

A case-control study of the association between self-reported occupational and recreational physical activity and lung cancer

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Abstract

This case-control study with a Fujian population investigated whether self-reported occupational and recreational physical activity may be associated with lung cancer.

The population comprised 1622 patients with newly diagnosed primary lung cancer and 1622 age- and gender-matched healthy controls.

High-intensity occupational physical activity was associated with significantly higher risk of lung cancer (OR=1.354, 95% CI: 1.068–1.717), especially nonsmall cell lung carcinoma (OR=1.384, 95% CI: 1.087–1.762). Moderate or low intensity recreational physical activity was associated with reduced risk of lung cancer. The protective effect of recreational physical activity was observed in current or former smokers, but not never-smokers, and in subjects with normal or high BMI, but not low BMI, as well as people without a history of chronic lung disease. The frequency of recreational physical activity was associated with a linear reduction in the risk of lung cancer ($P < .001$), and also specifically nonsmall cell lung cancer ($P < .001$).

Occupational and recreational physical activity was associated with different effects on the risk of lung cancer in a Fujian population. While recreational physical activity was associated with decreased risk of lung cancer, occupational physical activity was associated with increased risk of lung cancer.

Abbreviations: BMI = body mass index, CIs = confidence intervals, ETS = environmental tobacco smoke, IGF = insulin-like growth factor, IGFBP = IGF binding protein, ORs = odds ratios.

Keywords: body mass index, chronic lung disease, lung cancer, physical activity, smoking

1. Introduction

Lung cancer is one of the most common and serious types of cancer in the world. According to the GLOBOCAN 2012 report^[1] released by the International Agency for Research on Cancer, age-standardized morbidity and mortality rates for lung cancer were 34.2 per 100,000 and 30.0 per 100,000 respectively

in men, and 13.6 per 100,000 and 11.1 per 100,000 respectively in women. Lung cancer accounts for the largest proportion (13.0%) of newly diagnosed cancer cases in the world, and highest proportion of cancer death (19.4%).^[1] In China, the age standardized incidence rate of lung cancer among men is 48.4/100,000, making it the most common cancer in men. Among women, lung cancer incidence ranks second only after breast cancer, with an age standardized incidence rate of 21.9/100,000. Regardless of gender, lung cancer is ranked the leading cause of death among malignant tumors.^[2,3]

Smoking tobacco is the single most important risk factor for lung cancer.^[4] The risk of developing lung cancer is 14 times higher in smokers compared with nonsmokers.^[5] However, not all smokers suffer from lung cancer, suggesting that the etiology of lung cancer is multifactorial. Accumulating evidence suggests that lack of exercise may also be an important risk factor for cancer.^[6] Regular physical activity can improve lung function and reduce tobacco-induced lung and airway injury.^[7] Most studies on the subject have considered that smoking is a confounding factor. The results of a recent review^[8] suggested that the protective effect of physical activity is only found in current and former smokers, but not never-smokers. Other factors such as obesity and chronic lung disease are also possible confounding factors that may obscure an association between physical activity and lung cancer.

The association between physical activity and the risk of lung cancer is complex, and a recent study suggested that not all physical activity has the same effect.^[9] Most previous studies have focused on the role of recreational (as opposed to occupational) physical activity. A systemic review and meta-analysis of 28 relevant studies

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concluded that regular recreational physical activity may reduce lung cancer risk.^[10]

Studies on the effect of occupational physical activity have been less common. Some studies have reported that occupational physical activity may increase the risk of lung cancer in men,^[9] and that men with standing occupations had higher risk of lung cancer than did men with sitting occupations.^[9,11] However, other studies showed that occupational physical activity does not affect lung cancer risk.^[12,13]

The present case-control study explored an association between self-reported occupational and recreational physical activity and lung cancer in a Fujian population.

2. Methods

2.1. Study subjects

The Ethics Committee of Fujian Medical University approved the study and all the subjects signed the consent form. The present study applied a hospital-based on-going case-control design.

From January 2006 to June 2015, we enrolled cases of newly diagnosed primary lung cancer who were admitted to First Affiliated Hospital of Fujian Medical University, Fujian Medical University Affiliated Union Hospital, or Fuzhou General Hospital of Nanjing Military Region. The diagnoses were made by clinical examination and bronchoscopy. Control subjects were selected by frequency matching according to age (± 2 years) and gender, among the healthy visitors to nononcology departments during the same period and healthy people in the community. All the subjects had lived in Fujian province in China for more than 10 years and were willing to cooperate with the survey and able to answer the questions clearly.

2.2. Survey content and variable definition

The survey participants were interviewed by uniformly trained investigators according to a structured questionnaire.^[14,15] The interview included questions concerning the following broad areas: baseline characteristics; smoking status; exposure to environmental tobacco smoke (ETS); physical activity; history of chronic lung disease; family history of lung cancer; and alcohol and tea consumption.

Body mass index (BMI) was calculated as body weight (kg)/height² (m²), and categorized as low (<18.5), normal ($18.5 \leq \text{BMI} < 25.0$), and overweight or obese (≥ 25.00). A smoker was defined as someone who had cumulatively smoked >100 cigarettes. A former smoker was a person who previously smoked, but had not smoked for more than 3 consecutive months. Exposure to ETS was defined as never directly smoked, but inhales the smoke produced by cigarettes or exhaled by smokers >15 minutes per day. Drinking alcohol was considered as ≥ 1 time/week for more than 6 months, and drinking tea as ≥ 1 cup/week for more than 6 months.

Physical activity during the past 2 years was quantified. Occupational physical activity was rated as low, moderate, or high intensity, in accordance with the Reference Standard of Labor Intensity recommended by the Chinese Nutrition Society in the year 2000.^[16] Specifically, low intensity refers to activities performed by office workers; repairers of electrical appliances, watches, and clocks; sales staff; hotel attendants; chemical experiment operators; and lecturers. Moderate intensity occupations include those in which participants sit or stand for 25% of the work time, while 75% is spent on moderate intensity

special vocational activities such as student daily activities; motor vehicle driving; electrical installation; lathe operation; and metalwork cutting. High intensity occupations are those in which 40% of the time is spent sitting or standing, while 60% is spent on high intensity activities such as nonmechanized agricultural labor, steel, dance, sports, loading and unloading, and mining.

The intensity of recreational physical activity or exercise was classified as moderate (sweat inducing) or low (nonsweat-inducing, such as walking). Recreational physical activity was also rated as occasional ($2-3 \times/\text{week}$) or frequent ($>3 \times/\text{week}$).

2.3. Statistical analysis

All statistical analyzes in this study were performed using SPSS 23.0 statistical software. The Chi-squared test and *t* test were used to compare the baseline demographic characteristics of the case and control groups. An unconditional logistic regression model was used to analyze the correlation between physical activity and lung cancer. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated. Associations between physical activity and lung cancer were analyzed with logistic regression analysis based on smoking status, ETS exposure, history of chronic lung diseases, and BMI. Multiple logistic regression analysis was performed using the Backward Stepwise Wald method to identify the risk factors for lung cancer. The *P*-value of the results was 2-tailed, with a test level $\alpha = 0.05$.

3. Results

3.1. Baseline characteristics

The study population comprised 3244 individuals, including 1622 patients with lung cancer and 1622 age- and gender-matched healthy controls. The baseline characteristics are shown in Table 1. The age, gender, ethnicity, and marital status of the 2 groups were well-matched, but statistically significant differences were found with regard to BMI, education level, occupation, family history of lung cancer, history of chronic lung disease, smoking status, exposure to ETS, fruit, fish, alcohol and tea consumption (Table 1).

3.2. Association between physical activity and pathological types of lung cancer

The risk of any lung cancer was significantly higher (OR: 1.354, 95% CI: 1.068–1.717) in subjects who engaged in high intensity occupational physical activity compared to low intensity. Recreational physical activity at both moderate (frequent: OR=0.708, 95% CI: 0.578–0.867; occasional: OR=0.666, 95% CI: 0.535–0.830) and low intensity (frequent: OR=0.623, 95% CI: 0.519–0.748; occasional: OR=0.704, 95% CI: 0.565–0.876) was associated with a lower risk of any lung cancer (Table 2). A linear correlation was found between the frequency of recreational physical activity, regardless of intensity, and risk of any lung cancer ($P < .001$), that is, the more frequent the physical activity, the higher the risk reduction. A similar linear correlation ($P < .001$) was also observed when only nonsmall cell lung cancers were included. The risk of nonsmall cell lung cancer in those exposed to high intensity occupational activity was 1.384-fold (95% CI: 1.087–1.762) that of those only exposed to low intensity (Table 2).

Table 1**The baseline characteristics of the study population.**

Variables	Cases [n/%]	Controls [n/%]	<i>t</i> / \bar{x}	<i>P</i>
Age ($\bar{x} \pm s$)	59.14 \pm 10.61	59.11 \pm 10.56	-0.075	.940
BMI ($\bar{x} \pm s$)**	22.36 \pm 3.29	23.41 \pm 3.23	9.249	<.001
Ethnicity			0.360	.549
Han Chinese	1584 (97.7)	1589 (98.0)		
Others	38 (2.3)	33 (2.0)		
Gender			0.000	1.000
Male	1136 (70.0)	1136 (70.0)		
Female	486 (30.0)	486 (30.0)		
Education**			166.845	<.001
Primary school and below	856 (52.8)	533 (32.9)		
High school	607 (37.4)	723 (44.6)		
College and above	159 (9.8)	366 (22.6)		
Marital status			2.039	.153
Married	1516 (93.5)	1495 (92.2)		
Single or divorced	106 (6.5)	127 (7.8)		
Occupation**			81.677	<.001
Blue-collar worker	347 (21.4)	367 (22.6)		
Farmer	460 (28.4)	270 (16.6)		
White collar worker	706 (43.5)	906 (55.9)		
Manager	21 (1.3)	9 (0.6)		
Others	88 (5.4)	70 (4.3)		
Family history of lung cancer**			29.416	<.001
Yes	91 (5.6)	32 (2.0)		
No	1531 (94.4)	1590 (98.0)		
History of pulmonary disease**			16.605	<.001
Yes	205 (12.6)	134 (8.3)		
No	1417 (87.4)	1488 (91.7)		
Smoking**			167.484	<.001
Current smokers	635 (39.2)	443 (27.3)		
Former smokers	364 (22.4)	194 (12.0)		
Never-smokers	623 (38.4)	985 (60.7)		
ETS exposure**			187.291	<.001
Yes	1116 (68.8)	730 (45.0)		
No	506 (31.2)	892 (55.0)		
Alcohol consumption**			17.278	<.001
Yes	533 (32.9)	425 (26.2)		
No	1089 (67.1)	1197 (73.8)		
Tea consumption*			4.59	.032
Yes	795 (49.0)	856 (52.8)		
No	827 (51.0)	766 (47.2)		
Fruit consumption**			67.616	<.001
Yes	1412 (87.1)	1545 (95.3)		
No	210 (12.9)	77 (4.7)		
Vegetable consumption			0.301	.583
Yes	1597 (98.5)	1593 (98.2)		
No	25 (1.5)	29 (1.8)		
Fish consumption**			34.316	<.001
Yes	1473 (90.8)	1556 (95.5)		
No	149 (9.2)	66 (4.1)		
Meat consumption			0.317	.574
Yes	1579 (97.3)	1584 (97.7)		
No	43 (2.7)	38 (2.3)		
Pathological classification				
Adenocarcinoma	905 (56.3)			
Squamous cell carcinoma	428 (26.6)			
Small cell carcinoma	126 (7.8)			
Others	163 (10.0)			

BMI=body mass index, ETS=environmental tobacco smoke.

* *P* < .05.** *P* < .001.

Table 2**Association between different types of physical activity and lung cancer.**

Physical activity	Lung cancer			
	Cases [n/%]	Control [n/%]	OR (95% CI)	aOR (95% CI)
Occupational physical activity				
Low	477 (29.4)	641 (39.5)	1	1
Moderate	707 (43.6)	682 (42.0)	1.393 (1.189–1.632)	1.164 (0.966–1.402)
High	438 (27.0)	299 (18.4)	1.969 (1.630–2.378)	1.354 (1.068–1.717)
Recreational physical activity (moderate intensity)				
None	1140 (70.3)	888 (54.7)	1	1
Occasional	214 (13.2)	326 (20.1)	0.511 (0.421–0.620)	0.666 (0.535–0.830)
Frequent	268 (16.5)	408 (25.2)	0.512 (0.429–0.611)	0.708 (0.578–0.867)
Recreational physical activity (low intensity)				
None	603 (37.2)	401 (24.7)	1	1
Occasional	322 (19.9)	373 (23.0)	0.574 (0.472–0.698)	0.704 (0.565–0.876)
Frequent	697 (43.0)	848 (52.3)	0.547 (0.465–0.642)	0.623 (0.519–0.748)
Nonsmall cell lung cancer				
	Cases [n/%]	Control [n/%]	OR (95% CI)	aOR (95% CI)
Occupational physical activity				
Low	386 (29.0)	641 (39.5)	1	1
Moderate	594 (44.6)	682 (42.0)	1.417 (1.205–1.667)	1.200 (0.993–1.450)
High	343 (26.4)	299 (18.4)	1.962 (1.618–2.380)	1.384 (1.087–1.762)
Recreational physical activity (moderate intensity)				
None	929 (69.7)	888 (54.7)	1	1
Occasional	181 (13.6)	326 (20.1)	0.506 (0.415–0.617)	0.659 (0.527–0.824)
Frequent	223 (16.7)	408 (25.2)	0.505 (0.421–0.606)	0.697 (0.567–0.857)
Nonworking physical activity (low intensity)				
None	478 (35.9)	401 (24.7)	1	1
Occasional	279 (20.9)	373 (23.0)	0.584 (0.479–0.713)	0.718 (0.575–0.897)
Frequent	576 (43.2)	848 (52.3)	0.556 (0.472–0.656)	0.633 (0.526–0.762)
Small cell lung cancer				
	Cases [n/%]	Control [n/%]	OR (95% CI)	aOR (95% CI)
Occupational physical activity				
Low	40 (31.7)	641 (39.5)	1	1
Moderate	48 (38.1)	682 (42.0)	1.128 (0.731–1.739)	0.787 (0.491–1.263)
High	38 (30.2)	299 (18.4)	2.037 (1.280–3.241)	1.023 (0.590–1.772)
Recreational physical activity (moderate intensity)				
None	85 (67.5)	888 (54.7)	1	1
Occasional	18 (14.3)	326 (20.1)	0.577 (0.342–0.974)	0.763 (0.442–1.317)
Frequent	23 (18.3)	408 (25.2)	0.589 (0.366–0.947)	0.852 (0.516–1.407)
Recreational physical activity (low intensity)				
None	53 (42.1)	401 (24.7)	1	1
Occasional	23 (12.3)	373 (23.0)	0.467 (0.280–0.776)	0.557 (0.329–0.945)
Frequent	50 (39.7)	848 (52.3)	0.446 (0.298–0.668)	0.519 (0.340–0.793)

Adjusted by age, BMI (continuous variable); ethnicity, gender, education, marital status, occupation, history of chronic lung disease, family history of lung cancer, smoking, ETS exposure, fish, meat, fruit and vegetable consumption, alcohol and tea consumption (categorical variables).

aOR=adjusted odds ratio, CI=confidence interval, OR=odds ratio.

The significance for the bold values is $P < .05$.

3.3. Associations between lung cancer and physical activity of people according to BMI

After adjustment for other confounding factors, physical activity did not affect risk of lung cancer in subjects with low BMI. In subjects with normal, both moderate and low intensity recreational physical activity was associated with lower risk of lung cancer, both when performed occasionally (moderate intensity: OR=0.591, 95% CI: 0.453–0.771; low intensity: OR=0.744, 95% CI: 0.582–0.950) and frequently (moderate intensity: OR=0.744, 95% CI: 0.582–0.950; low intensity: OR=0.660, 95% CI: 0.529–0.823). In overweight and obese subjects, low intensity recreational physical activity was associated with lower risk of lung cancer (frequent: OR=

0.518, 95% CI: 0.355–0.758; occasional: OR=0.577, 95% CI: 0.369–0.903; Table 3).

3.4. Associations between lung cancer and physical activity in people according to smoking and ETS exposure status

After adjustment for other factors, in both the current and former smokers, recreational physical activity was associated with reduced risk of lung cancer. In current smokers, moderate intensity recreational physical activity was associated with 29.8% (95% CI: 0.495–0.997) lower risk when performed frequently and 60.1% (95% CI: 0.268–0.596) when performed

Table 3**Association between physical activity and lung cancer by BMI.**

Physical activity	BMI too low		
	Cases [n/%]	Control [n/%]	aOR (95% CI)
Occupational physical activity			
Low	48 (28.7)	30 (39.5)	1
Moderate	66 (39.5)	27 (35.5)	0.736 (0.320–1.694)
High	53 (31.7)	19 (25.0)	0.454 (0.162–1.272)
Recreational physical activity (moderate intensity)			
None	127 (76.0)	44 (57.9)	1
Occasional	13 (15.8)	12 (15.8)	0.510 (0.172–1.509)
Frequent	27 (16.2)	20 (26.3)	0.705 (0.289–1.722)
Recreational physical activity (low intensity)			
None	67 (40.1)	18 (23.7)	1
Occasional	28 (16.8)	12 (15.8)	0.927 (0.323–2.664)
Frequent	72 (43.1)	46 (60.5)	0.603 (0.283–1.286)
	BMI normal		
	Cases [n/%]	Control [n/%]	aOR (95% CI)
Occupational physical activity			
Low	331 (29.0)	425 (38.9)	1
Moderate	499 (43.7)	463 (42.4)	1.152 (0.919–1.445)
High	311 (27.3)	205 (18.8)	1.316 (0.986–1.757)
Recreational physical activity (moderate intensity)			
None	808 (70.8)	597 (54.6)	1
Occasional	143 (12.5)	228 (20.9)	0.591 (0.453–0.771)
Frequent	190 (16.7)	268 (24.5)	0.744 (0.582–0.950)
Recreational physical activity (low intensity)			
None	419 (36.7)	280 (25.8)	1
Occasional	231 (20.2)	253 (23.1)	0.753 (0.578–0.980)
Frequent	491 (43.1)	558 (51.1)	0.660 (0.529–0.823)
	BMI overweight and obesity		
	Cases [n/%]	Control [n/%]	aOR (95% CI)
Occupational physical activity			
Low	98 (31.2)	186 (41.1)	1
Moderate	142 (45.2)	192 (42.4)	1.231 (0.850–1.782)
High	74 (23.6)	75 (16.6)	1.597 (0.993–2.568)
Recreational physical activity (moderate intensity)			
None	205 (65.3)	247 (54.5)	1
Occasional	58 (18.5)	86 (19.0)	1.039 (0.679–1.591)
Frequent	51 (16.2)	120 (26.5)	0.682 (0.449–1.035)
Recreational physical activity (low intensity)			
None	117 (37.3)	101 (22.3)	1
Occasional	63 (20.1)	108 (23.8)	0.577 (0.369–0.903)
Frequent	134 (49.3)	244 (53.9)	0.518 (0.355–0.758)

Adjusted by age (continuous variable); ethnicity, gender, education, marital status, occupation, history of chronic lung disease, family history of lung cancer, smoking, ETS exposure, fish, meat, fruit and vegetable consumption, alcohol and tea consumption (categorical variables).

aOR = adjusted odds ratio, BMI = body mass index, CI = confidence interval.

The significance for the bold values is $P < .05$.

occasionally. Low intensity recreational physical activity was associated with 48.1% (95% CI: 0.380–0.708) lower risk when performed frequently and 47.9% (95% CI: 0.381–0.712) when performed occasionally.

In former smokers, frequent moderate-intensity recreational physical activity was associated with lower 39.6% (95% CI: 0.366–0.998) lower risk of lung cancer. Frequent low-intensity physical activity was associated with 52.6% (95% CI: 0.296–0.761) lower risk, while occasional low-intensity physical activity was associated with 49.3% (95% CI: 0.282–0.911) lower risk. Physical activity was not associated with altered risk for lung cancer in never-smokers (Table 4).

Recreational physical activity was also associated with lower lung cancer risk in both ETS-exposed and not ETS-exposed subjects. In subjects not exposed to ETS, the OR was 0.542 (95% CI:

0.391–0.751) for frequent moderate intensity recreational physical activity and 0.693 (95% CI: 0.494–0.974) for occasional moderate intensity recreational physical activity. Low intensity recreational physical activity was also associated with lower lung cancer risk when performed frequently (OR 0.550, 95% CI: 0.414–0.731). However, in ETS-exposed subjects, low-intensity recreational physical activity was only associated with 30.3% (95% CI: 0.547–0.890) lower risk when conducted frequently, and 29.4% (95% CI: 0.530–0.941) when conducted occasionally (Table 5).

3.5. Associations between lung cancer and physical activity according to chronic lung disease history

After adjustment for other confounding factors, subjects who suffer from a chronic disease only had a reduced risk of lung

Table 4**Association between physical activity and lung cancer according to smoking history.**

Physical activity	Cases [n/%]	Current smokers	
		Control [n/%]	aOR (95% CI)
Occupational physical activity			
Low	159 (25.0)	144 (32.5)	1
Moderate	274 (43.1)	189 (42.7)	1.186 (0.850–1.654)
High	202 (31.8)	110 (24.8)	1.244 (0.837–1.848)
Recreational physical activity (moderate intensity)			
None	472 (74.3)	269 (60.7)	1
Occasional	60 (9.4)	87 (19.6)	0.399 (0.268–0.596)
Frequent	103 (16.2)	87 (19.6)	0.702 (0.495–0.997)
Recreational physical activity (low intensity)			
None	251 (39.5)	122 (27.5)	1
Occasional	132 (20.8)	113 (25.5)	0.537 (0.374–0.771)
Frequent	252 (39.7)	208 (47.0)	0.521 (0.381–0.712)
Physical activity	Cases [n/%]	Former smokers	
		Control [n/%]	aOR (95% CI)
Occupational physical activity			
Low	91 (25.0)	62 (32.0)	1
Moderate	161 (44.2)	95 (49.0)	1.224 (0.757–1.980)
High	112 (30.8)	37 (19.1)	1.630 (0.888–2.993)
Recreational physical activity (moderate intensity)			
None	244 (67.0)	99 (51.0)	1
Occasional	61 (16.8)	38 (19.6)	0.984 (0.581–1.665)
Frequent	59 (29.4)	57 (29.4)	0.604 (0.366–0.998)
Recreational physical activity (low intensity)			
None	140 (38.5)	42 (21.6)	1
Occasional	63 (17.3)	41 (21.1)	0.507 (0.282–0.911)
Frequent	161 (44.2)	111 (57.2)	0.474 (0.296–0.761)
Physical activity	Cases [n/%]	Never-smokers	
		Control [n/%]	aOR (95% CI)
Occupational physical activity			
Low	227 (36.4)	435 (44.2)	1
Moderate	272 (43.7)	398 (40.4)	1.140 (0.876–1.484)
High	124 (19.9)	152 (15.4)	1.315 (0.918–1.884)
Recreational physical activity (moderate intensity)			
None	424 (68.1)	424 (68.1)	1
Occasional	93 (14.9)	93 (14.9)	0.820 (0.597–1.128)
Frequent	106 (17.0)	106 (17.0)	0.817 (0.606–1.102)
Recreational physical activity (low intensity)			
None	212 (27.9)	237 (24.1)	1
Occasional	127 (20.4)	219 (22.2)	0.919 (0.661–1.276)
Frequent	284 (45.6)	529 (53.7)	0.766 (0.583–1.007)

Adjusted by age, BMI (continuous variable); ethnicity, gender, education, marital status, occupation, history of chronic lung disease family history of lung cancer, ETS exposure, fish, meat, fruit and vegetable consumption, alcohol and tea consumption (categorical variables).

aOR=adjusted odds ratio, CI=confidence interval.

The significance for the bold values is $P < .05$.

cancer with frequent low intensity recreational physical activity (OR: 0.498, 95% CI: 0.254–0.975). Subjects who had never suffered from a chronic lung disease had a reduced risk of lung cancer when involved in moderate intensity recreational physical activity. Frequently performing moderate intensity recreational physical activity (OR=0.672, 95% CI: 0.542–0.834) and occasionally performing such (OR=0.643, 95% CI: 0.508–0.814) was associated with lower lung cancer risks (Table 6).

3.6. Risk factors for lung cancer identified by multiple logistic regression analysis

Multiple logistic regression using the Backward Stepwise Wald method identifies gender, education, marital status, occupation,

family history of lung cancer, history of chronic lung disease, current smoking, former smoking, ETS exposure, BMI, tea, fish and fruit consumptions are factors that can affect the risk for lung cancer. High intensity occupational physical activity ($P=.021$), low intensity ($P=.012$) and moderate intensity recreational physical activity ($P=.005$) have all been shown to affect lung cancer risk (Table 7). These variables are all adjusted for in the calculation of OR in the above analysis.

4. Discussion

Physical activity refers to activity that is produced by skeletal muscle contraction, resulting in energy expenditure, and is associated with daily life, work, and recreational activities, including occupational physical activity, commuting to and from

Table 5

Association between physical activity and lung cancer according to exposure to ETS.

Physical activity	Cases [n/%]	ETS-exposed	
		Control [n/%]	aOR (95% CI)
Occupational physical activity			
Low	331 (29.7)	296 (40.5)	1
Moderate	467 (41.8)	303 (41.5)	1.142 (0.895–1.459)
High	318 (28.5)	131 (17.9)	1.438 (1.051–1.968)
Recreational physical activity (moderate intensity)			
None	778 (69.7)	425 (58.2)	1
Occasional	142 (12.7)	146 (20.0)	0.677 (0.506–0.905)
Frequent	196 (17.6)	159 (21.8)	0.880 (0.671–1.153)
Recreational physical activity (low intensity)			
None	411 (36.8)	188 (25.8)	1
Occasional	223 (20.0)	175 (24.0)	0.706 (0.530–0.941)
Frequent	482 (43.2)	367 (50.3)	0.697 (0.547–0.890)

Physical activity	Cases [n/%]	Not ETS-exposed	
		Control [n/%]	aOR (95% CI)
Occupational physical activity			
Low	146 (28.9)	345 (38.7)	1
Moderate	240 (47.4)	379 (42.5)	1.238 (0.924–1.658)
High	120 (23.7)	168 (18.8)	1.269 (0.873–1.846)
Recreational physical activity (moderate intensity)			
None	362 (71.5)	463 (51.9)	1
Occasional	72 (14.2)	180 (20.2)	0.693 (0.494–0.974)
Frequent	72 (14.2)	249 (27.9)	0.542 (0.391–0.751)
Recreational physical activity (low intensity)			
None	192 (37.9)	213 (23.9)	1
Occasional	99 (19.6)	198 (22.2)	0.728 (0.516–1.027)
Frequent	215 (42.5)	481 (53.9)	0.550 (0.414–0.731)

Adjusted by age, BMI (continuous variable); ethnicity, gender, education, marital status, occupation, history of chronic lung disease, family history of lung cancer, fish, meat, fruit and vegetable consumption, alcohol and tea consumption (categorical variables).
aOR=adjusted odds ratio, CI=confidence interval, ETS=environmental tobacco smoke.
The significance for the bold values is $P < .05$.

Table 6

Association between physical activity and lung cancer according to history of lung disease.

Physical activity	Cases [n/%]	Chronic lung disease	
		Control [n/%]	aOR (95% CI)
Occupational physical activity			
Low	65 (31.7)	59 (44.0)	1
Moderate	86 (42.0)	56 (41.8)	1.453 (0.810–2.607)
High	54 (26.3)	19 (14.2)	1.639 (0.714–3.762)
Recreational physical activity (moderate intensity)			
None	124 (60.5)	67 (50.0)	1
Occasional	35 (17.1)	34 (25.4)	0.847 (0.445–1.614)
Frequent	46 (22.4)	33 (24.6)	1.013 (0.531–1.934)
Recreational physical activity (low intensity)			
None	66 (32.2)	21 (15.7)	1
Occasional	39 (19.0)	31 (23.1)	0.649 (0.294–1.432)
Frequent	100 (54.9)	82 (61.2)	0.498 (0.254–0.975)

Physical activity	Cases [n/%]	No chronic lung disease	
		Control [n/%]	aOR (95% CI)
Occupational physical activity			
Low	412 (29.1)	582 (42.1)	1
Moderate	621 (43.8)	626 (42.1)	1.141 (0.936–1.390)
High	384 (27.1)	280 (18.8)	1.316 (1.025–1.690)
Recreational physical activity (moderate intensity)			
None	1016 (71.7)	821 (55.2)	1
Occasional	179 (12.6)	292 (19.6)	0.643 (0.508–0.814)
Frequent	222 (15.7)	375 (25.2)	0.672 (0.542–0.834)
Recreational physical activity (low intensity)			
None	537 (37.9)	380 (25.5)	1
Occasional	283 (20.0)	342 (23.0)	0.702 (0.558–0.884)
Frequent	597 (42.1)	766 (51.5)	0.630 (0.520–0.763)

Adjusted by age, BMI (continuous variable), ethnicity, gender, education, marital status, occupation, family history of lung cancer, smoking, ETS exposure, fish, meat, fruit and vegetable consumption, alcohol and tea consumption (categorical variables).
aOR=adjusted odds ratio, CI=confidence interval.
The significance for the bold values is $P < .05$.

Table 7
Multiple logistic regression analysis of the risk factors for lung cancer.

	B	SE	Wald	P	OR	OR 95% CI
Constant*	0.73	0.359	4.121	.042	2.075	
Gender (female)***	0.855	0.123	47.95	<.001	2.351	1.846–2.995
Education***			45.28	<.001		
High school***	−0.47	0.091	26.96	<.001	0.62	0.518–0.743
College and above***	−0.83	0.135	37.55	<.001	0.435	0.334–0.568
Marital status (single or divorced)*	0.341	0.156	4.776	.028	1.407	1.035–1.911
Occupation**			13.42	.009		
Farmer**	0.362	0.121	8.954	.002	1.437	1.133–1.823
White collar worker*	0.254	0.11	5.328	.02	1.289	1.039–1.599
Manager	0.862	0.44	3.828	.05	2.367	0.998–5.615
Others*	0.457	0.202	5.124	.023	1.58	1.063–2.349
Family history of lung cancer (yes)***	1.218	0.231	27.73	<.001	3.383	2.149–5.326
History of pulmonary disease (yes)***	0.539	0.134	16	<.001	1.714	1.316–2.232
Smoking***			125.5	<.001		
Current smoking***	1.174	0.122	91.34	<.001	3.237	2.544–4.119
Former smoking***	1.475	0.141	109.4	<.001	4.372	3.316–5.764
ETS exposure (yes)***	0.793	0.082	93.18	<.001	2.211	1.882–2.598
Tea consumption (yes)***	−0.3	0.086	12.36	<.001	0.737	0.622–0.873
Fish consumption (yes)***	0.613	0.168	13.33	<.001	1.846	1.328–2.566
Fruit consumption (yes)***	0.874	0.152	32.88	<.001	2.398	1.778–3.233
Vegetable consumption (yes)	−0.54	0.314	2.942	.086	0.582	0.314–1.08
BMI***	−0.09	0.012	56.31	<.001	0.91	0.888–0.932
Occupational physical activity			5.557	.062		
Moderate intensity	0.158	0.095	2.756	.096	1.171	0.971–1.413
High intensity*	0.28	0.121	5.303	.021	1.323	1.042–1.68
Recreational physical activity (low intensity)***			17.24	<.001		
Occasional*	−0.28	0.113	6.29	.012	0.751	0.601–0.939
Frequent***	−0.39	0.095	17.06	<.001	0.673	0.558–0.812
Recreational physical activity (moderate intensity)**			10.26	.005		
Occasional**	−0.31	0.114	7.439	.006	0.731	0.584–0.915
Frequent*	−0.24	0.105	5.494	.019	0.78	0.634–0.96

BMI = body mass index, CI = confidence interval, ETS = environmental tobacco smoke, ORs = odds ratios, SE = standard error.

* $P < .05$.

** $P < .01$.

*** $P < .001$.

work, housework, shopping, sports, and exercise. Recreational physical activity is characterized by short-term, intensive energy consumption, whereas occupational physical activity is characterized by a lower energy consumption rate over a longer period of time.^[17] The present study showed that occupational and recreational physical activity was associated with different effects on lung cancer risk.

Physical activity is a diverse and complex concept. Several methods for quantification and categorization of physical activity can be found in the literature.^[10] The World Health Organization recommends ≥ 150 minutes of moderate physical activity per week or ≥ 75 minutes of high intensity physical activity per week. Moderate intensity physical activity is defined as activity that noticeably increases the heart rate such as brisk walking and dancing, while high intensity physical activity is defined as activity that causes rapid breathing and substantial increase in heart rate such as running and fast cycling.^[18]

The intensity of activity can also be measured according to the energy metabolic equivalent (MET) of the participant. The ratio of metabolic rate during exercise to the standard resting metabolic rate ($4.184 \text{ KJ kg}^{-1} \text{ h}^{-1}$) represents the intensity of a particular physical activity, and according to the activity type and intensity, different physical activity has a specific MET value. In the present study, information about the activity intensity and activity frequency were acquired through questionnaires or interviewing the subjects, and asking the subject to define their

own intensity level, generally defined as moderate or low. Moderate intensity refers to physical activity or physical exercise that reaches the degree of sweating, and low intensity to nonsweat-inducing exercise such as walking. The subjects were also asked to state their physical activity frequency in terms of the number of times physical activity was performed (times/week) during the last 2 years. Occasional was defined as recreational physical activity 2 to 3 times per week, and frequent as more than 3 times per week. The intensity of occupational physical activity was defined according to the Reference Standard of Labor Intensity recommended by the Chinese Nutrition Society in 2000.^[19]

Through a review of the literature, 8 case-control and 29 cohort studies were found, as well as studies with other designs that explored associations between physical activity and lung cancer. Eighteen of the studies^[20–36] found that physical activity and lung cancer was negatively correlated. Nineteen studies^[8,11–13,34,37–49] reported no association between physical activity and lung cancer. Eight studies looked specifically at occupational physical activity and lung cancer.^[11,13,21,34,37,38,48,50] Only Brownson et al^[21] reported that lung cancer had nothing to do with occupational physical activity. The present study found that high intensity occupational physical activity was associated with increased risk of lung cancer, especially nonsmall cell lung cancer. On the other hand, recreational physical activity was associated with

reduced risk of developing lung cancer, especially nonsmall cell lung cancer, in former and past smokers, non-ETS-exposed subjects, and subjects without a history of chronic lung diseases.

In the present study, the control group contained a higher percentage of never-smokers compared to the case group (Table 1). How smoking status affects the association between physical activity and lung cancer was assessed in a meta-analysis,^[8] which compared 25 observational studies. The results suggested that physical activity negatively correlated with lung cancer risk in former (RR=0.68, 95% CI=0.51–0.90) and current smokers (RR=0.80, 95% CI=0.70–0.90), but had no association with lung cancer risk of nonsmokers (RR=1.05, 95% CI=0.78–1.40, $P_{\text{interaction}} = .26$). Adjusting for the level of smoking did not change these results ($P_{\text{interaction}} = .73$). This is highly consistent with the results of the present study. In addition, this study further found that exposure to ETS did not affect the association between physical activity and lung cancer ($P_{\text{interaction}} = .16$). However, in the present study, high intensity occupational physical activity increased the risk of lung cancer in subjects exposed to ETS, but does not affect subjects that are not ETS-exposed. Recreational physical activity reduces lung cancer risk in both ETS-exposed and not ETS-exposed (Table 5).

The present study has a retrospective case–control design. Berklin bias was minimized by including subjects from four different hospitals in the Fujian province: First Affiliated Hospital of Fujian Medical University, Fujian Medical University Affiliated Union Hospital and Fuzhou General Hospital of Nanjing Military Region, and also including healthy controls subjects from the community. To eliminate potential confounding factors and objectively assess the association between physical activity and lung cancer, factors such as obesity, chronic lung disease, intake of fruit/vegetables/meat/fish and other factors must therefore be considered in addition to adjusting for smoking and ETS exposure. Air pollution is also a known risk factor for lung cancer.^[51] However, since all included subjects have lived in the Fujian province in China for more than 10 years, the exposure to air pollution was assumed to be similar among the subjects. In the present study, the control group had a higher mean BMI than did the lung cancer group. There is a difference in the level of physical activity for people with different BMI levels. One study^[52] showed that people with higher BMIs participated in more recreational physical activity, but they infrequently chose walking or cycling for commuting. A history of chronic lung disease is related to lung cancer risk, and disease itself can cause a lack of physical activity in patients.^[52] Thus, these factors' influence needed to be considered when studying the association between lung cancer and physical activity. Other factors that could potentially influence the validity of the conclusions drawn from the present study includes recall and selection biases. A prospective cohort study would be valuable to further confirm the effect of physical activity on lung cancer.

The present study found that low-intensity physical activity had a protective effect on subjects with BMI in the normal or overweight/obese range, but no effect in subjects with low BMI (Table 3). These results are in contrast to that of Mao et al^[30] in which physical activity was shown to significantly reduce the risk of lung cancer in people with low BMI, while no relation was found in people with high BMI. This may be caused by inconsistency in the stratification of BMI. Mao et al^[30] stratified BMI as <25, 25–30, and $\geq 30 \text{ kg/m}^2$, while the present study stratified BMI according to the criteria of the World Health

Organization for adults (<18.5, 18.5–24.9, $\geq 25 \text{ kg/m}^2$). To the authors' best knowledge, no previous study has included history of chronic lung disease as an adjustment factor or to stratify their analysis. The present study found that moderate intensity recreational physical activity negatively correlated and high intensity occupational physical activity positively correlated with lung cancer risk only in people without a history of chronic lung disease.

Several hypotheses may potentially explain a biological mechanism underlying a reduction in lung cancer risk through recreational physical activity. For example, exercise can affect growth factors such as insulin-like growth factor (IGF) and IGF binding protein (IGFBP), thereby altering tumor progression. High levels of circulating IGF-1 may increase lung cancer risk, while high levels of IGFBP-3 may reduce the risk of lung cancer.^[30]

In addition, physical activity can significantly reduce insulin, glucose, and triglyceride levels, and increase the level of high-density lipoprotein cholesterol, which may be associated with reduction in lung cancer risk.^[53] Another possibility is that physical activity may enhance immune system function^[12,38] by increasing the number and activity of macrophages, natural killer cells, lymphokine-activated killer cells, and lymphokine regulated cytokines, as well as increasing mitogen-induced lymphocyte proliferation rates. Smoking and ETS exposure can lead to respiratory inflammation and increase oxidative stress. Physical activity can increase the secretion of endogenous free radical scavengers which decrease oxidative stress and inflammation, thereby increasing lung ventilation and perfusion to reduce the risk of lung cancer.^[54–56]

5. Conclusion

In conclusion, we found a significant association between the type and intensity of physical activity and lung cancer in this Fujian population. Occupational and recreational physical activity was associated with different effects on lung cancer risk. High intensity occupational physical activity was associated with increased risk of lung cancer, especially nonsmall cell lung cancer, while recreational physical activity was associated with reduced risk of lung cancer, especially for nonsmall cell lung cancer, in current and former smokers, people with no history of chronic lung disease and people with normal or high BMI. Further research with a prospective design would be valuable to confirm the effect of physical activity on lung cancer.

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