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Original Article

Association Between Occupational Physicochemical Exposures and Headache/Eyestrain Symptoms Among Korean Indoor/Outdoor Construction Workers

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ABSTRACT

Background: Headache/eyestrain symptoms are common health problems that people experience in daily life. Various studies have examined risk factors contributing to headache/eyestrains, and physicochemical exposure was found to be a leading risk factor in causing such symptoms. The purpose of this study was to examine the relationship of headache/eyestrain symptoms with physicochemical exposure among Korean construction workers depended on worksite.

Methods: This study used data from the 4th Korean Workers Conditions Survey and selected 1,945 Korean construction workers as participants. Multivariable logistic regression analysis was used to determine the relationship.

Results: Exposure to vibrations among all construction workers affected the moderate exposure group [odds ratio (OR) 1.53, 95% confidence interval (CI) 1.01–2.32], the high exposure group (OR 1.77 95%CI 1.17–2.67), and the indoor high exposure group (OR 1.61, 95%CI 1.02-2.55) and among outdoor construction workers, the moderate group (OR 6.61, 95%CI 15.4–28.48) and the high group (OR 6.61, 95%CI 1.56–27.98). When exposed to mist, dust, and fumes, the indoor high exposure group was significantly affected (OR 1.63, 95%CI 1.07–2.47). All construction workers exposed to organic solvents were affected, high exposure group (OR 1.69, 95%CI 1.15–2.49) and indoor high exposure group (OR 1.77, 95%CI 1.08–2.89). The high exposure group in all construction worker (OR 1.70, 95%CI 1.20–2.42) and the indoor high exposure group (OR 1.83, 95%CI 1.17–2.89) also were affected by secondhand smoking exposure.

Conclusion: Many physicochemical exposure factors affect headache/eyestrain symptoms among construction workers, especially indoor construction workers, suggesting a deficiency in occupational hygiene and health environments at indoor construction worksites.

1. Introduction

Headaches are universally experienced, given that approximately 40% of adults in the United States experience daily headaches, and 90% of men and women have experienced at least one headache during their lifetime [1]. South Korean epidemiological research on headaches has shown that 63% of men and 73% of women have experienced a headache in the last year, also showing the symptom to be common among South Koreans [2]. The prevalence of headaches is constantly rising, and the socioeconomic burden that comes with headaches demands closer examination as a serious health issue [3].

Eyestrains are another common symptom among the general population. Eyestrains and headaches are known to be closely related to each other, and they often appear at the same time [4]. Other eyestrain-related ailments, such as dry-eye syndrome and blurred vision, increase the likelihood of headaches [5]. Long-term computer usage, exposure to digital display screens, and other digital factors are common causes of dry-eye syndrome and eyestrains nowadays, and headaches often appear concurrently [6]. Carruthers et al [7] theorized that the mechanism of the cause–effect relationship between eyestrains and headaches is irregular contractions of the orbicularis oculi muscle, the core component of

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the eye socket. The abovementioned studies all found a strong correlation between headaches and eyestrains [8,9].

There is a large body of research that aims to identify risk factors contributing to headaches and eyestrains, and physicochemical factors are among the most studied. For example, noise, a prevalent cause of physical discomfort, can act as a trigger for headaches [10], and the duration of exposure to noise increases sensitivity for headaches [11]. Exposure to vibrations also increases the chance of headaches [12], and the combination of noise and vibrations can sharply increase the risk of headaches and eyestrains [13]. The weather and indoor temperature can also affect the risk of headaches [14–17], and dust can induce bloodshot eyes, dry-eye syndrome, and place considerable strain on the eyes [18], all of which can be eventual triggers for headaches [19]. There are also many chemical exposure factors, such as organic solvents. While some are odorless, many have strong odors and merely being exposed to them may result in chronic headaches [20,21].

These physicochemical factors increase the risk of headaches and eyestrains from exposure in the environment, especially in construction worksites. Construction workers are inevitably exposed to noise and vibrations from heavy equipment, dust particles from cement and other materials, and emissions from various types of organic solvents. There have been numerous studies on the effects of physicochemical exposure on the health of construction workers. These include the effects of noise exposure in noise-induced sensory-neural hearing loss [22,23], respiratory diseases due to exposure to dust particles [24,25], musculoskeletal system disorders due to exposure to vibrations [26], and neuropsychiatric diseases caused by exposure to organic solvents [27]. Also, many studies have examined the relationship between physicochemical exposure and headaches and eyestrains [28,29]. However, only a few studies examined the symptoms of headaches and eyestrains experienced by construction workers exposed to physicochemical factors.

Construction workers suffering from symptoms of headaches and eyestrains can have decreased productivity, ability to complete tasks, and jeopardize occupational safety [30,31]. Such symptoms may lead to life-threatening accidents and injuries and destruction of property, making further research on causation and prevention of headaches and eyestrain crucial [32]. There are many differences in working conditions, procedures, and materials depending on whether the construction worksite is indoors or outdoors, which also affects the types of physicochemical exposure present in the worksite. Therefore, this study aimed to examine the relationship between physicochemical exposure and headache/eyestrain symptoms among construction workers and observe the differences between indoor and outdoor worksite conditions.

2. Materials and methods

2.1. Study subjects

This study used data from the 4th Korean Working Conditions Survey (KWCS) conducted by the Occupational Safety and Health Research Institute in 2014 and distributed in 2015. The survey consisted of door-to-door interviews targeting wage workers aged 15 years and above, guaranteeing anonymity and conducted under consent. The survey goal was to provide information about South Korean work environments and practices and their influence on health issues and work accidents to foster safer and healthier workplaces.

A total of 50,007 workers were surveyed; of these, 2,884 were construction workers identified by industry classification code. Then non-onsite workers, such as office administration and sales staff, were excluded, leaving only on-worksite construction workers. The final filter removed incomplete survey responses to arrive at a final number of 1,945 subjects (Fig. 1). This study was approved by the Institutional Review Board of Soonchunhyang University Hospital (SCHUH 2019-01-011).

2.2. Variables

2.2.1. General characteristics

General characteristics included sex, age (<39, 40~49, 50~59, ≥60), and level of education (≤middle school, high school, ≥college).

2.2.2. Occupational characteristics

Occupational characteristics included monthly income [<1,677 United States Dollars (USD), between 1,667 and 2,500 USD, and ≥2,500 USD], weekly working hours (<40, 40~47, 48~59, ≥60), employment status, number of employees (<5, ≥5), and personal protective equipment (PPE) status.

2.2.3. Worksite physicochemical factors

The survey categorized exposure as vibration, noise, high temperature, low temperature, dust particles (including smoke and fumes), organic solvents, chemical products, and secondhand tobacco smoke as worksite physicochemical factors. The survey asked, "How exposed are you to the following factors during work?" to which the survey participants could choose from seven possible responses: "Never exposed", "Almost never exposed", "A quarter of my work hours", "Half of my work hours", "Three-quarters of my work hours", "Almost always exposed", "Always

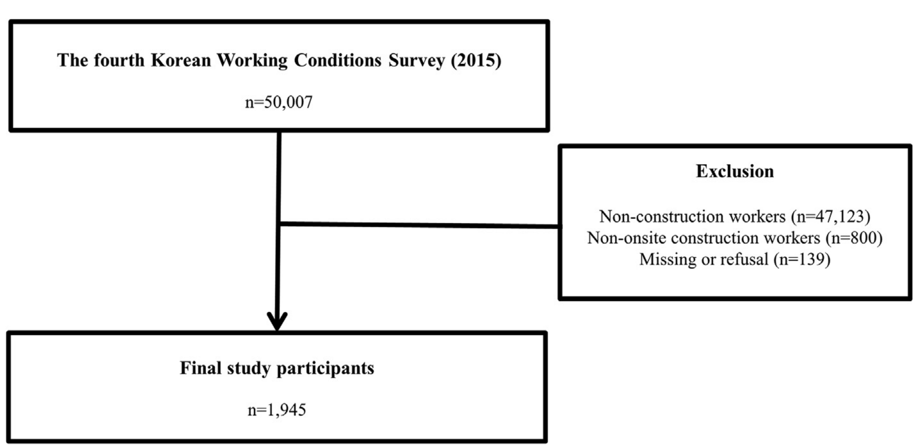

Fig. 1. Schematic flowchart depicting study participants.

exposed". Participants who answered "Never exposed" were categorized in the low-exposure group; those who answered "Almost never exposed" and "A quarter of my work hours" were categorized in the moderate-exposure group; and the rest of the participants were categorized in the high-exposure group [13].

2.2.4. Symptoms of headache/eyestrains

Symptoms of headaches and eyestrains, as dependent variables, were deemed to be present if participants answered "yes" to "headache/eyestrains" from the following question, "Have you experienced the following health issues in the last 12 months?" Those who responded "yes" were placed into the group with self-reported headache/eyestrain symptoms [33].

2.2.5. Indoor/outdoor construction workers

The division of labor of construction encompasses a diverse range of skilled and manual labor. Among the most common construction trades are those of carpenter, electrician, heavy equipment operator, ironworker, laborer, mason, plasterer, plumber, pipefitter, sheet metal worker, steel fixer, welder, and so on [34]. As far as we know, there is no clear standard for dividing construction workers into indoor and outdoor construction workers. In previous studies of outdoor and indoor construction workers, subjects were selected based on the worksite where they were mainly working [35]. In our study, subjects were divided into groups according to their response to the following question, "Where do you mostly work?" Those who responded "outdoor construction site" were defined as outdoor construction workers, and indoor construction workers were defined when they responded "customers", "home-site", or "indoor site" or "etc."

3. Statistical analysis

Analyses of all the construction workers, including a stratified analysis of indoor and outdoor construction workers, were performed. A Chi-square test was performed to show the distribution of headache/eyestrain symptoms according to sex, age, education level, monthly income, weekly working hours, employment status, number of employees, and PPE status. Another Chi-square test was used to determine the distribution of headache/eyestrain symptoms from exposure to physicochemical factors in the worksite. Finally, multivariable logistic regression analysis was performed to determine the strength of the relationship between exposure to physicochemical factors and headache/eyestrain symptoms. The level of significance was set to 0.05, and all statistical analyses were performed using SPSS (ver. 25.0. SPSS Inc., Chicago, IL).

4. Results

4.1. Distribution of headache/eyestrain symptoms by general and occupational characteristics

Of all the construction workers, those aged 40~49 years experienced the most symptoms of headaches and eyestrains. The proportion of headache/eyestrain symptoms was high in cases where the subject's level of education was equal to or higher than a college degree, and they worked more than 60 hours a week. The likelihood of headache/eyestrain symptoms increased as weekly working hours increased. Higher monthly incomes and compliance to PPE also showed increases in headache/eyestrain symptoms.

Indoor construction workers showed similar results, as workers in their forties experienced more headache/eyestrain symptoms than the rest, as did those with longer work hours. Wearing PPE also increased headache/eyestrain symptoms. Outdoor construction workers did not show significant statistical differences between any general or occupational characteristics (Table 1).

4.2. Distribution of headache/eyestrain symptoms according to physicochemical exposures in construction worksite

For all including both indoor and outdoor construction workers, increased exposure to vibration increased headache/eyestrain symptoms across all the groups. As exposure to organic solvents and secondhand smoke among all construction workers increased, so did the rate of headache/eyestrain symptoms. Indoor construction workers in the high-exposure group for mist, dust, and fumes also had a higher rate of headache/eyestrain symptoms. High exposure to secondhand smoke when analyzing all and indoor construction workers showed higher rates of headache/eyestrain symptoms. Moderate exposure to chemical agents showed a comparatively lower proportion of headache/eyestrain symptoms among indoor construction workers. Outdoor construction workers did not show significant responses to the physicochemical factors, with the exception of exposure to vibration as mentioned above (Table 2).

4.3. The risk of headache/eyestrain symptoms from exposure to physicochemical factors in the construction worksite

Analysis of all the construction workers showed a significant increase in risk of headache/eyestrain symptoms in moderate and high vibration exposure groups compared with the low-exposure group [odds ratio (OR) 1.53, 95% confidence interval (CI) 1.01–2.32; OR 1.77, 95% CI 1.17–2.67, respectively). High exposure to organic solvents increased the risk of headache/eyestrain symptoms compared with the low-exposure group (OR 1.69, 95% CI 1.15–2.49), and a similar pattern was identified for high exposure to secondhand smoke (OR 1.70, 95% CI 1.20–2.42).

This pattern continued among indoor construction workers exposed to vibrations, as high exposure came with higher risk (OR 1.61, 95% CI 1.02–2.55). High exposure to mist, dust, and fumes (OR 1.63, 95% CI 1.07–2.47), organic solvents (OR 1.77, 95% CI 1.08–2.89), and secondhand smoke (OR 1.83, 95% CI 1.17–2.89) also correlated strongly with increased risk of headache/eyestrain symptoms. Exposure to chemical agents showed a contrary pattern, as those in the moderate-exposure group showed less risk of symptoms compared with those in the low-exposure group (OR 0.68, 95% CI 0.50–0.93).

Among outdoor construction workers exposed to vibrations, the risk of headache/eyestrain symptoms increased as the level of exposure increased (moderate-exposure group: OR 6.61, 95% CI 1.54–28.48; high-exposure group: OR 6.61, 95% CI 1.56–27.98). No other physicochemical factors showed significant results among outdoor construction workers (Table 3).

5. Discussion

We were able to identify and analyze relationships between exposure to physicochemical factors and headache/eyestrain symptoms. Stratified analysis showed the risk differences of physicochemical factors in indoor and outdoor construction worksite environments and their effects on self-reported headache/eyestrain symptoms. We were able to confirm that indoor construction workers exposed to physicochemical factors showed more sensitivity to headache/eyestrain symptoms than outdoor construction workers.

The risk of headache/eyestrain symptoms increased for all the construction workers when they were exposed to vibrations, regardless of worksite conditions. Existing research conducted in a

Table 1
Distribution of headache/eyestrain symptoms by general and occupational characteristics

Distribution of headache/eyestrain symptoms by general and occupational characteristics	Headache/Eyestrain symptoms								
	All (n = 1,945)			Indoor (n = 1,163)			Outdoor (n = 782)		
	N (n,%)	Y (n,%)	p	N (n,%)	Y (n,%)	p	N (n,%)	Y (n,%)	p
Sex									
Male	1,514 (81.6)	342 (18.4)	0.15	872 (79.0)	232 (21.0)	0.17	642 (85.4)	110 (14.6)	0.35[†]
Female	78 (87.6)	11 (12.4)		51 (86.4)	8 (13.6)		27 (90.0)	3 (10.0)	
Age (years)									
<39	305 (86.2)	49 (13.8)	<0.05*	198 (85.3)	34 (14.7)	<0.05*	107 (87.7)	15 (12.3)	0.89
40∼49	459 (79.0)	122 (21.0)		274 (75.1)	91 (24.9)		185 (85.6)	31 (14.4)	
50∼59	543 (81.5)	123 (18.5)		299 (78.9)	80 (21.1)		244 (85.0)	43 (15.0)	
≥60	285 (82.8)	59 (17.2)		152 (81.3)	35 (18.7)		133 (84.7)	24 (15.3)	
Education									
≤Middle school	340 (81.3)	78 (18.7)	<0.05*	157 (78.1)	44 (21.9)	0.13	183 (84.3)	34 (15.7)	0.31
High school	820 (84.2)	154 (15.8)		451 (81.9)	100 (18.1)		369 (87.2)	54 (12.8)	
≥College	432 (78.1)	121 (21.9)		315 (76.6)	96 (23.4)		117 (82.4)	25 (17.6)	
Weekly working hours									
<40	245 (85.7)	41 (14.3)	<0.05*	111 (82.2)	24 (17.8)	<0.05*	134 (88.7)	17 (11.3)	0.11
40~47	539 (83.8)	104 (16.2)		319 (82.2)	69 (17.8)		220 (86.3)	35 (13.7)	
48~59	516 (83.1)	105 (16.9)		316 (81.0)	74 (19.0)		200 (86.6)	31 (13.4)	
≥60	292 (73.9)	103 (26.1)		177 (70.8)	73 (29.2)		115 (79.3)	30 (20.7)	
Number of employees									
<5	674 (82.7)	141 (17.3)	0.41	413 (79.6)	106 (20.4)	0.87	261 (88.2)	35 (11.8)	0.10
≥5	918 (81.2)	212 (18.8)		510 (79.2)	134 (20.8)		408 (84.0)	78 (16.0)	
Employment status									
Permanent	1,014 (80.9)	240 (19.1)	0.13	691 (79.2)	181 (20.8)	0.86	323 (84.6)	59 (15.4)	0.44
Temporary	578 (83.6)	113 (16.4)		232 (79.7)	59 (20.3)		346 (86.5)	54 (13.5)	
Monthly income (USD)									
<1,667	475 (83.6)	93 (16.4)	<0.05*	229 (80.9)	54 (19.1)	0.06	246 (86.3)	39 (13.7)	0.7
1,667–2,500	551 (83.7)	107 (16.3)		338 (82.2)	73 (17.8)		213 (86.2)	34 (13.8)	
≥2,500	566 (78.7)	153 (21.3)		356 (75.9)	113 (24.1)		210 (84.0)	40 (16.0)	
Personal protective equipment									
Yes	964 (80.1)	239 (19.9)	<0.05*	496 (76.7)	151 (23.3)	<0.05*	458 (84.2)	88 (15.8)	0.09
No	628 (84.6)	114 (15.4)		427 (82.8)	89 (17.2)		201 (88.9)	25 (11.1)	

* Based on Chi-square test
† Based on Fisher's exact test.

similar vein, although with different subjects, showed that South Korean wage workers exposed to vibrations were at increased risk of headaches and eyestrains [13]. There is also a body of international research exploring similar cases, such as the relationship between headaches and eyestrains and vibration exposure to agricultural machinery cables [12], and headaches among hand-arm vibration syndrome patients when exposed to local vibration apparatus [36]. Another study on airplane factory workers also showed increased risk of headaches when they endured high vibration exposure, although that test was conducted with a small sample [37].

The following mechanisms may apply when attempting to explain these results. First, exposure to vibration causes an imbalance in the human nervous system which may result in various physiological changes that predispose individuals to headaches [38]. Certain functions in the central nervous system are also hindered when exposed to vibration, affecting visual motor response times. This may result in eye fatigue and can cause headaches [39]. Considering the close relationship between the two symptoms, there are surprisingly few studies that combine headaches and eyestrains into one dependent variable. Further research is needed on their relationship among different occupations when exposed to vibrations.

Our study results showed that indoor construction workers with high exposure to dust or fume particles had more risk of headache/eyestrain symptoms compared with those with lower exposure. A study by Lakhani [40] on the effects of exposure to welding fumes and dust particles among female construction workers showed that the majority of participants reported headaches. Construction workers are also frequently exposed to cement powder, and Abou-Taleb et al [41] reported that those with higher exposure complained about headaches and dry-eye syndrome, an illness that can increase the likelihood of eyestrains. To our knowledge, there have not been many studies to date specifically examining the health of construction workers mainly working on indoor environments when exposed to dust particles. However, previous research on indoor air quality as affected by harmful dust particles across many occupations revealed increased headaches, eyestrains, and dry-eye syndrome, which supports our study results [42–44].

High exposure to organic solvents among all the construction workers also presented higher risk of headache/eyestrain symptoms. Studies focusing on construction workers and the effect of exposure to organic solvents on headaches and eyestrains are very rare, but work has been done on organic solvent exposure among gas station workers [45], shoe factory workers [46], and paint manufacturing workers [47], showing high risk of headaches and eyestrains when exposed. Indirect exposure to organic solvents may also increase the risk of headache/eyestrain symptoms, the most representative being the so-called "sick building syndrome" [48–50]. Most people affected by this syndrome work inside buildings, so their findings can support the results from this study that showed an increase in risk among indoor construction workers.

Table 2
Relationship between physicochemical risk exposures and headache/eyestrain symptoms

	Headache/Eyestrain symptoms								
	All (n = 1,945)			Indoor (n = 1,163)			Outdoor (n = 782)		
	N (n,%)	Y (n,%[1–58])	p	N (n,%)	Y (n,%)	p	N (n,%)	Y (n,%)	p
Vibration									
Low	243 (87.7)	34 (12.3)	<0.05*	173 (84.4)	32 (15.6)	<0.05*	70 (97.2)	2 (2.8)	<0.05*
Moderate	619 (82.2)	134 (17.8)		395 (80.8)	94 (19.2)		224 (84.8)	40 (15.2)	
High	730 (79.8)	185 (20.2)		355 (75.7)	114 (24.3)		375 (84.1)	71 (15.9)	
Noise									
Low	296 (84.1)	56 (15.9)	0.40	213 (81.3)	49 (18.7)	0.22	83 (92.2)	7 (7.8)	0.17
Moderate	764 (81.9)	169 (18.1)		469 (80.3)	115 (19.7)		295 (84.5)	54 (15.5)	
High	532 (80.6)	128 (19.4)		241 (76.0)	76 (24.0)		291 (84.8)	52 (15.2)	
High temperature									
Low	350 (83.9)	67 (16.1)	0.42	238 (80.7)	57 (19.3)	0.66	112 (91.8)	10 (8.2)	0.09
Moderate	557 (81.8)	124 (18.2)		344 (79.8)	87 (20.2)		213 (85.2)	37 (14.8)	
High	685 (80.9)	162 (19.1)		341 (78.0)	96 (22.0)		344 (83.9)	66 (16.1)	
Low temperature									
Low	532 (83.3)	107 (16.7)	0.52	322 (79.9)	81 (20.1)	0.81	210 (89.0)	26 (11.0)	0.14
Moderate	682 (81.0)	160 (19.0)		417 (78.5)	114 (21.5)		265 (85.2)	46 (14.8)	
High	378 (81.5)	86 (18.5)		184 (80.3)	45 (19.7)		194 (82.6)	41 (17.4)	
Mist, dust, or fumes									
Low	402 (84.6)	73 (15.4)	0.18	291 (83.9)	54 (16.1)	<0.05*	121 (86.4)	19 (13.6)	0.95
Moderate	615 (81.3)	141 (18.7)		381 (79.0)	101 (21.0)		234 (85.4)	40 (14.6)	
High	575 (80.5)	139 (19.5)		261 (75.4)	85 (24.6)		314 (85.3)	54 (14.7)	
Organic solvents									
Low	713 (83.4)	142 (16.6)	<0.05*	418 (80.2)	103 (19.8)	0.05	295 (88.3)	39 (11.7)	0.11
Moderate	738 (81.9)	163 (18.1)		429 (80.3)	105 (19.7)		309 (84.2)	58 (15.8)	
High	141 (74.6)	48 (25.4)		76 (70.4)	32 (29.6)		65 (80.2)	16 (19.8)	
Chemical agents									
Low	739 (81.5)	168 (18.5)	0.13	409 (77.0)	122 (23.0)	<0.05*	330 (87.8)	46 (12.2)	0.14
Moderate	732 (83.2)	148 (16.8)		438 (82.5)	93 (17.5)		294 (84.2)	55 (15.8)	
High	121 (76.6)	37 (23.4)		76 (75.2)	25 (24.8)		45 (78.9)	12 (21.1)	
Secondhand smoking									
Low	515 (83.6)	101 (16.4)	<0.05*	310 (80.5)	75 (19.5)	<0.05*	205 (88.7)	26 (11.3)	0.05
Moderate	862 (83.2)	174 (16.8)		507 (81.5)	115 (18.5)		355 (85.7)	59 (14.3)	
High	215 (73.4)	78 (26.6)		106 (67.9)	50 (32.1)		109 (79.6)	28 (20.4)	

* Based on Chi-square test.

Surprisingly, the moderate-exposure group in our study showed a decreased risk of headache/eyestrain symptoms. Our methodology may have contributed to this result, as participants who answered “Almost never exposed” to the question about exposure were categorized in the moderate-exposure group. In a future study, more systematic categories to filter the levels of exposure may produce stronger and more accurate correlations.

In analyzing all and indoor construction workers, this study also found a higher risk of headache/eyestrain symptoms when they were exposed to secondhand smoke. Many previous studies have been conducted on the effects of secondhand smoke, and this hazard is well known. People can experience blurred vision, headaches, and other similar conditions from carbon monoxide inside the body when exposed to secondhand smoke [51]. Secondhand smoke may also affect sleep quality and duration, which in turn, can increase the risk of headaches and eyestrains [52–54].

This study found that indoor construction workers were influenced by a broader range of physicochemical factors than outdoor construction workers. Although there has not been a study to date directly comparing the effects of physicochemical exposure on indoor and outdoor construction workers, one study on the level of polycyclic aromatic hydrocarbons, which originate in organic solvents and secondhand smoke, found that the level of polycyclic aromatic hydrocarbons was higher indoors than outdoors [55]. Secondhand smoke has a greater effect on health when exposed at indoors than outdoors [56]. Natural wind and ventilation in outdoor work environments may lessen the effects of certain physicochemical factors and might contribute to our study's results. Further study objectively examining the effects of physicochemical exposure on health may be required.

This study had the following limitations. First, a causal relationship between physicochemical factors exposure and headache/eyestrain symptoms could not be identified through this cross-sectional study. However, this approach allowed us to identify the existence of the phenomenon and construct a research model that can find a cause-and-effect relationship in future studies.

The second limitation was the data characteristics of the 4th KWCS. The survey did not contain other data that may contribute to headache/eyestrain symptoms, such as the amount of daily coffee consumed, average sleeping hours, and the existence hypertension, diabetes, or other conditions, which limited the scope of analysis. Headaches are also affected by occupational hazardous factors such as altitude and psychological factors such as depression [57,58]. To elucidate the specific cause-and-effect relationship between physicochemical exposure and headache/eyestrain symptoms among construction workers, a systematic study should be carried out that overcomes the abovementioned limitations.

Table 3
The odds ratios and 95% confidence intervals of physicochemical risk exposures on headache/eyestrain symptoms

	All		Indoor		Outdoor	
	OR	95% CI	OR	95% CI	OR	95% CI
Vibration						
Low	Reference		Reference		Reference	
Moderate	1.53	1.01–2.32	1.23	0.78–1.93	6.61	1.54–28.48
High	1.77	1.17–2.67	1.61	1.02–2.55	6.61	1.56–27.98
Noise						
Low	Reference		Reference		Reference	
Moderate	1.09	0.77–1.53	0.96	0.65–1.41	2.08	0.90–4.83
High	1.14	0.79–1.65	1.21	0.78–1.86	1.86	0.80–4.36
High temperature						
Low	Reference		Reference		Reference	
Moderate	1.10	0.79–1.53	1.00	0.68–1.47	1.80	0.85–3.81
High	1.16	0.84–1.60	1.06	0.72–1.57	1.95	0.96–3.97
Low temperature						
Low	Reference		Reference		Reference	
Moderate	1.17	0.89–1.54	1.06	0.76–1.48	1.45	0.85–2.47
High	1.05	0.76–1.45	0.87	0.57–1.33	1.62	0.94–2.78
Mist, dust, or fumes						
Low	Reference		Reference		Reference	
Moderate	1.20	0.87–1.65	1.30	0.89–1.90	0.99	0.54–1.81
High	1.29	0.92–1.80	1.63	1.07–2.47	0.99	0.55–1.77
Organic solvents						
Low	Reference		Reference		Reference	
Moderate	1.06	0.82–1.36	0.97	0.71–1.33	1.28	0.82–2.01
High	1.69	1.15–2.49	1.77	1.08–2.89	1.68	0.87–3.26
Chemical agents						
Low	Reference		Reference		Reference	
Moderate	0.84	0.65–1.077	0.68	0.50–0.93	1.22	0.79–1.89
High	1.35	0.89–2.04	1.12	0.67–1.88	1.77	0.85–3.66
Secondhand smoking						
Low	Reference		Reference		Reference	
Moderate	1.01	0.77–1.33	0.91	0.65–1.28	1.24	0.75–2.05
High	1.70	1.20–2.42	1.83	1.17–2.89	1.72	0.94–3.16

All results are calculated using multivariate logistic regression analysis and are adjusted by sex, age, education, weekly working hours, number of employees, employment status, monthly income, and PPE characteristics.
CI, confidence interval; OR, odds ratio; PPE, personal protective equipment.

Third, the responses for having symptoms of headaches and eyestrains, our dependent variables for this study, were self-reported, not as a medical diagnosis. Also, physicochemical exposure as independent variable was based on self-reporting, not a quantitative measurement, and may lack validity. For example, noise generated by vibration is very common and can be difficult to assess independently when assessed as an exposure factor. To elucidate the phenomena through this study, further research is needed to clarify the association with symptoms through quantitative measurement. In addition, KWCS questionnaire should be supplemented by reflecting these points.

Despite these limitations, our study was successful in identifying differences in health effects between indoor and outdoor construction workers when exposed to physicochemical factors. Indoor construction workers were more affected by more physicochemical factors, suggesting a deficiency in occupational hygiene and health environments in indoor construction worksites. We believe our results highlight the importance of further research into the topic and can be used to promote healthier work environments for construction workers, especially those working indoors.

This research was able to identify a significant relationship between headache/eyestrain symptoms and physicochemical factors, i.e., noise, vibration, dust particles, organic solvents, and secondhand smoke among construction workers, especially among indoor construction workers. Exposure to physicochemical factors may harm construction workers, which can result in worksite accidents and lower productivity. We believe our results can contribute to legislation and policies aimed at improving occupational safety and the management of physicochemical factors for construction workers. Especially crucial is providing adequate safety equipment and better ventilation for indoor working environments.

Ethics approval and consent to participate

Approved by the Institutional Review Board of Soonchunhyang University Hospital. (SCHUH 2019-01-011).

Consent for publication

Not applicable.

Availability of data and materials

The 4th KWCS data are publicly available.

Funding

Not applicable.

Conflicts of interest

The authors have no conflicts of interests.

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