European Journal of Clinical Nutrition (2008) 62, 1318–1325
 0954-3007/08 $32.00
www.nature.com/ejcn

ORIGINAL ARTICLE

Longitudinal relationships between occupational and domestic physical activity patterns and body weight in China

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Objectives: To examine the longitudinal relationship between occupational and domestic sources of physical activity and body weight in a sample of Chinese adults.
Methods: Population-based longitudinal observational study of Chinese adults (4697 women and 4708 men) aged 18–55 from the 1991, 1993, 1997, and 2000 waves of the China Health and Nutrition Survey. Measured height and weight and detailed self-reported energy expenditure from multiple occupational and domestic sources were assessed over a 9-year period. Longitudinal relationships were modeled using linear random effects models.
Results: Increased occupational physical activity resulted in overall lower body weight for both men and women (β-coefficients (95% confidence interval (CI)) for high levels: −0.46 (−0.76, −0.15) for men, −0.36 (−0.62, −0.10) for women, and increased domestic physical activity resulted in overall lower body weight in men (β-coefficient (95% CI): −0.40 (−0.62, −0.18)).
Conclusions: Physical activity that occurs in the occupational and domestic sectors is often overlooked; yet our research suggests they have important effects on body weight in Chinese adults. As China continues to urbanize, energy expenditure from these sources is decreasing, and our results point out the need to explore these types of physical activity more broadly across the world as potential sources of weight gain.
European Journal of Clinical Nutrition (2008) **62,** 1318–1325; doi:10.1038/sj.ejcn.1602849; published online 18 July 2007

Keywords: domestic activity; occupational activity; urbanization; body weight; longitudinal

Introduction

Obesity has become a global concern (WHO/FAO, 2003). While there is enormous heterogeneity in the prevalence of obesity throughout the world, overall obesity prevalence is lower in less-developed than in developed countries (Mendez *et al.*, 2005). Nonetheless, very high levels of overweight and obesity exist across the lower- and middle-income world and rates of increase are great (Mendez *et al.*, 2005; Popkin, 2006; Popkin *et al.*, 2006). This is certainly true in China, where there has been a recent and dramatic rise in the number of overweight adults in the recent past (Bell *et al.*, 2001; Du *et al.*, 2002). Further, rapid economic and social change has led to increased use of time- and laborsaving technologies, potentially reducing energy expenditure in both the home and occupational sectors (Popkin, 2003). In fact, some economists have argued that technological change is partly responsible for the obesity epidemic, because of its effect of reducing energy expenditure in the workplace (Lakdawalla and Philipson, 2002; Philipson and Posner, 2003).

Research examining the association between physical activity and overweight has largely focused on leisure-time physical activity rather than other sources of energy expenditure. However, evidence from studies that have examined physical activity in the domestic and occupational spheres has shown these sources to be important (Weller and Corey, 1998; Evenson *et al.*, 2003). In China, occupational activity has been shown to be the key modifiable determinant of weight gain (Bell *et al.*, 2001). However, there is limited population-based, longitudinal research on weight and activity trends. This study attempts to address these gaps by studying the longitudinal association of weight to energy expended in occupational and domestic physical activity in a diverse sample of Chinese adults.

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Received 8 November 2006; revised 13 June 2007; accepted 18 June 2007; published online 18 July 2007

Methods

Study population

Data were derived from the China Health and Nutrition Survey (CHNS), an ongoing longitudinal survey initially conducted in 1989 in eight provinces. While the survey is not nationally representative, the provinces do vary substantially in geography, stage of economic development and health status. Four counties within each province (1 low-, 2 middle- and 1 high-income, based on per capita income reported by the National Bureau of Statistics) were randomly selected using a weighted sampling scheme. In addition, the provincial capital city along with a lower-income city was selected. Villages and townships within the counties and urban, and suburban neighborhoods within the cities were selected randomly, for a total of 190 primary sampling units (PSU) at baseline. Twenty randomly selected households were surveyed within each PSU, and all individuals within a household were interviewed.

For these analyses, we used all available data from adults aged 18–55 years surveyed in 1991, 1993, 1997 and 2000 ($N=4697$ women and $N=4708$ men). Individuals missing data for any variable included in the final models were excluded, as were pregnant women ($n=97$). Response rates were 88.1, 88.2, 80.4 and 82.9% for the 1991, 1993, 1997 and 2000 survey years, respectively. Data from the 1989 survey were not used due to differences in the questionnaire over time.

Study variables

Anthropometrics and overweight status. Trained health workers (teams of two, four teams/PSU) collected anthropometric data during a comprehensive physical exam at a local clinic or at the respondent's home if necessary. Height was measured without shoes to the nearest 0.2 cm using a portable stadiometer; weight was measured without shoes and in light clothing to the nearest 0.1 kg on a calibrated beam scale. Overweight and obesity were defined using the body mass index (weight in kilograms/height meters^2) cut points of 25 and 30, respectively.

Occupational activity. Respondents reported wage-earning occupation(s) worked in the last year from jobs both outside the home (that is, market sector jobs such as working in an office) as well as those worked from home. Data were included from up to two market-based jobs; home-based jobs included working on a farm, working in a vegetable garden or orchard, raising livestock or poultry, work fishing and working in a home business. For each occupation, respondents reported the average number of hours per week worked in the last year.

To create a measure of energy expenditure, time spent in each occupation was multiplied by a specific metabolic equivalent (MET) intensity value; final units were MET-h/week. During a detailed interview, respondents were asked about the time spent sitting, standing, walking and lifting heavy loads during an average working day, and then were categorized as having light, moderate or heavy occupational activity. While formal reliability and validity analyses have not been run on this variable, several published studies have found it to be a significant predictor of weight (Paeratakul *et al*., 1998; Bell *et al*., 2001; Stookey *et al*., 2001). Further, it is closely related to several survey instruments, which have been shown to have good reliability and validity in diverse populations (Baecke *et al*., 1982; Philippaerts and Lefevre, 1998; Ainsworth *et al*., 1999; Reis *et al*., 2005). Reported occupations were then cross-tabbed against this self-reported measure of occupational activity; for each specific occupation, MET values of 2 (light), 4 (moderate) or 6 (heavy) (Pate *et al*., 1995) were assigned based on how the majority of respondents reporting this occupation were classified. Farming, fishing, working in a garden/orchard and working in livestock were reported as high-intensity occupations and was assigned a MET value of 6. MET values of 4 were assigned to those working as a skilled worker (foreman, group leader and craftsman), as a non-skilled worker (ordinary laborer and logger) and as a driver, homemaker, or student. MET values of 2 were assigned to those working in a home business, working as a senior or junior professional, working as an administrator, executive, manager, or office staff and working as an army or police officer. For those reporting more than one job, individual MET-h/week values were summed to obtain a measure of total occupational energy expenditure. This value was categorized based on a 40-h work week as <3 (light), 3–6 (moderate) and $\geqslant 6$ (vigorous) METs (that is, <120, 120–240 and $\geqslant 240$ MET-h/week).

Domestic activity. For an overall measure of domestic physical activity, we used four different activities that were available in all survey years: time spent preparing food, buying food, doing laundry and in childcare. All activities were reported in average h/week spent in the past year.

To create a measure of domestic energy expenditure, time spent in each activity was multiplied by a specific MET intensity value; final units were MET-h/week. We used the Compendium of Physical Activities (Ainsworth *et al*., 2000) to assign specific MET intensity values: 2.25 for preparing food, 2.3 for buying food, 2.15 for doing laundry and 2.75 for childcare. Although all of these activities are of light intensity, we hypothesized that the amount of time spent overall warranted their examination. Individual MET-h/week values were summed to obtain a measure of total domestic energy expenditure. Categories for domestic activity for women were created based on the observed relationship with overweight status in the data at baseline: 0, >0 to <50, 50–200 and $\geqslant 200$ MET-h/week. For men, who spent far less time in domestic activity, the variable was dichotomized as any versus none. On average, the majority of time was spent in childcare, and because these hours may be overestimated due to multitasking, we also ran analyses with this activity

separated out from the other three. Categories for men were still dichotomized as any versus none, while categories for women were, for childcare: 0, >0 to <200 and ⩾200 MET-h/week, and for the remaining three domestic activities: 0, >0 to <40, and ⩾40 MET-h/week.

Statistical analysis

Longitudinal linear random effects models were used to investigate the relationship of occupational and domestic activity to weight. These models assess the net effect of changing occupational or domestic activity category on change in weight over all survey periods. Further, they adjust for the correlation between repeated observations taken in the same subject and have the advantage of handling longitudinal data on subjects with varying number and unequally spaced observations.

All analyses were stratified by gender. Covariates were age and age-squared, total energy intake, and height (all used continuously); deflated household income per capita (comparing low to middle or high income); education (categorized as primary school or less, middle school, high school or college); urban (versus rural) residence; and survey year. Potential interactions between urban residence and activity and between survey year and activity were examined, but no meaningful effect modification was observed.

In our first model, occupational activity was included with domestic activity and covariates; our second model separated childcare out from the other three forms of domestic activity. Finally, longitudinal models were run to estimate the effect on weight of owning various laborsaving household devices. Statistical procedures were implemented using Stata version 9.1 (Stata Corporation, College Station, TX, USA).

Results

At baseline (1991), men and women with less occupational activity had higher overweight prevalence (Table 1). Overweight prevalence was higher in urban residents and individuals of middle or upper income. Among men only, overweight prevalence was significantly higher in those with some college or technical education.

Time trends of weight status and energy expenditure

Figure 1 shows trends in the prevalence of overweight and obesity between 1991 and 2000. Overweight increased in men from 7.9 to 19.4%, and in women from 12.2 to 20.7%. While the obese represent a small proportion, obesity increased 233 and 108% in the 9-year period for men and women, respectively.

Figure 2 shows trends in the average occupational and domestic energy expenditure by gender over the 9-year study period. Energy expenditure from occupational sources declined 22 and 24% in men and women, respectively, whereas that from domestic sources declined 57 and 51%. At baseline, women worked only marginally more occupational MET-h/week than men, but worked over four times as many domestic MET-h/week.

There have also been substantial shifts in the types of jobs commonly held by the adult populace. Although highly active farming was the most frequently reported occupation

Table 1 Baseline (1991) characteristics of men and women stratified by overweight status

	Men		*Women*	
	*Not overweight (*N = *2502)*	*Overweight (*N = *246)*	*Not overweight (*N = *2624)*	*Overweight (*N = *392)*
Age (years)	35.3 ± 9.8	39.2 ± 8.9**	34.6 ± 9.5	38.5 ± 8.3**
Urban residence (%)	27.9	51.6**	26.2	35.2**
Income tertiles (%)				
Low	32.7	12.6[a]	32.7	21.4[a]
Middle	34.4	42.3[b]	34.4	38.3[b]
High	32.9	45.1[b]	32.9	40.3[b]
Education (%)				
None/primary	36.5	28.9[a]	53.3	53.6
Middle school	42.0	40.7[a]	31.1	29.9
High school	14.9	17.9	11.5	11.0
College/technical	6.7	12.6[b]	4.1	5.6
Total energy intake (kJ)	12 113.4 ± 2853.2	12 052.3 ± 2779.1	10 622.8 ± 2676.9	10 650.4 ± 2663.1
Occupational activity (MET-h/week)	234.3 ± 139.7	180.1 ± 103.0**	254.4 ± 161.0	214.7 ± 146.9**
Domestic activity (MET-h/week)	18.0 ± 36.4	17.3 ± 25.8	64.9 ± 64.2	63.7 ± 53.9

Abbreviations: ANOVA, analysis of variance; MET, metabolic equivalent.
Continuous variables are mean ± s.d. and categorical variables are proportions.
*P<0.01; **P<0.001.
[a,b]Within income and education categories, proportions that differ from one another by ANOVA at P ⩽0.01 noted with different letters.

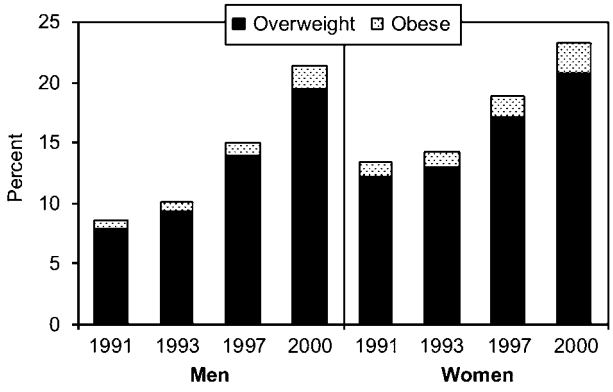

Figure 1 Trends in the prevalence of overweight (BMI ⩾ 25 to < 30) and obesity (BMI ⩾ 30) in adult men and women, CHNS 1991–2000. BMI, body mass index; CHNS, China Health and Nutrition Survey.

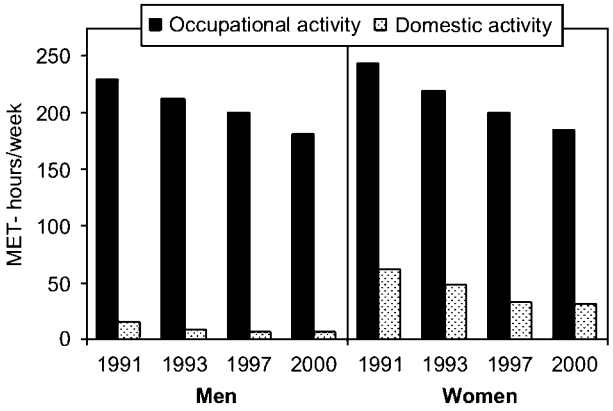

Figure 2 Trends in average energy expenditure in MET-h/week from occupational and domestic physical activity for adult men and women, CHNS 1991–2000. CHNS, China Health and Nutrition Survey; MET, metabolic equivalent.

in both 1991 and 2000 (56 and 50%, respectively), both it and moderately active occupational laborer have decreased. During the same period, sedentary occupations (those with MET values of <3) such as professionals, and office and service workers have risen from 22 to 32% of the workforce.

Between 1991 and 2000 acquisition of laborsaving household goods increased dramatically. Ownership of washing machines rose from 40 to 54%, and that of refrigerators from 17 to 38%. Cooking appliances, such as electric pots and pressure cookers, rose from 20 to 49% and 25 to 43%, respectively, whereas microwave ovens are still relatively uncommon, ownership rose from less than 1 to 6%. Overall ownership of appliances was higher in urban than in rural areas; however, the rate of acquisition in the rural areas exceeded that in the urban areas.

Determinants of body weight in men and women

Results of regressing weight on occupational and domestic activity are summarized in Table 2. Results from Model 1 show that for men, the net effect of increasing from a low-intensity occupation (<120 MET-h/week) to a moderate intensity occupation (120–240 MET-h/week) was a significant reduction in weight of, on average, 0.3 kg (β-coefficient: –0.29); increasing from a low to high-intensity occupation (⩾240 MET-h/week) had the net effect of significantly reducing weight, on average 0.5 kg (β-coefficient: −0.46). Similarly for women, increasing from a low to moderate or a low to high-intensity occupation had the net effect of significantly reducing weight 0.3 and 0.4 kg, respectively (β-coefficients: −0.29 and −0.36).

Results from total domestic activity (Model 1) indicate that, for men, the net effect of any domestic activity resulted in a significant reduction in weight of approximately 0.5 kg. When childcare was separated from the other three domestic tasks (Model 2), both had an inverse association with weight; however, the effect of childcare on weight was slightly less than that from the other three tasks, and failed to reach statistical significance.

For women, although coefficients from total domestic activity (Model 1) were in the expected inverse direction, they failed to reach statistical significance, and do not indicate a dose–response relationship with increasing levels of energy expenditure. Similarly, when childcare was separated from the other types of domestic activity (Model 2), the coefficients for both were in the expected inverse direction but again failed to reach statistical significance. While there was the suggestion of an inverse dose–response relationship with increasing levels of energy expenditure in childcare, this was not seen with the other types of activity.

Table 3 presents results from analyses in which we investigated the net effect of owning various laborsaving domestic appliances on weight in men and women. Results indicate that, in men, the net effect of ownership of any one of the appliances resulted in a significant increase in weight, most dramatically for refrigerators (β-coefficient: 1.37). In women, the net effect of owning a washing machine, refrigerator or an electric pot resulted in a significant increase in weight, whereas owning a microwave oven or a pressure cooker did not. To explore whether domestic activity was acting as a mediator in the relationship between ownership and weight, we ran a simple mediation analysis (Sobel, 1982). Results (data not shown) indicated that in both men and women for all five laborsaving devices examined, domestic activity acted as a partial mediator of the relationship between device ownership and body weight.

Discussion

In this diverse sample of Chinese men and women, the prevalence of overweight nearly doubled in women and more than doubled in men between 1991 and 2000, a

Table 2 Results from longitudinal models of occupational and domestic physical activity on weight in men and women, 1991–2000[a]

	Men		*Women*	
	Coefficient	*95% CI*	*Coefficient*	*95% CI*
Model 1				
Occupational activity				
<120 MET-h/week	Ref		Ref	
120 to <240 MET-h/week	−0.29*	−0.56, −0.01	−0.29*	−0.53, −0.05
⩾240 MET-h/week	−0.46**	−0.76, −0.15	−0.36**	−0.62, −0.10
Total domestic activity				
Any MET-h/week[b]	−0.45***	−0.67, −0.24	—	—
0 MET-h/week	—	—	Ref	
>0 to <50 MET-h/week	—	—	−0.22	−0.62, 0.18
50 to <200 Met-h/week	—	—	−0.17	−0.60, 0.25
⩾200 MET-h/week	—	—	−0.16	−0.82, 0.51
Model 2[c]				
Domestic activity: buying food, preparing food and laundry				
Any MET-h/week[b]	−0.40***	−0.62, −0.18	—	—
0 MET-h/week	—	—	Ref	
>0 to <40 MET-h/week	—	—	−0.24	−0.62, 0.15
⩾40 MET-h/week	—	—	−0.11	−0.51, 0.30
Domestic activity: childcare				
Any MET-h/week[b]	−0.34	−0.68, 0.01	—	—
0 MET-h/week	—	—	Ref	
>0 to <200 MET-h/week	—	—	−0.18	−0.41, 0.06
⩾200 MET-h/week	—	—	−0.44	−1.31, 0.43

Abbreviations: CI, confidence interval; Ref, referent category.
*$P<0.05$; **$P<0.01$; ***$P<0.001$.
[a]Longitudinal linear random effects models controlled for height, urban residence, age, income, education, total energy intake and survey year.
[b]None is referent.
[c]Model 2 also includes occupational activity as specified in Model 1, results did not substantially differ so are not shown above.

Table 3 Results from longitudinal models of ownership of laborsaving household devices on weight in men and women, 1991–2000[a]

	Men		*Women*	
	Coefficient	*95% CI*	*Coefficient*	*95% CI*
Washing machine	1.16**	0.87, 1.44	0.96**	0.71, 1.21
Refrigerator	1.37**	1.05, 1.69	1.29**	1.01, 1.57
Microwave	1.25**	0.53, 1.98	0.36	−0.27, 0.98
Electric pot	0.87**	0.60, 1.13	0.45**	0.21, 0.68
Pressure cooker	0.30*	0.01, 0.60	0.26	−0.01, 0.52

Abbreviation: CI, confidence interval.
*$P<0.05$; **$P\leqslant0.001$.
[a]Longitudinal linear random effects models controlled for urban residence, age, income, education, total energy intake and survey year.

troubling trend for the approximately 700 million Chinese adults. During the same period, energy expenditure from both occupational and domestic sources decreased. The primary results of this longitudinal study show that the net effect of increasing occupational physical activity resulted in overall lower body weight for both men and women, and increasing domestic physical activity resulted in overall lower body weight in men. We have also shown how the net effect of ownership of various laborsaving household devices resulted in overall increases in weight for both men and women.

While it is probable that some declines in occupational activity levels are occurring within job categories due to increasing technology and automation (Hill and Melanson, 1999; French *et al*., 2001), this study did not attempt to capture within-job activity changes. Rather, declines in occupational activity were due to (1) decreases in the time spent and (2) shifts over time in the types of jobs held. In these data, between 1991 and 2000 the biggest decline in job type was in farming and the biggest increase was in home businesses. Overall, both men and women transitioned from more physically exerting jobs into more sedentary occupations.

Results from studies examining the relationship between occupational activity and obesity are mixed. While some inverse associations have been reported between occupational activity and obesity and its associated sequelae (King *et al*., 2001; Barengo *et al*., 2004; Mummery *et al*., 2005), others have found no association (Ball *et al*., 2001; Gutierrez-Fisac *et al*., 2002). The majority of this work investigates

populations from higher-income countries where leisure-time physical activity is far more prevalent, and studies have shown the interaction of leisure time and occupational activity to be quite complex (Burton and Turrell, 2000; Salmon *et al*., 2000; King *et al*., 2001; Evenson *et al*., 2003). However, in many developing countries, China included, adults acquire the majority of their daily physical activity in their working lives and leisure-time physical activity is relatively uncommon (Popkin, 1999; Caballero, 2001); thus highlighting the importance in considering occupation when assessing overall energy expenditure. For instance, in an earlier study using this cohort, Bell *et al*. (2001) found that occupational activity was the key modifiable determinant of weight gain. Further studies in Chinese populations have shown occupational shifts from more strenuous to less strenuous jobs to be associated with adverse changes in cardiovascular risk factors (Xu *et al*., 1997; Zhou *et al*., 2003), and energy expenditure as measured by doubly labeled water in urban Chinese adults was found to be inversely associated with body fatness (Yao *et al*., 2003).

We have also illustrated the decline in domestic activity in this population. In developing countries such as China, it is possible that domestic tasks substantially contribute to overall physical activity due to lower household mechanization; however, urbanization has promoted the acquisition of laborsaving devices in the home, which have been shown to decrease energy expenditure (Lanningham-Foster *et al*., 2003). We hypothesized that the decline in domestic activity was partially attributable to the increasing availability and purchase of time-saving household devices not easily obtained in the past, and have demonstrated that not only has ownership of a number of these devices dramatically increased over the study period, but also that ownership is associated with increased weight in both men and women, after controlling for socioeconomic factors and urban residence. Obviously, ownership of these devices does not, *per se*, make one overweight; rather, we postulate that it operates by reducing time spent in domestic tasks. Alternatively, these measures might represent proxies for long-term overall wealth and may not affect time utilization patterns. Controlling for income, as we have done, is not equal to controlling for wealth. Thus, these effects may suffer to some degree from residual confounding. We did in fact find that domestic activity does not completely mediate the ownership—body weight relationship—suggesting not only that ownership has independent effects but also that there are other unknown potential mediating factors.

Recent research has highlighted the importance of including domestic activity in assessing total energy expenditure, primarily in women. In a prospective study examining the relationship between physical activity and mortality in women, Weller and Corey (1998) concluded that the inverse relations were mainly due to the contribution of domestic physical activity, whereas Phongsavan *et al*. (2004) concluded that inclusion of domestic sources of activity was important in women attaining sufficient levels of activity. In a cross-sectional study, however, while Lawlor *et al*. agreed that domestic activity was important in assessing sufficient levels of activity, it had no independent effect on levels of overweight in elderly white women (Lawlor *et al*., 2002).

Our results suggest an inverse dose–response relationship of occupational activity with weight in men and women, whereas in men, we found a statistically significant inverse relationship between any domestic activity and weight. Differences between men and women in domestic activity could be due to the vigorousness with which tasks were completed, or perhaps that men tend to assume the more labor-intensive tasks within the household. In fact, research on rural Chinese men who undertake domestic work indicates they are generally middle-aged and married with no other women in the family to help with domestic duties (Jacka, 1997). Thus, it may be incumbent on these men to contribute in ways that are more vigorous and labor-intensive.

A major strength of this study is that we were able to include multiple sources of occupational activity. Many Chinese hold multiple jobs, both at home and away from home; thus, the inclusion of all activity allows a more complete assessment of total work. This may be especially important for women in developing countries because of the multiple responsibilities that women have (McGuire and Popkin, 1989, 1990; Donahoe, 1999; Short *et al*., 2002). This importance is borne out when we examine the proportion of women who report having multiple work burdens: over 1/3 of women overall and over 40% of women residing in rural areas report doing three or more types of occupational work, in addition to their domestic responsibilities. A further strength of this study is our ability to assess and quantify domestic activity. While researchers have acknowledged its importance, this source of activity has been understudied and appears to be an important source of energy expenditure for this population.

A few limitations of this work warrant addressing. First, both occupational and domestic activity data rely on self-report, which can lead to recall bias. Studies have shown that overweight individuals tend to over-report their physical activity (Lichtman *et al*., 1992; Buchowski *et al*., 1999); however, the majority of this work has not been done in populations from lower-income developing countries where the stigma with being overweight is much less established. Nonetheless, if this were the case in these data, over-reporting of activity data would only serve to attenuate the estimates by misclassifying overweight individuals as being more active than they truly are. Second, it is possible that overweight individuals may self-select into specific job types, although this may be slightly less of a problem in China because jobs have tended to be more circumstantial with less mobility and job choice. Third, the use of job description to assess energy expenditure has been criticized because it can be subject to mismeasurement due to within-job variability and job intensity misclassification (Evenson *et al*., 2003; Vaz and Bharathi, 2004). Yet, it has been shown that methods

similar to ours of assessing occupational activity by way of hours worked per week and the average MET intensities of job activities provide good validity (Ainsworth *et al*., 1993). Finally, using METs to quantify energy expenditure does not take into account individual differences such as age, sex, and geographic and environmental conditions that may alter the energy cost of movement (Ainsworth *et al*., 2000). However, despite its limitations, the MET approach remains the best available way to systematically apply energy cost estimates in self-report measures (Matthews, 2002).

The trend toward increasing overweight and obesity continues unabated in this sample of Chinese adults, and, as we have seen in many other countries throughout all regions of the world, few of the individuals who gain weight lose that weight. Further, with ever increasing urbanization and technological advances as China continues in its social and economic transformation, increasing sedentariness in both occupational and domestic work appears to be inevitable (Monda *et al*., 2007). It is unrealistic to expect that this trend will lessen in upcoming years, and adults will continue to transition into more sedentary jobs, and jobs that were once more labor-intensive will become more sedentary. If we look to developed countries as an example, we might expect that as young people enter the work force, their first jobs will more probably be sedentary, and their home lives will similarly be less active and more efficient, freeing up more leisure time. From a public health standpoint, it seems important that as this transition continues, the populace should be encouraged and advised to use the advent of more leisure time to engage in active pursuits in attempts to prevent and control a widespread obesity epidemic.

Acknowledgements

Financial assistance for this research has come from the US National Institutes of Health (NIH) (RO1-HD30880 and R01-HD38700). We thank Ms Frances L Dancy for her administrative assistance, Jim Terry for programming support, Tom Swasey for his work on the graphics, and David Guilkey for statistical and methodological advice.

References

Ainsworth BE, Haskell WL, Whitt MC, Irwin ML, Swartz AM, Strath SJ *et al*. (2000). Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc* **32**, S498–S504.

Ainsworth BE, Jacobs Jr DR, Leon AS, Richardson MT, Montoye HJ (1993). Assessment of the accuracy of physical activity questionnaire occupational data. *J Occup Med* **35**, 1017–1027.

Ainsworth BE, Richardson MT, Jacobs Jr DR, Leon AS, Sternfeld B (1999). Accuracy of recall of occupational physical activity by questionnaire. *J Clin Epidemiol* **52**, 219–227.

Baecke JA, Burema J, Frijters JE (1982). A short questionnaire for the measurement of habitual physical activity in epidemiological studies. *Am J Clin Nutr* **36**, 936–942.

Ball K, Owen N, Salmon J, Bauman A, Gore CJ (2001). Associations of physical activity with body weight and fat in men and women. *Int J Obes Relat Metab Disord* **25**, 914–919.

Barengo NC, Hu G, Lakka TA, Pekkarinen H, Nissinen A, Tuomilehto J (2004). Low physical activity as a predictor for total and cardiovascular disease mortality in middle-aged men and women in Finland. *Eur Heart J* **25**, 2204–2211.

Bell AC, Ge K, Popkin BM (2001). Weight gain and its predictors in Chinese adults. *Int J Obes* **25**, 1079–1086.

Buchowski MS, Townsend KM, Chen KY, Acra SA, Sun M (1999). Energy expenditure determined by self-reported physical activity is related to body fatness. *Obes Res* **7**, 23–33.

Burton NW, Turrell G (2000). Occupation, hours worked, and leisure-time physical activity. *Prevent Med* **31**, 673–681.

Caballero B (2001). Introduction. Symposium: obesity in developing countries: biological and ecological factors. *J Nutr* **131**, 866S–8870.

Donahoe D (1999). Measuring women's work in developing countries. *Popul Dev Rev* **25**, 543–576.

Du S, Lu B, Zhai F, Popkin BM (2002). A new stage of the nutrition transition in China. *Public Health Nutr* **5**, 169–174.

Evenson KR, Rosamond WD, Cai J, Pereira MA, Ainsworth BE (2003). Occupational physical activity in the atherosclerosis risk in communities study. *Ann Epidemiol* **13**, 351–357.

French SA, Story M, Jeffery RW (2001). Environmental influences on eating and physical activity. *Annu Rev Public Health* **22**, 309–335.

Gutierrez-Fisac JL, Guallar-Castillon P, Diez-Ganan L, Lopez Garcia E, Banegas Banegas JR, Rodriguez Artalejo F (2002). Work-related physical activity is not associated with body mass index and obesity. *Obes Res* **10**, 270–276.

Hill JO, Melanson EL (1999). Overview of the determinants of overweight and obesity: current evidence and research issues. *Med Sci Sports Exerc* **31**, S515–S521.

Jacka T (1997). *Women's Work in Rural China*. Cambridge University Press: New York.

King GA, Fitzhugh EC, Bassett DR, McLaughlin JE, Strath SJ, Swartz AM *et al*. (2001). Relationship of leisure-time physical activity and occupational activity to the prevalence of obesity. *Int J Obesity* **25**, 606–612.

Lakdawalla D, Philipson T (2002). The growth of obesity and technological change: a theoretical and empirical examination, NBER Working Paper no. 8946. National Bureau of Economic Research, Cambridge, MA.

Lanningham-Foster L, Nysse LJ, Levine JA (2003). Labor saved, calories lost: the energetic impact of domestic labor-saving devices. *Obes Res* **11**, 1178–1181.

Lawlor DA, Taylor M, Bedford C, Ebrahim S (2002). Is housework good for health? Levels of physical activity and factors associated with activity in elderly women. Results from the British Women's Heart and Health Study. *J Epidemiol Community Health* **56**, 473–478.

Lichtman SW, Pisarska K, Berman ER, Pestone M, Dowling H, Offenbacher E *et al*. (1992). Discrepancy between self-reported and actual caloric intake and exercise in obese subjects. *New Engl J Med* **327**, 1893–1898.

Matthews CE (2002). Use of self-report instruments to assess physical activity. In: GJ Welk, (ed). *Physical Activity Assessments for Health-Related Research*. Human Kinetics Publishers, Inc.: Champaign, IL, pp 107–123.

McGuire J, Popkin BM (1989). Beating the zero-sum game: Women and nutrition in the third world. Part I. *Food Nutr Bull* **11**, 38–63.

McGuire J, Popkin BM (1990). Beating the zero-sum game: women and nutrition in the third world. Part II. *Food Nutr Bull* **12**, 3–11.

Mendez MA, Monteiro CA, Popkin BM (2005). Overweight exceeds underweight among women in most developing countries. *Am J Clin Nutr* **81**, 714–721.

Monda KL, Gordon-Larsen P, Stevens J, Popkin BM (2007). China's transition: the effect of rapid urbanization on adult occupational physical activity. *Soc Sci Med* **64**, 858–870.

Mummery WK, Schofield GM, Steele R, Eakin EG, Brown WJ (2005). Occupational sitting time and overweight and obesity in Australian workers. *Am J Prev Med* **29**, 91–97.

Paeratakul S, Popkin BM, Ge K, Adair LS, Stevens J (1998). Changes in diet and physical activity affect the BMI of Chinese adults. *Int J Obes* **22**, 424–431.

Pate RR, Pratt M, Blair SN, Haskell WL, Macera CA, Bouchard C *et al.* (1995). Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA* **273**, 402–407.

Philippaerts RM, Lefevre J (1998). Reliability and validity of three physical activity questionnaires in Flemish males. *Am J Epidemiol* **147**, 982–990.

Philipson TJ, Posner RA (2003). The long-run growth in obesity as a function of technological change. *Perspect Biol Med* **46**, S87–S107.

Phongsavan P, Merom D, Marshall A, Bauman A (2004). Estimating physical activity level: the role of domestic activities. *J Epidemiol Community Health* **58**, 466–467.

Popkin BM (1999). Urbanization, lifestyle changes and the nutrition transition. *World Dev* **27**, 1905–1916.

Popkin BM (2003). Dynamics of the nutrition transition and its implications for the developing world. *Forum Nutr* **56**, 262–264.

Popkin BM (2006). Global nutrition dynamics: the world is shifting rapidly toward a diet linked with noncommunicable diseases. *Am J Clin Nutr* **84**, 289–298.

Popkin BM, Conde W, Hou N, Monteiro C (2006). Is there a lag globally in overweight trends for children compared with adults? *Obesity (Silver Spring)* **14**, 1846–1853.

Reis JP, Dubose KD, Ainsworth BE, Macera CA, Yore MM (2005). Reliability and validity of the occupational physical activity questionnaire. *Med Sci Sports Exerc* **37**, 2075–2083.

Salmon J, Owen N, Bauman A, Schmitz MK, Booth M (2000). Leisure-time, occupational, and household physical activity among professional, skilled, and less-skilled workers and homemakers. *Prev Med* **30**, 191–199.

Short S, Chen F, Entwisle B, Fengying Z (2002). Maternal work and child care in China: a multi-method analysis. *Popul Dev Rev* **28**, 31–57.

Sobel ME (1982). Asymptotic confidence intervals for indirect effects in structural equation models. In: S Leinhardt (ed). *Sociological Methodology*. American Sociological Association: Washington DC, pp 290–312.

Stookey JD, Adair L, Stevens J, Popkin BM (2001). Patterns of long-term change in body composition are associated with diet, activity, income and urban residence among older adults in China. *J Nutr* **131**, 2433S–2440S.

Vaz M, Bharathi AV (2004). How sedentary are people in 'sedentary' occupations? The physical activity of teachers in urban South India. *Occup Med (Lond)* **54**, 369–372.

Weller I, Corey P (1998). The impact of excluding non-leisure energy expenditure on the relation between physical activity and mortality in women. *Epidemiology* **9**, 632–635.

WHO/FAO (2003). Expert consultation on diet, nutrition and the prevention of chronic diseases. Report of the joint WHO/FAO expert consultation. WHO Technical Report Series, No. 916 (TRS 916). World Health Organization, Geneva.

Xu X, Niu T, Christiani DC, Weiss ST, Zhou Y, Chen C *et al.* (1997). Environmental and occupational determinants of blood pressure in rural communities in China. *Ann Epidemiol* **7**, 95–106.

Yao M, McCrory MA, Ma G, Tucker KL, Gao S, Fuss P *et al.* (2003). Relative influence of diet and physical activity on body composition in urban Chinese adults. *Am J Clin Nutr* **77**, 1409–1416.

Zhou B, Li Y, Stamler J, Tao S, Davis CE, Wu Y *et al.* (2003). Relation of occupational change to cardiovascular risk factor levels in rural Chinese men: the People's Republic of China-United States Collaborative Study on Cardiovascular and Cardiopulmonary Epidemiology. *Am J Public Health* **93**, 2049–2051.