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Why have physical activity levels declined among Chinese adults? Findings from the 1991–2006 China health and nutrition surveys

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ABSTRACT

Between 1991 and 2006, average weekly physical activity among adults in China fell by 32%. This paper discusses why total and occupational physical activity levels have fallen, and models the association between the rapid decline and various dimensions of exogenous community urbanization. We hypothesize that a) physical activity levels are negatively associated with urbanization; b) urbanization domains that affect job functions and opportunities will contribute most to changes in physical activity levels; and c) these urbanization domains will be more strongly associated for men than for women because home activities account for a larger proportion of physical activity for women. To test these hypotheses, we used longitudinal data from individuals aged 18–55 in the 1991–2006 China Health and Nutrition Surveys. We find that physical activity declines were strongly associated with greater availability of higher educational institutions, housing infrastructure, sanitation improvements and the economic wellbeing of the community in which people function. These urbanization factors predict more than four-fifths of the decline in occupational physical activity over the 1991–2006 period for men and nearly two-thirds of the decline for women. They are also associated with 57% of the decline in total physical activity for men and 40% of the decline for women. Intervention strategies to promote physical activity in the workplace, at home, for transit and via exercise should be considered a major health priority in China.

Introduction

As countries develop, they experience a reduction in mortality and morbidity due to infectious diseases. Concurrently, the prevalence of chronic non-communicable diseases and associated risks has risen rapidly. This has generally been referred to as the epidemiological transition (Omran, 1971). Burden of disease studies have found a marked increase in the proportion of deaths due to non-communicable disease, mainly cardiovascular diseases and cancers (Lopez, Mathers, Ezzati, Jamison, & Murray, 2006). These diseases are strongly associated with being overweight and obese (Reddy & Katan, 2004) and are now rising in developing countries at a faster rate than that experienced by developed countries (Raymond, Leeder, & Greenberg, 2006).

This paper focuses on China as a case study. As the most populous country in the world, rising rates of chronic diseases among this population will have striking consequences. The incidence of heart disease among adults in China has risen remarkably quickly over the past several decades (Wu et al., 2001). Estimates from the 2001 Inter-ASIA survey indicate that 28.2% of the adult Chinese population had hypertension (Gu et al., 2003). Additionally, the percentage with diabetes or high cholesterol levels was 5.2 and 32.8%, respectively (Reynolds et al., 2003). The growing prevalence of such chronic diseases will negatively affect economic productivity and implies that greater financial resources are being spent on health care needs; it is estimated that the cost of overweight and related diseases will be almost 9% of China's gross national product (GNP) by 2025 (Popkin, Kim, Rusev, Du, & Zizza, 2006).

Reasons for the increasing burden of these chronic disease risk factors have not been elucidated, but it has been suggested that urbanization and associated adverse changes in physical activity levels have played a role (Janus, Postiglione, Singh, & Lewis, 1996; Popkin, 1999). In the context of the United States, one framework for examining this issue is the SLOTH model. This time–budget model incorporates individual decisions to be active or inactive in the five domains of Sleep, Leisure, Occupation, Transportation and Home activities, based on individual, economic and environmental

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factors (Cawley, 2004; Pratt, Macera, Sallis, O'Donnell, & Frank, 2004; Sturm, 2004)

In the SLOTH model, sleep is considered inactive, but influences activity through time spent sleeping. Occupational activity may become more sedentary due to technological advancements in the work environment, as well as via changing labor opportunities. Physical demands of home activities vary depending on technological advances, such as the availability and growing affordability of microwaves or washing machines. Transportation activities depend heavily on the built environment, accessibility and reliability of public transportation, as well as ownership and use of motorized vehicles. Engagement in leisure activities can be determined by neighborhood design and societal promotion of active participation in sports and exercise as well as technological advances that either lead to sedentary lifestyles or make exercise more attractive.

The SLOTH model suggests that it is important to consider various sources of activities, and that infrastructural development, services and facilities in communities in which people live and work can be significant factors in determining declines in physical activity. Studies in developed countries indicate that neighborhood design affects whether people walk and/or use bicycles as modes of transportation (Oakes, Forsyth, & Schmitz, 2007; Saelens, Sallis, & Frank, 2003), and influences individuals' choices to exercise (Sallis, Bauman, & Pratt, 1998). Perceptions of access and safety for physical activity may also determine physical activity levels for financially disadvantaged populations (Wilson, Kirtland, Ainsworth, & Addy, 2004). In addition, occupational opportunities affect the proportion of the workforce employed in sedentary occupations and the use of modern labor-saving technologies at the workplace (Harnack & Schmitz, 2006). In a cross-national analysis of European countries, Rabin, Boehmer, and Brownson (2007) found associations between weight gain and obesogenic environments in the domains of economic, food, urban population, transport, policy.

Since the bulk of this research focuses on developed countries, it is not clear whether these associations may be applicable to developing countries, such as China, where urbanization has occurred more rapidly and may have more immediate effects on physical activity decisions. Studies undertaken in China attribute the decline in physical activity to greater use of motorized transportation (Bell, Ge, & Popkin, 2002), use of computers and various work technologies (Bell, Ge, & Popkin, 2001; Popkin, 2006), greater access to markets, improved neighborhood facilities (Popkin, Paeratakul, Zhai, & Ge, 1995) and urbanization (Caballero, 2001; Monda, Gordon-Larsen, Stevens, & Popkin, 2007). Of these studies, only one looked specifically at physical activity as the outcome of interest. Monda, Gordon-Larsen, et al. (2007) used an urbanization index to examine its effects on the occupational physical activity patterns of Chinese adults using three waves of the China Health and Nutrition Survey (CHNS). They ran simulations that showed that the likelihood of having low occupational activity increased linearly with increasing urbanization, and that the urbanization index explained 54% and 40% of the variance in occupational activity for men and women, respectively.

While these findings provide some insights, consideration of other forms of activities such as in transportation, leisure and domestic chores are also important if one wants to fully understand the shifts in individual activity levels. This is particularly true because of the potential for substitution across various forms of activities, and the changing circumstances of these decisions over time. Moreover, even though the use of a composite urbanization index is an improvement over the classic urban–rural dichotomy that presumes homogeneity in unmeasured aspects of community environments with rural and urban settings (McDade & Adair, 2001), it is still not clear how each of the separate dimensions of urbanization contribute to declining physical activity levels.

Based on the findings from the limited work done in China previously, we hypothesize that a) physical activity levels are negatively associated with urbanization; b) urbanization domains that affect job functions and opportunities will contribute most to changes in physical activity levels; and c) these urbanization domains will be more strongly associated for men than for women because home activities account for a larger proportion of physical activities for women.

We will test these hypotheses by using six waves of the longitudinal China Health and Nutrition Surveys (CHNS) as described in the next section.

Data and empirical framework

Data

This paper uses comprehensive longitudinal data from the six most recent waves (1991, 1993, 1997, 2000, 2004 and 2006) of the China Health and Nutrition Survey (CHNS) on all adults (18–55 years old) interviewed during any of the survey waves. The CHNS was conducted in nine diverse provinces (Guangxi, Guizhou, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Liaoning, and Shandong) of China, and contains detailed individual-level information on income, diet, health and demography for all members of sampled households as well as detailed community level data on infrastructure, public services and facilities. A multistage, random cluster process was used to draw the sample surveyed in each of the provinces. Counties in the nine provinces were stratified by income and a weighted sampling scheme was used to randomly select four counties in each province. Villages and townships (the CHNS definition of communities) within the counties and urban and suburban neighborhoods within the cities were selected randomly into primary sampling units (PSUs), which we call 'communities'. The neighborhoods and villages were defined politically and geographically based on the communist party definitions. The same households were surveyed over time whenever possible and newly formed households were included beginning in 1993. Rural communities had populations ranging from 125 to 14,964 people and urban communities had populations ranging from 167 to 86,733 people. These differences in population across communities were controlled for in the analysis. English language versions of the questionnaires used for the CHNS can be found at the CHNS website (CPC, 2008).

After limiting the sample to those between 18 and 55 years old who were not disabled, pregnant or lactating during a particular wave and had complete data, there were 16,753 male-wave observations and 18,033 female-wave observations for the 1991–2006 analysis, and 11,234 male-wave observations and 12,092 female-wave observations for the 1997–2006 analysis.

Dependent variables

All measures of physical activity were in terms of metabolic equivalent (MET)-hours per week to account for both intensity of activities and time spent on activities. A unit of MET is defined as the ratio of a person's working metabolic rate relative to his/her resting (basal) metabolic rate (Sallis et al., 1985).

Occupational activity was measured by using self-reported occupation(s) and the average number of hours spent working per week in the last year for up to two market-sector jobs as well as hours worked from home (working on a farm, in a garden or orchard, raising livestock or poultry, fishing, and working on craft or in a home business). Adult respondents were also asked about the activity levels of their occupations, which interviewers categorized into five levels (very light, light, moderate, heavy, and very heavy) based on respondents' job descriptions and the time spent sitting, standing, walking and lifting heavy loads during an average work day. Reported occupations were then cross-tabbed against these occupational activity levels and specific MET (metabolic equivalent) values were assigned based on how the majority of respondents reported the activity level of their occupation. Farming, fishing, working in a garden or orchard, and working with livestock were reported as high activity occupations and assigned a MET value of six per hour of work. Four METs per hour worked were assigned to those working as foremen, group leaders, craftsmen, ordinary laborers, loggers, drivers, homemakers or students. Two METs per hour worked were assigned to those working as senior or junior professionals, administrators, executives, managers or office staff, and working as army or police officers. Time spent in each occupation was multiplied by these MET values to get MET-hours per week. For respondents who reported having more than one job, their total occupation MET-hours per week were derived by summing across all occupations. Occupational activity makes up the bulk of activities for both men and women (see Fig. 1), and so is used as a dependent variable in the analysis.

Home activity was measured based on four activities: time spent preparing food, buying food, doing laundry, and in childcare. Note that measurements of household chores did not include a number of other key domestic work tasks such as cleaning the house and home maintenance or repairs because these were not included in the survey before 1997. All activities were reported in average hours/week spent in the past year. Time spent in each activity was multiplied by specific MET values based on the Compendium of Physical Activities (Ainsworth et al., 2000): 2.3 for buying food, 2.25 for preparing food or cooking, 2.15 for doing laundry, and 2.75 for childcare. Individual MET-hours per week were summed to obtain total home activity energy expenditure. Women expend over three times as many METs on home activities as men (see Table 1). Both men and women have decreased their home activities over time, with women decreasing them from 61.3 in 1991 to 25.3 MET-hours per week in 2006, and men decreasing them from 19.1 to 5.6 MET-hours per week over the same period.

Since 1997, adults have been asked about their participation in leisure physical activities in the past year, and the average time spent per week. They have also been asked about their transportation mode (motorized vehicle, bicycle, or walking) and time spent traveling to and from work or school. Using the Compendium of Physical Activities (Ainsworth et al., 2000), METs per hour used for leisure activities were: 4.5 for marital arts, 7.5 for jogging or swimming, five for dancing or aerobics, six for playing basketball, volleyball or soccer, and five for playing tennis, badminton or ping-pong. For transportation activities, METs per hour used were: 1.5 for taking a motorized vehicle, four for bicycling, and three for walking. Time spent in each activity was multiplied by these specific MET intensity values and aggregated to get each individuals' leisure and transportation MET-hours per week, respectively. Based on data from 1997 onwards, leisure and transportation were not significant activities for either men or women, but leisure activities do appear to be increasing, while transportation activities are declining slightly (see Table 1). These together with occupational and home activities provide the measure for total activity for the four waves of data from 1997 through 2006. Consequently, the sample used for the total activity analysis is a subset of the sample used in the occupational physical activity analysis, which uses 1991 through 2006 data.

Fig. 1 shows that among Chinese men, physical activities declined significantly with most of the decline occurring due to changes in occupational activities. Among Chinese women, there have been even faster declines due to both occupational and home activities falling over time. Additional descriptive statistics on control variables used in the analyses are also found in Table 1.

Table 1 also shows some descriptive information about the participation rates and time spent in various activities. We see that over time, the percentage of both men and women in the labor force and the percentage of those that do domestic chores have fallen, as has the time spent doing domestic chores. More striking is the decline in the proportion of adults who averaged more than 30 min per day on active transportation (walked or bicycled) or leisure (exercised) from 46–51% in 1997 to 28–33% in 2006. However, note that due to the longitudinal nature of the data, the sample is aging over time, which may partly explain the decline in physical activities as well as labor force participation.

Key independent variables

The main independent variables of interest are time-varying and arguably exogenous dimensions of urbanization of each community. China's household registration (*hukou*) system and the longitudinal nature of the CHNS data ensure that selection into communities and inclusion in the data was as independent of individual or household choices and behavior as possible. The CHNS community level measures on various dimensions of urbanization

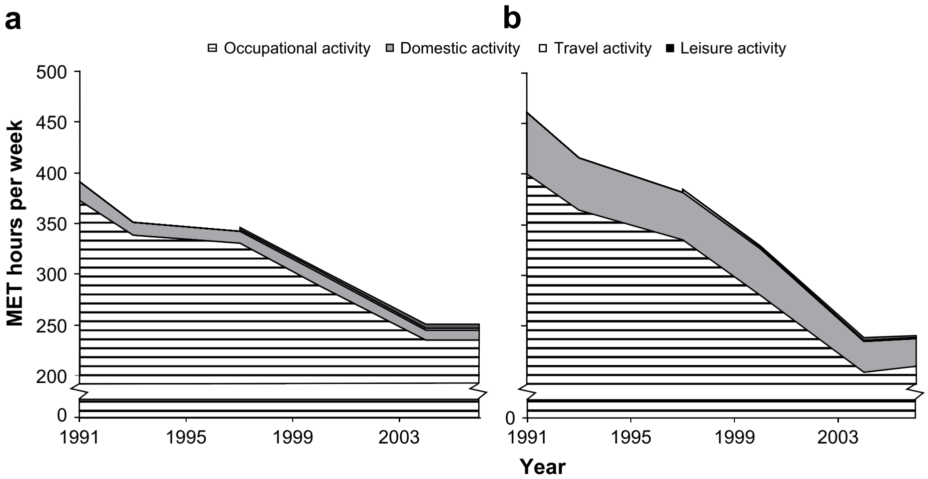

Fig. 1. Change in physical activity levels among Chinese adults. a. Chinese Men, b. Chinese Women.

Table 1
Descriptive statistics of individual level variables for adult Chinese men and women from selected waves of the China Health and Nutrition Surveys.

	Men			Women		
	1991	1997	2006	1991	1997	2006
Physical Activity (MET-hrs/week)						
Occupational Activity	370.6 (218.0)	334.4 (214.2)	241.5 (177.5)	399.7 (264.6)	340.1 (242.5)	217.1 (191.8)
Home Activity	19.1 (34.6)	11.7 (31.6)	5.6 (18.3)	61.3 (58.5)	46.8 (56.9)	25.3 (47.7)
Leisure Activity	No data	1.4 (7.6)	3.6 (16.0)	No data	0.6 (4.9)	2.3 (15.0)
Transportation Activity		2.6 (9.7)	1.9 (10.3)		2.5 (11.0)	1.3 (5.0)
Total Activities		350.0 (214.7)	252.7 (176.9)		390.0 (252.0)	246.1 (196.4)
Control Variables						
Age (years)	35.2 (9.9)	36.7 (10.2)	40.4 (9.8)	35.0 (9.9)	37.5 (9.8)	40.9 (9.2)
Married (%)	79.7	78.7	83.9	81.0	84.1	89.4
Living Alone (%)	0.2	0.2	0.3	0.1	0.1	0.3
Predicted real household income (in 2006 yuan)	2227.2 (1447.8)	2546.0 (2361.3)	5242.8 (8046.9)	2240.1 (1595.7)	2550.3 (2264.4)	5075.9 (7785.6)
No education (%)	15.0	9.8	6.5	34.0	27.9	17.8
Completed primary education (%)	62.7	64.5	55.9	50.1	52.9	53.6
Completed secondary education (%)	15.3	17.6	20.6	11.5	12.5	14.4
Completed technical or vocational training (%)	3.2	4.1	9.0	2.5	4.4	7.2
Completed university (%)	3.8	4.0	9.0	1.9	2.4	7.0
Participation in Activities						
In paid, market or self employment (%)	96.72	94.03	86.81	92.92	88.53	78.16
Did any domestic chores (%)	52.48	45.07	40.83	92.44	90.35	89.36
Time spent on domestic chores (in hours per week)[a]	14.99 (16.11)	10.88 (16.55)	5.77 (10.66)	28.01 (23.03)	22.14 (22.26)	11.86 (19.04)
Exercised for leisure (%)[b]	No data	15.58	13.15	No data	6.85	8.44
Time spent exercising (in hours per week)[a]		4.84 (5.05)	5.63 (5.81)		4.38 (5.22)	5.81 (7.65)
Bicycled for transportation (%)		34.64	19.26		27.27	17.40
Time spent bicycling (in hours per week)[a]		4.56 (3.15)	4.58 (3.86)		3.80 (3.15)	3.16 (1.47)
Walked for transportation (%)		58.41	38.29		63.38	38.48
Time spent walking (in hours per week)[a]		3.83 (2.15)	3.87 (3.70)		4.35 (3.01)	3.28 (2.18)
Averaged ≥30 min/day on transportation or leisure activities (%)[c]		50.65	32.72		46.30	28.25
N	2864	2949	2601	3109	2963	2903

Figures in parentheses denote standard deviation. Only reporting data from 1991, 1997 and 2006 because these are the baselines and final wave of interest.
[a] Among those who participated.
[b] More than 12 times in the past year.
[c] CDC, American College of Sports Medicine, and the WHO recommends ≥30 min/day for any activity (Haskell et al., 2007), but here we limit to only transportation and leisure activities for the China adult population due to high labor and domestic activities.

have been previously used in papers by Monda, Gordon-Larsen, et al. (2007), and Zimmer, Kaneda, and Spess (2007). The ten community level dimensions of interest in this paper are: population, density, access to markets for household goods, economic wellbeing, transportation, communications, educational institutions, health facilities, sanitation and housing infrastructures. These reflect changes in the various dimensions of infrastructure development over time and reflect the environment in which people function. Each of these dimensions was given a score from zero to ten and was comprised of data collected from local area administrators or official records (see Table 2).

For a country as large and diverse as China, one would expect there to be variation in the urbanization process across communities. Even though overall scores did increase over time, some communities experienced declines in some dimensions, while others saw large improvements. Over time, the infrastructure component scores changed at varying rates (see Table 2).

Empirical framework

The empirical model uses a longitudinal random effects model with year, *t*, nested within individuals, *i*, and communities, *c*. Analyses for men and women were run separately due to the differing activity trends of the two genders. The model can be written as:

$$\mathrm{PA}_{tic} = \lambda + Z_{tc}\cdot\gamma + P_{tc}\cdot\zeta + \pi\cdot T_{tic} + X_{ti}\cdot\alpha + \mu_{ti} + \varepsilon_{tic},$$

where PA_{tic} denotes individual activity level (occupational or total), λ represents the overall mean base year activity level; Z_{tc} represents the time-varying community level urbanization dimensions; the coefficient γ represents the vector of change in activity given a unit change in the different urbanization dimensions; P_{tc} represents the time-varying community consumer price index; the coefficient ζ represents the vector of change in activity given a one percent change in prices; the coefficient π represents change in activity between the base year and specific years, *T*; X_{ti} is a vector of individual and household level characteristics such as age, education attainment, marital status, living situation and predicted real per capita household income; the vector of coefficients α_1 represents the change in activity given a one unit change in these characteristics; μ_{ti} is the time-varying individual error; and ε_{tic} is the random effect error term.

For the model on total physical activity, inclusion of occupational physical activity as an explanatory variable poses statistical problems due to multicollinearity between total and occupational physical activity. Including an indicator variable for occupational change is not ideal either because what we are trying to estimate should not be conditional on changes on occupational choice. In addition, it is not clear if those who changed jobs did so from more physically active jobs to less active ones or vice versa. It also does not capture changes in physical activity within the same type of occupation (investigation into this reveals that significant declines in occupational physical activity occurred even among those who remained in the same job codes). Thus, we used the same specification for both occupational and total physical activity.

The coefficients of interest are those of the ten urbanization dimensions, denoted by γ (results are in Table 3). We did not test each community dimension in separate models because while they might be correlated with each other, they were not collinear and

Table 2
Community level explanatory variables over time CHNS 1991–2006.

	Community level explanatory variables Community Infrastructure Scores (each standardized to 0–10 points)	Statistics	1991	1997	2006
Population	2, 4, 6, 8 and 10 points assigned based on cut-points of 1000,1500, 2000, 3000 people determined by the distribution of the CHNS data and the standard strategies for classifying areas as urban or rural (United Nations Economic and Social Commission for Asia and the Pacific, 1993)	Mean	6.1	5.8	7.2
		Std. Deviation	2.9	3.0	3.0
		% < 3 points	19.2	23.0	13.8
		% ≥ 3 & <6 points	22.3	23.5	13.8
		% ≥ 6 points	58.5	53.5	72.5
Density	2, 4, 6, 8 and 10 points assigned based on cut-points of 250, 5000, 1000 and 2000 persons/km^2 determined by the distribution of the CHNS data and the standard strategies for classifying areas as urban or rural (United Nations Economic and Social Commission for Asia and the Pacific, 1993).	Mean	6.8	6.3	6.6
		Std. Deviation	2.8	3.1	3.0
		% < 3 points	12.8	23.0	18.4
		% ≥ 3 & <6 points	17.6	15.5	14.7
		% ≥ 6 points	697	61.5	67.0
Access to markets	Sum of the availability of seven goods (gains, oil, vegetable, meat, fish, beancurd, and fuel) in major shopping areas within each community at each wave, where one point was assigned for each good available within the community and half-a point was assigned for each good available in a neighboring community <1 km away[a]	Mean	4.6	5.1	4.9
		Std. Deviation	3.1	3.5	3.9
		% < 3 points	36.2	28.9	37.6
		% ≥ 3 & <6 points	26.1	28.3	27.5
		% ≥ 6 points	37.8	42.8	34.9
Transportation infrastructure	Communities were assigned two points each if their leaders reported that the community had mostly paved roads, a bus-stop or train station within their perceived community boundaries and were assigned one point if there was a bus-stop or train station in a neighboring community <1 km away[a]	Mean	4.9	5.3	5.8
		Std. Deviation	3.0	2.6	2.6
		% < 3 points	25.5	17.7	11.5
		% ≥ 3 & <6 points	32.5	38.0	32.1
		% ≥ 6 points	42.0	44.4	56.4
Communication infrastructure	Availability of provincial newspaper, a TV station, a radio station, telephone network, postal service, facsimile and telegraph services and a movie theatre. The information on the TV and radio station availability is based on whether ≥20% of households in a community reported having a TV or radio.	Mean	6.5	7.5	6.3
		Std. Deviation	2.5	2.4	2.0
		% < 3 points	16.0	9.1	8.3
		% ≥ 3 & < 6 points	28.7	18.2	44.0
		% ≥ 6 points	55.3	72.7	47.7
Economic Wellbeing	Based on community records or leaders' report of % employment in non-agricultural jobs, % employment fully within the community, and average male wage.	Mean	3.4	4.9	6.7
		Std. Deviation	1.1	2.4	1.9
		% < 3 points	47.9	29.4	0.9
		% ≥ 3 & <6 points	52.1	44.9	35.8
		% ≥ 6 points	0.0	25.7	63.3
Educational Institution	Each of the five possible levels of schooling (preschool, elementary, middle, high, and vocational schools) was assigned two points if the school was located within the community. For all institutions except preschools and elementary schools, one point was assigned if the school was not in the community but was < 5 km outside the community[a]	Mean	6.0	7.0	8.1
		Std. Deviation	2.8	2.7	2.6
		% < 3 points	19.7	8.6	6.9
		% ≥ 3 & <6 points	19.7	18.7	9.6
		% ≥ 6 points	60.6	72.7	83.5
Health Facilities	Health facilities available within the community were given 1 point for each village or work unit clinic, 2 points for neighborhood or maternal child health (MCH) clinics, 3 points for town hospital, 4 points for district hospital, 5 points for county, work unit or army hospital, 6 points for private for city hospital, and 7 points for university hospital. Facilities available outside the community but <10 km away[a] were given half of the listed points.	Mean	6.7	6.8	5.8
		Std. Deviation	2.2	2.3	2.7
		% < 3 points	4.8	8.6	21.1
		% ≥ 3 & <6 points	33.5	28.3	26.2
		% ≥ 6 points	61.7	63.1	52.8
Sanitation infrastructure	Based on percentage of households in each community reporting availability of water treatment plant, and each household's overall index of the presence or absence of excreta in the vicinity (based on interviewers' observation).	Mean	5.9	6.7	7.7
		Std. Deviation	4.0	3.7	3.1
		% < 3 points	23.9	16.0	6.4
		% ≥ 3 & <6 points	33.0	33.7	33.9
		% ≥ 6 points	43.1	50.3	59.6
Housing infrastructure	Based on percentage of households in each community reporting use of natural gas, piped water, indoor toilets and electric lighting, and on community level reports on the availability and reliability of electricity (hours/day).	Mean	3.6	5.5	7.3
		Std. Deviation	2.7	2.9	2.2
		% < 3 points	55.3	30.5	4.6
		% ≥ 3 & <6 points	28.2	25.1	28.0
		% ≥ 6 points	16.5	44.4	67.4
	Community Consumer Price Index (100 = 2006 urban Liaoning)	Mean	41.9	84.1	90.3
		Std. Deviation	3.6	10.0	9.7
		% < 40	42.0	0.0	0.0
		% ≥ 40 and <80	58.0	42.3	14.7
		% ≥ 80	0.0	57.8	85.3
	Number of communities		188	187	218

Only reporting data from 1991, 1997 and 2006 because these are the baselines and final wave of interest.
Questionnaires used in the China Health and Nutrition Surveys can be found at the survey's website (CPC, 2008).
[a] For items involving distances, these were relative to the center of the community, determined by latitudes and longitudes on official maps.

Table 3
Longitudinal regression coefficients and robust standard errors of community components on physical activity among adult Chinese men and women.

Community infrastructure components	Men		Women	
	Occupational activity 1991–2006	Total activities 1997–2006	Occupational activity 1991–2006	Total activities 1997–2006
Population	−0.37 (1.30)	−1.25 (1.50)	2.61 (1.73)	0.43 (1.90)
Density	−3.24* (1.39)	−0.88 (1.48)	−2.87 (1.80)	−0.01 (1.86)
Access to markets	−1.88* (0.92)	−2.72* (1.09)	−3.06** (1.15)	−3.12* (1.37)
Transportation Infrastructure	−1.06 (1.29)	−0.17 (1.52)	−2.03 (1.43)	−3.19 (1.70)
Communications Infrastructure	−1.85 (1.51)	−0.42 (1.64)	−4.21* (2.11)	−1.41 (2.41)
Economy	−7.08** (1.46)	−6.39** (1.54)	−9.22** (1.59)	−8.84** (1.79)
Educational Institution	−12.97** (1.80)	−12.91** (2.19)	−17.00** (2.39)	−16.22** (2.85)
Health Facilities	−2.93* (1.46)	−2.15 (1.70)	−3.50* (1.72)	−3.64 (1.95)
Sanitation Infrastructure	−9.13** (1.22)	−8.43** (1.44)	−9.82** (1.59)	−6.12** (1.93)
Housing Infrastructure	−9.15** (1.82)	−10.18** (2.61)	−10.54** (2.16)	−12.49** (3.18)
Statistics for regression models				
# of observations	16753	11234	18033	12092
# of unique individuals	6740	5450	7188	5669
# of communities	235	225	235	225
Wald	2545.71**	1608.64**	2283.50**	1241.87**
Degrees of freedom	27	25	27	25
σ_u (Std error of random error)	82.71	77.63	89.81	90.69
σ_e (Std error of residual)	136.39	137.65	151.32	152.41

** Denotes significance at the 1% level; * denotes significance at 5% level.
Controlling for year dummies, age, age-squared, age-cubed, individual educational attainment, marital status, living situation, predicted household income tercile and community level CPI.

needed to be studied jointly to allow us to test the multiple dimensions of urbanization.

Our first hypothesis is that these coefficients will be negative, and jointly statistically significant. In order to get an idea of the contribution of the various community measures to declines in physical activity, we derive the marginal effect of each of the community measures and multiply those by the change in each measure between the base year and 2006. Then, we calculate the proportion of that figure that explains the total decline in physical activity over the same period (results are in Table 4). Based on our second hypothesis, we would expect that the contribution of the dimensions of economic wellbeing, transportation and educational institutions would account for most of the decline in physical activity levels, especially for occupational physical activity. If our third hypothesis is correct, we would expect the calculated contribution of the urbanization dimensions to be larger for men than for women.

We first start with a model that includes only time, to see how variation in physical activity is allocated across the levels. Evidence of between-person and between-community variation justifies including individual and community level predictors. Next, cross-level interactions are tested to evaluate whether the effects of community level characteristics on physical activity levels and dietary intake differ over time. These interaction terms are included in the final models only if they improve the model fit significantly. We correct for heteroskedasticity by clustering at the outer-most (community) level. This approach allows for inclusion of two potential sources of heterogeneity, which captures both individual-specific unobserved factors, and unobserved community-specific unobserved factors that affect physical activity levels over time, and is equivalent to a multi-level model (Angeles et al., 2002).

Results

Basic results

Results from the estimations show that urbanization is negatively associated with both occupational and total physical activity levels for both adult men and women in China. They also show that community economic wellbeing, availability of educational institutions, improved sanitation and housing infrastructures are the factors most strongly associated with declines in occupational and total physical activity levels, for both men (Table 3, columns 1 and 2) and women (Table 3, columns 3 and 4).

For men, a one point increase in the education facility score decreases physical activity by almost 13 MET-hours per week; a one point increase in housing or sanitation scores decreases physical activity by between eight and ten MET-hours per week; and a one point increase in the community's economic wellbeing score decreases physical activity by six to seven MET-hours per week. For women, the marginal effect of these component scores on physical activity declines was more pronounced. A one point increase in the education facility score decreases physical activity by 16–17 MET-hours per week; a one point increase in housing infrastructure scores has a greater impact than for men; a one point increase in sanitation scores decreases physical activity six to ten MET-hours per week; and a one point increase in the community's economic wellbeing score decreases physical activity by around nine MET-hours per week.

Access to markets (a measure on the availability and distance of various types of household goods) is also significantly associated with declines in both occupational activity and total activity for men and women, but appears to be slightly more strongly predictive of total activity. This seems possible since shopping for food or other items involves both home and transportation activity. Health facility services is significantly associated with declines in occupational activity for both men and women, but is not associated with declines in total activity. The other four components do not appear to be strongly associated with physical activity levels at all. It is somewhat surprising that transportation infrastructure is not significantly associated with physical activity levels, but this finding is possible because transportation activity constituted a small proportion of total physical activity in this population.

Model specifications that include interactions between year dummies and the community level variables result in very similar results, and do not improve the model fit significantly.

Main contributing factors

Next, we calculated the contribution of these community level factors to declines in physical activity by multiplying the change

Table 4
Contribution of key community components in explaining physical activity decline among adult Chinese men and women.

Occupational physical activity (1991–2006)	Change (1991–2006)	Coef.	Change × Coef.	% Contribution of explained change	% Contribution of total change in PA	
					Mean	Bootstrapped 95% CI
Men						
Housing Infrastructure	3.79	−9.15	−34.66	33.27%	26.79%	(22.18, 85.40)
Educational Institution	2.36	−12.97	−30.61	29.39%	23.66%	(20.97, 26.35)
Economy	3.36	−7.08	−23.78	22.82%	18.38%	(14.67, 22.09)
Sanitation Infrastructure	1.80	−9.13	−16.44	15.78%	12.71%	(11.24, 14.18)
Other components			1.32	−1.26%	−1.02%	
Total			−104.17	100.00%	80.52%	(75.63, 85.40)
Women						
Housing Infrastructure	3.65	−10.54	−38.49	32.72%	21.05%	(17.60, 24.50)
Educational Institution	2.19	−17.00	−37.17	31.60%	20.37%	(18.37, 22.37)
Economy	3.34	−9.22	−30.79	26.18%	16.85%	(14.23, 19.48)
Sanitation Infrastructure	1.67	−9.82	−16.37	13.91%	8.97%	(7.89, 10.05)
Other components			5.19	−4.41%	−2.84%	
Total			−117.66	100.00%	64.39%	(60.66, 68.12)
Total physical activity (1997–2006)	**Change (1997–2006)**	**Coef.**	**Change × Coef.**	**% Contribution of explained change**	**% Contribution of total change in PA**	
					Mean	Bootstrapped 95% CI
Men						
Housing Infrastructure	1.89	−10.18	−19.24	34.71%	19.85%	(15.55, 24.16)
Educational Institution	1.38	−12.91	−17.81	32.14%	18.38%	(15.61, 21.15)
Economy	1.82	−6.39	−11.63	20.98%	12.00%	(9.18, 14.82)
Sanitation Infrastructure	0.90	−8.43	−7.59	13.69%	7.83%	(6.56, 0.10)
Other components			0.85	−1.53%	−0.87%	
Total			−55.41	100.00%	57.19%	(51.78, 62.60)
Women						
Housing Infrastructure	1.79	−12.49	−22.36	38.91%	15.64%	(12.55, 18.72)
Educational Institution	1.21	−16.22	−19.63	34.25%	13.73%	(11.86, 15.59)
Economy	1.80	−8.84	−15.91	27.69%	11.12%	(9.24, 13.00)
Sanitation Infrastructure	0.86	−6.12	−5.26	9.14%	3.68%	(2.77, 4.59)
Other components			5.74	−9.98%	−4.01%	
Total			−57.45	100.00%	40.16%	(36.21, 44.12)

Bootstrapped confidence interval derived from 1000 replications.

in each measure between the base year and 2006 (Table 4, column 1), by each urbanization dimension's marginal effects (Table 4, column 2) and then attributing the proportion of that figure to the decline in occupational activity (129.1 MET-hours per week for men and 182.6 MET-hours per week for women) and total physical activity (97.3 MET-hours per week for men and 143.9 MET-hours per week for women) over the same period (Table 4, column 5).

The ten community level urbanization dimensions are associated with 80.5% of the decline in occupational activity from 1991 to 2006 and 57.2% of the decline in total activity from 1997 to 2006 (see Table 4) for men. These dimensions do not appear to be as strongly associated with the decline among women: the ten community level urbanization dimensions are associated with 64.4% of the decline in occupational activity from 1991 to 2006 and 40.2% of the decline in total activity from 1997 to 2006 (see Table 4). This is because females had more rapid declines in physical activity than men, due to declines in both occupational and home activities. These results are consistent for both occupational and total physical activity for both men and women; in all cases, most of the physical activity decline is strongly related to housing, education, economy and sanitation changes (Fig. 2).

Why are these four factors so important? There are a number of possible explanations relating to time allocation decisions towards human capital investments and changing job markets. The housing measure is based on having piped water and reliable electricity access into homes. As this access improves, people can reduce energy and time spent obtaining water and fuel. Meanwhile, better sanitation services result in fewer and less severe illnesses. Both improved housing and sanitation may allow individuals to put more time into human capital investments such as education and health, and income-generating activities.

The educational institution score is a measure of investment in educational infrastructures in the community. Having access to schools (from primary level to higher educational institutions) can help enhance the skills of the community's workforce, attract more capital and less labor intensive types of enterprises and result in higher marginal rate of return for work. These effects can be seen in the fact that communities with higher educational institutions also have higher economy scores. The changing job opportunities and declining physical labor needs of these jobs have been cited as important reasons for activity declines.

When interpreting these results, one should bear in mind that the estimated contribution of each of these factors is taken ceteris paribus (holding all else constant). In reality, however, the community components are not independent of each other or of urbanization in general. For example, higher educational institutions tend to be in areas where they are sufficient populations to attend them. These are often more urbanized communities with denser population bases. Therefore, despite being able to calculate the stand alone effect of each of these community components, it is also not clear if each of these components has specific separable results from urbanization in general, or whether the various community components affect physical activity in convergent or divergent ways.

Discussion

This paper found that urbanization as measured by a collection of dimensions is associated with a significant proportion of the

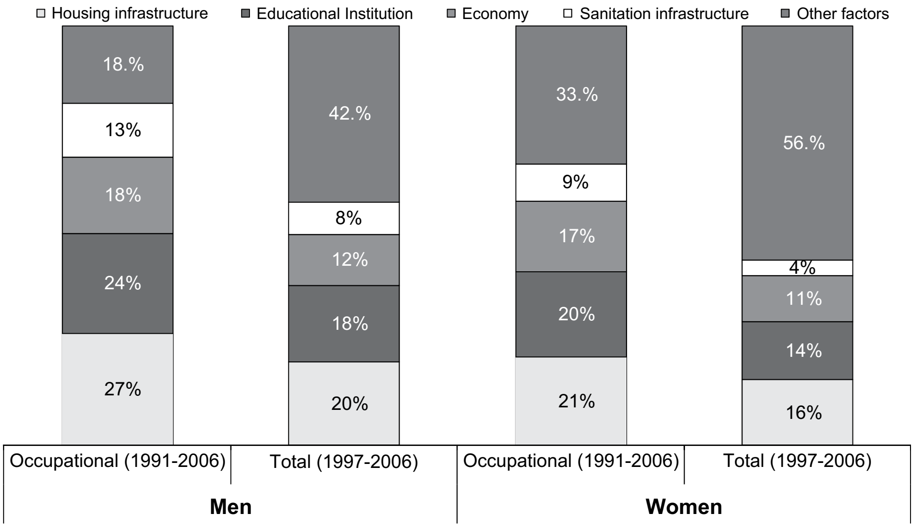

Fig. 2. Contribution of community infrastructure components in explaining physical activity decline.

decline in physical activities, particularly occupational physical activities, among Chinese adults. Improved housing infrastructures, better access to educational institutions, higher economic opportunities and improved sanitation services are the key community level factors that explain this decline. These findings suggest that improvements in community infrastructures and services may have affected the environments in which the Chinese live, the choices available to them, and consequently the choices they make.

Is urbanization bad?

While the results may suggest that improvements in community infrastructure and services are significantly associated with declines in physical activity, it does not mean that urbanization is necessarily detrimental. Declines in occupational activity are signs of shifts in the job market towards less labor intensive occupations. Descriptive statistics show that leisure activity is gradually on the rise in China among both men and women, which might help attenuate the effects of declines in physical activity at work and in the home. While this is promising, active leisure activity levels are clearly not rising fast enough to make up for the declines in occupational and home activities. In fact, only 13.2% of Chinese men and 8.4% of Chinese women engaged in any exercise in 2006 (see Table 1), and among those who participated in leisure activities, the percentage of their total activity due to leisure was less than 5%.

Declines in physical activities are not necessarily negative per se, because they may reflect more efficient allocation of energy. However, they can be a problem when declines in caloric intake are not moving at equally rapid rates, since caloric imbalance will lead to higher body mass index, and more importantly the development of many chronic diseases such as type II diabetes, high blood pressure, and cardiovascular disease (Popkin, 2007). Furthermore, lack of physical activity poses major risks for cancer and a range of metabolic diseases (National Institutes of Health, 1995; World Cancer Research Fund-American Institute for Cancer Research, 2007). These diseases will create new health and financial challenges for developing countries such as China.

Policy implications

In the United States and Europe, physical activity has been considered the 'best buy' in public health (CDC, 2000; De Backer & De Bacquer, 2004; Morris, 1994), which may be the case in a developing country like China as well.

In China, declines in physical activity have occurred mostly at work, therefore intervention strategies to increase physical activity levels at the workplace are one possible strategy. Examples include encouraging stair use in buildings by placing signs near stairways and escalators, or by making stairways more centrally located and escalator use less convenient. To increase physical activity in other domains, active leisure and transportation activities such as walking and bicycling can be promoted by designing built environments that are safe and conducive for such transit or exercise modes (Forsyth, Hearst, Oakes, & Schmitz, 2008; Nagel, Carlson, Bosworth, & Michael, 2008). It is also possible that parking can be made less accessible to promote walking, or improved access to public transit can help promote walking (Rodriguez, Aytur, Forsyth, Oakes, & Clifton, 2008) or bicycling – a diminishing activity in urban and rural China. Pricing policies in the form of higher taxes on automobiles, lower entry fees to parks and government run health facilities can also help promote physical activity. Moreover, disincentives for automobile ownership can discourage motorized transportation and help reduce air pollution and provide more pleasant environments for outdoor exercise. These policies can be province or community specific depending on geographical, cultural and socio-economic circumstances.

Local governments should take advantage of current transformations in infrastructural changes to incorporate such considerations into town or city planning, land-use development decisions, and provision of services. In the long-run, increased physical activities will not only be beneficial for individual health, they also have the potential to decrease both private and public health care expenditures.

Limitations and future directions

While this paper has provided insights into the association between community level infrastructure and service and their relationship with occupational and total physical activity levels over time, there are a number of limitations with this analysis.

First, modeling the relationships between environment and physical activity choices is difficult because the direction of the relationship is unclear. It is possible that individuals' decisions and preferences about where to live and work (such as individual preference for big cities) help determine both physical activity levels as well as living environments. For example, if people tend to move to more urbanized areas with better occupational prospects and no longer want to engage in labor intensive occupations, then our coefficients will overestimate the effects of urbanization as determinants of behaviors. However, this endogeneity problem is somewhat less problematic in the context of China where the household registration (*hukou*) system limits mobility and determines access to public services and subsidies. Nonetheless, there is still significant rural–urban migration.

Second, there are some data limitations that may compromise our findings. For example, the use of MET-hours per week to quantify energy expenditure does not take into account individual differences that may alter the energy cost of movements. Nonetheless, this approach is the best available way to systematically apply average energy cost estimates in self-reported measures (Matthews, 2002), and has been shown to be valid at least in the area of occupational activity (Ainsworth, Richardson, Jacobs, Leon, & Sternfeld, 1999). Moreover, we included multiple sources of occupational and domestic activity to allow a more complete assessment of physical activity; this may be especially important for women in developing countries because of their multiple responsibilities (Short, Chen, Entwisle, & Zhai, 2002). We investigated the possible gender, age and geographical differentials by conducting separate analyses for men and women, controlling for age and community level factors. One way to validate the physical activity measures that were used is through studies that investigate the link between physical activity levels and outcomes such as weight and chronic diseases. Other published studies (Bell et al., 2001; Monda, Adair, Zhai, & Popkin, 2007; Monda & Popkin, 2005) have used the CHNS physical activity data for these purposes. Nonetheless, our model specifications might still be problematic because the random effects model assumes that the errors are orthogonal to all explanatory variables. If this is not the case, the estimated coefficients may be biased, even though the standard errors are smaller.

This paper only looks at one of main drivers of why health indicators have deteriorated among Chinese adults. Ultimately, two components determine Body Mass Index (BMI), which is a major determinant of numerous health risks: physical activity and diet. Future work will include estimating a dynamic panel model that incorporates the community, household and individual-level factors and relate them to changes in BMI over time. Such a model will address both the problem of endogeneity and the fact that BMI is a stock variable that depends on prior BMI, dietary intake and activity levels. Due to possible endogeneity issues, our analysis did not account for ownership of technological assets (motorized vehicles, washing machines, etc.), which are factors that might provide further insights and deserve attention in future work. Future work should also be considered regarding joint decisions about time and energy allocation among household members, instead of just considering individuals alone.

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