary history, humans and earlier hominids lived a hunter-gatherer existence, while recent advances in agriculture and technology have occurred over a comparatively short time frame (~10,000 y), drastically changing our energy balance profiles.[18] Specifically, under primitive hunter-gatherer and early subsistence agricultural conditions, the primary motives to be physically active included acquiring food, water and shelter, escaping predation, and procreation. Over time, our reliance on physical activity to fulfill these requirements has decreased substantially. Indeed, in developed countries we have nearly engineered the need for physical activity completely out of our everyday lives. In today's Western society, the reasons why humans might choose to be physically active include enjoyment (through active leisure time pursuits), occupational and domestic burdens (although taxing demands continue to diminish), maintenance of body weight, and the prevention of chronic disease. Thus, for the majority of our existence as hominids, the focus has been on *maintaining* the energy intake side of the energy balance equation to sustain sufficient physical activity for living, while more recently the physical activity engaged in is used in an increasingly feeble attempt to *offset* the energy intake side of the equation.

Acquiring sufficient energy for survival at the lowest possible energetic cost has been a powerful selective force throughout the evolutionary history of hominids.[18] In a hunter-gatherer or subsistence-level lifestyle, this is an important adaptive trait. Perhaps we

have reached a peak of energetic efficiency with modern Western society—it is very easy to obtain an abundance of calories from food with an extremely low physical effort! Within this context, the low levels of physical activity that are observed in many societies today can be considered a normal response to millions of years of evolution.

With this background, we assert that the currently observed low physical activity levels are counteracting the gains in life expectancy that might occur in the later stages of the epidemiological transition.[5,6] To support this assertion, we will provide evidence that 1) physical activity levels influence mortality rates and life expectancy in humans, and 2) physical activity levels of humans have declined over time.

Physical Activity and Mortality Rates

The notion that physical activity is important for maintaining health has its roots in antiquity, as physicians from Asia and Europe have recognized the importance of physical activity from as long ago as 3000 to 2500 BC.[19,20] The French physician, Dr. Nicholas Andry, understood the health benefits of physical activity very well, as he described in a thesis he first defended before the College of Physicians in 1723:[21]

> Exercise is more effectual than medicines for the preservation of health: It is delightful and pleasing, more certain in its effects, and does more immediate service both to the solids and fluids; whereas medicines are unpleasant, and more doubtful consequences, for the most part exert their force entirely upon the fluids; and, before they can reach the blood, are so changed, that in great measure they lose their virtues. p. 213.

It is generally acknowledged that the modern field of physical activity epidemiology began with the early work of Dr. Jeremy Morris from the United Kingdom whose work in the middle of the last century among employees of the London Transit Executive and among postal workers demonstrated that men in more sedentary occupations such as bus drivers and civil servants had higher mortality rates from coronary heart disease than the more active bus conductors and postal carriers, respectively.[22] In the intervening years an impressive body of literature has amassed documenting the relationship between physical activity and health. This evidence has been summarized in several consensus documents and texts,[23–25] and was the topic of the U.S. Surgeon General's report in 1996.[26]

Given that a physically active lifestyle lowers the risk of several medical conditions, it is not surprising that physically active individuals have a lower risk of premature mortality.[27] Several studies have documented lower mortality rates among physically active individuals, and there is also evidence for an inverse dose-response relationship between physical activity levels and mortality rates. The classic studies of Dr. Ralph Paffenbarger and colleagues using cohorts of college alumni illustrate the relationship between physical activity and mortality quite clearly. Figure 1 (Panel A) presents the all-cause mortality rates (per 10,000 man years of follow-up) across successively higher levels of physical activity in men from the Harvard Alumni Study, followed for 12 to 16 years.[28] There is a clear dose-response relationship ($P < .0001$) between physical activity level and mortality rates in these men. Further, men who expended less than 2000 kcal/week in walking, climbing stairs, and playing sports had a 31% elevated risk of death from all causes compared with men who expended more than 2000 kcal/week.[28]

In addition to the studies of physical activity and mortality, there is evidence that poor physical fitness is also associated with premature mortality. Figure 1 (Panel B) demonstrates the relationship between cardiorespiratory fitness level and all-cause mortality in men and women from the Aerobics Center Longitudinal Study.[29] There is a strong dose-response relationship between cardiorespiratory fitness and all-cause mortality rates in both men and women. Men and women in the least fit quintile of cardiorespiratory fitness had 244% and 365% higher risks of all-cause mortality than men and women in the most fit quintile, respectively.[29] Subsequent studies from this cohort have since indicated that the relationship between physical fitness and mortality rates is robust, and is independent of obesity,[30] diabetes,[31] hypertension[32] or metabolic syndrome.[33]

Physical Activity and Life Expectancy

Life expectancy is a statistic that applies to populations rather than to individuals. It is an estimate of how long a person can expect to live, based on characteristics of the population to which they belong. Thus, estimates of life expectancy are population specific, and changes in life expectancy can occur through changes in overall mortality rates in a population over time as well as shifts in relative mortality rates in particular age groups within the population. Life expectancy at birth in the United States was 77.8 years in 2004, which is a dramatic increase from 49.2 years in 1900 to 1902.[34] Noncommunicable (chronic) diseases are now a major contributor to human mortality worldwide.[2] Indeed, type 2 diabetes, cardiovascular disease, and cancer currently account for two thirds of all deaths in the United States alone.[35] Given the mortality burden associated with chronic disease, it follows that changes in the incidence and prevalence of common chronic disease risk factors across the lifespan have the potential to influence estimates of population life expectancy. For example, if all people in Canada stopped smoking completely, it would translate into gains in population life expectancy at the age of 45 years of 2.6 years in men and 3.1 years in women.[36] Similarly, it has been estimated that if obesity was eliminated, the potential gains in life expectancy at birth in the United States would be between 0.21 to 1.08 years, depending on sex and ethnicity.[37]

There are few data on the effects of physical activity on population-level estimates of life expectancy. One study in the Canadian population estimated that physical

Figure 1 — All-cause mortality rates A) across levels of physical activity in 16,936 Harvard Alumni, followed for 12 to 16 years, and B) across levels of cardiorespiratory fitness in 10,224 men and 3,120 women followed for 8 years. Figure constructed from data presented in references.[28,29]

inactivity was accounting for 0.86 years of life expectancy at birth.[38] Unfortunately there are no data available on the effects of physical activity on population estimates of life expectancy in other countries for comparison.

Although limited, data from some longitudinal cohort studies also provide evidence that physical activity increases longevity. For example, results from the Harvard Alumni Study, in which 16,936 men 35 to 79 years of age were followed for mortality up to the age of 80 years between 1962 and 1978, indicated that physically active men (expending ≥ 2000 kcal/week) lived an average of 2.2 years longer than physically inactive men (expending < 500 kcal/week; 28). Further, a study of Finnish middle-aged men followed for 20 years also estimated that the survival advantage of physically active men was 2.1 years by comparison with physically inactive men in the cohort, after adjustment for age, smoking status, systolic blood pressure, serum cholesterol, and body mass index.[39] A study of elderly U.S. men and women found that physical activity was related to life expectancy at age 65 years in both smokers and

nonsmokers.[40] Among never-smokers, moderately active and highly active individuals had higher life expectancy by 3.3 years and 5.1 years in men and 3.5 years and 5.7 years in women than those who were physically inactive, respectively.[40]

It should be noted that there is a difference between estimating the difference in years of life expectancy between active and inactive participants in cohort studies and estimating the effects of physical activity on a population-level estimate of life expectancy. By design, the impact on population life expectancy is expected to be much smaller, as there are a finite number of people in the population who would be classified as physically active; thus, the population prevalence of physical activity plays an important role in the estimate.

The weighted evidence suggests that physical activity impacts mortality rates among humans. Maintaining moderate levels of physical activity and aerobic fitness provide a protective effect against premature mortality in both men and women. This translates into greater longevity among physically active people, which implies that increasing physical activity levels in the population will have a positive influence on estimates of life expectancy.

Temporal Trends in Physical Activity Levels

The broad-based demographic and socioeconomic forces linked to changes in fertility, morbidity, and mortality patterns characteristic of the epidemiological transition are similarly related to important changes in physical activity and in body composition. Throughout the 20th century, rapid technological advancement has occurred hand in hand with widespread urbanization, the rise of more service-based economies, significant changes to traditional food and transportation systems, and new opportunities for sedentary leisure pursuits (eg, television and other electronic media).

Given that objective measures of physical activity have only recently been developed and that surveillance data are not available for any country over long-term periods of time, it is virtually impossible to reconstruct reliable long-term trends, let alone derive empirically based estimates of how the energy expenditure of populations has changed over the course of agrarian, industrial, and technological revolutions. Consequently, long term changes in physical activity levels must be inferred from a variety of sources. In one example of a comparative study across species, Hayes and colleagues[41] compared physical activity levels among samples of humans to the mean of all free-ranging mammals. The average PAL (total energy expenditure / resting energy expenditure) of the free-ranging mammals was 3.1, compared with 1.67 in humans living in modern society.[41] The results provide support to the hypothesis that modern humans living in advanced settings have much lower levels of physical activity than we likely had in the distant past when we were also theoretically governed by similar needs and demands as other mammals.

Comparisons limited to much more recent periods of our evolutionary history have highlighted differences in physical activity patterns associated with acculturation toward a postindustrial, technologically-dependent 'Western' lifestyle in several populations. Much can be learned by studying groups that live a less than "modern" existence and from populations currently undergoing rapid lifestyle transitions. For example, Bassett et al[42,43] used pedometers to assess physical activity in a Canadian Old-Order Amish community, where residents abstain from the use of gasoline-powered transportation, electricity, and other modern conveniences. In this population, traditional labor-intensive farming has remained the principal occupation among men, while women are primarily responsible for child-care, food preparation, cooking, and cleaning. Figure 2 compares the step counts obtained in the Amish men, women, boys and girls to samples from contemporary Western populations (specifically from Canada, Colorado and South Carolina). First, it is clear that in all four sex-by age groups the Amish accumulate more steps each day than people living in contemporary society. Second, it is interesting that the age-related declines in physical activity levels that are often observed in modern populations with the transition from childhood to adulthood are not evident in the Amish population. Furthermore, in direct contrast to the high prevalence of obesity observed among the general Canadian adult population, no Amish men and 9% of Amish women were classified as obese based on a BMI ≥ 30 kg/m^2.[42]

In another cross-sectional comparison, Snodgrass et al[44] used doubly labeled water to examine the influence of subsistence activities (ie, tending domesticated animals, cutting hay, hunting, fishing, etc.) and material quality of life (ownership of various consumer goods and livestock) on energetic parameters in an indigenous Siberian population in transition to a more Western lifestyle. In this sample, total energy expenditure (TEE) adjusted for body mass was significantly correlated with both the degree of participation in subsistence activities and the possession of material goods, such that more traditionally living people had higher energy expenditures than those living a more modern lifestyle.

Decreased aerobic fitness and other health-related fitness parameters have been well documented in a northern Canadian Inuit community during a short period of rapid acculturation to an increasingly sedentary lifestyle. In a study published in 1971, there was already a cross-sectional association between the degree of participation in hunting activities and maximal aerobic capacity (Figure 3; 45). While the traditional hunting, trapping and fishing activities of the Igloolik community demanded a large daily energy expenditure and were associated with high levels of aerobic fitness and muscle strength as well as with low body fatness, a marked deterioration in aerobic fitness and muscular

Figure 2 — Number of steps/day from pedometer counts among A) Amish and Canadian boys and girls, and B) Amish men and women compared with U.S. adults in Colorado and South Carolina. Data for Old-Order Amish from Bassett et al;[42,43] Canadian children from the national CANPLAY study;[82] Colorado adults from Wyatt et al;[83] South Carolina adults from Tudor-Locke et al.[84]

strength, and a concomitant increase in average fatness, were measured over a 20-y period during which summer fishing camps and winter Igloos were abandoned in favor of permanent homes with indoor plumbing and sanitation, hunting excursions by dog-sled or kayak were replaced by snowmobiles or powerboat, and new power-equipment was imported to carry out routine daily tasks.[46,47]

Few studies have used longitudinal samples of the same individuals to study changes in physical activity over time. One study using a population-based cohort of Swedish men (n = 33,466) reported that irrespective of age, both total daily physical activity and occupational physical activity decreased significantly over the last 60 years.[48]

In addition to the studies described above, several attempts have been made to study changes in leisure-time physical activity at the population level in select countries. The results of these studies generally show a slight increase in leisure-time physical activity levels over time.[49–53] Two things that these studies have in common is that they all relied on a self-reported measure of physical activity, and they all measured an aspect of *leisure-time* physical activity levels only. The use of self-reported questionnaires, although practical for assessing physical activity in populations, may lack the sensitivity to capture small changes in energy expended in light to moderate activities since these are recalled less accurately and reliably than heavy-intensity activity.[54] Thus, it is difficult to infer changes in total daily physical activity levels or changes in total daily energy expenditure from these studies.

The use of more objective measures such as doubly labeled water can only feasibly be carried out in small

Figure 3 — Cardiorespiratory fitness levels among Igloolik Eskimos living a traditional hunting lifestyle, those that live an intermediate pattern, and those that have adopted an urban lifestyle. Error bars represent 1 standard deviation. Data from Rode and Shephard.[45]

samples, limiting the generalizability of the results. However, we have begun to see the use of objective physical activity monitors such as accelerometers being used in national surveys such as the U.S. National Health and Nutrition Examination Survey[4] and the Canadian Health Measures Survey.[55] These devices have the potential to provide useful information on future trends in physical activity. Further studies are needed to quantify temporal changes in total, leisure-time and occupational physical activity levels using objective measurements and robust sampling designs.[56]

Physical Activity and the Changing Global Demography

Globally, the changing spatial distribution of populations appears to be one of the most far-reaching shifts in population demographics impacting physical activity patterns and the rise in chronic disease. In 2007, the world's urban population was 3.3 billion, compared with only 1.5 billion in 1975 and 0.7 billion in 1950.[57] In 2008, for the first time in human history, more of the world's population lives in urban areas than rural ones, and it is projected that rapid urbanization will continue through the coming decades.[57] Increasing urbanization is closely associated with greater mechanization and a host of socioeconomic changes that influence labor demands, transportation choices, and food systems. Indeed, a variety of urban-rural comparisons have documented significant differences in physical activity patterns and related health outcomes,[58–64] and comparisons from regions where rural life is still predominantly characterized by small-scale farming practices and the limited use of motorized transportation are particularly informative in this regard.

In Cameroon, a country in the relatively early stages of epidemiological and nutrition transition, the difference in total energy expenditure between urban- and rural-dwelling adults was estimated to be approximately 300 to 600 kJ/day.[65] The disparity in energy expenditure was attributed to differences in both time spent and intensity in all domains of physical activity (ie, work, household, transport, leisure). Urban subjects spent less time walking at a brisk pace than their rural counterparts (urban: 2 to 17 min/day; rural: 29 to 54 min/day) and were less likely to report intense occupational activity (2.7% vs 79.6%) than their rural counterparts. Urban-dwellers reported nearly twice as much time engaged in leisure activities; however, the majority was spent in sedentary activities. These geographic differences in physical activity among Cameroonians were associated with significant variation in the prevalence of obesity, type 2 diabetes, and cardiovascular risk such that there was a 5-fold gradient in obesity and 1.5 to 2 times more diabetes and hypertension in urban compared with rural dwelling adults.[65]

Even more pronounced differences in energy expenditure were recently documented in a comparison of the Masai people to rural and urban dwelling-Bantu populations in Tanzania.[66] The Masai are seminomadic pastoralists who have low BMIs and favorable blood lipid profiles despite a staple diet high in animal fat. In contrast, urban Bantu exhibit a high prevalence of obesity and levels of blood pressure and blood lipids comparable to many Western societies. A striking gradient

in physical activity was observed across the three groups. The mean daily activity energy expenditure of the Masai was 2565 kcal (45.2 kcal/kg/day), compared with 1500 kcal (24.65 kcal/kg/day) among rural Bantu and 891 kcal (16.5 kcal/kg/day) among urban Bantu. The authors point out that the reported physical activity accounting for the high energy expenditures, particularly in Masai and rural regions, were work and transportation-related, rather than for leisure. In the absence of regular public transportation, bicycles and walking are common physical activities. Elsewhere it has been estimated that physically inactive Westerners would have to walk at least an additional 19 km per day to expend an equivalent amount of energy as the Masai.[67]

A climb in motor vehicle ownership associated with economic growth and rising per capita income has been well documented in populations around the world.[68] A limited number of cross-sectional comparisons provide good evidence that the human energy cost of transportation is reduced dramatically when motorized transport is more readily available owed largely to less time spent walking.[65,69,70] Even in developed countries where car ownership appears to be reaching a plateau due to market saturation, decreases in transportation-related activity have been reported over time. For example, in a Spanish sample, the percentage of the population who walked to work at least 30 minutes decreased from 19% to 16% in men and 25% to 19% in women during the 10 year period between 1992–1993 and 2002–2003.[71] Similarly, small declines in walking and cycling to work were reported in the Australian population between 1996 and 2001.[72] Moreover, these trends are not limited to adults. It was recently reported that the percentage of American children who walked or biked to school decreased from 42% in 1969 to only 16.2% in 2001.[73]

A shift in occupational structure favoring large-scale manufacturing and service-based industries, and a gradual increase in the availability of time for leisure pursuits typically accompany urbanization and the adoption of mechanized technology. The implications of this for population levels of physical activity are particularly vivid in China. Recently, Monda et al[16] used multilevel modeling to examine the effect of urbanization on occupational physical activity in China, where the proportion of persons engaged in agriculture, fishing, and forestry work has steadily decreased since the 1950s and the proportions of persons earning wages from industry and service-based occupations have increased 15.1 and 18.4%, respectively.[74] After controlling for individual-level sociodemographic factors, the degree of community-level urbanization was positively associated with levels of light occupational physical activity. For each unit increase in urbanization, men had a 7% and women had a 6% higher odds of engaging in light occupational activity.[16] Based on self-reported physical activity in population surveys, it has been estimated that the average energy expenditure from occupational sources declined 22 and 24% in Chinese men and women, respectively, over the 9 year period between 1991 to 2000.[75] Meanwhile, a notable rightward shift in the distribution of BMI among Chinese adults has occurred[74] and 71 million Chinese adults now meet metabolic syndrome criteria,[76] foreshadowing further increases in cardiovascular morbidity and mortality in the world's most populous country.

A more objective estimate of the magnitude of difference in energy requirements for Chinese adults engaged in varying types of occupational activity has been attempted using doubly-labeled water.[77] In a sample of men and women 35 to 49 y of age, the average PAL of individuals performing heavy physical activity at work was 2.04 by comparison with 1.72 and 1.61 for individuals performing moderate and light occupational activity, respectively. In this study, examples of heavy physical activity occupations included steel factory workers, dancers and textile factory workers, moderate occupations included students, electricians and truck drivers, and light occupations included secretaries, teachers, and laboratory technicians. These results suggest that changes in occupational physical activity demands over time may portend the loss of a critical source of energy expenditure for populations in developing countries, such as China, where participation in sport and other forms of active recreation are often even less prevalent than in developed countries and where available leisure-time is heavily devoted to popular sedentary pursuits, namely TV viewing.[78,79] In fact, while TV ownership in Chinese households reportedly rose from 88.2% to 96.4% of urban households and 52.5% to 89.0% of rural households between 1989 and 2000,[74] reports of regular leisure-time physical activity are low, ranging from 2% to 24.5%.[79–81]

The process of urbanization appears to be characterized predominantly by 1) a decrease in the intensity of occupational and domestic activity, and 2) the replacement of walking for personal transportation with mechanized modes. Increased personal efficiency is rewarded with greater time availability for leisure, which is, owing to the popularity of a wide and growing array of electronic media, heavily devoted to sedentary pursuits. Marginal increases in leisure-time physical activity levels are likely not sufficient to offset the decreases in energy expenditure associated with fewer requirements for engaging in more vigorous activities of daily living.

A Model of Physical Activity Transition

Figure 4 presents a model that describes the upstream (contributing factors) and the downstream effects (health consequences) associated with the physical activity transition. The forces of economic transition and urbanization lead to wide-scale changes in the built environment and social climate that lead to reductions in physical activity and thus daily energy expenditure in large segments of the population. These reductions in energy

Figure 4 — Model of contributing factors and health outcomes associated with the physical activity transition.

expenditure are largely the result of lower occupational and domestic requirements, diminishing occasions for active transportation, and the domination of available leisure time by sedentary pursuits. The resulting reallocated patterns and levels of physical activity generate a milieu conducive for positive energy balance (ie, weight gain). Practiced by a population, these behaviors manifest themselves as a public health concern by leading to increased rates of chronic diseases and ultimately in higher overall mortality rates and lower life expectancy.

Summary

Overall, socioeconomic and demographic changes occurring in concert with the epidemiological transition appear to be associated with the adoption of a lifestyle characterized by lower energy requirements at work and for the procurement of food, less dependence on walking as a primary means of transportation, and the popularity of sedentary activities to fill a growing availability of leisure time no longer needed to carry out activities related to securing food and shelter.

The limited availability of physical activity and/or energy expenditure data and significant methodological differences in data collection make direct comparisons between populations and within populations over time very difficult. Based on existing data, it is impossible to make definitive conclusions regarding the magnitude of change in activity-related energy expenditure throughout the physical activity transition; rather conditions specific to individual countries and cultures play an important role. This is an area where considerably more work is needed. Measures of activity performed at work, in the home, for transport, and in leisure time in a wide variety of social, economic, and environmental contexts will be integral to advancing our current understanding of how macro-level factors shape physical activity patterns and the true contribution of decreasing energy expenditure to shifting patterns of morbidity and mortality.

Nevertheless, there is good evidence that the implications of low or declining physical activity levels for health are universal. A growing body of data provides compelling evidence that physical inactivity is associated with chronic disease morbidity and mortality, and that high rates of physical inactivity have the potential to attenuate future gains in life expectancy associated with the epidemiological transition. The sizeable gains in life expectancy that should be anticipated by addressing infectious disease and malnutrition in developing

countries may be attenuated in the face of rising obesity and other hypokinetic diseases associated with rapid acculturation to sedentary living.

Over the next few decades, the majority of the world's population growth is projected to occur in the urban areas of Asia and Africa.[57] Not coincidentally, the costs associated with chronic diseases are also projected to be the greatest in these regions. Yet, as developing countries continue to experience rapid changes in urban environments, technological advancement, industrialization, and material prosperity, unique opportunities to apply lessons learned in Western countries hold potential to make a significant contribution to lessening the burden of disease in these regions.

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