American Journal of Epidemiology
Vol. 165, No. 12
DOI: 10.1093/aje/kwm088
Advance Access publication May 2, 2007

Original Contribution

Influence of Exercise, Walking, Cycling, and Overall Nonexercise Physical Activity on Mortality in Chinese Women

Charles E. Matthews[1], Adriana L. Jurj[2], Xiao-ou Shu[1], Hong-Lan Li[3], Gong Yang[1], Qi Li[3], Yu-Tang Gao[3], and Wei Zheng[1]

[1] Department of Medicine, Division of General Internal Medicine and Public Health, Vanderbilt Epidemiology Center, Vanderbilt University Medical School, Nashville, TN.
[2] Department of Epidemiology and Biostatistics, Norman J. Arnold School of Public Health, University of South Carolina, Columbia, SC.
[3] Department of Epidemiology, Shanghai Cancer Institute, Shanghai, People's Republic of China.

Received for publication August 1, 2006; accepted for publication November 8, 2006.

This investigation described the effects of exercise, walking, and cycling for transportation, as well as the effect of overall nonexercise physical activity, on mortality in the Shanghai Women's Health Study (1997–2004). Women without heart disease, stroke, or cancer were followed for an average of 5.7 years ($n = 67{,}143$), and there were 1,091 deaths from all causes, 537 deaths from cancer, and 251 deaths from cardiovascular diseases. Information about physical activity and relevant covariates was obtained by interview. Proportional hazards models were used to estimate adjusted hazard ratios and 95% confidence intervals. Exercise and cycling for transportation were both inversely and independently associated with all-cause mortality ($p_{trend} < 0.05$), but walking for transportation was less strongly associated with reduced risk ($p_{trend} = 0.07$). Women reporting no regular exercise but who reported 10 or more metabolic equivalent (MET)-hours/day of nonexercise activity were at 25–50% reduced risk ($p_{trend} < 0.01$) relative to less active women (0–9.9 MET-hours/day). Among women reporting the least nonexercise activity (0–9.9 MET-hours/day) but reporting regular exercise participation, exercise was associated with reduced mortality (hazard ratio = 0.78, 95% confidence interval: 0.62, 0.99). These findings add new evidence that overall physical activity levels are an important determinant of longevity, and that health benefit can be obtained through an active lifestyle, exercise, or combinations of both.

cardiovascular diseases; cohort studies; exercise; mortality; motor activity; neoplasms

Abbreviations: CI, confidence interval; HR, hazard ratio; ICD-9, *International Classification of Diseases,* Ninth Revision; MET, metabolic equivalent.

Editor's note: *An invited commentary on this article appears on page 1351, and the authors' response appears on page 1354.*

Current national and international health promotion campaigns encourage adults to increase their overall physical activity levels to achieve health benefit by incorporating regular exercise and/or nonexercise activities into their daily lives (1–3). Nonexercise activities, such as housework and activity associated with domestic responsibilities, are a particularly important source of energy expenditure among women. Women consistently report spending more time in these activities than men (4, 5), and light- to moderate-intensity nonexercise activities such as these contribute substantially to overall physical activity energy expenditure (6–8).

Correspondence to Dr. Charles E. Matthews, Institute for Medicine and Public Health, Vanderbilt University Medical School, Sixth Floor (suite 600), 2525 West End Avenue, Nashville, TN 37203–1738 (e-mail: charles.matthews@vanderbilt.edu).

However, the influence of specific types of these activities or the level of overall nonexercise activities on disease risk and mortality has not been systematically described, in part because of limitations in the structure and content of the physical activity assessments utilized in most epidemiologic studies that were initiated prior to the development of the current public health recommendations (9).

Although recent investigations have provided compelling evidence that moderate-intensity walking is associated with reduced risk of cardiovascular disease (10–12) and early mortality among women (13, 14), the inability of many of the existing cohort studies to isolate and evaluate the influence of specific nonexercise activities that contribute importantly to overall activity levels in women, as well as the low prevalence of certain behaviors in these study populations (e.g., walking and cycling for transportation), has limited the accumulation of evidence to directly support the recommendations relative to mortal and incident disease endpoints. Accordingly, the purpose of this report was to describe the influence of exercise, walking, and cycling for transportation, as well as that of overall nonexercise physical activity, on mortality among Chinese women.

MATERIALS AND METHODS

Study population

The Shanghai Women's Health Study is a prospective, population-based, cohort study that is being conducted in seven communities in urban Shanghai, China. A detailed description of the rationale and methods for the study can be found elsewhere (15). Briefly, the seven study communities were selected on the basis of their similarity with respect to disease rates and demographic characteristics of urban Shanghai. Between 1997 and 2000, all females aged 40–70 years who were permanent residents in the study communities were approached in their homes by a local community health worker and study staff to evaluate interest in participating in the study. Interested women provided consent and were scheduled for a second study visit in order to collect questionnaires, conduct an interview, and obtain anthropometric measures and biologic samples. Study visits were typically completed in the participant's home. Interviewers completed standardized training/certification sessions, and each interview was tape recorded. The protocols used were approved by the institutional review boards of the institutions involved in this study.

Of the 81,170 eligible women approached, 75,221 (92.7 percent) of them enrolled in the study. Subsequently, 279 women were found to be outside the 40- to 70-year age range and were excluded. Thus, 74,942 women formed the longitudinal cohort. In this report, we excluded women with heart disease ($n = 5{,}499$), stroke ($n = 647$), or cancer ($n = 1{,}267$) at baseline; those lost to follow-up ($n = 10$); and those missing baseline covariates ($n = 376$). This left 67,143 women for analyses.

Follow-up and ascertainment of mortality outcomes

The cohort is followed by active follow-up (interviews) and record linkage to vital statistics and cancer registries. Every 2 years, interviewers visited the last known address of participants to ascertain vital status and gather relevant medical information about the decedents (e.g., hospital where treated, cause of death). For decedents and those lost to follow-up, vital status was determined through record linkage. Mortality follow-up has been completed for more than 99 percent of the cohort through June 2004. The cause of death was ascertained from record linkage information, death certificates, and in-person interviews with next of kin and classified by use of the *International Classification of Diseases*, Ninth Revision (ICD-9), for cancer (ICD-9 codes 140–208), cardiovascular (ICD-9 codes 390–459 and 798), and other deaths.

Physical activity levels

Information about exercise participation, household activities, walking and cycling for transportation, and occupational type was assessed by interview. Up to three exercise activities were reported for the 5-year period before the interview, and quantitative data were obtained for each activity reported (i.e., type/intensity, duration, years of participation). Exercise in adolescence (13–19 years) was assessed as the number of years of participation and weekly duration. Time spent in nonexercise activities was evaluated for the year before the interview. Transportation-related activity was assessed with four questions that asked about time spent (minutes/day) walking to and from work, walking for other reasons (e.g., household errands), cycling to and from work, and cycling for other reasons. Time spent in housework (hours/day) and stairs climbed each day (flights/day) were also assessed. Summary estimates of physical activity energy expenditure were calculated by use of standard metabolic equivalents (METs) as MET-hours/day (16). Nonexercise activity energy cost was estimated as follows: housework (2.0 METs), walking (3.3 METs), cycling (4.0 METs), and per flight of stairs (0.075 MET-hours). One MET-hour/day of expenditure is roughly equivalent to 15 minutes of participation in a moderate-intensity (4 METs) activity (17). We have found this instrument to be able to stratify women by their activity levels in these domains (18). Spearman's correlations for each activity type, compared with repeated 7-day recalls obtained over 12 months, were as follows: adult exercise ($r = 0.62$); walking and cycling to and from work ($r = 0.67$ and 0.66, respectively); walking and cycling for other reasons ($r = 0.33$ and 0.66, respectively); stair climbing ($r = 0.73$); and household activities ($r = 0.46$). Lifetime occupational history was assessed for jobs held at least a year. For each job, the workplace name, title, major work products, and years spent at each job were obtained. Occupational titles were classified into high, medium, or low levels of activity and into sitting time, using the titles (19), and weighted averages of the activity levels across all jobs were calculated.

Information on covariates

Information on demographic characteristics, disease and surgical histories, personal habits (i.e., cigarette smoking, alcohol consumption, tea drinking, ginseng use), menstrual history, residential history, occupational history, and family history of cancer was gathered by self-administered questionnaire. The interviewers also gathered exposure information regarding dietary habits (20).

Statistical analysis

Participants were classified by physical activity levels thought to be most informative for understanding the health effects of specific amounts of activity. We examined the distribution of covariates according to level of overall nonoccupational physical activity using χ^2 tests for proportions and analysis of variance to compare means. Person-years of follow-up were calculated as the interval between the baseline interview date and the occurrence of death or date of last contact. Cox proportional hazards models were used to estimate hazard ratios and 95 percent confidence intervals for comparison of mortality risk by level of physical activity while controlling for relevant covariates. Age was used as the timescale in the Cox models as described by Korn et al. (21). Tests for linear trend were performed by entering the median values of the respective category as continuous parameters.

In preliminary analyses, we examined associations between all-cause mortality and the individual items as reported on the physical activity questionnaire at baseline. In our primary analyses, we fit models to estimate hazard ratios while controlling for the other types of activity and relevant covariates. In these analyses, we created summary indices of physical activity from adulthood, including exercise participation, walking (to and from work and for other reasons), cycling (to and from work and for other reasons), overall nonexercise activities (walking, cycling, household, and stair climbing), and overall physical activity energy expenditure (exercise, walking, cycling, household, and stair climbing). We also evaluated the joint effects of exercise and nonexercise activity on all-cause mortality.

We tested our primary activity exposures for possible violations of the proportional hazard assumption using standard methods (22), and the assumption was satisfied. Unless otherwise noted, hazard ratios were adjusted for the following covariates: age, marital status, education, household income, smoking, alcohol drinking, number of pregnancies, oral contraceptive use, menopausal status, and several chronic medical conditions, such as diabetes, hypertension, respiratory disease, and chronic hepatitis.

Each of these covariates was initially selected for evaluation because of its potential for confounding the activity–mortality associations, and each of the covariates showed some evidence of an independent association ($p < 0.10$) with at least one of the mortality endpoints, except marital status. We also conducted secondary analyses that excluded participants with less than 2 years of follow-up and for specific causes of death not attributed to cancer or cardiovascular disease and evaluated overall nonexercise activity associations stratified by presence of diabetes, hypertension, respiratory disease, and chronic hepatitis. Analyses were performed using SAS, version 9.1, software (SAS Institute, Inc., Cary, North Carolina), and all tests of statistical significance were based on two-sided probability.

RESULTS

Among 67,143 women without a history of heart disease, stroke, or cancer who were followed for an average of 5.7 years (383,036 person-years), there were 1,091 deaths from all causes and 537 cancer, 251 cardiovascular, and 303 deaths from other causes. Table 1 describes the characteristics of the cohort across quartiles of overall nonexercise physical activity. In preliminary analyses, we examined the effects of the individual physical activity items on the survey relative to all-cause mortality. There was consistent evidence of a 20–40 percent reduction in risk among the most active women, and results were significant ($p_{\text{trend}} \leq 0.05$) for exercise participation in both adolescence and adulthood, walking for other reasons, stair climbing, and household activities. For example, women reporting 4 or more hours/day of household activity were at reduced risk (hazard ratio (HR) = 0.60, 95 percent confidence interval (CI): 0.50, 0.71) compared with women reporting less than 2 hours/day. Among women working for pay at baseline (n = 36,708; 55 percent), participants that reported walking to and from work for more than an hour each day were at reduced risk for all-cause mortality (HR = 0.65, 95 percent CI: 0.45, 0.92). Occupational activity indices were not associated with all-cause mortality ($p_{\text{trend}} > 0.15$).

In order to isolate and evaluate the influences of exercise and of walking and cycling for transportation, we fit models that controlled for other types of physical activity not being examined as a primary exposure, as well as other covariates (table 2). Adult exercise and cycling for transportation were both inversely and independently associated with all-cause mortality ($p_{\text{trend}} < 0.05$), but the independent effect of walking for transportation was only weakly and nonsignificantly associated with all-cause mortality ($p_{\text{trend}} = 0.07$). When all nonexercise activities were examined in aggregate, reductions in mortality of about 20–50 percent were evident for all-cause, cardiovascular, cancer, and other causes of death when comparing lower and higher categories (all, $p_{\text{trend}} \leq 0.06$). Furthermore, addition of the exercise activity expenditure information to the nonexercise activities to form an index of overall nonoccupational physical activity resulted in a consistent graded reduction in risk for all-cause, cardiovascular, cancer, and other causes of mortality ($p_{\text{trend}} \leq 0.01$; table 2).

To estimate the potential mortality benefit from either exercise participation or nonexercise activities (by quartile), or both, we calculated the joint effect of these activity exposures on all-cause mortality (figure 1). Women who reported no regular exercise participation but who reported more nonexercise activity were at 25–50 percent reduced risk ($p_{\text{trend}} < 0.001$) relative to women reporting no exercise in the lower quartile of nonexercise activity. Importantly, women who reported the least nonexercise activity but who reported regular exercise participation were found to be at lower risk for early mortality (HR = 0.78, 95 percent CI: 0.62, 0.99). There were only minimal differences in the hazard ratio between women reporting and not reporting exercise at the highest levels of nonexercise activity (figure 1).

We also conducted analyses of the overall activity–all-cause mortality association stratified by the presence of

TABLE 1. Descriptive characteristics of the cohort at baseline, by overall nonexercise physical activity* levels, the Shanghai Women's Health Study, 1997–2004

Covariates	Overall nonexercise physical activity (MET†-hours/day)‡			
	≤9.9 (n = 13,453)	10–13.6 (n = 17,065)	13.7–18.0 (n = 17,405)	≥18.1 (n = 19,220)
Age (years)	50.9 (8.5)	51.7 (8.7)	52.3 (9.0)	51.7 (8.9)
Body mass index (kg/m^2)	23.6 (3.4)	23.8 (3.4)	24.0 (3.4)	24.0 (3.3)
Pregnancies (no.)	2.6 (1.4)	2.7 (1.4)	2.8 (1.5)	2.8 (1.5)
Educational attainment (%)				
Elementary school or less	14.0	17.9	21.7	22.3
Middle school	30.9	35.4	39.6	45.4
High school	32.5	30.4	27.4	25.5
College or more	22.6	16.3	11.4	6.9
Household income (%)				
Low	23.0	24.6	27.0	30.6
Middle	34.4	38.1	40.2	41.4
High	42.6	37.4	32.8	28.0
Married (%)	88.2	89.1	89.6	90.2
Postmenopausal (%)	41.7	45.5	47.9	45.9
Oral contraceptive use (%)	18.9	20.5	20.8	20.7
Hypertension (%)	19.1	19.9	21.1	19.9
Diabetes mellitus (%)	4.1	3.6	3.8	2.9
Chronic bronchitis (%)	7.3	7.2	6.8	6.5
Asthma (%)	2.6	2.1	2.0	2.0
Tuberculosis (%)	5.8	5.3	5.1	4.9
Chronic hepatitis (%)	2.8	2.5	2.5	2.2
Smoking (ever, %)	3.0	2.4	2.6	2.7
Alcohol drinking (ever, %)	2.4	2.1	2.2	2.4

* Overall physical activity consists of adult exercise, transportation-related activity (walking, cycling), household activity, and stair climbing.

† MET, metabolic equivalent.

‡ Values are mean (standard deviation) or percent reporting (%).

diabetes, hypertension, respiratory diseases, and chronic hepatitis reported at baseline (table 3). The presence of these conditions did not substantively modify the effect of overall nonoccupational physical activity on all-cause mortality. Inverse associations were clearly evident among women with and without these conditions (table 3). We also carefully considered the potential for preclinical disease to influence our results. When deaths occurring early in the first 2 years of follow-up were excluded, the magnitudes of associations reported were not substantively altered. We also carefully examined the effect of overall activity on the major other causes of death. Overall nonoccupational activity, fit as a continuous variable, was inversely associated with deaths from diseases of the endocrine glands, mostly diabetes related (HR = 0.89, 95 percent CI: 0.85, 0.93; ICD-9 codes 250–259; 75 deaths); respiratory diseases (HR = 0.88, 95 percent CI: 0.81, 0.96; ICD-9 codes 460–519; 23 deaths); genitourinary diseases including renal failure (HR = 0.88, 95 percent CI: 0.81, 0.95; ICD-9 codes 580–629; 27 deaths); but not accidental deaths (HR = 0.98, 95 percent CI: 0.94, 1.02; ICD-9 codes 800–999; 60 deaths) or deaths due to digestive disorders such as cirrhosis of the liver (HR = 0.97, 95 percent CI: 0.92, 1.02; ICD-9 codes 570–579; 44 deaths). Exclusion of the small number of deaths due to respiratory and genitourinary diseases (n = 50 deaths) did not materially alter the magnitude of association between overall physical activity and all-cause mortality.

DISCUSSION

In this prospective study of Chinese women, we found that exercise participation, cycling for transportation, and higher levels of overall nonexercise physical activity were associated with about a 35 percent reduction in risk for all-cause mortality. Walking for transportation was less strongly associated with reduced risk, and tests for trend were only of borderline statistical significance (p_{trend} = 0.07). Importantly, women who reported either regular exercise participation or a higher level of nonexercise activity were at

TABLE 2. Independent effects of overall physical activity, adult exercise and nonexercise, walking, and cycling* on mortality risk, the Shanghai Women's Health Study, 1997–2004

	% reporting	Person-years (no.)	All causes			Cardiovascular diseases			Cancer			Other causes		
			Deaths (no.)	Hazard ratio†	95% confidence interval	Deaths (no.)	Hazard ratio†	95% confidence interval	Deaths (no.)	Hazard ratio†	95% confidence interval	Deaths (no.)	Hazard ratio	95% confidence interval
Overall activity (MET‡-hours/day)														
≤9.9	20.0	78,421	268	1.00		55	1.00		110	1.00		103	1.00	
10.0–13.6	25.4	97,963	295	0.81	0.69, 0.96	71	0.94	0.66, 1.33	155	1.03	0.81, 1.32	69	0.51	0.38, 0.70
13.7–18.0	25.9	98,661	271	0.67	0.57, 0.80	65	0.75	0.52, 1.08	138	0.84	0.65, 1.08	68	0.46	0.34, 0.63
≥18.1	28.6	107,992	257	0.61	0.51, 0.73	60	0.66	0.46, 0.95	134	0.77	0.60, 1.00	63	0.42	0.30, 0.57
p_{trend}				0.000			0.012			0.012			0.000	
Adult exercise (MET-hours/day)														
0	66.5	255,584	637	1.00		140	1.00		303	1.00		194	1.00	
0.1–3.4	6.6	108,214	376	0.84	0.74, 0.96	96	0.91	0.70, 1.19	191	0.95	0.79, 1.15	89	0.62	0.48, 0.80
3.5–7.0	7.5	15,589	66	0.77	0.59, 0.99	14	0.68	0.39, 1.18	34	0.91	0.63, 1.30	18	0.64	0.39, 1.05
≥7.1	19.5	3,649	12	0.64	0.36, 1.14	1	0.23	0.03, 1.64	9	1.06	0.55, 2.07	2	0.35	0.09, 1.42
p_{trend}				0.008			0.038			0.780			0.007	
Nonexercise (MET-hours/day)														
≤9.9	23.3	78,503	289	1.00		61	1.00		122	1.00		106	1.00	
10.0–13.6	26.8	115,391	349	0.81	0.69, 0.94	81	0.87	0.63, 1.22	185	0.99	0.79, 1.25	83	0.55	0.41, 0.74
13.7–18.0	24.7	94,221	232	0.63	0.53, 0.75	56	0.70	0.49, 1.01	117	0.75	0.58, 0.96	59	0.47	0.34, 0.65
≥18.1	25.2	94,922	221	0.66	0.55, 0.79	53	0.73	0.50, 1.06	113	0.79	0.61, 1.02	55	0.49	0.35, 0.68
p_{trend}				0.000			0.063			0.016			0.000	
Walking (MET-hours/day)														
0–3.4	20.9	81,848	297	1.00		60	1.00		134	1.00		103	1.00	
3.5–7.0	36.3	138,996	422	0.94	0.81, 1.09	98	1.09	0.79, 1.51	213	1.02	0.82, 1.26	111	0.77	0.59, 1.01
7.1–10.0	21.2	80,395	197	0.83	0.69, 1.00	55	1.14	0.79, 1.66	93	0.82	0.63, 1.08	49	0.67	0.47, 0.95
≥10.1	21.7	81,798	175	0.86	0.71, 1.05	38	0.92	0.60, 1.40	97	0.98	0.75, 1.28	40	0.67	0.46, 0.98
p_{trend}				0.071			0.719			0.555			0.027	
Cycling (MET-hours/day)														
0	75.5	289,283	1,001	1.00		235	1.00		486	1.00		280	1.00	
0.1–3.4	19.3	73,896	73	0.79	0.61, 1.01	13	0.75	0.41, 1.37	43	0.82	0.59, 1.14	17	0.74	0.43, 1.24
≥3.5	5.3	19,856	17	0.66	0.40, 1.07	3	0.63	1.20, 2.01	8	0.55	0.27, 1.11	6	0.92	0.40, 2.11
p_{trend}				0.018			0.254			0.048			0.438	

* Overall activity consists of adult exercise, walking, cycling, household activity, and stair climbing. Nonexercise consists of walking, cycling, household activity, and stair climbing. Walking consists of walking to/from work and for other reasons but not for exercise. Cycling consists of cycling to/from work and for other reasons but not for exercise.

† Hazard ratios adjusted for age (years); marital status (yes, no); education (elementary school or less, junior high school, high school, college or more); household income (low, middle, high); smoking (ever, never); alcohol drinking (ever, never); number of pregnancies; oral contraceptive use (ever, never); menopausal status (yes, no); other types of physical activity; and several chronic medical conditions, such as diabetes (yes, no), hypertension (yes, no), respiratory disease (yes, no; asthma, chronic bronchitis, or tuberculosis), and chronic hepatitis (yes, no).

‡ MET, metabolic equivalent.

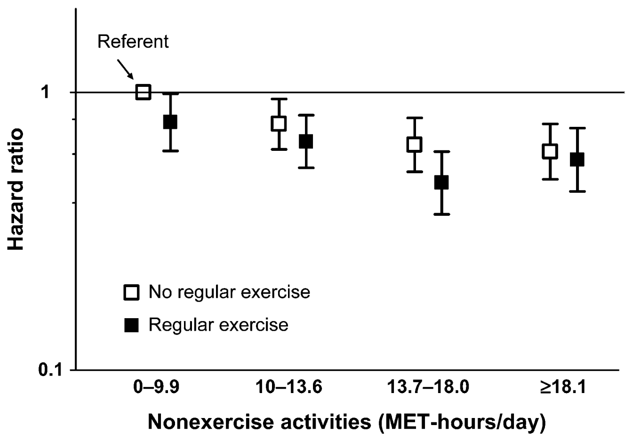

FIGURE 1. Risk for all-cause mortality, by exercise and nonexercise physical activity, the Shanghai Women's Health Study, 1997–2004. Values are hazard ratios and 95% confidence intervals. Compared with the referent level (no exercise, 0–9.9 MET-hours/day), 95% confidence intervals for each of the individual hazard ratios did not include the null value ($p < 0.05$). Adjusted for age (years), marital status (yes, no), education (elementary school or less, junior high school, high school, college/post-high school), household income (low, middle, high), smoking (ever, never), alcohol drinking (ever, never), number of pregnancies, oral contraceptive use (ever, never), menopausal status (yes, no), and several chronic medical conditions, such as diabetes (yes, no), hypertension (yes, no), respiratory disease (yes, no; asthma, chronic bronchitis, or tuberculosis), and chronic hepatitis (yes, no). MET, metabolic equivalent.

a 25–50 percent lower risk for early mortality compared with less active women. In detailed analyses, there was no evidence that existing health conditions accounted for these associations. Collectively, our results indicate that increased participation in a broad range of purposeful activities can provide important mortality benefits among women.

The association between physical activity and mortality among women has been examined in more than 40 prospective studies (9, 23); however, a limitation of this body of evidence is that few of these investigations have been able to isolate and evaluate the influence of exercise and specific nonexercise activities, such as walking and cycling for transportation, that are currently advocated by public health agencies. For example, Oguma et al. (9) recently reviewed the existing literature for physical activity and all-cause mortality among women and, of the 34 studies examined, 23 (67 percent) evaluated only leisure-time activities; only six (18 percent) assessed nonexercise activities separately. Recent prospective studies in women that have evaluated aspects of the current recommendations have focused primarily on moderate-intensity leisure-time activity (10–13), particularly walking, which is the most prevalent leisure-time activity reported in the United States. Similar reductions in mortality risk have been noted for moderate-intensity leisure-time activities (14).

Studies that have examined the role of transportation-related activity on disease risk in women are scarce, and this may be because of the low prevalence of walking and cycling for transportation in many Western countries.

TABLE 3. Association between overall physical activity* levels and all-cause mortality, by comorbid health conditions reported at baseline, the Shanghai Women's Health Study, 1997–2004

	Person-years (no.)	Overall physical activity (MET†-hours/day)												p_{trend}
		≤9.9		10–13.6			13.7–18.0			≥18.1				
		Deaths (no.)	Hazard ratio‡ (referent)	Deaths (no.)	Hazard ratio‡	95% confidence interval	Deaths (no.)	Hazard ratio‡	95% confidence interval	Deaths (no.)	Hazard ratio‡	95% confidence interval		
Diabetes mellitus														
No	370,041	220	1.00	266	0.86	0.72, 1.03	239	0.70	0.58, 0.84	228	0.62	0.51, 0.75		0.000
Yes	12,995	48	1.00	29	0.57	0.36, 0.91	32	0.55	0.35, 0.87	29	0.63	0.40, 1.01		0.063
Hypertension														
No	306,964	188	1.00	198	0.79	0.64, 0.96	177	0.64	0.52, 0.79	184	0.63	0.51, 0.77		0.000
Yes	76,072	80	1.00	97	0.89	0.66, 1.20	94	0.75	0.55, 1.01	73	0.58	0.42, 0.79		0.000
Respiratory diseases														
No	334,216	203	1.00	241	0.86	0.71, 1.04	229	0.74	0.61, 0.89	219	0.67	0.55, 0.81		0.000
Yes	48,820	65	1.00	54	0.65	0.46, 0.94	42	0.47	0.32, 0.70	38	0.42	0.28, 0.64		0.000
Chronic hepatitis														
No	373,611	247	1.00	280	0.83	0.70, 0.99	256	0.69	0.58, 0.82	242	0.62	0.52, 0.74		0.000
Yes	9,425	21	1.00	15	0.52	0.26, 1.02	15	0.48	0.25, 0.95	15	0.50	0.26, 0.99		0.079

* Overall physical activity consists of adult exercise, transportation-related activity (walking, cycling), household activity, and stair climbing.
† MET, metabolic equivalent.
‡ Hazard ratios adjusted for age (years); marital status (yes, no); education (elementary school or less, junior high school, high school, college or more); household income (low, middle, high); smoking (ever, never); alcohol drinking (ever, never); number of pregnancies; oral contraceptive use (ever, never); menopausal status (yes, no); and several chronic medical conditions, such as diabetes (yes, no), hypertension (yes, no), respiratory disease (yes, no; asthma, chronic bronchitis, or tuberculosis), and chronic hepatitis (yes, no).

Andersen et al. (24) reported a significant reduction in mortality risk among Danish adults who reported cycling to and from work (relative risk = 0.72, 95 percent CI: 0.6, 0.9), but because of the small number of women who reported cycling to work, results were not significant for women in stratified analyses. Barengo et al. (25) reported a significant reduction in risk for cardiovascular mortality among women reporting 15–29 minutes of walking or cycling to work (HR = 0.78, 95 percent CI: 0.6, 1.0; <15 vs. 15–29 minutes/day) but not for 30 or more minutes/day (HR = 0.97, 95 percent CI: 0.8, 1.2). In this report, we evaluated the independent effects of cycling for transportation and found a clear inverse relation between cycling for transportation and all-cause mortality ($p_{\text{trend}} < 0.05$). These data are the first of which we are aware to indicate a significant inverse relation between early mortality and cycling for transportation in healthy women.

The amount of energy expended in nonexercise physical activity that we found to be associated with reduced mortality risk merits comment. The amount of physical activity energy expenditure captured by a survey is dependent on the breadth of activity types and activity intensities assessed by the instrument. In our study, the time spent in a broad range of light, moderate, and vigorous activities was assessed, and the median level of energy expenditure was about 13 MET-hours/day. In contrast, Weller and Corey (26) assessed light, moderate, and vigorous activity from both leisure and nonleisure sources among healthy, middle-aged Canadian women and reported median values of about 7 MET-hours/day. It is not immediately clear if the somewhat higher levels of activity in the present study are due to the inherent differences in methods of assessment that we employed, constitutive differences in the activity levels of Chinese women, or perhaps important differences in the demands on energy expenditure of the urban environment in which women in our study live.

The strengths of this study are numerous. The Shanghai Women's Health Study is a large, population-based, prospective cohort study that has experienced little or no loss to follow-up during the time period of this analysis (<1 percent). We had trained staff to conduct in-person interviews that gathered detailed information about a broad range of physical activities that contribute to overall energy expenditure using a validated instrument. An additional strength of this investigation was our ability to control for confounding by age, socioeconomic status, major lifestyle factors, and many preexisting medical conditions. The comprehensiveness of our physical activity assessment was also an important strength. We found our most consistent and graded reductions in risk for all-cause, cardiovascular, and cancer mortality with higher levels of activity when we used an integrated index of overall nonoccupational activity. This result underscores the importance of capturing the full range of physical activities that contribute to overall energy expenditure in studies of physical activity and health.

There are also potential limitations in this research that should be considered. We used self-reported information about a wide range of recent physical activity behaviors. Our measures may be susceptible to systematic reporting errors (27), misclassification due to the natural variability of activity behaviors (28), and the potential for lower validity for our measure of our nonexercise behaviors. Our study of the measurement properties of this activity questionnaire revealed higher reliability and validity coefficients for our exercise measures compared with the nonexercise activities (18). While the level of measurement error in self-reported activity levels can be substantial, the recent report of Manini et al. (29) that evaluated the effect of objectively measured physical activity energy expenditure on mortality using doubly labeled water appears to confirm the long-held belief that errors in self-reported activity result in bias toward the null. Therefore, the risk estimates reported in this investigation may underestimate the true benefits of activity on mortality.

Additional limitations of this study include our inability to rule out the possible effects of residual confounding or the effect of unmeasured (unknown) confounding factors on our results. We took a number of steps to minimize and understand the potential for reverse causality (30) to bias our results. First, we excluded from analyses women who reported major chronic diseases at baseline. Second, we conducted subgroup analyses by several comorbid conditions reported at baseline that could induce such bias. Third, we also carefully examined associations between overall activity and the major individual causes of death that were not attributable to cardiovascular disease or cancer. Results from these detailed analyses indicated that reverse causality was unlikely to account for the major effects of physical activity on all-cause mortality in this report. Indeed, we believe that physical inactivity that is induced by certain disease states or preclinical conditions may contribute to the increased risk for mortality commonly found among individuals with such conditions.

In this large, population-based, prospective study, we found that women who reported regular exercise, cycling for transportation, or a higher level of nonexercise activity were at a 20–50 percent lower risk for early mortality compared with the less active women. These findings provide new evidence that health benefits can be obtained through regular exercise participation, an active lifestyle, or combinations of both. These findings provide direct support for current national and international health promotion campaigns that encourage adults to increase their activity levels for health benefit by any means necessary.

ACKNOWLEDGMENTS

This work was supported by grant CA70867 to Dr. Zheng from the National Cancer Institute.

The authors thank Dr. Russell R. Pate for his thoughtful comments on an early draft of this report.

Conflict of interest: none declared.

REFERENCES

1. Pate RR, Pratt M, Blair SN, et al. Physical activity and public health. A recommendation from the Centers for Disease

Control and Prevention and the American College of Sports Medicine. JAMA 1995;273:402–7.
2. American Cancer Society. Cancer facts and figures—2005. Atlanta, GA: American Cancer Society, 2005.
3. World Health Organization. Global strategy on diet, physical activity and health. Geneva, Switzerland: World Health Organization, 2004.
4. Masse LC, Ainsworth BE, Tortolero S, et al. Measuring physical activity in midlife, older, and minority women: issues from an expert panel. J Womens Health 1998;7: 57–67.
5. Ainsworth B, Richardson M, Jacobs D, et al. Gender differences in physical activity. Women Sport Phys Act J 1993;2: 1–16.
6. Levine JA, Eberhardt NL, Jensen MD. Role of nonexercise activity thermogenesis in resistance to fat gain in humans. Science 1999;283:212–14.
7. Levine JA, Lanningham-Foster LM, McCrady SK, et al. Interindividual variation in posture allocation: possible role in human obesity. Science 2005;307:584–6.
8. Westerterp KR. Pattern and intensity of physical activity. Nature 2001;410:539–40.
9. Oguma Y, Sesso HD, Paffenbarger RS Jr, et al. Physical activity and all cause mortality in women: a review of the evidence. Br J Sports Med 2002;36:162–72.
10. Manson JE, Greenland P, LaCroix AZ, et al. Walking compared with vigorous exercise for the prevention of cardiovascular events in women. N Engl J Med 2002;347: 716–25.
11. Manson JE, Hu FB, Rich-Edwards JW, et al. A prospective study of walking as compared with vigorous exercise in the prevention of coronary heart disease in women. N Engl J Med 1999;341:650–8.
12. Lee IM, Rexrode KM, Cook NR, et al. Physical activity and coronary heart disease in women: is ‘‘no pain, no gain’’ passe? JAMA 2001;285:1447–54.
13. Gregg EW, Gerzoff RB, Caspersen CJ, et al. Relationship of walking to mortality among US adults with diabetes. Arch Intern Med 2003;163:1440–7.
14. Kushi LH, Fee RM, Folsom AR, et al. Physical activity and mortality in postmenopausal women. JAMA 1997;277: 1287–92.
15. Zheng W, Chow WH, Yang G, et al. The Shanghai Women's Health Study: rationale, study design, and baseline characteristics. Am J Epidemiol 2005;162:1123–31.
16. Ainsworth B, Haskell W, Whitt M, et al. Compendium of physical activities: an update of activity codes and MET intensities. Med Sci Sports Exerc 2000;32(suppl):S498–516.
17. Ainsworth B, Haskell W, Leon A, et al. Compendium of physical activities: classification of energy costs of human physical activities. Med Sci Sports Exerc 1993;25:71–80.
18. Matthews CE, Shu XO, Gong Y, et al. Reproducibility and validity of the Shanghai Women's Health Study Physical Activity Questionnaire. Am J Epidemiol 2003;158:1114–22.
19. Zheng W, Shu XO, McLaughlin JK, et al. Occupational physical activity and the incidence of cancer of the breast, corpus uteri, and ovary in Shanghai. Cancer 1993;71:3620–4.
20. Shu XO, Gong Y, Jin F, et al. Validity and reproducibility of the food frequency questionnaire used in the Shanghai Women's Health Study. Eur J Clin Nutr 2003;58:17–23.
21. Korn EL, Graubard BI, Midthune D, et al. Time-to-event analysis of longitudinal follow-up of a survey: choice of the time-scale. Am J Epidemiol 1997;145:72–80.
22. Hosmer DW, Lemeshow S. Applied survival analysis: regression modeling of time to event data. New York, NY: John Wiley & Sons, Inc, 1999.
23. Katzmarzyk PT, Janssen I, Ardern CI, et al. Physical inactivity, excess adiposity and premature mortality. Obes Rev 2003;4: 257–90.
24. Andersen LB, Schnohr P, Schroll M, et al. All-cause mortality associated with physical activity during leisure time, work, sports, and cycling to work. Arch Intern Med 2000;160:1621–8.
25. Barengo NC, Hu G, Lakka TA, et al. Low physical activity as a predictor for total and cardiovascular disease mortality in middle-aged men and women in Finland. Eur Heart J 2004;25:2204–11.
26. Weller I, Corey P. The impact of excluding non-leisure energy expenditure on the relation between physical activity and mortality in women. Epidemiology 1998;9:632–5.
27. Adams SA, Matthews CE, Moore CG, et al. The effect of social desirability and social approval on self-reports of physical activity. Am J Epidemiol 2005;161:389–98.
28. Matthews CE, Hebert JR, Freedson PS, et al. Sources of variance in daily physical activity levels in the Seasonal Variation of Blood Cholesterol Study. Am J Epidemiol 2001;153:987–95.
29. Manini TM, Everhart JE, Patel KV, et al. Daily activity energy expenditure and mortality among older adults. JAMA 2006; 296:171–9.
30. Rockhill B, Willett WC, Manson JE, et al. Physical activity and mortality: a prospective study among women. Am J Public Health 2001;91:578–83.