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Workplace Exposure to Cigarette Smoking and Secondhand Smoke Associated with Physical Pain among Taiwanese Male Workers: A Cross-Sectional Study from the Taiwan Biobank

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Abstract

Background

Physical pain is a major contributor of productivity loss and disability-adjusted life years (DALYs). Cigarette smoking and secondhand smoking (SHS) remain prevalent among male workers in Taiwan and may represent modifiable occupational risk factors for physical pain.

Objectives

This study examined associations of active smoking and SHS exposure with physical pain among Taiwanese male workers.

Methods

This cross-sectional study analyzed 8,561 male workers from the Taiwan Biobank (TWB). Physical pain status was defined by self-reported pain during previous three months. Logistic regression estimated associations between cigarette smoking and SHS exposure with physical pain, reporting odds ratios (ORs) and 95% confidence intervals (CIs) in crude and adjusting for potential confounders.

Results

Overall, 64.54% of participants reported physical pain. Cigarette smoking (OR = 1.210, 95% CI = 1.105–1.326, $p < 0.0001$) and secondhand smoke (SHS) exposure (OR = 1.426, 95% CI = 1.270–1.601, $p < 0.0001$) were independently associated with physical pain. Notably, workers exposed to SHS alone had the highest risk of pain (adjusted OR = 1.532, 95% CI = 1.304-1.800, $p < 0.0001$). No synergistic interaction between cigarette smoking and SHS was observed (p-interaction = 0.0629).

Conclusions

Both cigarette smoking and SHS exposure were independently associated with physical pain among Taiwanese male workers. These findings support strengthening workplace tobacco-control programs to reduce pain-related burdens among workers.

1. INTRODUCTION

Physical pain is a significant occupational health concern that contributes to reduced work productivity, absenteeism, and contributing substantially to DALYs [1, 2]. Globally, DALYs rose from 2.63 to 2.88 billion between 2010 and 2021, with non-communicable diseases contributing 1.73 billion DALYs [3]. In Taiwan,

40.51% of DALYs are attributed to behavioral factors, and 10.69% DALYs are attributed with musculoskeletal pain and other pains [3]. Workers in physically demanding industries experience higher rates of musculoskeletal disorders (MSDs) than general population [4].

Pain among workers is multifactorial, influenced by physical workload, psychosocial stress, and lifestyle [5–7]. Exercise has been shown to reduce musculoskeletal pain, whereas unhealthy behaviors such as cigarette smoking may exacerbate inflammatory processes [8, 9]. A national survey reported that cigarette use remains more prevalent among Taiwanese male workers than women [10]. These behaviors have been linked to various adverse health outcomes, including cancer and chronic disease [10–12], and are often accompanied by poor diet and insufficient physical activity, contributing to systemic inflammation and oxidative stress, potentially contributing to chronic pain [9, 13, 14].

Few population-based studies have simultaneously examined active smoking and SHS exposure in relation to physical pain in occupational population. In Taiwan, smoking remains more prevalent among male workers, and workplace SHS exposure continues to occur. This study investigated the independent and combined associations of cigarette smoking and SHS exposure with physical pain among male workers using TWB, with implication for occupational health strategy.

2. METHODS

2.1. Study Design and Population

This cross-sectional study used baseline data from the Taiwan Biobank (TWB), a nationwide cohort enrolling adults aged 20–70 years through standardized questionnaire, physical examinations, and laboratory assessments [15].

Male workers were analyzed separately because smoking prevalence in Taiwan is higher among men, while pain reporting patterns differ by sex, which could introduce effect heterogeneity. We excluded non-workers; participants with cancers; missing pain data; missing key variables; and female worker. The final sample comprised 8,561 male workers (Fig. 1).

2.2. Outcome and Exposure Variable

Physical pain was assessed using a standardized TWB question: “Have you had any physical pain in the past three months?”. Responses were classified as reporting pain or not. Smoking status was defined as current smoking (yes/no), and SHS exposure was assessed based on self-reported regular exposure to cigarette smoke from others. This measure is widely used in large-scale epidemiologic studies to assess pain prevalence [15].

Pain location categories included general pain, neck pain, back pain, joint pain, and sciatica for sensitivity analysis. A four-level combined variable was created to address the interdependence between cigarette smoker and SHS.

2.3. Covariates

Covariates were selected based on prior evidence link to pain, and included age, income, body mass index (BMI), job type, alcohol drinking, betel nut chewing, exercise, abdominal obesity, hypertension, hyperlipidemia, diabetes [16]. BMI and abdominal obesity were measured anthropometrically; comorbidities were identified by self-report and laboratory assessments, following standard clinical criteria.

2.4. Statistical Analysis

Descriptive statistics summarized participant characteristics. Logistic regression models estimated crude and adjusted odd ratios (ORs) with 95% confidence intervals (CIs). Subgroup analyses evaluated combined alcohol, betel nut, and cigarette (ABC) use behaviors and joint effects of smoking and SHS exposure. To evaluate the interaction between active and passive smoking, joint exposure groups were analyzed and an interaction term (smoking x SHS) were tested. Participants with missing smoking or SHS data (n = 2) were excluded from subgroup analyses. All analyses were performed in SAS 9.4 (SAS Institute, Cary, NC), with p values < 0.05 indicating significant.

3. RESULTS

3.1. Participant characteristics

Among 8,561 male workers, 64.54% reported physical pain. Physical pain was more prevalent among participants who were current smokers, exposed to SHS, aged 31–40 years old, workers in physically demanding work, or had abdominal obesity (Table 1).

Table 1
Association between lifestyle, occupational, and clinical factors and physical pain among Taiwanese workers

	No Physical Pain		Physical Pain			
	N = 3036		N = 5525			
Variables	**N**	**(%)**	**N**	**(%)**	**OR (95% CI)**	***p* value**
Age group (years)						
< 30	432	(14.23)	592	(10.71)	Ref	
30–39	810	(26.68)	1791	(32.42)	1.614 (1.390–1.873)	< 0.0001*
40–49	755	(24.87)	1623	(29.38)	1.569 (1.349–1.825)	< 0.0001*
50–59	757	(24.93)	1116	(20.20)	1.076 (0.922–1.825)	0.9878
60–69	271	(8.93)	395	(7.15)	1.064 (0.872–1.297)	0.9225
≥ 70	11	(0.36)	8	(0.14)	0.531 (0.212–1.331)	0.0691
Individual income (NTD)						
< 30,000	768	(25.30)	1339	(24.24)	1.035 (0.921–1.163)	0.3518
30,000–60,000	1200	(39.53)	2387	(43.20)	1.181 (1.066–1.309)	0.0013*
> 60,000	1068	(35.18)	1799	(32.56)	Ref	
BMI						
Underweight	55	(1.81)	86	(1.56)	0.929 (0.657–1.313)	0.3431
Normal	1155	(38.08)	1944	(35.20)	Ref	
Overweight	1050	(34.62)	1903	(34.46)	1.077 (0.970–1.196)	0.6591
Obese	773	(25.49)	1590	(28.79)	1.222 (1.092–1.368)	0.0071*
Job type						
Non-physical work	423	(13.93)	613	(11.10)	Ref	

** p < 0.05*

	No Physical Pain		Physical Pain			
	N = 3036		N = 5525			
Variables	**N**	**(%)**	**N**	**(%)**	**OR (95% CI)**	***p* value**
Physical work	2613	(86.07)	4912	(88.90)	1.297 (1.136–1.481)	0.0001*
Alcohol drinking						
No or occasional drinking	2518	(82.94)	4580	(82.91)	Ref	
Yes	518	(17.06)	944	(17.09)	1.002 (0.891-127)	0.9745
Betel nut chewing						
No	2636	(86.85)	4749	(85.97)	Ref	
Yes	399	(13.15)	775	(14.03)	1.078 (0.947–1.228)	0.256
Cigarette Smoking						
No	1936	(63.77)	3273	(59.25)	Ref	
Yes	1100	(36.23)	2251	(40.75)	1.21 (1.105–1.326)	< 0.0001*
SHS						
No	2540	(83.66)	4320	(78.22)	Ref	
Yes	496	(16.34)	1203	(21.78)	1.426 (1.270–1.601)	< 0.0001*
Exercise						
No	1852	(61.00)	3771	(68.27)	Ref	
Yes	1184	(39.00)	1753	(31.73)	0.727 (0.663–0.797)	< 0.0001*
Abdominal obesity						
No	1963	(64.66)	3305	(59.82)	Ref	
Yes	1073	(35.34)	2220	(40.18)	1.229 (1.121–1.347)	< 0.0001*
Hypertension						
No	2558	(94.18)	4692	(92.82)	Ref	

** p < 0.05*

	No Physical Pain		Physical Pain			
	N = 3036		N = 5525			
Variables	**N**	**(%)**	**N**	**(%)**	**OR (95% CI)**	***p* value**
Yes	217	(7.82)	363	(7.18)	0.912 (0.766–1.086)	0.302
Hyperlipidemia						
No	2871	(94.57)	5181	(93.77)	Ref	
Yes	165	(5.43)	344	(16.23)	1.155 (0.954–1.399)	0.1388
Diabetes						
No	2794	(94.11)	5155	(95.34)	Ref	
Yes	175	(5.89)	252	(4.66)	0.78 (0.640–0.952)	0.0143*
** p < 0.05*						

3.2. Univariate Associations

In crude analyses, aged 31–40 (OR = 1.614, 95% CI = 1.390–1.873) and 41–50 (OR = 1.569, 95% CI = 1.349–1.825) had higher odds of pain. Physical workers (OR = 1.297, 95% CI = 1.136–1.481), cigarette smoker (OR = 1.210, 95% CI = 1.105–1.326), and SHS exposure (OR = 1.426, 95% CI = 1.270–1.601) also had higher pain odds, while exercise was protective (OR = 0.727, 95% CI = 0.663–0.797). Abdominal obesity was also positively associated (OR = 1.229, 95% CI = 1.121–1.347). Alcohol, betel nut chewing, hypertension, and hyperlipidemia were not significant predictors (Table 1).

3.3. Multivariate analysis

After adjustment (Table 2), both smoking and SHS exposure remained significant predictors. In Model 1, smoker had OR = 1.153 (95% CI: 1.046–1.271, $p < 0.0001$) and SHS exposure had OR = 1.392 (95% CI: 1.235–1.569, $p < 0.0001$); similar results appeared in Model 2. Physical work (OR = 1.228, 95% CI: 1.072–1.407, $p < 0.0110$) and abdominal obesity (OR = 1.182, 95% CI: 1.035–1.350, $p < 0.0001$) were additional risk factors, while exercise remained protective (OR = 0.786, 95% CI: 0.714–0.866, $p < 0.0001$). Alcohol and betel nut use were not significantly associated with pain.

Table 2
Multivariate logistic regression analysis of factors associated with the risk of physical pain

Variables	Model 1		Model 2	
	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Age group				
< 30	Ref		Ref	
31–40	1.582 (1.353–1.849)	0.0021*	1.583 (1.354–1.852)	< 0.0001*
41–50	1.552 (1.320–1.825)	0.0057*	1.579 (1.341–1.860)	0.0005*
51–60	1.116 (0.945–1.317)	0.1799	1.105 (0.931–1.310)	0.4666
61–70	1.147 (0.927–1.419)	0.2167	1.115 (0.887–1.401)	0.5773
> 70	0.692 (0.262–1.826)	0.3382	0.672 (0.222–2.032)	0.1049
Individual income (NTD)				
< 30,000	1.124 (0.992–1.273)	0.4095	1.121 (0.984–1.277)	0.4467
30,000–60,000	1.160 (1.042–1.291)	0.2355	1.155 (1.033–1.292)	0.0610
> 60,000	Ref		Ref	
BMI				
Underweight	0.936 (0.656–1.335)	0.9157		
Normal	Ref		NA	
Overweight	1.026 (0.914–1.152)	0.9328		
Obese	1.030 (0.876–1.212)	0.7814		
Job type				
Non-physical work	Ref		Ref	
Physical work	1.228 (1.072–1.407)	0.0110*	1.246 (1.082–1.435)	0.0062*
Cigarette Smoking				
No	Ref		Ref	

Model 1: Includes variables with significant associations (p < 0.05) in univariate analysis.

Model 2: Variables selected using the stepwise selection method.

NA: Not applicable; variable not selected for Model 2.

** p < 0.05*

Variables	Model 1		Model 2	
	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Age group				
Yes	1.153 (1.046–1.271)	< 0.0001*	1.161 (1.046–1.289)	< 0.0001*
SHS				
No	Ref		Ref	
Yes	1.392 (1.235–1.569)	< 0.0001*	1.417 (1.250–1.605)	< 0.0001*
Exercise				
No	Ref		Ref	
Yes	0.786 (0.714–0.866)	< 0.0001*	0.787 (0.712–0.871)	< 0.0001*
Abdominal obesity				
No	Ref		Ref	
Yes	1.182 (1.035–1.350)	0.0048*	1.243 (1.123–1.376)	0.0005*
Diabetes				
No	Ref		Ref	
Yes	0.759 (0.617–0.933)	0.0399*	0.760 (0.603–0.957)	0.0089*
Model 1: Includes variables with significant associations (p < 0.05) in univariate analysis.				
Model 2: Variables selected using the stepwise selection method.				
NA: Not applicable; variable not selected for Model 2.				
** p < 0.05*				

3.4. ABC Habits Combinations

Analysis of ABC habit combinations showed that smoking alone (OR = 1.236, 95% CI: 1.101–1.387, *p* = 0.0003), smoking and betel nut (OR = 1.296, 95% CI: 1.078–1.557, *p* = 0.0058), and smoking with alcohol (OR = 1.235, 95% CI: 1.014–1.503, *p* = 0.0355) were associated with higher pain odds compared to individuals with none of these habits. After adjustment for covariates, only smoking alone remained significant (adjusted OR = 1.190, 95% CI: 1.058–1.339, *p* = 0.0039). A significant trend indicated increasing pain risk with a higher number of unhealthy habits (*p* for trend = 0.0013) (Table 3).

Table 3
Association between ABC habits (Alcohol, Betel nut, and Cigarette) and physical pain: Individual and combined effects

ABC habits	No Physical Pain	Physical Pain				
	n (%)	n (%)	Crude OR (95% CI)	*p* value	Adjusted OR (95% CI) [a]	*p* value
None	1728 (56.93)	2920 (52.85)	Ref		Ref	
A alone	166 (5.47)	280 (5.07)	0.998 (0.816–1.220)	0.9859	0.935 (0.765–1.147)	0.5205
B alone	24 (0.79)	44 (0.80)	1.085 (0.657–1.790)	0.7498	1.025 (0.618–1.701)	0.9204
C alone	580 (19.11)	1211 (21.92)	1.236 (1.101–1.387)	0.0003*	1.190 (1.058–1.339)	0.0039*
A and B	17 (0.56)	29 (0.52)	1.010 (0.553–1.842)	0.9754	0.904 (0.491–1.664)	0.7456
A and C	162 (5.34)	338 (6.12)	1.235 (1.014–1.503)	0.0355*	1.157 (0.947–1.414)	0.1545
B and C	185 (6.10)	405 (7.33)	1.296 (1.078–1.557)	0.0058*	1.187 (0.983–1.433)	0.0745
A, B, and C	173 (5.70)	297 (5.38)	1.016 (0.835–1.237)	0.8747	0.897 (0.733–1.099)	0.2957
P for trend				0.0013*		0.0558
P for interaction				0.0892		0. 0892

[a] *Adjusted for age group, job type, exercise, secondhand smoking, and abdominal obesity*

* *p < 0.05*

3.5. Combined Effects of Cigarette Smoking and SHS Exposure on Physical Pain

The subgroup analysis demonstrated that both cigarette smoking and SHS were independently associated with higher risk of physical pain. Column percentages were calculated separately for

participants with and without physical pain. Compared with participants without smoking exposure, SHS-only exposure showed the highest odds of physical pain (adjusted OR = 1.536), followed by smokers and SHS (adjusted OR = 1.466), and then smokers without SHS exposure (adjusted OR = 1.196). The interaction test (p = 0.0629) indicated that cigarette smoking and SHS contribute additively, rather than synergistically to pain risk (Table 4).

Table 4
Combined effects of cigarette smokers and SHS exposure on physical pain

Smoking Status	**No Physical Pain**	**Physical Pain**				
	n (%)	**n (%)**	**Crude OR (95% CI)**	***p* value**	**Adjusted OR (95% CI) [a]**	***p* value**
No smoke exposure	1684 (55.48)	2668 (48.29)	Ref		Ref	
Only SHS	252 (8.30)	605 (10.95)	1.515 (1.292–1.777)	0.0001*	1.532 (1.304-1.800)	0.0001*
Only smoker	856 (28.20)	1652 (29.90)	1.218 (1.099–1.350)	0.0002*	1.196 (1.076–1.330)	0.0009*
Smoker and SHS	244 (8.04)	598 (10.82)	1.547 (1.317–1.817)	0.0001*	1.466 (1.246–1.726)	0.0001*
P for trend				0.0001*		0.0001*
P for interaction				0.8380		0.0629

[a] *Adjusted for age group, job type, exercise, and abdominal obesity*

** p < 0.05*

3.6. Sensitivity Analyses

General pain occurred in 64.54% of participants, followed by neck pain (2,251/26.29%), back and waist pain (1,683/19.66%), joint pain (1,553/18.14%), and sciatica (468/5.47%). Sensitivity analysis across different pain locations confirmed consistent association for smoking and SHS, particularly for general, back, joint pain, and sciatica (Table S1).

4. DISCUSSION

The main findings of this study indicate that both active smoking and SHS exposure were independently associated with physical pain among Taiwanese male workers. Notably, SHS exposure showed a

stronger association than active smoking, suggesting that prolonged involuntary exposure in occupational settings may contribute meaningfully to occupational pain burden.

Smoking was identified as an independent lifestyle risk factor to pain, consistent with prior studies linking tobacco exposure to inflammation, leading to tissue damage and pain [17–19]. The findings regarding back pain risk are consistent with large cohort study reporting higher pain risk among male smokers (95% CI = 1.36–1.55) [20]. Nicotine and other toxic components may reduce blood flow, delay healing, and increase susceptibility to pain [14, 21, 22].

Interestingly, Tables 2 and 4 consistently show that SHS exposure demonstrated a higher OR for pain than active smokers. SHS contains many of the same harmful chemicals that induces oxidative stress and vascular dysfunction [19, 23]. Prolonged SHS exposure, often occurring unknowingly, may exacerbates these effects through repeated low-dose inhalation in enclosed environments, as smoking rooms and filters are ineffective and even brief exposure can be harm [24, 25]. From an occupational perspective, SHS exposure should be considered a modifiable workplace risk factor. These findings support that tobacco-control evidence that there is no safe level of SHS exposure and that comprehensive smoke-free laws are needed to protect nonsmokers [26, 27].

In contrast, the absence of significant associations between alcohol or betel nut use with physical pain. Alcohol has complex effects on pain perception, acting as both analgesic and hyperalgesia effects, depending on dose and individual responses [28]. Betel nut chewing, while linked to various health risks, may not directly influence pain pathways. Further research is needed to explore these relationships and potential mediators, such as occupational stress and genetic factors [18].

Exercise was protective against physical pain, consistent with evidence that an active lifestyle, especially strength or resistance training such as Pilates can prevent and reduce pain severity, possibly by releasing endorphins and stronger analgesic response during higher-intensity exercises [29–33].

Strengths of the study include its large population-based sample and adjustment of multiple covariates which strengthening the results. Focusing on homogeneous (male) population reduced variability unrelated to the exposures of interest, enhancing internal consistency. The integrated smoking x SHS model provides more accurate risk estimates. Limitations include the cross-sectional design and reliance on self-reported behaviors and pain, which may introduce measurement or recall bias. Future longitudinal studies are needed to assess causal relationships.

5. CONCLUSSIONS

In conclusion, cigarette smoking and SHS exposure were significant contributors to physical pain among Taiwanese male workers, while regular exercise appeared to be a protective factor against physical pain. These findings suggest workplace health programs should emphasize smoking cessation and promoting exercise to mitigate pain-related health burdens. Future research can include female participants to investigate potential gender differences in these associations.

Abbreviations

ABC	Alcohol, Betel nut, and Cigarette
BMI	Body Mass Index
CI	Confidence Interval
DALYs	Disability-Adjusted Life Years
DM	Diabetes Mellitus
HTN	Hypertension
MSDs	Musculoskeletal Disorders
OR	Odds Ratio
SHS	Secondhand Smoke
TMU	Taipei Medical University
TWB	Taiwan Biobank
WHO	World Health Organization

Declarations

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The authors have nothing to report.

Author Contributions

R.S. conceived the ideas, analyzed the data, and wrote the manuscript; M.J.S. and F.I.H. critically reviewed the manuscript and contributed to reference completion; C.C.Y. provided data access, contributed data analysis, supervised the study, and reviewed the manuscript. All authors meet ICMJE authorship criteria, approved the final version, and agree to be accountable for all aspects of the work.

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Data Availability Statement

The data that support the findings of this study are available from the Taiwan Biobank (TWB). Access to these data can be accessed with a formal request and approval from the Taiwan Biobank. The data are not publicly available due to ethical and legal restriction, all requests should be directed to biobank@gate.sinica.edu.tw.

Declarations

Consent for publication

Not applicable

Competing interests

The authors declare no competing interests.

Ethics approval and consent to participate

Data were collected with written informed consent obtained from all participants at the time of enrollment in the Taiwan Biobank [15]. Ethical approval for this secondary analysis was waived by the Institutional Review Board of Taipei Medical University and the Hospital Research Ethics Committee, Taipei Medical University, Taiwan (TMU-JIRB No.: N202005033). All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the Declaration of Helsinki.

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Figures

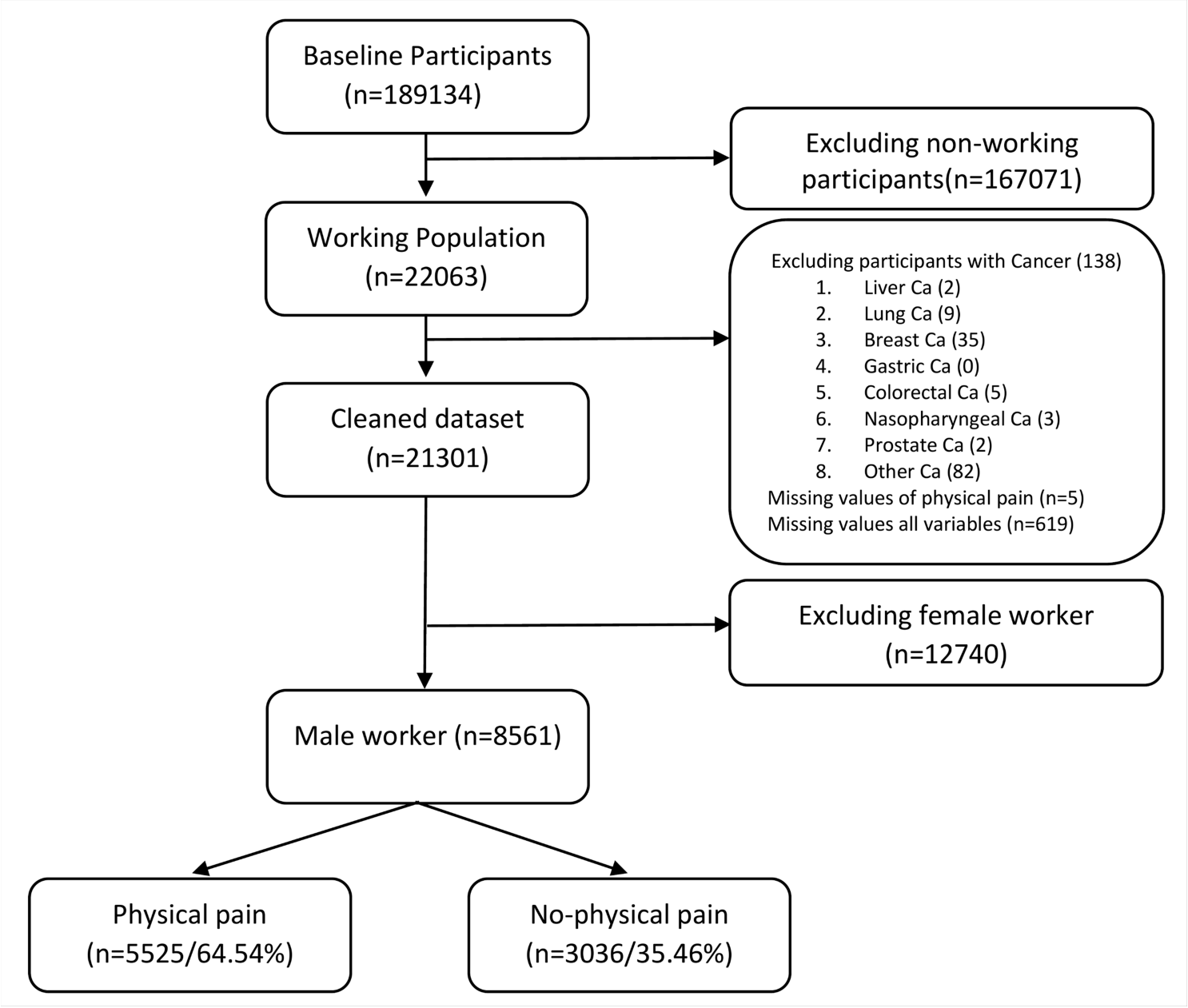


Figure 1

Flowchart of participant selection from the Taiwan Biobank

Legend: the figure shows the selection step of participant from the TWB. Exclusion criteria included non-working participant, cancer cases, missing values for variables, and female workers.

Caption: Out of 189,134 baseline participants, 167,071 non-working participants were excluded. Additional exclusion included cancer cases (n = 138), missing values of physical pain (n = 5), missing values covariates data (n = 619), and female workers (n = 12,740). The final analytic sample consisted of 8,561 male workers, of whom 64.54% reported physical pain and 35.46% did not.

Supplementary Files

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- SupplementaryMaterials.docx