



Minimum amount of physical activity for reduced mortality and extended life expectancy: a prospective cohort study

Chi Pang Wen*, Jackson Pui Man Wai*, Min Kuang Tsai, Yi Chen Yang, Ting Yuan David Cheng, Meng-Chih Lee, Hui Ting Chan, Chwen Keng Tsao, Shan Pou Tsai, Xifeng Wu

Summary

Background The health benefits of leisure-time physical activity are well known, but whether less exercise than the recommended 150 min a week can have life expectancy benefits is unclear. We assessed the health benefits of a range of volumes of physical activity in a Taiwanese population.

Methods In this prospective cohort study, 416 175 individuals (199 265 men and 216 910 women) participated in a standard medical screening programme in Taiwan between 1996 and 2008, with an average follow-up of 8·05 years (SD 4·21). On the basis of the amount of weekly exercise indicated in a self-administered questionnaire, participants were placed into one of five categories of exercise volumes: inactive, or low, medium, high, or very high activity. We calculated hazard ratios (HR) for mortality risks for every group compared with the inactive group, and calculated life expectancy for every group.

Findings Compared with individuals in the inactive group, those in the low-volume activity group, who exercised for an average of 92 min per week (95% CI 71–112) or 15 min a day (SD 1·8), had a 14% reduced risk of all-cause mortality (0·86, 0·81–0·91), and had a 3 year longer life expectancy. Every additional 15 min of daily exercise beyond the minimum amount of 15 min a day further reduced all-cause mortality by 4% (95% CI 2·5–7·0) and all-cancer mortality by 1% (0·3–4·5). These benefits were applicable to all age groups and both sexes, and to those with cardiovascular disease risks. Individuals who were inactive had a 17% (HR 1·17, 95% CI 1·10–1·24) increased risk of mortality compared with individuals in the low-volume group.

Interpretation 15 min a day or 90 min a week of moderate-intensity exercise might be of benefit, even for individuals at risk of cardiovascular disease.

Funding Taiwan Department of Health Clinical Trial and Research Center of Excellence and National Health Research Institutes.

Introduction

Much evidence suggests that 150 min or more a week of leisure-time physical activity (LTPA) can have substantial health benefits for an individual.^{1,2} Guidelines such as the 2008 physical activity guidelines for Americans¹ and WHO's 2010 Global Recommendations on Physical Activity for Health^{1,3} have drawn attention to the health benefits of this amount of weekly exercise. Because barriers exist to meet this 30 min a day, 5 day a week recommendation (eg, time constraints or an individual's uncertainty about the amount of exercise needed to benefit health), LTPA is an underused public health intervention. East Asians tend to be less physically active than individuals in western countries, and also tend to exercise at lower intensity.^{4,5} A third of the American adult population met this recommendation,¹ whereas less than a fifth of the adult population did in East Asian countries such as China, Japan, or Taiwan.^{4,5} Whether levels of physical activity below the recommended 150 min a week are adequate to generate health benefits is unclear.

Identification of a minimum amount of exercise—or minimum dose¹—sufficient to reduce mortality is desirable because a small amount of exercise can be easier to achieve. Furthermore, patients might be more easily

motivated to exercise if their doctor recommends an easily manageable amount, especially if health messages are simple. Because east Asians visit their doctors frequently,⁶ plenty of opportunities for health communication and prescription of exercise exist.⁷ However, such opportunities to prescribe exercise are sometimes missed because most doctors are expected to treat only diseases, having little time to modify a behaviour that is not directly related to the disease if not requested by a patient. If health-enhancing physical activity were to be prescribed, it should be related to the disease in question, and the recommended amount should be kept to a minimum to increase the chances of adherence.

The objective of this study is to assess the health benefits of different volumes of physical activity in a large cohort in Taiwan, and to investigate whether less than 150 min a week of exercise is sufficient to reduce mortality or extend life expectancy.

Methods

Data collection

In this historically prospective cohort study, the cohort consisted of 416 175 healthy individuals aged 20 years or older (199 265 men and 216 910 women) who participated

Lancet 2011; 378: 1244–53

Published Online

August 16, 2011

DOI:10.1016/S0140-

6736(11)60749-6

See Comment page 1202

*These authors shared first authorship

Institute of Population Science, National Health Research Institutes, Zhunan, Taiwan

(C P Wen MD, M K Tsai MS,

Y C Yang MS, H T Chan MS);

China Medical University

Hospital, Taichung, Taiwan

(C P Wen, M K Tsai, Y C Yang);

Laboratory for Exercise

Physiology Research, Institute

of Sport Science, National

Taiwan Sport University,

Taoyuan, Taiwan

(J P M Wai PhD); Department of

Epidemiology, University of

Washington, Seattle, WA, USA

(T Y D Cheng MS); Institute of

Medicine and Department of

Family and Community

Medicine, Chung Shan Medical

University and Hospital,

Taichung, Taiwan

(M-C Lee MD); MJ Health

Management Institution,

Taipei, Taiwan (C K Tsao BS);

University of Texas School of

Public Health, Houston, TX,

USA (S P Tsai PhD); and

Department of Epidemiology,

MD Anderson Cancer Center,

Houston, TX, USA (X Wu MD)

Correspondence to:

Dr Chi Pang Wen, National

Health Research Institutes,

35 Keyan Road, Zhunan,

Miaoli County 350, Taiwan

cwengood@nhri.org.tw

in a standard medical screening programme run by a private firm (MJ Health Management Institution, Taipei, Taiwan)—all participants were followed up between 1996 and 2008.⁸ The 13-year study period yielded 3·35 million person-years of follow-up, with an average follow-up of 8·05 years (SD 4·21). Every individual's identification number was matched with the National Death file and the National Cancer Registry file.⁸

Every participant signed a consent form authorising MJ Health Management Institution to process data generated from medical screening. Ethical reviews (Institutional Review Boards) were processed and approved at MJ Health Management Institution and at National Health Research Institutes in Taiwan. Data related to individual identification were removed and remained anonymous during the entire study process.

Every participant completed a self-administered questionnaire of their medical history and lifestyle information. All participant were encouraged to visit on a yearly basis; the same questionnaires were filled out on every visit, but results from the initial visit only were used. An individual's LTPA level was ascertained through three multiple-choice questions. First, participants were asked to classify the types and intensities of weekly LTPAs that they did during the previous month, with several examples of exercise types given under four intensity categories: light (eg, walking), moderate (eg, brisk walking), medium-vigorous (eg, jogging), or high-vigorous (eg, running). On the basis of Ainsworth's compendium of physical activities,⁹ we assigned a metabolic equivalent value (MET; 1 MET=1 kcal per h per kg of bodyweight) of 2·5 for light, 4·5 for moderate, 6·5 for medium-vigorous, or 8·5 for

	Inactive	Low volume	Physical activity meeting recommendation			
			Medium volume	High volume	Very high volume	Total
All participants	226 493 (54%)	90 663 (22%)	56 899 (14%)	21 730 (5%)	20 390 (5%)	99 019 (24%)
Sex						
Male	96 798 (49%)	44 246 (22%)	31 593 (16%)	13 184 (7%)	13 444 (7%)	58 221 (29%)
Female	129 695 (60%)	46 417 (21%)	25 306 (12%)	8546 (4%)	6946 (3%)	40 798 (19%)
Age (years)						
20–39	137 307 (59%)	54 832 (24%)	24 898 (11%)	8366 (4%)	5823 (3%)	39 087 (17%)
40–59	67 311 (50%)	27 545 (21%)	21 580 (16%)	9834 (7%)	7384 (6%)	38 798 (29%)
≥60	21 875 (43%)	8286 (16%)	10 421 (20%)	3530 (7%)	7183 (14%)	21 134 (41%)
Education						
Middle school or lower	57 633 (54%)	17 789 (17%)	15 911 (15%)	6752 (6%)	7997 (8%)	30 600 (29%)
High school	54 252 (57%)	20 469 (21%)	11 666 (12%)	4267 (4%)	4589 (5%)	20 522 (22%)
Junior college	46 289 (54%)	21 139 (25%)	11 221 (13%)	3959 (5%)	3270 (4%)	18 450 (21%)
College or higher	50 202 (46%)	30 357 (28%)	17 431 (16%)	6440 (6%)	4319 (4%)	28 190 (26%)
Physical labour at work						
Mostly sedentary	110 178 (50%)	54 326 (25%)	33 304 (15%)	11 932 (5%)	9867 (4%)	55 103 (25%)
Sedentary with occasional walking	61 627 (54%)	25 685 (23%)	15 493 (14%)	6004 (5%)	5246 (5%)	26 743 (23%)
Mostly standing or walking	24 509 (60%)	6877 (17%)	4745 (12%)	2198 (5%)	2833 (7%)	9776 (24%)
Hard labour	6733 (62%)	1397 (13%)	1105 (10%)	561 (5%)	1008 (9%)	2674 (25%)
Smoking						
Never smoker	140 169 (52%)	62 478 (23%)	38 867 (14%)	13 986 (5%)	12 896 (5%)	65 749 (24%)
Ex-smoker	10 338 (44%)	5016 (21%)	4139 (18%)	1905 (8%)	2202 (9%)	8246 (35%)
Smoker	50 272 (56%)	18 829 (21%)	11 819 (13%)	4561 (5%)	4414 (5%)	20 794 (23%)
Drinking						
Never drinker	157 766 (54%)	67 506 (23%)	41 113 (14%)	14 719 (5%)	13 216 (4%)	69 048 (23%)
Occasional drinker	26 122 (45%)	13 955 (24%)	9287 (16%)	4191 (7%)	4213 (7%)	17 691 (31%)
Regular drinker	14 938 (54%)	5102 (19%)	3934 (14%)	1622 (6%)	1949 (7%)	7505 (27%)
Body mass index						
18·5–24 kg/m ²	143 870 (53%)	60 640 (23%)	37 156 (14%)	14 148 (5%)	13 190 (5%)	64 494 (24%)
25–29 kg/m ²	49 035 (51%)	19 621 (21%)	14 665 (15%)	5991 (6%)	5911 (6%)	26 567 (28%)
≥30 kg/m ²	8989 (58%)	3194 (20%)	2019 (13%)	763 (5%)	662 (4%)	3444 (22%)
Systolic blood pressure						
<120 mm Hg	130 465 (58%)	51 187 (23%)	26 414 (12%)	9531 (4%)	7497 (3%)	43 442 (19%)
120–139 mm Hg (pre-hypertension)	63 579 (52%)	26 578 (22%)	18 476 (15%)	7322 (6%)	6798 (6%)	32 596 (27%)
≥140 mm Hg or receiving drugs (hypertension)	31 517 (47%)	12 866 (19%)	11 991 (18%)	4871 (7%)	6090 (9%)	22 952 (34%)

(Continues on next page)

	Inactive	Low volume	Physical activity meeting recommendation			
			Medium volume	High volume	Very high volume	Total
(Continued from previous page)						
Fasting blood glucose						
<6.1 mmol/L	201 128 (55%)	82 342 (22%)	49 589 (13%)	18 818 (5%)	17 087 (5%)	85 494 (23%)
6.1–6.9 mmol/L (pre-diabetes)	11 548 (50%)	4542 (20%)	3734 (16%)	1558 (7%)	1673 (7%)	6965 (30%)
≥7 mmol/L or receiving drugs (diabetes)	9666 (50%)	3428 (18%)	3402 (18%)	1297 (7%)	1592 (8%)	6291 (32%)
Total cholesterol						
<6.2 mmol/L	200 392 (55%)	80 754 (22%)	48 930 (13%)	18 648 (5%)	17 217 (5%)	84 795 (23%)
≥6.2 mmol/L or receiving drugs (hypercholesterolaemia)	24 950 (51%)	9849 (20%)	7941 (16%)	3075 (6%)	3166 (6%)	14 182 (29%)
Metabolic syndrome (NCEP-ATP III)						
No	198 154 (55%)	80 133 (22%)	48 002 (13%)	18 693 (5%)	16 830 (5%)	83 525 (23%)
Yes	28 339 (52%)	10 530 (19%)	8897 (16%)	3037 (6%)	3560 (7%)	15 494 (29%)
Chronic kidney disease						
No	187 187 (54%)	77 335 (22%)	48 026 (14%)	18 430 (5%)	16 750 (5%)	83 206 (24%)
Yes	24 209 (52%)	8906 (19%)	7113 (15%)	2806 (6%)	3341 (7%)	13 260 (29%)
Data are n (%). NCEP-ATP III=National Cholesterol Education Program-Adult Treatment Panel III.						
Table 1: Characteristics of the participants, by volume of leisure-time physical activity						

high-vigorous exercise. For individuals who indicated activities in more than one intensity category, a weighted MET value was assigned, dependent on the length of time engaged in each category. The second question asked for the duration per week spent on the different LTPA activities within the previous month. Most individuals classified as inactive did no LTPA at all, but a small proportion (12.5%, 28 311 of 226 493) exercised less than 1 h a week, an amount regarded as inactive elsewhere.⁹

With LTPA volume being the product of intensity (MET) and duration of exercise (h), the calculated MET-h per week of each individual was placed into one of the five categories: inactive (<3.75 MET-h), low (3.75–7.49 MET-h), medium (7.50–16.49 MET-h), high (16.50–25.49 MET-h), or very high (≥25.50 MET-h), in accordance with classifications in the 2008 physical activity guidelines for Americans.¹ In each LTPA category, we also classified each participant by exercise intensity into one of two groups: moderate-intensity exercise or vigorous-intensity exercise. The moderate-intensity category consisted of individuals who did no vigorous-intensity exercise, by excluding those who indicated that they did no medium-vigorous or high-vigorous exercise. All other individuals were put in the vigorous-intensity group. The third question was about the amount of physical activity done at work, classifying individuals into one of four different activity levels, from a low level of mainly sedentary work to a high level of hard physical labour.

Participants were classified as obese on the basis of the Asian definition of a body mass index (BMI) of 25 or more.¹⁰ Metabolic syndrome was defined on the basis of US National Cholesterol Education Program-Adult Treatment Panel III criteria¹¹ and chronic kidney disease, defined by the Kidney Disease Outcomes Quality Initiative

clinical practice guidelines.^{12,13} Individuals were defined as having diabetes if they had a history of diabetes or if they had positive diabetes screening results (fasting blood glucose concentration ≥7 mmol/L). Hypertension was identified by medical history or positive screening results (systolic pressure ≥140 mm Hg). Pre-hypertension (a systolic pressure of 120–139 mm Hg) and pre-diabetes (a fasting blood glucose concentration of 6.1–6.9 mmol/L) were defined on the basis of screened laboratory results. Individuals were regarded as regular alcohol drinkers if they consumed two or more alcoholic drinks a day on three or more days a week, and occasional drinkers if they consumed less than regular drinkers.

Statistical analysis

The primary analysis was done with data from all participants who completed the LTPA questionnaire—participants were excluded only in the subgroup analyses. We calculated hazard ratios (HR) to compare mortality risks between individuals in different exercise groups (grouped by volume of exercise) and those in the inactive group. We used a Cox proportionate model to analyse categorical and continuous variables for LTPA. Categorical variables were sex, education (four levels), physical labour at work (four levels), smoking (never smoker, ex-smoker, and smoker), drinking (non-drinker, occasional drinker, and regular drinker), diabetes, hypertension, and history of cancer. Continuous variables were age, fasting blood glucose, systolic blood pressure, total cholesterol, and BMI. The proportional hazard assumption was examined and met by plotting the log minus log survival curves and survival times against cumulative survival. Two-way interactions between each of 13 confounders and LTPA volumes

	Low volume			Physical activity meeting recommendation											
	Total	Moderate	Vigorous	Medium volume			High volume			Very high volume			Total		
				Total	Moderate	Vigorous	Total	Moderate	Vigorous	Total	Moderate	Vigorous	Total	Moderate	Vigorous
Number of individuals (%)	90 663 (22%)	86 424 (21%)	4239 (1%)	56 899 (14%)	43 924 (11%)	12 975 (3%)	21 730 (5%)	15 215 (4%)	6515 (2%)	20 390 (5%)	9595 (2%)	10 795 (3%)	99 019 (24%)	68 734 (17%)	30 285 (7%)
Duration (min per week)	91.9 (10.5)	92.0 (10.7)	90.0 (0)	222.1 (85.7)	254.0 (66.7)	114.1 (44.9)	361.6 (120.2)	411.9 (103.8)	243.9 (57.7)	523.5 (161.6)	614.4 (128.4)	442.7 (144.3)	314.8 (164.8)	339.3 (154.6)	259.1 (173.4)
Intensity (MET)	3.0 (0.8)	3.0 (0.8)	3.8 (0.2)	3.7 (1.5)	3.0 (0.8)	6.0 (1.1)	4.1 (1.5)	3.4 (0.9)	5.7 (1.2)	5.0 (1.7)	3.6 (1.0)	6.2 (1.1)	4.0 (1.6)	3.2 (0.9)	6.0 (1.1)
Volume (MET-h per week)	4.6 (1.3)	4.6 (1.3)	5.7 (0.2)	11.9 (2.9)	12.3 (3.0)	10.7 (2.0)	22.0 (2.8)	22.0 (3.2)	21.9 (1.3)	40.7 (13.5)	35.8 (8.8)	45.2 (15.4)	20.1 (13.1)	17.7 (9.3)	25.4 (17.9)
Energy expended (kcal per week)	285.8 (103.6)	282.8 (104.0)	347.3 (69.7)	751.8 (233.3)	770.4 (244.9)	688.7 (175.1)	1406.9 (321.0)	1397.5 (340.5)	1428.9 (268.9)	2576.0 (930.4)	2256.3 (733.6)	2865.8 (993.0)	1268.3 (858.4)	1116.6 (643.8)	1615.0 (1141.9)

Data are n (%) or mean (SD). MET=metabolic equivalent.

Table 2: Mean activity characteristics of participants, by exercise volume and intensity

	Number of individuals	Inactive		Low volume		Physical activity meeting recommendation							
		Deaths (n)	HR	Deaths (n)	HR (95% CI)	Medium volume		High volume		Very high volume		Total	
						Deaths (n)	HR (95% CI)	Deaths (n)	HR (95% CI)	Deaths (n)	HR (95% CI)	Deaths (n)	HR (95% CI)
All-cause mortality for all individuals	416 175	5688	1	1877	0.86* (0.81-0.91)	1660	0.80* (0.75-0.85)	742	0.71* (0.65-0.77)	813	0.65* (0.60-0.70)	3215	0.74* (0.70-0.77)
Moderate	..	..	..	1830	0.86* (0.82-0.92)	1484	0.82* (0.77-0.87)	660	0.73* (0.66-0.80)	499	0.68* (0.62-0.75)	2643	0.77* (0.73-0.81)
Vigorous	..	..	..	47	0.73* (0.54-0.98)	176	0.67* (0.57-0.78)	82	0.60* (0.48-0.76)	314	0.60* (0.53-0.68)	572	0.62* (0.57-0.68)
All cancer	..	2185	1	755	0.90* (0.83-0.99)	659	0.85* (0.77-0.93)	318	0.85* (0.75-0.97)	355	0.78* (0.69-0.88)	1332	0.83* (0.77-0.90)
Moderate	..	..	..	736	0.91* (0.83-0.99)	576	0.86* (0.78-0.95)	274	0.86* (0.75-0.99)	211	0.81* (0.70-0.95)	1061	0.85* (0.78-0.92)
Vigorous	..	..	..	19	0.77 (0.48-1.23)	83	0.80 (0.63-1.00)	44	0.80 (0.59-1.11)	144	0.74* (0.62-0.88)	271	0.76* (0.67-0.88)
Cardiovascular disease	..	1100	1	357	0.81* (0.71-0.93)	352	0.79* (0.69-0.90)	138	0.61* (0.50-0.74)	155	0.55* (0.46-0.66)	645	0.68* (0.61-0.76)
Moderate	..	..	..	348	0.82* (0.72-0.93)	325	0.81* (0.71-0.93)	123	0.62* (0.50-0.76)	100	0.56* (0.45-0.70)	548	0.71* (0.63-0.80)
Vigorous	..	..	..	9	0.70 (0.31-1.57)	27	0.56* (0.37-0.86)	15	0.55* (0.32-0.94)	55	0.54* (0.41-0.72)	97	0.55* (0.44-0.69)
Ischaemic heart disease	..	310	1	89	0.75* (0.58-0.96)	104	0.80 (0.63-1.02)	26	0.39* (0.24-0.61)	51	0.57* (0.41-0.80)	181	0.65* (0.52-0.79)
Moderate	..	..	..	88	0.75* (0.58-0.97)	96	0.82 (0.64-1.06)	24	0.40* (0.25-0.65)	36	0.64* (0.43-0.94)	156	0.69* (0.55-0.85)
Vigorous	..	..	..	1	0.41 (0.06-2.91)	8	0.61 (0.29-1.30)	2	0.29 (0.07-1.17)	15	0.45* (0.25-0.81)	25	0.47* (0.30-0.74)
Stroke	..	459	1	154	0.88 (0.72-1.07)	141	0.76* (0.62-0.94)	68	0.73* (0.55-0.98)	55	0.48* (0.35-0.65)	264	0.67* (0.57-0.80)
Moderate	..	..	..	151	0.88 (0.72-1.07)	131	0.80* (0.65-0.99)	63	0.76 (0.56-1.03)	35	0.47* (0.33-0.69)	229	0.72* (0.60-0.86)
Vigorous	..	..	..	3	0.90 (0.29-2.80)	10	0.38* (0.17-0.86)	5	0.53 (0.22-1.27)	20	0.49* (0.30-0.78)	35	0.47* (0.32-0.68)
Diabetes mellitus	..	358	1	117	0.89 (0.71-1.12)	110	0.77* (0.61-0.97)	53	0.73 (0.52-1.01)	41	0.50* (0.35-0.72)	204	0.69* (0.57-0.84)
Moderate	..	..	..	113	0.88 (0.70-1.11)	101	0.78* (0.61-0.99)	51	0.77 (0.55-1.08)	34	0.71 (0.49-1.04)	186	0.77* (0.63-0.93)
Vigorous	..	..	..	4	1.60 (0.56-4.55)	9	0.66 (0.31-1.40)	2	0.37 (0.09-1.50)	7	0.12* (0.04-0.38)	18	0.30* (0.17-0.53)

HR=hazard ratio *Indicates a significantly (p<0.05) lower death rate compared with the inactive group.

Table 3: Mortality risk, by exercise volume and intensity

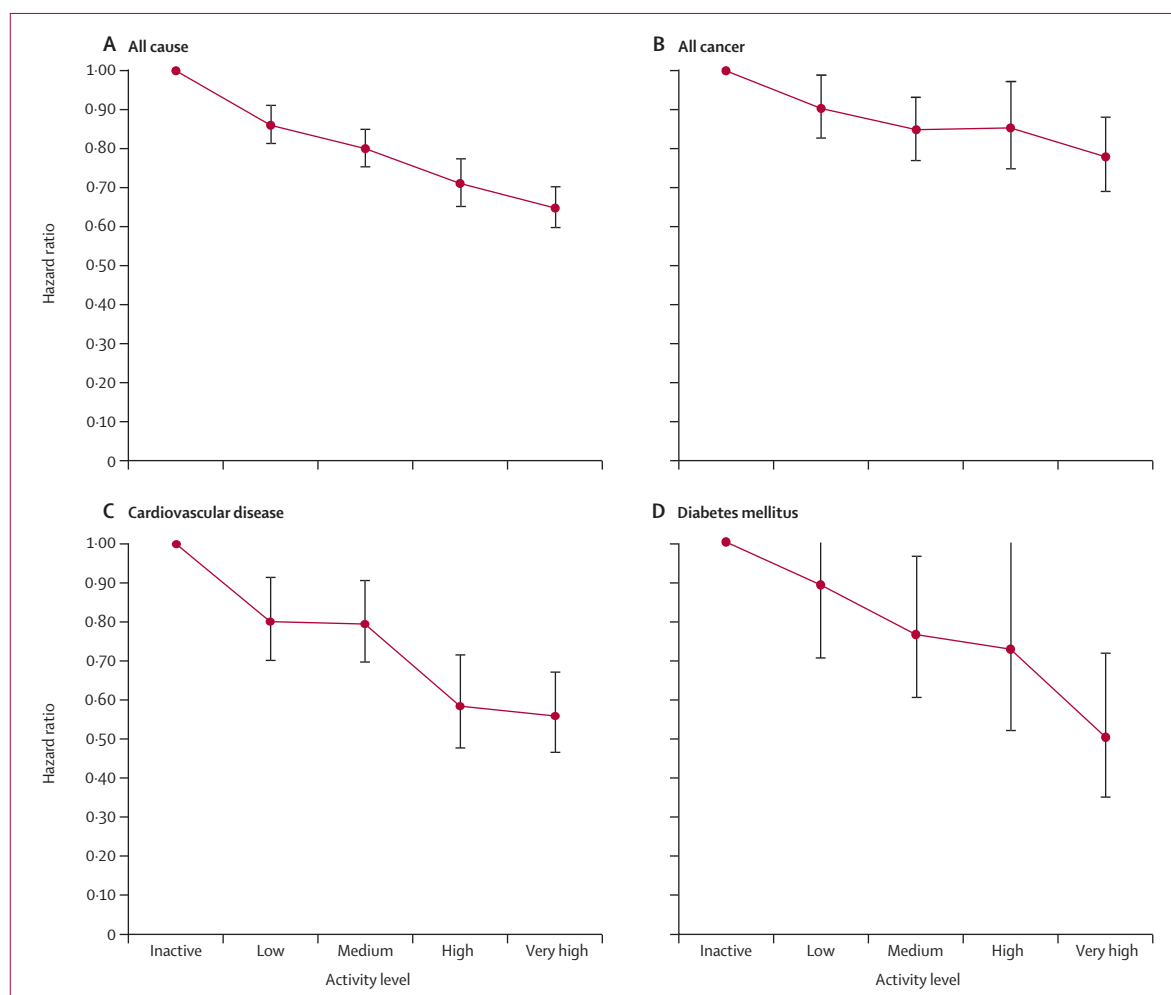


Figure 1: Relation between physical activity volume and mortality reduction compared with individuals in the inactive group
Bars show 95% CIs.

were assessed for all mortality outcomes, and we recorded no significant interaction between any of them. The 13 pre-specified confounders were age, sex, education, physical labour at work, smoking, drinking, fasting blood glucose, systolic blood pressure, total cholesterol, BMI, diabetes, hypertension, and history of cancer. The life table method was used to estimate life expectancy.^{6,14} We calculated adjusted odds ratios and 95% CIs (webappendix p 1) by comparing the proportion of individuals meeting activity recommendations with the proportion of those who were inactive within each characteristic group (eg, sex, age, etc).

Estimated national prevalence of physical activity in Taiwan was validated against nationally representative data from the health interview survey.¹⁵ We tested the reliability of questionnaire data by examining the consistency or the test-retest stability of participants' answers with the Spearman's correlation tested within a given period.

We assessed content validity of the questionnaire by examining the relation between exercise volume and

selected physiological characteristics related to physical activity, such as obesity (BMI), percent body fat or high density lipoprotein, and the ability to predict similar mortality outcome when the same volume activity was recorded by different individuals.

All statistical tests were two-sided with the alpha level set at 0.05. Analyses were done with SAS, version 9.2.

Role of funding source

The funding source had no role in study design, data collection, data analysis, data interpretation, writing of the report, or in the decision to submit the paper for publication. All authors had full access to all the data in the study and CPW, JPMW, MKT, YCY, and XFW had final responsibility for the decision to submit for publication.

Results

Table 1 shows the proportion of individuals in each LTPA volume category and selected characteristics of all

See Online for webappendix

individuals in the cohort. Table 2 shows activity characteristics (duration, intensity, volume, and energy expenditure) for each LTPA volume category (webappendix p 2 shows mean activity characteristics by sex and age groups).

Compared with individuals in the low-volume activity group, those in the inactive group had a 17% increased all-cause mortality risk (HR 1.17, 95% CI 1.10–1.24) and an 11% increased cancer mortality risk (1.11, 1.01–1.22; webappendix p 4). Table 3 shows mortality risks for individuals in all activity groups compared with those in the inactive group (webappendix p 3 shows all-cause mortality risks by subgroup). Of those who met the physical activity recommendation (medium to very high volume activity) and did moderate-intensity exercise, we recorded a dose-response relation to health outcome, in that those who were most active had a reduced risk of all cause mortality (figure 1; table 3).

Figure 2 shows the relation between daily physical activity and reduction in all-cause mortality compared with individuals in the inactive group. After the minimum recommended 15 min a day of exercise, every additional 15 min of daily exercise (up to 100 min a day, after which additional exercise gave no additional health benefit) is expected to generate an additional reduction of 4% (95% CI 2.5–7.0) all-cause and 1% (0.3–4.5) all-cancer mortality.

Subgroup analysis for sex, age, and cardiovascular disease risks showed that, when compared with individuals in the inactive group, those in the low-volume activity group had a lower risk of all-cause mortality, irrespective of their sex, age, or health status, or whether or not they smoke, drink, or have cardiovascular disease risk (figure 3; webappendix p 3).

Compared with individuals in the inactive group, all-cancer mortality and incidence were significantly lower in those in the low-volume activity group and in those in all three groups that met the physical recommendation guidelines (table 4). Both all-cancer mortality and all-cancer incidence decreased as the amount of exercise an individual did increased ($p < 0.0001$ for both trends). Compared with individuals in the low-volume activity group, those in the inactive group had 11% increased all-cancer risks (HR 1.11, 95% CI 1.01–1.22; webappendix p 4).

Vigorous-intensity exercise yielded similar or greater health benefits in terms of all-cause mortality reduction than did moderate-intensity exercise at the same volume of activity or at the next higher volume of activity (table 3). The relation between mortality reduction (for all different causes of death analysed) and activity level was much the same in a sensitivity analysis, which excluded individuals with a history of cancer ($n=4752$) or cardiovascular disease ($n=51051$), and those who died within 3 years of enrolment ($n=2357$; webappendix p 9).

Compared with individuals in the inactive group, at age 30 years, life expectancy for individuals in the low-volume activity group was 2.55 years longer for men and

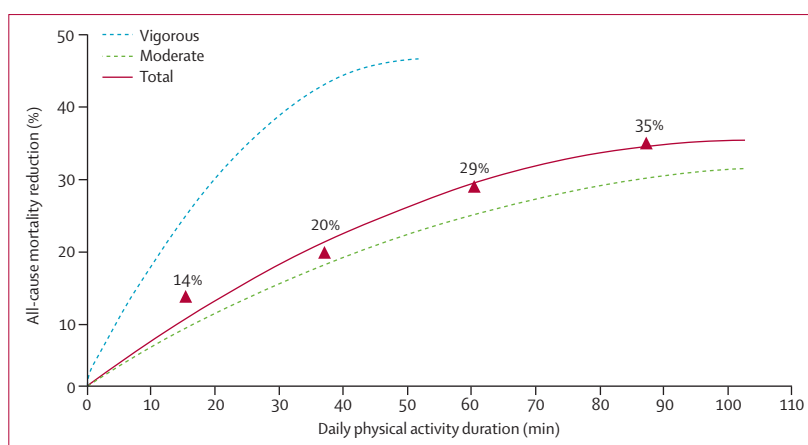


Figure 2: Daily physical activity duration and all-cause mortality reduction

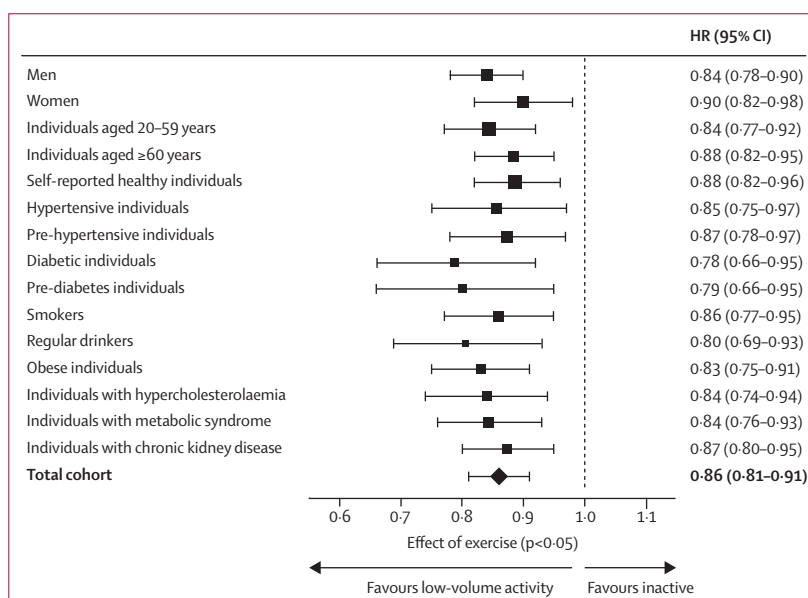


Figure 3: Adjusted all-cause mortality hazard ratio for individuals in the low-volume activity group compared with individuals in the inactive group, by participant characteristic
All hazard ratios (HR) are relative to health outcomes in individuals in the inactive group.

3.10 years longer for women, and life expectancy in those who met the recommended amount of daily exercise was 4.21 years longer for men and 3.67 years longer for women (webappendix p 10).

Discussion

Individuals who did a daily average of 15 min of moderate-intensity exercise had significant health benefits when compared with individuals who were inactive. In Taiwan, if inactive individuals engage in low-volume daily exercise, one in six all-cause deaths could be postponed—mortality reductions of similar magnitude have been estimated for a successful tobacco control programme in the general population.¹⁶ The minimum amount of exercise reported in this study is half of that recommended worldwide,¹ but individuals are more likely to do 15 min of daily exercise

	Total cohort	Inactive		Low		Physical activity meeting recommendation								p for trend
	N	n	HR§	n	HR (95% CI)	Medium		High		Very high		Total		
						n	HR (95% CI)	n	HR (95% CI)	n	HR (95% CI)	n	HR (95% CI)	
Cancer mortality														
All cancer	4272	2185	1	755	0.90* (0.83–0.99)	659	0.85* (0.77–0.93)	318	0.85* (0.75–0.97)	355	0.78* (0.69–0.88)	1332	0.83* (0.77–0.90)	<0.0001
Colon and rectum cancer	421	201	1	86	1.08 (0.83–1.41)	63	0.71* (0.52–0.96)	33	0.84 (0.56–1.25)	38	0.77 (0.53–1.12)	134	0.75* (0.58–0.95)	0.039
Liver cancer	924	485	1	166	0.97 (0.80–1.18)	142	0.92 (0.75–1.12)	65	0.80 (0.60–1.07)	66	0.65* (0.49–0.86)	273	0.82* (0.69–0.98)	0.004
Lung cancer	917	490	1	129	0.73* (0.59–0.90)	156	0.93 (0.77–1.14)	61	0.78 (0.59–1.04)	81	0.79 (0.61–1.02)	298	0.85* (0.72–0.99)	0.031
Breast cancer	179	90	1	36	0.99 (0.64–1.52)	30	1.40 (0.89–2.21)	17	1.73 (0.96–3.11)	6	0.86 (0.37–2.01)	53	1.37 (0.94–2.03)	0.229
Cancer incidence														
All cancer	11 802	6015	1	2233	0.94* (0.89–0.99)	1781	0.87* (0.82–0.92)	787	0.86* (0.79–0.93)	986	0.93 (0.86–1.00)	3554	0.88* (0.84–0.93)	<0.0001
Colon and rectum cancer	1509	713	1	300	1.02 (0.88–1.19)	234	0.86 (0.73–1.02)	108	0.84 (0.67–1.06)	154	1.04 (0.86–1.26)	496	0.91 (0.79–1.03)	0.406
Liver cancer	1676	890	1	305	0.95 (0.82–1.10)	247	0.85* (0.73–1.00)	116	0.87 (0.70–1.08)	118	0.70* (0.56–0.86)	481	0.81* (0.71–0.92)	0.004
Lung cancer	1266	650	1	195	0.83* (0.69–0.99)	204	0.98 (0.83–1.17)	84	0.87 (0.68–1.12)	133	1.12 (0.91–1.37)	421	1.00 (0.87–1.15)	0.626
Breast cancer	1364	760	1	299	0.95 (0.82–1.10)	173	0.88 (0.73–1.06)	82	1.13 (0.88–1.45)	50	0.79 (0.58–1.09)	305	0.92 (0.79–1.07)	0.304
Breast cancer (age >50 years)	540	262	1	106	0.89 (0.69–1.14)	95	0.89 (0.69–1.16)	42	0.93 (0.65–1.33)	35	0.86 (0.59–1.24)	172	0.89 (0.72–1.11)	0.330
Hazard ratios (HR) for mortality are adjusted for age, sex, education, activity at work, smoking, drinking, fasting blood glucose, systolic blood pressure, body mass index, diabetes history, and hypertension history. HR calculations for cancer incidences exclude individuals with a history of cancer before they entered the cohort. *Indicates a significantly (p<0.05) lower incidence or mortality rate compared with the inactive group.														
Table 4: Hazard ratios for cancer mortality and incidence, by volume of leisure-time physical activity														

Hazard ratios (HR) for mortality are adjusted for age, sex, education, activity at work, smoking, drinking, fasting blood glucose, systolic blood pressure, body mass index, diabetes history, and hypertension history. HR calculations for cancer incidences exclude individuals with a history of cancer before they entered the cohort. *Indicates a significantly ($p < 0.05$) lower incidence or mortality rate compared with the inactive group.

Table 4: Hazard ratios for cancer mortality and incidence, by volume of leisure-time physical activity

than they are 30 min of daily exercise. Furthermore, once an individual does 15 min of daily exercise regularly, they might be more likely to increase the amount of time they spend exercising per day, possibly leading to a change in the social norm by increasing the amount of LTPA done in a largely inactive society. With this potential increase in exercise in mind, a recommendation of 15 min of daily exercise should be promoted to east Asian populations.

Although the reduction of all-cause mortality with exercise is an important focus for health communication messages, the reduction in cancer risk with exercise is equally important. Such cancer-related messages can be a powerful motivation for Asians to exercise because cancer is by far the leading cause of death in this population.^{8,17} Our results suggest that one in nine deaths from cancer in individuals in the inactive group could have been averted if they did 15 min of moderate-intensity daily exercise. We know of no other studies to report protection against all cancer from a dose below the recommended 30 min a day,¹⁸ or the graded dose-response relation of moderate intensity LTPA (panel).^{1,2,19} The relation between exercise and reductions in frequency of site-specific cancers was less consistent than it was for all cancers, however, for reasons that have not been explored.^{19,20}

The magnitude of all-cause mortality reduction from 15 min a day exercise was consistent in men and women across all age groups (webappendix pp 5–8), with results much the same after controlling for 13 confounders. These findings, particularly in individuals with cardiovascular disease risk, have important implications for clinical practice. Such people can benefit substantially from incorporating this low level of exercise into their treatment modalities. The universal nature of this advice for inactive individuals would greatly reduce the need to individualise an exercise prescription on the basis of an individual's physical capability.²¹

Health gains achieved below the recommended level have been reported,^{22,23} but a minimum dose for life prolongation has not been identified. Endpoints in some studies focused more on disease incidence^{22–28} than they did on mortality,^{25,29–32} and focused largely on elderly women.^{22,23,26,29,33} Furthermore, many studies were unable to quantify the benefits of moderate-intensity exercise because they included individuals who did some vigorous-intensity exercise.^{24,30,32}

The reason why the small amounts of LTPA provided significant health benefits needs further discussion. First, the dose-response gradient between exercise time and mortality benefits was not linear but curvilinear (figure 2),

with the largest health gains from the first 1–2 h of exercise a week. This curvilinear relation between exercise and health gains has been reported in other studies.^{1,2,34,35} Second, mortality reduction at an exercise volume less than the recommended 150 min a week has also been recorded elsewhere,^{24–26,29–32} but these other studies were unable to identify a threshold volume of exercise at which health gains were achieved. When sample size limitations were overcome in pooled studies or meta-analyses, statistically significant health benefits of a minimum amount of exercise have been recorded.^{34–36} Third, half our cohort self-reported as being inactive, which is more than double the number of people who did so in the USA (23.7%),³⁷ implying that the habit of regular exercise is far from being adopted as the social norm in east Asia. As the Taiwanese population has become wealthier, they have done less manual labour and have increased their use of motor vehicles for transportation—Taiwan has the greatest density of motorcycles in the world.³⁸ Against this backdrop of an inactive majority as a reference population, low-volume exercise as defined in this study is not actually very low because such exercise needs to be done for most days of the week for many years. Fourth, individuals in all three activity groups that met the physical activity recommendation and those who engaged in low-volume activity had fewer health risks (eg, diabetes, smoking, or obesity) compared with individuals in the inactive group. This finding is intriguing because differences in risk factors were controlled in our adjustment process, and, therefore, health benefits recorded in these individuals were probably attributable to their physical effort and not to the lower prevalence of risk factors. Although physical activity alone can improve health, increasing physical activity can indirectly improve health by decreasing other health risks (eg, lifestyle risks) that are associated with inactivity.^{5,39} The fact that ex-smokers exercised more than smokers suggests that physical activity might have helped smokers to quit. In this way, exercisers might be more likely to quit smoking, lose weight, or reduce their chances of developing diabetes.^{5,39} Fifth, the psychological effect of walking to work and walking as a leisure activity differ. Only leisure-time walking, when done regularly, has been hypothesised to release endorphins,⁴⁰ the release of which, even in small amounts, can be associated with mental wellbeing.⁴¹ Such wellbeing can help in the prevention and management of cardiovascular disease.⁴²

Vigorous-intensity activities are usually associated with a larger volume of exercise than are moderate-intensity activities, and therefore offer greater health benefits.^{2,34} We know of no other studies that have shown the advantages of vigorous-intensity activities over moderate-intensity activities at an identical volume or the next higher volume of activity. Our findings suggest that, for example, 2 h a week of vigorous-intensity exercise could generate similar health benefits as would 4 h a week of moderate-intensity exercise. Therefore, people who want

Panel: Research in context

Systematic review

We searched PubMed, Medline, and Google Scholar with the search terms “leisure-time physical activity”, “exercise”, “dose-response”, “intensity”, and “mortality”. We also searched the reference lists of relevant papers identified. Cohort studies on leisure-time physical activity (LTPA) that recorded significant health benefits, particularly from all-cause mortality, without meeting the 150 min per week recommendation, were given preference. Of 12 studies identified (webappendix p 11), three reported reduction in occurrence of cardiovascular disease or diabetes, mostly in women aged 50–79 years. In the nine studies of mortality, identification of a minimum amount of exercise was not possible, because they either included vigorous-intensity exercise components or individuals who exercised more than the recommended level.

Interpretation

In this study, 15 min a day or 90 min a week provided a reduction in all-cause and all-cancer mortality and extended an individual's lifespan for an average of 3 years. This minimum amount of exercise is applicable to men and women of all ages, even those with cardiovascular diseases or lifestyle risks. Use of this exercise recommendation in clinical practice could help most patients to become more active and, ultimately, healthier.

to exercise but claim not to have much available time can benefit from the positive health effects of exercise if they do vigorous-intensity exercise once or even twice a week (eg, at weekends). Although such people—termed weekend warriors elsewhere⁴³—could achieve significant health benefits and should not be discouraged, they are not to be encouraged, either, because of the potential for increased injury and cardiovascular risks.

Reliability of our questionnaire, measured by consistency in answers given on consecutive visits, is important because it affects the quality of our findings. Reliability of our questionnaire was much the same as that of other questionnaires that are widely accepted as reliable.² We compared outcomes in individuals who made at least two visits and were consistent in their reporting of exercise volumes. Compared with individuals in the inactive group, individuals in the low-volume exercise group had HRs for all-cause mortality of 0.86 (95% CI 0.77–0.98) on their first visit and 0.90 (0.80–1.02) on their second visit, and individuals who met or exceeded the 2008 recommendations had HRs for all-cause mortality of 0.74 (0.60–0.92) on their first visit and 0.79 (0.72–0.87) on their second visits, which were sufficiently close to make the validity of our questionnaire within an acceptable range.

One of the strengths of this study is the expression of the benefits of LTPA in both mortality reduction and extension of life. Life expectancy, not presented in most studies, can be calculated only when the study population is sufficiently large. Health messages in terms of life extension are easy to understand and can motivate inactive individuals to take up exercise.⁴⁴

This study had several limitations. First, because this was an observational study, we cannot attribute the recorded health outcomes entirely to physical activity.

Although healthier individuals tend to exercise more, our findings show that individuals who were less healthy—those with risk factors or with cardiovascular diseases—had improvement in health when they did exercise above the 15 min daily amount. Second, people have a tendency to over-report LTPA because it is a socially desirable behaviour.⁴⁵ However, such over-reporting of LTPA would bias the findings in support of a null hypothesis. Third, results from this cohort, who were recruited from participants with above average socioeconomic status, might not be generalisable to all east Asians, and the proportion of individuals who are inactive could be an underestimate. Nevertheless, the risks calculated for HRs, internally standardised with socioeconomic status adjusted, should be valid estimates. Fourth, of the four domains of physical activity (work, transportation, household, and LTPA), only leisure-time activity was studied. However, of these four domains, LTPA is the most related with health benefits.⁴¹ Furthermore, only LTPA is effort-related and promotable. Fifth, the validity of HRs depends on the completeness of follow-up. Because Taiwan has a national death file that records all deaths, we believe that few individuals were lost to follow-up. Results from the death file data were very similar to those from the cancer registry, which is a different set of national data supported with laboratory confirmation.

If the minimum amount of exercise we suggest is adhered to, mortality from heart disease, diabetes, and cancer could be reduced. This low-volume of physical activity could play a central part in the global war against non-communicable diseases,^{46,47} reducing medical costs and health disparities.

Contributors

CPW and JPMW had the idea for and designed the study. JPMW developed the analytical methodology on leisure-time physical activity. SPT and YCY developed the analytical methodology on life expectancy. CPW, JPMW, SPT, M-CL, MKT, YCY, and HTC analysed and interpreted the data. CPW and JPMW drafted the article and submitted the paper for publication. CPW, JPMW, M-CL, YCY, and XFW critically revised the article for important intellectual content. CPW, JPMW, MKT, and YCY had final approval of the article. CKT provided study materials and was responsible for quality control of data from the leisure-time physical activity questionnaire. SPT, MKT, YCY, HTC, and TYDC provided statistical expertise. MKT, YCY, and HTC provided administrative, technical, or logistical support. CKT was responsible for collection and assembly of data.

Conflicts of interest

We declare that we have no conflicts of interest.

Acknowledgments

We thank MJ Health Management Institution for making their large dataset available to us. We thank Nelson Wen for his help in revising the English in this manuscript. This study was supported by Taiwan Department of Health Clinical Trial and Research Centre of Excellence (DOH 100-TD-B-111-004) and the institutional support from National Health Research Institutes.

References

- Physical Activity Guidelines Advisory Committee. Physical activity guidelines advisory committee report and 2008 physical activity guidelines for Americans. <http://www.health.gov/paguidelines/committeereport.aspx> and <http://www.health.gov/paguidelines/pdf/paguide.pdf> (accessed March 9, 2011).
- Lee I-M, Blair S, Manson J, Paffenbarger RS. Epidemiologic methods in physical activity studies, 1st edn. New York: Oxford University Press, 2009.
- WHO. Global Recommendations on physical activity for health. http://www.who.int/dietphysicalactivity/factsheet_recommendations/en/index.html (accessed May 20, 2011).
- Ku P-W, Fox KR, McKenna J, Peng T-L. Prevalence of leisure-time physical activity in Taiwanese adults: results of four national surveys, 2000–2004. *Prev Med* 2006; **43**: 454–57.
- Wai JPM, Wen CP, Chan HT, et al. Assessing physical activity in an Asian country: low energy expenditure and exercise frequency among adults in Taiwan. *Asia Pac J Clin Nutr* 2008; **17**: 297–308.
- Wen CP, Tsai SP, Chung W-SI. A 10-year experience with universal health insurance in Taiwan: measuring changes in health and health disparity. *Ann Intern Med* 2008; **148**: 258–67.
- Warburton DER, Nicol CW, Bredin SSD. Prescribing exercise as preventive therapy. *CMAJ* 2006; **174**: 961–74.
- Department of Health Executive Yuan Taiwan. National death file and national cancer registry file. http://www.doh.gov.tw/CHT2006/DM/DM2_2_p02.aspx?class_no=440&now_fod_list_no=11668&level_no=5&doc_no=78419 and <http://cph.ntu.edu.tw/main.php?Page=A5#t01> (accessed March 2, 2011).
- Carlson SA, Densmore D, Fulton JE, Yore MM, Kohl HW. Differences in physical activity prevalence and trends from 3 US surveillance systems: NHIS, NHANES, and BRFSS. *J Phys Act Health* 2009; **6**: S18–S27.
- Wen CP, Cheng TYD, Tsai SP, et al. Are Asians at greater mortality risks for being overweight than Caucasians? Redefining obesity for Asians. *Public Health Nutr* 2008; **12**: 497–506.
- National Institutes of Health. National Cholesterol Education Program (NCEP) expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (Adult Treatment Panel III) final report. *Circulation* 2002; **106**: 3143–421.
- K/DOQI clinical practice guidelines for chronic kidney disease: evaluation, classification, and stratification. *Am J Kidney Dis* 2002; **39**: s1–s266.
- Wen CP, Cheng TYD, Tsai MK, et al. All-cause mortality attributable to chronic kidney disease: a prospective cohort study based on 462,293 adults in Taiwan. *Lancet* 2008; **371**: 2173–82.
- Chiang CL. The life table and its applications. Malabar, FL: RE Krieger Pub Co, 1984.
- National Health Research Institutes. National Health Interview Survey (NHIS) in 2005: Bureau of Health Promotion and National Health Research Institutes 2005. <http://nhis.nhri.org.tw> (accessed May 3, 2011).
- Wen CP, Tsai SP, Chen CJ, Cheng TY, Tsai MC, Levy DT. Smoking attributable mortality for Taiwan and its projection to 2020 under different smoking scenarios. *Tobacco Control* 2005; **14**(suppl 1): i76–80.
- Foundation for Promotion of Cancer Research (FPCR). Cancer statistics in Japan 2010. Tokyo: Foundation for Promotion of Cancer Research, 2008.
- Friedenreich CM, Orenstein MR. Physical activity and cancer prevention: etiologic evidence and biological mechanisms. *J Nutr* 2002; **132**: 3456S–64S.
- World Cancer Research Fund and American Institute for Cancer Research. Food, nutrition, physical activity, and the prevention of cancer: a global perspective. Washington DC: American Institute for Cancer Research, 2007.
- Thune I, Furberg A-S. Physical activity and cancer risk: dose-response and cancer, all sites and site-specific. *Med Sci Sports Exerc* 2001; **33**: S530–50.
- American College of Sports Medicine. ACSM's guidelines for exercise testing and prescription, 6th edn. USA: Lippincott Williams and Wilkins, 2000.
- Lee I-M, Rexrode KM, Cook NR, Manson JE, Buring JE. Physical activity and coronary heart disease in women—is no pain, no gain passe? *JAMA* 2001; **285**: 1447–54.
- 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.

- 24 Bijnen FCH, Caspersen CJ, Feskens EJM, Saris WHM, Mosterd WL, Kromhout D. Physical activity and 10-year mortality from cardiovascular diseases and all causes. *Arch Intern Med* 1998; **158**: 1499–505.
- 25 Gregg EW, Gerzoff RB, Caspersen CJ, Williamson DF, Narayan KM. Relationship of walking to mortality among US adults with diabetes. *Arch Intern Med* 2003; **163**: 1440–47.
- 26 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.
- 27 Tanasescu M, Leitzmann MF, Rimm EB, Hu FB. Physical activity in relation to cardiovascular disease and total mortality among men with type 2 diabetes. *Circulation* 2003; **107**: 2435–39.
- 28 Wisloff U, Nilsen TIL, Droyvold WB, Morkved S, Slordahl SA, Vatten LJ. A single weekly bout of exercise may reduce cardiovascular mortality: how little pain for cardiac gain? The HUNT study, Norway. *Eur J Cardiovasc Prev Rehabil* 2006; **13**: 798–804.
- 29 Kushi LH, Fee RM, Folsom AR, Mink PJ, Anderson KE, Sellers TA. Physical activity and mortality in postmenopausal women. *JAMA* 1997; **277**: 1287–92.
- 30 Leitzmann MF, Park Y, Blair A, et al. Physical activity recommendations and decreased risk of mortality. *Arch Intern Med* 2007; **167**: 2453–60.
- 31 Schnohr P, Scharling H, Jensen JS. Intensity versus duration of walking, impact on mortality: the Copenhagen City Heart Study. *Eur J Cardiovasc Prev Rehabil* 2007; **14**: 72–78.
- 32 Schooling CM, Lam TH, Li ZB, et al. Obesity, physical activity, and mortality in a prospective Chinese elderly cohort. *Arch Intern Med* 2006; **166**: 1498–504.
- 33 Hu FB, Sigal RJ, Rich-Edwards JW, et al. Walking compared with vigorous physical activity and risk of type 2 diabetes in women. *JAMA* 1999; **282**: 1433–39.
- 34 Lollgen H, Bockenhoff A, Knapp G. Physical activity and all-cause mortality: an updated meta-analysis with different intensity categories. *Int J Sports Med* 2009; **30**: 213–24.
- 35 Woodcock J, Franco OH, Orsini N, Roberts I. Non-vigorous physical activity and all-cause mortality: systematic review and meta-analysis of cohort studies. *Int J Epidemiol* 2010; **40**: 121–38.
- 36 Sattelmair J, Pertman J, Ding EL, et al. Dose response between physical activity and risk of coronary heart disease: a meta-analysis. *Circulation* 2011; **124**: 789–95.
- 37 US CDC. Trends in leisure-time physical inactivity by age, sex, and race/ethnicity—United States, 1994–2004. *MMWR Morb Mortal Wkly Rep* 2005; **54**: 991–94.
- 38 Chung W-SI, Tsai SP, Tsai MK, Wen CP. Analysis of the association of urban/rural gap between motor vehicle accidents and life expectancy in Taiwan. *Taiwan J Public Health* 2010; **29**: 261–72.
- 39 Carlsson S, Andersson T, Wolk A, Ahlbom A. Low physical activity and mortality in women: baseline lifestyle and health as alternative explanations. *Scand J Public Health* 2006; **34**: 480–87.
- 40 Boecker H, Sprenger T, Spilker ME, et al. The runner's high: opioidergic mechanisms in the human brain. *Cereb Cortex* 2008; **18**: 2523–31.
- 41 Cerin E, Leslie E, Sugiyama T, Owen N. Associations of multiple physical activity domains with mental well-being. *Ment Health Phys Act* 2009; **2**: 55–64.
- 42 Warburton DER, Nicol CW, Bredin SSD. Health benefits of physical activity: the evidence. *CMAJ* 2006; **174**: 801–09.
- 43 Lee I-M, Sesso HD, Oguma Y, Paffenbarger RS. The “Weekend Warrior” and risk of mortality. *Am J Epidemiol* 2004; **160**: 636–41.
- 44 Ziegelmann JP, Lippke S, Schwarzer R. Subjective residual life expectancy in health self-regulation. *J Gerontol B Psychol Sci Soc Sci* 2006; **61**: P195–P201.
- 45 Adams SA, Matthews CE, Ebbeling CB, et al. The effect of social desirability and social approval on self-reports of physical activity. *Am J Epidemiol* 2005; **161**: 389–98.
- 46 Beaglehole R, Bonita R, Alleyne G, et al. UN High-Level Meeting on Non-Communicable Diseases: addressing four questions. *Lancet* 2011; **378**: 449–55.
- 47 Global Advocacy for Physical Activity. The Toronto Charter for Physical Activity: a global call for action. <http://www.globalpa.org.uk> (accessed June 20, 2011).