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China's transition: The effect of rapid urbanization on adult occupational physical activity

Keri L. Monda, Penny Gordon-Larsen, June Stevens, Barry M. Popkin*

Department of Nutrition, University of North Carolina at Chapel Hill, University Square, CB# 8120, 123 W. Franklin Street, Chapel Hill, NC 27516-3997, USA

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Abstract

China has recently undergone rapid social and economic change. Increases in urbanization have led to equally rapid shifts toward more sedentary occupations through the acquisition of new technology and transitions away from a mostly agricultural economy. Our purpose was to utilize a detailed measure of urbanicity comprising 10 dimensions of urban services and infrastructure to examine its effects on the occupational physical activity patterns of Chinese adults. Longitudinal data were from individuals aged 18–55 from the years 1991–1997 of the China Health and Nutrition Survey ($N = 4376$ men and 4384 women). Logistic multilevel regression analyses indicated that men had 68% greater odds, and women had 51% greater odds, of light versus heavy occupational activity given the mean change in urbanization over the 6-year period. Further, simulations showed that light occupational activity increased linearly with increasing urbanization. After controlling for individual-level predictors, community-level urbanization explained 54% and 40% of the variance in occupational activity for men and women, respectively. This study provides empirical evidence of the reduction in intensity of occupational activity with modernization. It is likely that urbanization will continue unabated in China and this is liable to lead to further transitions in the labor market resulting in additional reductions in work-related activity. Because occupational activity remains the major source of energy expenditure for adults, unless alternative forms are widely adopted, the Chinese population is at risk of dramatic increases in the numbers of overweight and obese individuals.

Keywords: China; Nutrition transition; Urbanization; Physical activity; Obesity; Multi-level modeling

Introduction

China has undergone tremendous urbanization and economic development over the last few decades, and concurrently has entered a stage of the nutrition transition defined by levels of over-nutrition and non-communicable diseases such as hypertension, cardiovascular diseases, and cancers that have become important public health concerns (Du, Lu, Zhai, & Popkin, 2002; Gu et al., 2005; Lee, 2004; Popkin, Kim, Rusev, Du, & Zizza, 2006). According to the year 2000 census, the urban population has reached a staggering 459 million people (36% of the national population) and continues to grow at rate of 4.7% annually (Friedman, 2005). At the same time, urban functions have spread rapidly to smaller towns and even villages

*Corresponding author. Tel.: +1 919 9661732.
E-mail addresses: monda@unc.edu (K.L. Monda), pglarsen@unc.edu (P. Gordon-Larsen), june_stevens@unc.edu (J. Stevens), popkin@unc.edu (B.M. Popkin).

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(Mendez & Popkin, 2005). Overall, urbanization of the environment has resulted in remarkable changes in terms of infrastructure, land use, transportation planning, and urban design (Friedman, 2005; Popkin, 2001b, 2002); and growth in technology and information capabilities has brought with it significant structural transitions in employment and altered the occupational landscape (Popkin, 1999). Concurrent with major shifts from agricultural employment to industrial, commercial, or service-based employment has been a transition away from labor intensive occupations to jobs that are more sedentary (Popkin, Paeratakul, Zhai, & Ge, 1995b; Popkin, 2001b; Zhou et al., 2003). However, while overall demographic and infrastructure changes are well documented, very little systematic exploration has been done of the independent effect urbanization has had on the physical activity patterns of adults in countries undergoing transition (Lambert et al., 2001; Popkin et al., 1995b).

Most research utilizes the classic urban–rural dichotomy, although some researchers have employed more nuanced indices, such as continuous measures of population size and density (Brockerhoff, 1995), or more detailed classifications delineating areas as ''urban squatter'' versus ''peri-urban,'' among others (McDade & Adair, 2001). However, in the absence of other variables, these terms may be lacking in precision and presume homogeneity in unmeasured aspects of community environments within each grouping (McDade & Adair, 2001). This study utilizes a much more complex time-varying continuous measure of urbanization in an attempt to capture many of the nuances of social and economic change at the community level that may influence changes in occupations in a developing counrty (Mendez & Popkin, under review).

Occupational activity is the major source of activity for adults in China, since leisure time activity and sports have not become prevalent means of exercise as they have in more developed nations (Bell, Ge, & Popkin, 2001; Bell, Ge, & Popkin, 2002; Fu & Fung, 2004; Hu, Pekkarinen, Hanninen, Yu, Guo, et al., 2002; Hu et al., 2002). In fact, fewer than 10% of Chinese adults report participating in any leisure time physical activity at all. Consequently, shifts from labor intensive to sedentary occupations may portend the removal of a source of energy expenditure important for weight maintenance and overall health status. While occupational activity is studied less frequently than leisure time physical activity, a number of studies have shown it to be an important source of energy expenditure that should not be neglected (Dorn et al., 1999; Evenson, Rosamond, Cai, Pereira, & Ainsworth, 2003; King et al., 2001; Salmon, Owen, Bauman, Schmitz, & Booth, 2000). Relevant to shifting activity patterns we note that China has recently had a remarkable increase in the number of overweight adults (Bell et al., 2001; Gu et al., 2005; Popkin, 2001a; Zhou et al., 2002). Urban residence is an important predictor of overweight and obesity in many developing countries, including China (Adair, 2004; Caballero, 2001; Lee, 2004; Popkin & Doak, 1998; Popkin & Gordon-Larsen, 2004; Qu et al., 2000), and it is possible that one mechanism through which this is operating is the decreasing occupational activity of its residents; in other words, occupational activity may be an important mediator of the relationship between urbanization and overweight. Thus, it was our goal to assess the relationship of urbanization on the occupational physical activity patterns of adults in China, hypothesizing that increases in urbanization have led to decreases in overall occupational activity. To our knowledge, this potentially important relationship has been unstudied until now. We contend that as urbanization continues to increase it is important for researchers to be aware of the public health significance of such changes, as they are likely to play a large role in the overall health of individuals.

Understanding the effect that environmental factors have on physical activity behaviors is an area of recent interest and there has been important research examining neighborhood effects on the physical activity patterns of both adults and children (Craig, Brownson, Cragg, & Dunn, 2002; Diez Roux, 2003; Duncan, Duncan, Strycker, & Chaumeton, 2002; Humpel, Owen, & Leslie, 2002; Ross, 2000). Investigations assessing the environmental effects on activity tend to primarily explore recreational or leisure time activity (De Bourdeaudhuij, Sallis, & Saelens, 2003; Reis et al., 2004), as well as transportation activity via walking or bicycling (Bell et al., 2002; Owen, Humpel, Leslie, Bauman, & Sallis, 2004; Saelens, Sallis, & Frank, 2003). To our knowledge there have been no earlier studies examining the effect of macro-level environmental characteristics on occupational physical activity as we do in this paper. This lack may be partly attributable to the fact that the majority of this body of research focuses on the developed world where occupational activity patterns are less dynamic than in countries where rapid urbanization and development is occurring.

Methods

Study population

Data were derived from the China Health and Nutrition Survey (CHNS), an ongoing, longitudinal study of a socioeconomically and demographically diverse sample of the Chinese population. Counties within each of eight provinces varying substantially in geography, economic development, as well as other indicators were stratified by income (low, middle, high) and multistage random sampling was used to select four counties in each province (1 high-, 2 middle-, and 1 low-income). In addition, the provincial capital city and a lower-income city were selected. Within each county/city, neighborhoods were randomly selected from urban and suburban areas, townships, and villages. Twenty randomly selected households were surveyed within each neighborhood, and all adults living within the household were interviewed.

Longitudinal data on 4376 men and 4384 women between the ages of 18 and 55 in a given wave who participated in the 1991, 1993, or 1997 CHNS were used for these analyses. Thus an individual 55 years old at baseline would not be included in follow-up waves. Each individual provided information for between 1 and 3 measurement occasions corresponding with waves of data collected in the three survey years, resulting in 8518 and 8694 total responses for men and women, respectively. Women who were pregnant or breastfeeding during a survey year were excluded, but included during other years if not pregnant or breastfeeding. Further, we excluded any individuals missing information on occupational activity or any of the predictor variables within a survey year. The individuals were clustered within 189 communities each of which included between 6 and 72 individuals, with a mean of 35.5 individuals/community. Only three communities contained fewer than 10 individuals.

Dependent variable

Adult respondents were directly interviewed as part of their individual dietary intake survey about their occupations that produced income in cash or kind. Questions included the average time spent sitting, standing, walking, and lifting heavy loads during an average working day and were used along with others related to the overall strenuousness of the work. The interviewers categorized each respondent into a set of six levels of activity. The Chinese Center for Disease Control has utilized this approach for over 30 years as these data are used to categorize persons into their overall energy expenditure level for purposes of measuring the adequacy of their diet. Given the enormous heterogeneity in activities within a narrow occupation, this provides a much more precise measure of energy expenditures at work than a classical measure of occupation. While formal reliability and validity analyses have not been run on this variable, several published studies have found it to be a more significant predictor of weight than classical measures of occupation (Bell et al., 2001; Paeratakul, Popkin, Ge, Adair, & Stevens, 1998; Stookey, Adair, Stevens, & Popkin, 2001). Further, it is closely related to several survey instruments which have been shown to have good reliability and validity in diverse populations (Ainsworth, Richardson, Jacobs, Leon, & Sternfeld, 1999; Baecke, Burema, & Frijters, 1982; Philippaerts & Lefevre, 1998; Reis, Dubose, Ainsworth, Macera, & Yore, 2005).

For this study we collapsed the occupation activity measure into a 3-way categorization of light, moderate and heavy work. Models were first run using this 3-level categorical variable; however, upon testing each individual coefficient using a pooled dataset and clustering on the uppermost level (community), we found that the moderate and light categories were not different from each other. Thus, these categories were collapsed to form a dichotomous variable indicating light or moderate (‘‘light’’ from this point forward) vs. heavy occupational activity. In all analyses, heavy activity was used as the referent category.

Community level variable

Urban–rural disparities are a major field of study in public health, in both the developed and developing worlds, and studies have reported both positive and negative health outcomes with urban living (Galea & Vlahov, 2005; McDade & Adair, 2001; Sobngwi et al., 2004; Torun et al., 2002; Verheij, 1996). In these analyses we utilize a multidimensional measure designed specifically for the CHNS to capture urbanization from the physical, social, cultural, and economic environments (Mendez &

Popkin, 2005). The urbanization variable was developed using data from community surveys and household-level information, and comprised the following 10 components: communication, economic, housing-related, and transportation infrastructure, the availability of schools, markets, and health care, environmental sanitation, and population size and density. Community-level information regarding local electricity, transportation, and communication infrastructures, as well as health care services, schools, markets, economic indicators, and population size and density were collected from area administrators and official records. Community-level indicators of housing-related infrastructure and sanitation were derived from aggregated household-level data on such factors as the availability of sewer lines for indoor toilets, tap water, and natural gas, the source of water, and the presence of excreta around dwellings. The data were used to generate an urbanization score for each community for each data collection period, where each component was assigned 10 possible points and summed for a maximum value of 100 points, with higher values indicating a higher degree of urbanicity. The index is advantageous not only in that it allows for a more meaningful classification of communities rather than the traditional urban/rural dichotomy, but also the time-varying quality of the index allows us to explore changes in urbanization over time. More information on the development of the urbanization index can be found elsewhere (Mendez & Popkin, under review). For our sample at baseline (1991) the mean index value was 50.4 and ranged from 18.6 to 84.4. By 1997 the average index was 55.0, ranging from 21.1 to 89.4. Urbanization was included as a higher-level continuous variable in statistical models.

Individual level variables

All analyses were stratified by gender because physical activity and the occupational environment tend to differ for men and women in China. Age, age-squared, and age-cubed were used to model the observed curvilinear relationship between age and occupational activity in the data. Individual income included the sum of all sources of income and was divided into tertiles according to annual per capita household income, comparing low income to middle or high income. Education was categorized as having a primary school education or less, a middle school education, and a high school or college education. Time was coded categorically with wave 1991 used as the referent category. We also tested smoking status and self-reported health status, but they were found to not significantly alter the estimates and were excluded from the final models.

Statistical analysis

We used a three-level logistic random intercept multilevel model with measurement occasions (level 1) nested within individuals (level 2) and communities (level 3). We selected this strategy to provide a framework with which we could assess the effects of covariates measured at different levels of a hierarchy on the outcome. Further, multilevel models correct the biases in parameter estimates and provide correct standard errors and thus correct confidence intervals and significance tests because they account for the clustering of data (Guo & Zhao, 2000; Von Korff, Koepsell, Curry, & Diehr, 1992). Using this strategy we constrain the effect of urbanization on individual occupational activity to be the same across all communities. This model is justifiable because it is plausible to assume that, regardless of community, the same ingredients for urbanization are likely to result in similar occupational activity opportunities for residents.

The logistic multilevel model is described by the series of equations outlined below. The first level equation for the probability of light occupational activity is defined as

$$\text{logit}(Y_{tij}) = \pi_{0ij} + \pi_1(\text{TIME})_{tij}, \quad (1)$$

where the indices t, i, and j are used to denote measurement occasions, individuals, and communities, respectively. π_{0ij} represents the initial status of individual ij; TIME represents indicator variables denoting the time periods; and the coefficients π_1 represent the change in the log odds of light occupational activity.

Adding in individual-level predictors, the second level equation is defined as follows:

$$\pi_{0ij} = \beta_{0j} + X_{tij}\beta_1 + r_{ij}, \quad (2)$$

where β_{0j} represents the mean initial occupational activity within community j; X_{tij} represents a matrix of time-variant predictor variables; the coefficients β_1 represent the "gap" in initial occupational activity between the referent group and the indicated group within community j for income and education, and the expected change in the log odds of light occupational activity given a one year increase in age; and r_{ij} is the random intercept for subject i in community j, which varies at level 2.

Adding in predictors at the community level. The third-level equation is defined as follows:

$$\beta_{0j} = \gamma_0 + Z_{tj}\gamma + \mu_j, \tag{3}$$

where γ_0 represents the overall mean initial occupational activity for the referent individual; Z_{tj} represents time-varying community-level variables; the coefficient γ represents the expected change in the log odds of light occupational activity given a one-unit change in urbanization; and μ_j is the random intercept for community j, which varies at level 3 and represents place differences after controlling for individual-level predictor composition.

Substituting, the final model for the probability of light occupational activity is as follows:

$$\text{logit}(Y_{tij}) = \underbrace{\gamma_0 + \pi_1(\text{TIME})_{tij} + X_{tij}\beta_1 + Z_{tj}\gamma}_{\text{Fixed effects}} + \underbrace{r_{ij} + \mu_j}_{\text{Random effects}}. \tag{4}$$

A fully unconditional model including only time was fit first, providing us with an indication of how variation in occupational activity is allocated across the levels (Bryk & Raudenbush, 1992). Including time in this model should not alter the variance structure of the outcome because time is not clustered within communities. Evidence of between-person and between-community variation at this step justifies our addressing individual-level and community-level predictors that may "explain" variation in the intercept (Bryk & Raudenbush, 1992; Diez Roux, 2004; Wright, Bobashev, & Novak, 2005). Cross-level interactions were tested during model building to evaluate whether the effects of community-level characteristics differ by demographic characteristics of residents; and the interaction between urbanization and time was tested to evaluate whether the impact of urbanization on the outcome differed by time period. Interaction terms were included in the final model only if they improved the model fit significantly. Nested models were compared using the difference between the deviances as a likelihood ratio statistic, which has an approximate χ^2 distribution and indicates whether one model is a significant improvement over the other (Guo & Zhao, 2000; Kreft & De Leeuw, 1998). Generalized linear mixed models were operationalized using the GLLAMM program (www.gllamm.org) within Stata/SE version 8.2, which estimates parameters using adaptive Gaussian quadrature (Rabe-Hesketh, Skrondal, & Pickles, 2002).

Results

Population characteristics

At baseline, all individual- and community-level characteristics were associated with level of occupational activity, most notably income, education level, and community-level urbanization quartile (Table 1). Overall, the proportion of men and women with light occupational activity was about equal and increased with increasing level of income, education, and urbanization. Heavy occupational activity was highest in the mid-adult years. In the follow-up years of 1993 and 1997, the majority of shifts were from heavy to light occupational activity.

In Tables 2a (males) and b (females), we show results for nested models in which additional parameters were subsequently added to the fully unconditional model (Model 1). This preliminary model indicated significant variance in occupational activity at both the individual and community levels, implying that further investigation of hypothesized covariates was warranted in attempts to explain this variance.

Fixed effects: individual main effects

Individual-level fixed effects are interpreted as the average effect of the variable across communities. For both men and women, the odds of light occupational activity increased with increasing education and income, were the highest among younger workers, and increased again as retirement age approached. The relationship with time differed by gender, with null results for men in 1993 and 1997 versus baseline after controlling for individual- and group-level predictors (Model 3). However, for women light occupational activity in 1991 was significantly more than that in 1993 and significantly less than levels in 1997, indicating a j-shaped relationship.

The wave variables represent the time-associated effect of urbanization not picked up by the other time-varying variables in the model. In the case of males, the time-varying variable urbanization picked up the majority of the time effect for men.

Table 1
Descriptive statistics for baseline (1991) and selected follow-up characteristics of adults in CHNS sample by gender and type of occupational physical activity

	Men			Women		
	Number	Light or moderate OA[a] (%)	Heavy OA (%)	Number	Light or moderate OA (%)	Heavy OA (%)
Total sample	3034	43.7	56.3	3201	44.2	55.8
Age categories (years)						
18–30	1105	44.0	56.0	1099	48.6	51.4
31–40	910	46.1	53.9	1018	43.8	56.2
41–50	752	39.4	60.6	802	36.3	63.7
51+	267	46.1	53.9	282	50.7	49.3
Income						
Low	987	20.5	79.5	1006	22.0	78.0
Middle	1059	48.3	51.8	1128	49.2	50.8
High	988	61.9	38.1	1067	59.8	40.2
Education						
None/primary	1096	22.4	77.6	1709	24.6	75.4
Middle school	1258	44.9	55.1	982	58.2	41.8
High school+	680	75.7	24.3	510	82.8	17.2
Urbanization index quartiles						
First (17.2-38.2)	791	8.0	92.0	796	8.2	91.8
Second (38.3-49.2)	854	26.2	73.8	897	23.1	76.9
Third (49.3-65.9)	656	57.0	43.0	709	59.9	46.1
Fourth (66.0-89.4)	733	90.6	9.4	799	95.1	4.9
Urban/rural dichotomy						
Rural	2125	24.9	75.1	2217	23.9	76.1
Urban	909	87.5	12.5	984	89.8	10.2
Occupational activity (follow-up years)[b]						
1993 Light OA	971	81.7	18.3	1001	85.3	14.7
1993 Heavy OA	1274	10.3	89.7	1497	12.8	87.2
1997 Light OA	675	71.8	28.2	698	68.9	31.1
1997 Heavy OA	912	10.2	89.8	921	9.1	90.9

[a]*Note*: OA = occupational activity.
[b]Ns indicate those who had data in both 1991 and 1993 or 1991 and 1997. Totals differ due to loss to follow up.

For women, however, the significant relationship between time and occupational activity indicates that the urbanization index may not similarly capture the variability surrounding occupational activity. Thus, urbanization may not have as marked an effect on women's versus men's occupational activity, possibly due to differences in job structures and participation in the labor force for men and women in China.

Fixed effects: community main effects

Tables 2a and b also show the results from the fixed effects for community-level urbanization. For both men and women, after adjustment for individual-level predictors, urbanization was strongly associated with occupational activity (fixed effects, Model 3), with a one unit change in urbanization resulting in a 7% (males) and 6% (females) increase in the odds of light occupational activity. Given that the mean change in urbanization between 1991 and 1997 in communities that were sampled at both time periods was 7.8 index points, this translates to an increase in the odds of light occupational activity of 68% for men and 51% for women.

Using the coefficients from Model 3, we predicted the probability of light occupational activity according to the deciles of urbanization index and demonstrate how the odds of light occupational activity clearly increased with increasing urbanization (Fig. 1), ranging from 24.5% (males) and 30.2% (females) at lowest to 72.0% (males) and 64.8% (females) at highest urbanization index. Therefore there was a 47.5% and 34.6% higher

Table 2a
Odds ratios and 95% confidence intervals from logistic random intercept multilevel models for men predicting the probability of having light or moderate occupational physical activity

Fixed effects	Model 1[a]	Model 2[a]	Model 3[a]	Model 4[a]
Year				
Wave 1991	Ref[b]	Ref	Ref	Ref
Wave 1993	1.34 (1.11, 1.62)**[c]	1.23 (1.01, 1.48)*	1.04 (0.86, 1.26)	1.04 (0.85, 1.26)
Wave 1997	2.58 (2.09, 3.18)***	2.18 (1.76, 2.69)***	1.21 (0.94, 1.55)	1.19 (0.93, 1.54)
Age (in years)				
Age		0.44 (0.31, 0.64)***	0.45 (0.32, 0.65)***	0.10 (0.03, 0.40)**
Age squared		1.02 (1.01, 1.03)***	1.02 (1.01, 1.03)***	1.06 (1.02, 1.10)**
Age cubed		1.00 (1.00, 1.00)**	1.00 (1.00, 1.00)**	1.00 (1.00, 1.00)**
Income				
Low income		Ref	Ref	Ref
Middle income		2.21 (1.76, 2.77)***	2.16 (1.73, 2.70)***	2.18 (1.75, 2.72)***
High income		3.77 (2.93, 4.87)***	3.65 (2.84, 4.68)***	3.69 (2.87, 4.73)***
Education				
None/primary school		Ref	Ref	Ref
Middle school		3.27 (2.53, 4.23)***	3.26 (2.54, 4.19)***	3.28 (2.59, 4.20)***
High school or above		8.69 (6.27, 12.06)***	8.73 (6.36, 11.99)***	8.80 (6.41, 12.07)***
Urbanization index			1.07 (1.05, 1.09)***	1.07 (1.05, 1.09)***
Interaction terms				
Index*age interaction				1.03 (1.00, 1.06)*
Index*age squared				1.00 (1.00, 1.00)*
Index*age cubed				1.00 (1.00, 1.00)*
Random effects	Variance (SE)[b] Z	Variance (SE) Z	Variance (SE) Z	Variance (SE) Z
Person level (r_{ij})	3.1372 (0.3789) 8.280***	2.2867 (0.3134) 7.296***	2.0949 (0.2897) 7.231***	2.0721 (0.2873) 7.212***
Community level (μ_j)	15.5741 (2.1468) 7.255***	11.1125 (1.5459) 7.188***	5.1652 (0.9382) 5.505***	5.0678 (0.9223) 5.495***
Test statistics				
Deviance	6517.9064	6140.4662	6088.6192	6078.8842
Degrees of freedom	5	13	12	16
Likelihood ratio test	—	377.4402 (7)***	51.847 (1)***	9.735 (4)*
Intra-community correlation (ρ)[d]	0.83	0.83	0.71	0.71
% community-level variance explained with added parameters[e]	—	28.6% (over Model 1)	66.8% (over Model 1) 53.5% (over Model 2)	1.9% (over Model 3)

[a]Model 1 controls only for time factors to determine between-community variance in outcome variable; Model 2 includes individual-level factors; Model 3 includes the community-level predictor, urbanization; Model 4 contains relevant interaction terms.
[b]*Notes*: SE = standard error; Ref = referent category.
[c]*$p<0.05$, **$p<0.01$, ***$p<0.001$.
[d]ICC for level 2 within level 3 (people within communities) = $\mu_j/(\mu_j + r_{ij})$.
[e]$(\text{Model}_{\text{adjusted}}-\text{Model}_{\text{unadjusted}})/\text{Model}_{\text{unadjusted}}*100\%$.

chance of having light occupational activity for men and women, respectively, given residence in the most urban versus the most rural communities.

Cross-level interaction effects

As a final step, we tested cross-level interactions between urbanization and all individual-level variables to determine whether the effect of urbanization differed by individual characteristics. We found no evidence of significant interaction between any individual-level variable and urbanization for women. However, for men there was a significant interaction between urbanization and age (Table 2a, Model 4), suggesting that for men the relationship between urbanization and occupational activity differs by age. We further tested the interaction between time and urbanization and found no

Table 2b
Odds ratios and 95% confidence intervals from logistic random intercept multilevel models for women predicting the probability of having light or moderate occupational physical activity

Fixed effects	Model 1[a]	Model 2[a]	Model 3[a]
Year			
Wave 1991	Ref[b]	Ref	Ref
Wave 1993	0.89 (0.74, 1.08)	0.88 (0.73, 1.06)	0.79 (0.65, 0.96)*
Wave 1997	3.06 (2.49, 3.75)***[c]	2.92 (2.36, 3.62)***	1.85 (1.43, 2.39)***
Age (in years)			
Age		0.41 (0.29, 0.59)***	0.41 (0.29, 0.59)***
Age squared		1.02 (1.01, 1.03)***	1.02 (1.01, 1.03)***
Age cubed		1.00 (1.00, 1.00)**	1.00 (1.00, 1.00)**
Income			
Low income		Ref	Ref
Middle income		2.08 (1.67, 2.60)***	2.01 (1.62, 2.50)***
High income		2.90 (2.26, 3.71)***	2.78 (2.18, 3.55)***
Education			
None/primary school		Ref	Ref
Middle school		2.46 (1.94, 3.12)***	2.50 (1.98, 3.17)***
High school or above		6.57 (4.64, 9.32)***	6.69 (4.74, 9.45)***
Urbanization index			1.06 (1.04, 1.08)***

Random effects	Variance (SE)[b] Z	Variance (SE) Z	Variance (SE) Z
Person level (r_{ij})	1.8888 (0.2838) 6.655***	1.3194 (0.2339) 5.641***	1.2796 (0.2272) 5.632***
Community level (μ_j)	16.9632 (2.4458) 6.936***	13.3766 (1.9071) 7.014***	7.9937 (1.3632) 5.864***

Test statistics			
Deviance	6147.3198	5694.0796	5660.1464
Degrees of freedom	5	12	13
Likelihood ratio test	—	453.2402(7); $p<0.001$	33.9332(1); $p<0.0001$
Intra-community correlation (ρ)[d]	0.90	0.91	0.86
% Community-level variance explained with added parameters[e]	—	21.1% (over Model 1)	52.9% (over Model 1) 40.2% (over Model 2)

[a]Model 1 controls only for time factors to determine between-community variance in outcome variable; Model 2 includes individual-level factors; Model 3 includes the community-level predictor, urbanization.
[b]*Notes*: SE = standard error; Ref = referent category.
[c]$*p<0.05$, $**p<0.01$, $***p<0.001$.
[d]ICC for level 2 within level 3 (people within communities) $= \mu_j/(\mu_j + r_{ij})$.
[e]$(\text{Model}_{\text{adjusted}} - \text{Model}_{\text{unadjusted}})/\text{Model}_{\text{unadjusted}} * 100\%$.

significant result for either men or women. This suggests that urbanization's effect on occupational activity is not increasing (nor decreasing) over time; rather, that during the time period we sampled (1991–1997) this relationship was constant.

Random effects

Model 1 (Tables 2a and b) is clearly under-specified, but it allowed for exploration of community-level variability in occupational activity. In both men and women we observed a significant level of extra-individual variability and thus can reasonably address predictors that may "explain" group-level variation in the intercept. First, however, we added individual-level predictors (Model 2) because variation may arise not because place per se is important, but because individuals with certain characteristics (e.g. higher income or education) may cluster in select communities and give rise to spatially differentiated population compositions. There was a decline in community-level variation

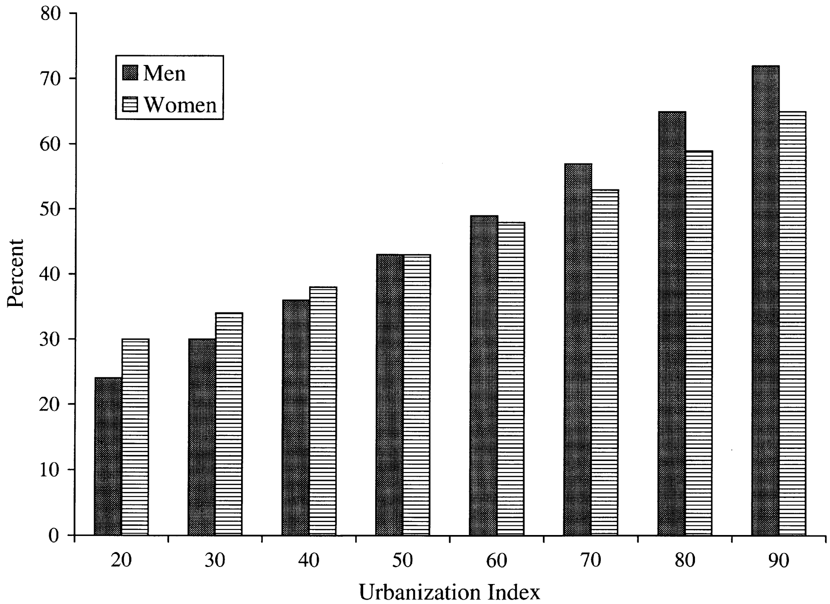

Fig. 1. Predicted proportion of population (a) participating in light or moderate occupational physical activity by decile of urbanization index (b). (a) Predicted probability calculated using coefficients from Model 3 (shown in Tables 2a and 2b), (b) Urbanization index ranges from most rural (21.1) to most urban (89.4).

with the addition of individual-level predictors, which explained 29% and 21% (Tables 2a and b, Model 2, see footnote e) of the variation for men and women, respectively, indicating community-level population differences. A goodness-of-fit test based upon the difference in the deviance between the two models, indicated that Model 2 was a significantly better fit than Model 1 (for men: $\chi^2 = 377$ with 7° of freedom, $p<0.001$). Next, adding the urbanization measure resulted in an additional, and larger, decline in community-level variance, explaining 54% and 40% (Tables 2a and b, Model 3, see footnote e) of the variance in occupational activity for men and women, respectively. Further, including urbanization in the model led to a substantial reduction in the likelihood (for men: $\chi^2 = 52$ with 1° of freedom, $p<0.001$). The high intraclass correlation values, as a measure of the similarity of people from the same community, indicated substantial clustering of occupational activity in community and a strong community influence on individual occupational activity for both men and women.

Discussion

Our results, based upon data from a diverse sample of Chinese adults, showed that community-level urbanization was importantly associated with occupational activity among men and women after adjustment for individual-level sociodemographic factors. In fact, between-community differences explained over half of the total variability in occupational activity in this population for men, and 40% in women. Further, the measure of intraclass correlation indicated that urbanization was a more important determinant of occupational activity than the individual factors we assessed. Our results showed that for every one-unit increase in urbanization in a given community, men had 7% and women 6% higher odds of light occupational activity, which translates to an increase in odds of 68% for men and 51% for women given the mean change in urbanization over the time period. Considering that there is no foreseeable decline of urbanization in China, our results herald a dramatic decline in overall occupational activity in the adult populace.

While occupational activity is studied less frequently than other forms of activity, a number of studies have demonstrated the importance of work as a source of energy expenditure (Dorn et al., 1999; Evenson et al., 2003; King et al., 2001; Salmon et al., 2000). In developed countries such as the United States, those with the light occupational activity are more likely to have higher levels of leisure time activity (Burton & Turrell, 2000; Evenson et al., 2003; Salmon et al., 2000). However, leisure time activity is not yet common for the Chinese, thus it can be postulated that through the decline of work-related activity many adults will lose a substantial amount of their overall physical activity. Nonetheless, we note that these patterns might be specific to countries or levels of economic development. Recent econometric research has examined the consequences of technological change on rising obesity incidence, partly through its effects on declining work-related physical activity (Lakdawalla & Philipson, 2002; Philipson & Posner, 2003). These studies, while not utilizing direct measurement of activity patterns by occupation, found that occupational activity change was a key component of the increase in obesity seen in the United States. While it was not the purpose of this paper to examine the effect of urbanization on the rising obesity rates in China, the important connection found between technological forces (as enacted through urbanization) and occupational physical activity, which we have shown to be an important determinant of weight in earlier work (Bell et al., 2001; Du et al., 2002; Paeratakul et al., 1998; Popkin, Paeratakul, Zhai, & Ge, 1995a; Stookey et al., 2001), is evidence of a possible connection between the two.

Our results show a monotonic increase in sedentariness in work with increased income and education for both men and women. It is of interest to note that while in developing countries lower socioeconomic status is protective against obesity (Monteiro, Conde, Lu, & Popkin, 2004; Philipson & Posner, 2003; Popkin & Gordon-Larsen, 2004), as urbanization continues and more individuals transition into sedentary jobs, we might expect obesity not only to increase but also to impact those of lower socioeconomic status. We further see that younger workers are the most sedentary. Technology-driven jobs which thrive in an urbanizing environment tend to draw a younger work force while those who are older and have a more limited skill set and are obliged to continue in jobs requiring more physical labor. Of course, as workers age and approach retirement they again become more sedentary.

This study has a number of limitations. First the activity data used were based on self-report, and thus potentially subject to reporting biases. Nonetheless, our measure of occupational activity is assessed for each individual in a manner that differentiates between people in the same occupation subgroup but with different activity patterns, and it has been successfully used in past analyses (Bell et al., 2001; Paeratakul et al., 1998; Stookey et al., 2001). Second, assessment at the community level may not be the most theoretically relevant level because the occupational environment may be quite heterogeneous within a community (Friedman, 2005; Li et al., 2005). Thus, a potentially better measure would be the immediate surrounding area encompassing an individual's direct occupational opportunity. However, we note that the likely effect of our using the more heterogeneous area would be a reduced ability to detect any ecological effect (Blakely & Woodward, 2000). Third, unexplained area effects at the community level demonstrate that there are still differences between communities that are not being captured by the explanatory variables (Snijders & Bosker, 1999), and there is a need to try and account for this between-place variation in occupational activity. One option is to consider other possible sources of contextual variation, including selection effects arising from compositional differences between communities.

We note that if aspects of the environment act as determinants of individual characteristics, adjustment for these characteristics at the individual level may over-adjust the true effects of the context (Diez Roux, 2002). This is possible in our models where it is plausible to imagine that, for instance, an individual's income may influence the make-up of the urbanization of the environment, but also that the environment may influence the income potential of the individuals that live within it. Blakely and Woodward suggest that analyses with and without the individual level covariate should be presented to give an upper and lower bound within which the reader may judge the 'true' ecological effect (Blakely & Woodward, 2000). We ran models both with education and income included as well as with them excluded and found little effect on either the coefficient for urbanization or the precision of the estimate (data not shown). Thus, though these individual-level predictors do not appear to be operating as confounders of the association between urbanization and occupational activity, we thought it important to include them to account for the compositional effect of the community on occupational activity variance as well as to follow established precedent in the literature.

This study has a number of strengths. First, the use of multilevel modeling helped to separate the community effects from the individual effects on occupational activity. Second, our contextual variable, urbanization, was composed of ten different dimensions of infrastructure, economic and demographic items for each community surveyed. This vastly improves our ability to discern influences of urbanization over the oft-used urban/rural dichotomy, which not only assumes homogeneity within the categories "urban" and "rural," but also is unable to account for change over time. Third, our use of multiple waves of data enabled us not only to test for time-dependent influences of urbanization on occupational activity, but also to have increased precision when estimating coefficients.

In conclusion, as China continues to urbanize and to shift from an agricultural to a service-based economy, we can expect further declines in work-related activity. Without substitutions of alternative forms of energy expenditure, we expect increases in the numbers of overweight and obese individuals. Future policy responses need to address mechanisms that compensate for increasing sedentariness in occupational life, while remaining aware of features of the environment that facilitate or impede different types of physical activity. China's transition to a more urbanized and technological society is likely to also impact transportation and leisure time activity. While there has been some research surrounding this in developed countries (Craig et al., 2002; Handy, Boarnet, Ewing, & Killingsworth, 2002; Prentice & Jebb, 1995; Sturm, 2004, 2005), additional research is necessary to understand the influence of such changes in developing economies. Chinese society cannot be expected to revert to its traditional way of life associated with labor-intensive occupations, high levels of activity commuting, and limited leisure time. Urbanization and modernization represent substantial progress and should be expected to continue. As individuals in China live in increasingly technology-dependent environments, findings from this study suggest that those involved in public health promotion efforts, urban planning, and transportation science need to target alternative forms of physical activity in efforts to benefit the health of many millions of humans.

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