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[A: We have edited your paper to avoid repetition, enhance readability, reduce length, and achieve consistency with *Lancet* style. Your webappendix will need to be formatted as per our guidelines—I will send you a copy of the guidelines with the first proof. The webappendix needs to be supplied as one PDF document with numbered pages, and with every new section on a new page because in the main text of the paper, we reference the webappendix by page number.]

Minimum amount of physical activity for reduced mortality in Taiwan: a historically prospective cohort study

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Summary

Background **The health benefits of leisure-time physical activity are well known but the minimum amount needed for mortality reduction in east Asians is not clear. We estimated the minimum amount of exercise needed to reduce mortality in a Taiwanese population.**

Methods **In this historically 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 daily exercise indicated in a self-administered questionnaire, participants were placed into one of five categories: inactive, 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 min) 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 at age 30 years. Every additional 15 mins of daily exercise beyond the minimum amount of 15 mins a day further reduced all-cause mortality by 4%. 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 **[A: some information deleted to avoid repetition] 15 minutes of daily exercise can benefit most east Asians and should be prescribed by clinicians in east Asian countries [A: addition OK?].**

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[A: *Lancet* style allows only one degree for each author. Could you please confirm that the degrees listed are all authors' preferred degrees? Also, please indicate any full professors]

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Introduction

In 2008, the US Department of Health and Human services recommended 150 mins or more a week of leisure-time physical activity (LTPA),[1] and much evidence suggests that this level of exercise can have substantial health benefits for an individual [A: refs? Or was the "overwhelming evidence" included in the 2008 report?]. Because barriers [A: such as?] exist to meet this 30 min a day, 5 day a week recommendation,[2] LTPA is an under-used public health intervention in Asian countries. East Asians [A: OK?] tend to be less physically active than Americans, and tend to exercise at lower intensity [A: correct to compare with Americans?].[3,4] Half of the American adult population met or exceeded this recommendation,[1] whereas less than one-fifth of the adult population did in East Asian countries like China, Japan, or Taiwan.[3,4] With a smaller body size and lower caloric intake [A: than which populations in America?],[5] whether levels of physical activity lower than what is recommended for Americans [A: some information deleted to avoid repetition] are adequate to generate health benefits in the Asian population is not clear.

Identification of a minimum amount of exercise—or minimum dose[1]—sufficient to reduce mortality is desirable because a smaller amount of exercise can be easier to achieve. Furthermore, patients might be more easily motivated to exercise if their doctor recommends a minimum 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 **[A: reworded for clarity. OK. Also, in your original sentence, did you mean that these opportunities are being missed at the moment?]**.[7] The availability of a minimum dose of exercise will enable such opportunities to be taken and will benefit patients, especially those with cardiovascular disease or lifestyle risks **[A: such as?]**.

In this study, we investigate whether the amount of exercise needed to generate health benefits for east Asians is similar to that recommended for Americans.[1] The objective of this study is to assess the health benefits of graded physical activity volumes with data from a large cohort in Taiwan, and to find out the lowest amount of exercise that can reduce mortality **[A: do you mean morbidity here? If not, please explain the difference between a reduction in mortality and prolongation of life]** or prolong life.

Methods

Data collection

In this historically prospective cohort study, the cohort consisted of 416 175 healthy individuals older than

20 years (199 265 men and 216 910 women) who participated in a standard medical screening programme run by a private firm (MJ Health Management Institution, Taipei, Taiwan) [A: company info taken from reference 8. OK?]—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 person-years (SD 4·21). Every individual's identification number was matched with the National Death file and the National Cancer Registry file [A: refs?].

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. Data related to individual identification were removed and remained anonymous during the entire study process. [A: ethical review and consent information taken from ref 8. OK? Please reword as appropriate.]

Every participant completed a self-administered questionnaire of their medical history and lifestyle information. The same questionnaires were filled out on every visit [A: please give an indication of the visit schedule], but results from only the initial visit were used. An individual's LTPA level was ascertained through three multiple-choice questions. First,

	Inactive	Low volume	Meeting physical activity recommendation			
			Medium volume	High volume	Very high volume	Total
All participants	226 493 (54·4%)	90 663 (21·8%)	56 899 (13·7%)	21 730 (5·2%)	20 390 (4·9%)	99 019 (23·8%)
Sex						
Male	48·6%	22·2%	15·9%	6·6%	6·7%	29·2%
Female	59·8%	21·4%	11·7%	3·9%	3·2%	18·8%
Age (years)						
20–39	59·4%	23·7%	10·8%	3·6%	2·5%	16·9%
40–59	50·4%	20·6%	16·1%	7·4%	5·5%	29·0%
≥60	42·6%	16·2%	20·3%	6·9%	14·0%	41·2%
Education						
Middle school or lower	54·3%	16·8%	15·0%	6·4%	7·5%	28·9%
High school	57·0%	21·5%	12·2%	4·5%	4·8%	21·5%
Junior college	53·9%	24·6%	13·1%	4·6%	3·8%	21·5%
College or higher	46·2%	27·9%	16·0%	5·9%	4·0%	25·9%
Physical labour at work						
Mostly sedentary	50·2%	24·7%	15·2%	5·4%	4·5%	28·9%
Sedentary with occasional walking	54·0%	22·5%	13·6%	5·3%	4·6%	21·5%
Mostly standing or walking	59·5%	16·7%	11·5%	5·3%	6·9%	21·5%
Hard labour	62·3%	12·9%	10·2%	5·2%	9·3%	25·9%
Smoking						
Never smoker	52·2%	23·3%	14·5%	5·2%	4·8%	24·5%
Ex-smoker	43·8%	21·3%	17·5%	8·1%	9·3%	34·9%
Smoker	55·9%	20·9%	13·1%	5·1%	4·9%	23·1%
Drinking						
Never drinker	53·6%	22·9%	14·0%	5·0%	4·5%	23·5%
Occasional drinker	45·2%	24·2%	16·1%	7·3%	7·3%	30·6%
Regular drinker	54·2%	18·5%	14·3%	5·9%	7·1%	27·2%
Body mass index						
18·5–24 kg/m^2	53·5%	22·5%	13·8%	5·3%	4·9%	24·0%
25–29 kg/m^2	51·5%	20·6%	15·4%	6·3%	6·2%	27·9%
≥30 kg·m^{-2}	57·5%	20·4%	12·9%	4·9%	4·2%	22·0%
Systolic blood pressure						
<120 mm Hg	58·0%	22·7%	11·7%	4·2%	3·3%	19·3%
Pre-hypertension						
120–139 mm Hg	51·8%	21·7%	15·1%	6·0%	5·5%	26·6%
Hypertension						
≥140 mm Hg or receiving drugs	46·8%	19·1%	17·8%	7·2%	9·0%	34·1%

(Continues on next page)

	Inactive	Low volume	Meeting physical activity recommendation			
			Medium volume	High volume	Very high volume	Total
(Continued from previous page)						
Fasting blood glucose						
<6·1 mmol/L [A: conversion OK?]	54·5%	22·3%	13·4%	5·1%	4·6%	23·2%
Pre-diabetes						
6·1–6·9 mmol/L [A: conversion OK?]	50·1%	19·7%	16·2%	6·8%	7·3%	30·2%
Diabetes						
≥7 mmol/L [A: conversion OK?] or receiving drugs	49·9%	17·7%	17·5%	6·7%	8·2%	32·5%
Total cholesterol						
<6·2 mmol/L [A: conversion OK?]	54·8%	22·1%	13·4%	5·1%	4·7%	23·2%
≥6·2 mmol/L [A: conversion OK?] or receiving drugs	50·9%	20·1%	16·2%	6·3%	6·5%	29·0%
Metabolic syndrome (NCEP-ATP III)						
No	54·8%	22·1%	13·3%	5·2%	4·7%	23·1%
Yes	52·1%	19·4%	16·4%	5·6%	6·5%	28·5%
Chronic kidney disease						
No	53·8%	22·2%	13·8%	5·3%	4·8%	23·9%
Yes	52·2%	19·2%	15·3%	6·1%	7·2%	28·6%

Data are n (%). [A: some data removed to avoid repetition of methods] NCEP-ATP III=National Cholesterol Education Program-Adult Treatment Panel III. [A: mean LTPA data have been removed from table 1 to avoid repetition of data in table 2.] [A: The column title "overall" has been removed. Please instead give the exact number for all data—eg for men in the inactive group=96 843 (48·6%). MET values for each group have been removed to avoid repetition of methods.] [A: Are some data missing for Education? The number of individuals in each category (high school, junior college, etc) do not add up to the total N]

***Table 1*: Characteristics of the participants, by volume of leisure-time physical activity**

participants were asked to classify the types and intensities of LTPAs that they did regularly 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; resting rate of energy expenditure) per hour per week [A: units correct?] of 2·5 for light, 4·5 for moderate, 6·5 for medium-vigorous, or 8·5 for high-vigorous exercise. For individuals indicated activities in more than one intensity category, a weighted MET value was assigned, dependent on the relative length of time engaged in each category. The second question asked for the duration per week spent on different LTPA activities [A: possible to list all activities?] within the previous month. Those who indicated that they did less than 1 h a week [A: "none" deleted because it is less than 1 h. OK?] for all LTPAs were classified as inactive. With LTPA volume being the product of intensity (MET) and duration of exercise, the calculated MET per hour per week of each individual was placed into one of the five distinct categories: inactive (<3·75 h), low (3·75–7·49 h), medium (7·50–16·49 h), high (16·50–25·49 h), or very high (≥25·50 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 included 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 asked 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 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 less.[5] Metabolic syndrome was defined on the basis of National Cholesterol Education Program-Adult Treatment Panel III [A: correct criteria? Is it used in ref 10?] criteria[10] and chronic kidney disease, defined by the Kidney Disease Outcomes Quality Initiative clinical practice guidlines.[8] [A: please give a reference directly to this initiative – Ref 8 males only an indirect reference. Thanks] 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 [A: we use SI untis for such value. Please check conversion]). Hypertension was also defined 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 defined as regular alcohol drinkers if they consumed two or more alcoholic drinks a day on three or more days a week [A: how was "occasional drinker" defined?].

Statistical analysis

The primary analysis was done with data from all participants who completed the LTPA questionnaire—participants were only excluded in the subgroup analyses.

	Low volume			Medium volume			High volume			Very high volume			Total		
	Total	Moderate	Vigorous	Total	Moderate	Vigorous	Total	Moderate	Vigorous	Total	Moderate	Vigorous	Total	Moderate	Vigorous
Total	21·80%	20·80%	1·00%	13·70%	10·60%	3·10%	5·20%	3·70%	1·60%	4·90%	2·30%	2·60%	23·80%	16·50%	7·30%
Duration (min per week)	92	92	90	222	254	114	362	412	244	523	614	443	315	339	259
Intensity (MET)	3	3	3·8	3·7	3	6	4·1	3·4	5·7	5	3·6	6·2	4	3·2	6
Volume (MET-hours per week)	4·6	4·6	5·7	11·9	12·3	10·7	22	22	21·9	40·7	35·8	45·2	20·1	17·7	25·4
Energy expended (kcal per week)	286	283	347	752	770	689	1407	1397	1429	2576	2256	2866	1268	1117	1615
Men	21·80%	20·70%	1·00%	15·90%	11·20%	4·60%	6·60%	4·30%	2·30%	6·70%	2·70%	4·00%	29·20%	18·30%	11·00%
Duration (minute per week)	92	92	90	206	245	110	339	396	236	517	630	440	308	338	257
Intensity (MET)	3·2	3·2	3·8	4·1	3·2	6·1	4·4	3·6	5·8	5·3	3·8	6·3	4·4	3·4	6·1
Volume (MET-hours per week)	4·9	4·9	5·7	12	12·6	10·6	22·3	22·5	22	42·6	38·2	45·6	21·4	18·8	25·8
Energy expended (kcal per week)	337	335	390	827	867	727	1536	1544	1521	2825	2573	3002	1444	1282	1716
Women	21·40%	20·40%	1·00%	11·70%	9·90%	1·70%	3·90%	3·10%	0·90%	3·20%	1·90%	1·30%	18·80%	14·90%	3·90%
Duration (minute per week)	92	92	90	242	263	124	396	433	264	536	594	452	325	340	264
Intensity (MET)	2·8	2·8	3·7	3·2	2·8	5·7	3·6	3·1	5·2	4·4	3·4	6	3·5	2·9	5·7
Volume (MET-hours per week)	4·3	4·3	5·6	11·8	12	10·9	21·5	21·4	21·8	37·2	32·5	44	18·2	16·6	24·3
Energy expended (kcal per week)	237	234	304	658	670	595	1207	1210	1199	2101	1840	2488	1009	931	1356
Age 20–39 years	23·70%	22·50%	1·20%	10·80%	7·40%	3·40%	3·60%	2·20%	1·40%	2·50%	0·80%	1·80%	16·90%	10·40%	6·50%
Duration (minute per week)	91	91	90	190	226	111	316	370	232	445	537	405	255	279	216
Intensity (MET)	3·2	3·1	3·8	4·2	3·4	6	4·6	3·9	5·8	5·8	4·3	6·4	4·5	3·5	6·1
Volume (MET-hours per week)	4·8	4·7	5·7	11·8	12·4	10·5	22·4	22·7	21·8	41·3	38·6	42·5	18·5	16·5	21·5
Energy expended (kcal per week)	296	293	345	753	788	678	1464	1481	1439	2723	2569	2792	1193	1067	1403
Age 40–59 years	20·60%	19·60%	1·00%	16·10%	12·70%	3·40%	7·40%	5·30%	2·00%	5·50%	2·00%	3·50%	29·00%	20·10%	8·90%
Duration (minute per week)	93	93	90	229	259	118	393	447	250	474	541	434	317	338	271
Intensity (MET)	2·9	2·8	3·8	3·5	2·9	5·9	3·9	3·2	5·6	5·4	4·1	6·2	4	3·1	5·9
Volume (MET-hours per week)	4·4	4·3	5·6	11·8	12·1	10·9	22·4	22·5	22	41·2	36·6	43·9	20·1	17·3	26·3
Energy expended (kcal per week)	276	272	351	745	756	704	1419	1418	1421	2619	2287	2815	1271	1087	1688
Age ≥60 years	16·20%	15·90%	0·30%	20·30%	19·10%	1·20%	6·90%	5·80%	1·10%	14·00%	9·90%	4·10%	41·20%	34·80%	6·40%
Duration (minute per week)	96	96	90	284	295	126	382	400	282	638	681	533	421	422	413
Intensity (MET)	2·6	2·6	3·7	2·8	2·6	5·8	3·3	3	5·1	4	3·1	6·1	3·3	2·8	5·9
Volume (MET-hours per week)	4·2	4·1	5·6	12·5	12·6	11·3	19·9	19·4	22·3	39·8	34·3	53·2	23	19·9	40
Energy expended (kcal per week)	254	252	350	763	766	714	1238	1206	1411	2411	2131	3136	1396	1228	2350

[A: some data removed to avoid repetition of methods] Data are n (%) unless otherwise stated [A: please give the exact number of individuals in each group—eg, for total number of individuals in the low volume group give 90 726 (21·8%)]. [A: mean LTPA data have been removed from table 1 to avoid repetition of data in table 2. Please provide 95%CI/SDs (as appropriate) for all data in table 2]. MET=metabolic equivalent.

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

We calculated hazard ratios (HR) to compare mortality risks between individuals in different exercise groups (grouped by volume of exercise) and individuals 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 history, hypertension history, and cancer history. 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 risk factors and LTPA volumes were assessed for all mortality outcomes [A: result moved to results section]. 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 history, hypertension history, and cancer history. The life table method was used to estimate life expectancy.[6] [A: Ref 6 refers the reader to another reaserach paper. Can you please supply a more direct reference to explain this technique?]

Data were validated against the nationally representative health interview survey in Taiwan [A: ref?]. The reliability and validity of questionnaire data were tested by examination of the correlation between consistencies in recall of exercise volumes and closeness of mortality outcome between two visits when the reported volume of exercise was identical in participants with two [A: ore more?] visits (mean interval of two visits was 21 months, SD 13·1).

All statistical tests were two-sided with the alpha level set at 0·05. Analyses were done with SAS, version 9.2.

	Number of individuals	Inactive		Low volume		Medium volume		High volume		Very high volume		Total	
		Deaths (n)	HR	Deaths (n)	HR (95% CI)	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)

(Continues on next page)

	Number of individuals	Inactive		Low volume		Medium volume		High volume		Very high volume		Total	
		Deaths (n)	HR	Deaths (n)	HR (95% CI)	Deaths (n)	HR (95% CI)	Deaths (n)	HR (95% CI)	Deaths (n)	HR (95% CI)	Deaths (n)	HR (95% CI)
(Continued from previous page)													
All cause mortality for subgroups													
Men	199 265	3381	1	1076	0·84* (0·78–0·90)	1011	0·78* (0·72–0·84)	483	0·74* (0·67–0·82)	618	0·66* (0·60–0·72)	2112	0·73* (0·69–0·78)
Women	216 910	2307	1	801	0·90* (0·82–0·98)	649	0·85* (0·77–0·93)	259	0·66* (0·57–0·77)	195	0·60* (0·51–0·71)	1103	0·75* (0·69–0·81)
Individuals aged 20–59 years	364 880	2458	1	764	0·84* (0·77–0·92)	534	0·89* (0·81–0·99)	241	0·80* (0·70–0·93)	192	0·72* (0·61–0·84)	967	0·83* (0·77–0·90)
Individuals aged ≥60 years	51 295	3230	1	1113	0·88* (0·82–0·95)	1126	0·75* (0·70–0·81)	501	0·67* (0·61–0·75)	621	0·62* (0·57–0·68)	2248	0·70* (0·66–0·74)
Self-reported healthy individuals	361 555	3287	1	976	0·88* (0·82–0·96)	774	0·81* (0·74–0·88)	357	0·76* (0·68–0·86)	391	0·72* (0·64–0·81)	1522	0·77* (0·72–0·83)
Hypertensive individuals	67 335	951	1	395	0·85* (0·75–0·97)	362	0·72* (0·63–0·82)	160	0·64* (0·54–0·78)	185	0·58* (0·49–0·69)	707	0·66* (0·60–0·74)
Pre-hypertensive individuals	122 753	1539	1	488	0·87* (0·78–0·97)	435	0·82* (0·73–0·92)	192	0·68* (0·58–0·80)	220	0·69* (0·59–0·81)	847	0·75* (0·68–0·82)
Diabetic individuals	19 385	630	1	224	0·78* (0·66–0·92)	249	0·74* (0·63–0·86)	95	0·58* (0·45–0·73)	115	0·60* (0·49–0·75)	459	0·67* (0·58–0·76)
Pre-diabetes individuals	23 055	566	1	178	0·79* (0·66–0·95)	163	0·73* (0·60–0·88)	75	0·62* (0·48–0·81)	82	0·56* (0·43–0·72)	320	0·65* (0·56–0·76)
Individuals who smoke	89 895	1840	1	520	0·86* (0·77–0·95)	420	0·83* (0·74–0·92)	166	0·71* (0·60–0·83)	222	0·74* (0·64–0·86)	808	0·78* (0·71–0·85)
Obese individuals	110 850	2016	1	650	0·83* (0·75–0·91)	578	0·81* (0·73–0·90)	269	0·68* (0·59–0·79)	286	0·68* (0·59–0·78)	1133	0·75* (0·69–0·81)
Individuals with hypercholesterolaemia	48 981	1218	1	412	0·84* (0·74–0·94)	382	0·77* (0·68–0·88)	146	0·69* (0·57–0·83)	175	0·68* (0·57–0·81)	703	0·73* (0·66–0·81)
Individuals with metabolic syndrome	54 363	1981	1	646	0·84* (0·76–0·93)	622	0·78* (0·71–0·86)	222	0·65* (0·65–0·56)	254	0·62* (0·54–0·72)	1098	0·71* (0·66–0·77)
Individuals with chronic kidney disease	46 375	2354	1	749	0·87* (0·80–0·95)	670	0·72* (0·65–0·79)	309	0·69* (0·61–0·79)	316	0·62* (0·54–0·70)	1295	0·68* (0·63–0·74)

[A: some information deleted to avoid repetition of methods and results (trend test result)] HR=hazard ratio *Indicates a significantly (p<0·05) lower death rate compared with the inactive group [A: addition OK?].

Table 3: **Mortality risk, by participant characteristic and exercise intensity and volume**

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, and YCY had final responsibility for the decision to submit for publication

See Online for webappendix

Results

[A: data have been removed from this section to avoid repetition of data in tables] [A: mean LTPA data have been removed from table 1 to avoid repetition of data in table 2. Please provide 95%CI/SDs for all data in table 2] Table 1 shows the proportion of individuals in each LTPA volume category and characteristics of all individuals in the cohort [A: please describe any differences in characteristics (table 1) between individuals in all groups]. Table 2 shows mean activity characteristics (duration, intensity, volume, and energy expenditure) for each LTPA volume category, by sex and age group.

Compared with individuals in the low volume activity group, individuals 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 [A: correct to say cancer mortality?] risk (1·11, 1·01–1·22; webappendix p x [A: please give page number. Please format your webappendix according to our guidelines and resupply to me as one pdf with pages numbered. We then refer in the text to a specific page of that document]). Table 3 shows mortality risks for individuals in all activity groups compared with individuals in the inactive group. 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 more active, had lower risk of all cause mortality (table 3) [A: reworded for clarity. OK?].

Figure 1 shows the relation between daily physical activity and reduction in mortality compared with individuals in the inactive group. After the minimum

recommended 15 mins a day exercise, every additional 15 mins of daily exercise (up to 100 mins a day) is expected to generate an additional reduction of 4% all-cause and 1% all-cancer mortality. [A: please provide a range or CI for this effect estimate][A: please describe the relation after 100 mins per day]

Subgroup analysis [A: was this pre-specified? If not, please indicate so] showed that, when compared with individuals in the inactive group, individuals in the low-volume activity group (those who did less than 15 mins a day of exercise) had a lower risk of all cause mortality, irrespective of their sex, age, or health status, or whether or not they smoke (table 3; figure 2) [A: reworded for clarity. OK?]. [A: please describe data for those who drink alcohol never/occasionally/regularly] None of the 13 confounding risk factors affected any mortality outcome (data not shown) [A: result moved from methods section].

Compared with individuals in the inactive group, cancer-related mortality and incidence of cancer were lower in those in the low-volume activity group and in those who met the physical recommendation guidelines (table 4). Both cancer-related mortality and incidence of cancer decreased as the amount of exercise an individual did increased (p<0·0001 for both trends). [A: reworded for clarity. OK?] Compared with individuals in the low-volume activity group, those in the inactive group had 11% increased all-cancer risks (HR 1·11 [A: please provide 95%CIs]; webappendix p x [A: please give page number]).

Vigorous-intensity exercise yielded greater health benefits in terms of all-cause mortality reduction than did moderate-intensity exercise at the same volume of activity or moderate-intensity exercise at the next higher or next lower volume of activity (table 3) [A: reworded for clarity and brevity. OK?]. The relation between mortality reduction (for all different causes of death analysed) and activity level was much the same in a sub-cohort 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=2 357; webappendix p x [A: please give page number]). [A: reworded for clarity. OK?]

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 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 [A: reworded for clarity. OK?] (webappendix p x [A: please give page number]).

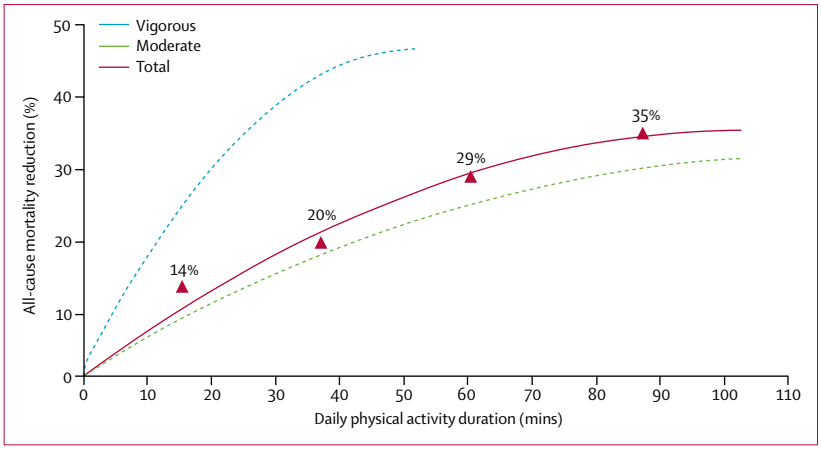

Figure 1: **Relation between daily physical activity duration and all-cause mortality reduction compared with individuals in the inactive group**
[A: some information removed to avoid repetition of results]

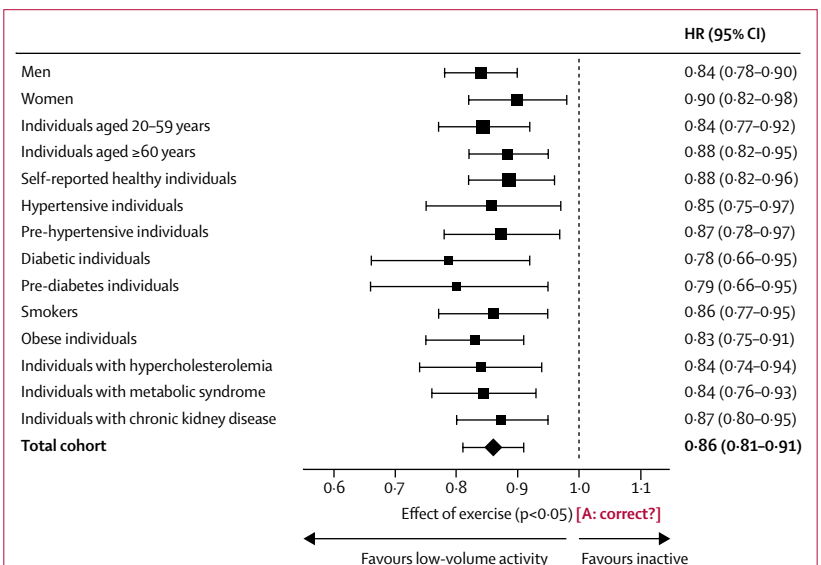

Figure 2: **Adjusted all-cause mortality hazard ratio for individuals in the low-volume activity group compared with individuals in the inactive group, by participant characteristic**
All hazard ratios (HR) are relation to health outcomes individuals in the inactive group. [A: information deleted to avoid repetition of methods]

Discussion

Individuals who did a daily average of 15 mins of moderate-intensity exercise, had significant health benefits when compared with individuals who did less than 1 h of exercise a week. [A: sentence deleted to avoid repetition of results]. In Taiwan, if individuals who do less than 1 h of exercise a week engage in low-volume daily exercise, one in six all-cause deaths could be avoided—similar reductions in deaths were achieved after a successful tobacco control programme in the same population [A: is reference 11 an estimation of possible benefits or actual results of the tobacco control programme?].[11] The minimum amount of exercise reported in this study is half of what is recomended for Americans,[1] but individuals are more likely to do 15 mins of daily exercise than they are 30 mins of daily exercise. Furthermore, once an individual does 15 mins of daily exercise regularly, they might be more likely to increase the amount of time they spend exercising per day. With this potential increase in exercise in mind, this 15 min daily exercise recommendation should be promoted to east Asian populations. [A: reworded for clarity. OK?]

	Total cohort	Inactive		Low			Meeting physical activity recommendation												p for trend
							Medium			High			Very high			Total			
	N	n	HR§	N‡	HR§	95% CI	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)	1–781	0·87	(0·82–0·92)	787	0·86	(0·79–0·93)	986	0·93	(0·86–1·00)	3–554	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 [A: reworded for brevity. OK?]. *Indicates a significantly (p<0·05) lower incidence or mortality rate compared with the inactive group [A: addition OK?]. [A: Number and proportion of individuals in each group have been removed to avoid repetition of data in table 1]

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

[A: the following sentence was removed from the results because that data were given in table 4 and we try not to "cherry pick" specific data in the results section—if you would like to discuss this finding further, please do so here. "It was intriguing to see for the low volume group 27% reduction in mortality and 17% in incidence for lung cancer."]

[A: some information deleted to avoid repetition of results] The relation between an increase in daily exercise and reduction in all-cause and cancer-related mortality recorded in this study has been recorded elsewhere [A: "an estimated reduction, 20%-27% from 1.5 to 3 hours/week, reported in a summary from all available major studies (page G1-20)."[1] I cannot find these data in Ref 1. Please indicate where this data is from and what the reduction is—ie, all-cause or cancer-related mortality? Thanks].[1] Although the benefits of reductions in 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 east Asians [A: or all Asian countries?] to exercise because cancer is by far the leading cause of death in this population.[12,13] Our results suggest that one in nine deaths from cancer in individuals in the inactive group could have been averted if they did 15 mins of moderate-intesity exercise such as brisk walking. We know of no other studies to report protection against all cancer from a dose below the recommended 30 mins a day,[14] or the graded dose-response relation of moderate intensity LTPA for all cancer mortality (panel) [A: reworded for clarity because we avoid claiming firsts in research. OK? Also, please explain why refs 14, 1, 2, and 15 are cited].[1,2,15] The relation between exercise and reductions in incidence of site-specific cancers was less consistent, however, for reasons that have not been explored.[15,16] [A: please explain why these refs are cited]

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 xx [A: please give page numbers]), with results much the same after controlling for 13 confounders. [A: information deleted to avoid repetition] These findings have important implications for clinical practice because most patients seen in a doctor's office [A: In Taiwan?] are inactive individuals with lifestyle risks [A: possible to reference this?]. 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 the exercise prescription on the basis of an individual's physical capability.[17]

Health gains recorded in this study are lower than health gains recorded in other studies of the 2008 LTPA recomendations,[18–29] **[A: are all these references necessary to support one point, especially as some are quite old?]** but endpoints in these other studies focused more on incidence of cardiovascular disease[18,19,23–26,29] than they did on mortality,[21,22,25,27,28] and focused largely on elderly women **[A: please explain why health gains would be better in a study of elderly women]**.[18–20,27,29] Furthermore, in studies that explored the health benefits of a low volume of exercise,[21,22,24] inclusion of people that did vigorous exercise **[A: refs?]**, and inclusion of people who did exercise above the recommended level,[23,25,26,28] made the identification of a minimum amount of moderate-intensity exercise that would be beneficial to an individual's health difficult. **[Reworded for clarity. OK?]**

The reason why the small amounts of LTPA provided significant health benefits needs further investigation **[A: please explain how the following five points indicate further research]**. First, the dose-response gradient between exercise time and mortality benefits was curvilinear (figure 1; webappendix p **x [A: please give page number]**), with the largest health gains from additional exercise noted when an individual did between 1 h and 2 h **[A 1–2 h of exercise a week?]**. This curvilinear relation between additional exercise and health gains has been reported in other studies.[1,2,30,31] Second, many studies[21,22,24,25,27–29] recorded mortality reductions at an exercise volume less than the recommended amount of 150 min a week, but none were able to establish a minimum amount of activity that did not include any vigorous exercise **[A: reworded for clarity. OK?]**.[21,24] When sample size limitations were overcome in pooled studies or meta-analyses, statistically significant health benefits of a minimum amount of exercise **[A: addition OK?]** have been recorded.[30,31] **[A: some information deleted to avoid repetition]** Third, half of our cohort self-reported as being inactive, which is more than double the number of people who self-reported as being inactive in the USA (21·3%),[32] which implies that the habit of regular exercise is far from being adopted as the social norm in east Asia. As the Taiwanese population have become wealthier, they have done less manual labour and have increased their use of motor vehicles for transportation **[A: refs?]**—Taiwan has the greatest density of motorcycles in the world.[33] Because this population is largely inactive, any increase in activity, even the minimum amount, is likely to be sufficient to provide health benefits **[A: reworded for clarity and brevity. OK?]**. Fourth, individuals in the inactive group were likely to have more lifestyle risks than were individuals in the other groups,[4,34] and, although we controlled for such risk factors, poor health outcomes in individuals in the inactive group could probably have been because of their poor health behaviours and not entirely because of a lack of exercise **[A: reworded for clarity. OK?]**. However, increased LPTA can decrease unhealthy behaviours such as smoking.[4,34] Fifth, the physiological 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,[35] the release of which, even in small amounts, can be associated with mental well-being.[36]

Vigorous-intensity activities usually involve a larger volume of exercise than do moderate-intensity activities, and therefore offer greater health benefits.[2,30] We know of no other studies that have shown the advantages of vigorous-intensity activities over moderate-intensity activities at identical or smaller volumes of activity **[A: reworded because we try to avoid claiming firsts]**. Our findings suggest that, for example, 7 h a week of moderate-intensity exercise could generate similar health benefits as would 2 h a week of vigorous-intensity exercise **[A: reworded for brevity. OK?]**. Therefore, people who want 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

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 **[A: rewording OK? Some information has been deleted to avoid repletion of contributions]** Cohort studies on leisure-time physical activity (LTPA) that recorded statistically significant health benefits, particularly from all-cause mortality, without meeting the current 150 mins per week recommendation were given preference **[A: rewording OK?]**. Of 12 studies identified (webappendix p **x [A: please give page number]**), three reported reduction in incidence of cardiovascular disease or diabetes, mostly in elderly women **[A: please give age range]**. In the nine studies on mortality, identification of a minimum amount of exercise was not possible, because they either included vigorous-intensity exercise components or included individuals who recommended more than the recommended level **[A: rewording OK?]**.

Interpretation

[A: some information deleted to avoid repletion] In this study, 15 mins a day or 1·5 h a week provided a reduction in all-cause and all-cancer mortality and to prolonged 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.

people—termed weekend warriors elsewhere[37]—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.

[A: this paragraph has been reworded for clarity and data have been moved to results] Reliability of our questionnaire, measured by consistency in answers given on consecutive visits, is import because it affects the quality of our findings. Reliability of our questionnaire was similar to the reliability of other questionnaire that are widely accepted as reliable.[2] **[A: Please be more specific about the criteria by which you believe the questionnaire is reliable]** Although many people could change their LTPA level over time, most maintained their level throughout a substantial portion of their life (eg, a decade). This seemingly low level of reliability **[A: This appears to contradict your earlier statement about reliability. It might help to set out the points for questionnaire reliability (eg the different domains of validity such as contruct validity, predictive validity, consistency, and sensitivity) and show how your questionnaire performs in these areas]** is characteristic of most LTPA questionnaires, with respondents answers varying with seasonal or temporal changes and their ability to recall. We compared outcomes in individuals with two visits who were consistent in their reporting of exercise volumes. Compared with individuals in the inactive group, individuals in the low-volume exercise group had HRs **[A: for all-cause mortality?]** of 0·86 on their first visit and 0·90 on their second visit, and individuals who met or exceeded the 2008 recommendations had HRs **[A: for all-cause mortality?]** of 0·74 on their first visit and 0·79 on their second visit **[A: please give 95% CIs for all data. Please explain how these data support the validity of your questionnaire. Also, are these data provided anywhere in the results section or webappendix? If not, we will move them to the results section]**, which were sufficiently close to make the validity of our questionnaire within an acceptable range.

This study had several limitations. First, because this was an observational study, we cannot attribute the recorded health outcomes to physical activity. **[A: Might it help to mention the concept of reverse causality here?]** 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 better health **[A: compared with?]** when they did exercise above the minimum recommended amount **[A: or the 15 mins daily amount in this study? Reworded for clarity. OK?]**. Second, people have a tendency to over-report LTPA because it is a socially desirable behaviour **[A: possible to give reference for this?]**. However, such over-reporting of LTPA would bias the findings in support of a null hypothesis **[A: rewording OK?]**. 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 **[A: please give the other three domains of physical activity]**, only leisure-time activity was studied. However, of these four domains, LTPA is most related with health benefits.[36] Furthermore, only LTPA is effort-related and promotable. Fifth, the validity of hazard ratios 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 national death file data **[A: correct to say national death file data?]** were very similar to those from cancer registry, a different set of national data supported by pathological confirmation.

[A: please supply a concluding paragraph outline the clinical relevance of your findings, with an "eye to the future" if possible]

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, MCL, MKT, YCY, and HTC analysed and interpreted the data. CPW and JPMW drafted the article and submitted the paper for publication. CPW, JPMW, MCL, YCY, and XFW critically revised the article for important intellectual content. CPW and JPMW 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 Nelson Wen **[A: please provide a signed letter or email from Nelson Wen, stating that he is happy to be acknowledged]** for his help in revising the English in this manuscript. This study was supported by Taiwan Department of Health Clinical Trial and Research Center of Excellence (DOH 99-TD-B-111-004) and the institutional support from National Health Research Institutes.

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