Prevalence of psychological distress and its association with perceived indoor environmental quality and workplace factors in under and aboveground workplaces

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Abstract

Developing underground spaces serves a range of common urban functions, including workspaces. However, underground workplaces, work-related factors and the indoor environmental quality (IEQ) parameters within them may negatively affect worker's mental health. This study assessed the prevalence of psychological distress with repeated measures over time in aboveground and underground workspaces, and assessed the association between perceived IEQ parameters and work-related factors with psychological distress. A total of 329 workers in similar aboveground and underground workspaces were followed-up in three assessments over 12 months in Singapore. Psychological distress was assessed using the 12-item General Health Questionnaire (GHQ-12) and defined as a GHQ-12 score ≥2. Perceived IEQ (air quality, temperature, noise, light) in the workplace were collected using the OFFICAIR questionnaire. We used generalised estimating equation models to assess the association between working underground, perceived IEQ, and work-related factors with psychological distress. The overall prevalence of psychological distress was 21.9%, 26.1% and 21.9%, at baseline, 3- and 12-months follow-up, respectively. The fully-adjusted multivariable analysis did not show any association between working underground and psychological distress however, perceived IEQ parameters and longer working hours were significantly associated with psychological distress. Regardless of working in under or aboveground workplaces, perceived IEQ was associated with psychological distress. Future studies are needed in order to examine the relationship between objective measures of IEQ and psychological distress and the impact of healthy building policies and improved IEQ on psychological distress.

Keywords: mental health; psychological distress; workplace health; cohort study; underground workplaces, perceived indoor environmental quality

1. Introduction

Psychological distress is considered an indicator of mental health status and has been defined as a non-specific syndrome that encompasses feelings of anxiety, depression, irritability, anger or cognitive problems, each of which, depending on their severity and impact may be classified as a mental health disorder (MHD) [1]. MHDs are one of the main contributors of the overall disease burden worldwide and originate from a complex array of genetic, biological, psychological, social, political and environmental factors [2]. The lifetime prevalence of common mental health disorders is almost 1 in 3, with 1 in 5 people reported to have experienced a common mental health disorder in the past 12 months [3]. MHDs are therefore a massive public health concern in their own right. Moreover, MHDs may also lead to the development of physical health conditions [4-6]. Data from the 45 and Up Study recently reported a strong, dose-dependent association between psychological distress and myocardial infarction in a cohort of over 220,000 participants [6].

The workplace plays a significant role in the mental health of individuals [7, 8]. Psychological distress in the workplace comes at a significant cost to the individuals concerned, employers and wider society [9]. Employers must be cognizant of the importance of mental health in the workplace [9]. The Organisation for Economic Co-operation and Development (OECD) states that mental health in the workplace is an upcoming priority challenge for the labour market due to its impact on unemployment, sick leave and reduced productivity at work [10]. As a result, there have been calls for a stronger focus on policies addressing mental health and work issues [10].

Urbanization continues to increase, with 55% of the world's population now living urban areas [11]. These areas need to plan and adapt to the challenge of accommodating larger population densities and to do so in a sustainable manner. One approach to this end, is subterranean development, creating areas for people to work, commute and shop that are underground. While mining may be the first occupation that springs to mind when one considers occupations involved in working underground, modern underground workspaces may be designed and built to resemble typical indoor aboveground workspaces, and thus encompass a range of professions in standard office environments. An example of a city maximising its usage of underground urban space is in Montreal, Canada, in what is commonly referred to as 'The Underground City', which contains over 1,200 offices and 2000 businesses [12]. 'The Underground City' provides Montreal's inhabitants a network of passageways to navigate the city and totals 32 kilometers' worth of tunnels over twelve square kilometers on one of the most densely populated parts of Montreal [12]. While many examples of urban city utilisation of underground spaces exist in Western cities, including in Helsinki, Paris, and Stockholm, the largest increase of UG development has been in cities in Asia [13], with three million m^2 of underground space being developed in Beijing each year [14]. With the expansion of underground spaces, consideration needs to be given to the potential adverse health effects for occupants spending time in these environments, especially those working in these environments. In terms of mental health, the majority of studies on those working in underground spaces have been conducted on miners [15-17]. These studies have reported a high prevalence of depressive symptoms and anxiety disorders among this population [15-17]. However, this may primarily be due to the extreme working conditions experienced in such an occupation. Less research has been conducted with those working in less extreme underground workplaces i.e. office spaces which are underground. Studies have, however, examined window-less workspaces, which to some extent exhibit similarities to working underground due to the lack of natural light. These studies reported that a lack of workplace exposure to natural light was related to depressive symptoms and worse mental health [18, 19]. With the expansion of underground environments, more people are likely to work in such spaces, thus additional research has been called for on the psycho-social and health aspects of underground spaces [20]. Indoor environmental quality (IEQ) parameters are reported to be of concern to occupants in underground workspaces [21-23]. Previous research has demonstrated that workers perceive the environment to be too noisy and consisting of unpleasant lighting [21], while also expressing concern about air quality [22]. Humidity and thermal comfort are also common complaints in underground workplaces [23]. This is concerning as poor IEQ parameters have been shown to be associated with poor psychological health in aboveground workspaces [24-26].

With this background, the aims of this study were: to estimate and compare the prevalence of psychological distress over time in aboveground and underground workspaces; and to assess the association between perceived IEQ parameters and work-related factors with psychological distress.

2. Materials and Methods

2.1 Study design and participants

We conducted a repeated cross-sectional analysis of 329 adults from a workplace cohort study in Singapore. Details of the cohort study design are published elsewhere [27]. We recruited 464 full-time workers from four companies in Singapore and followed them up after 3 and 12 months. The companies were from the transport industry, cooling plants and the university sector. All workers in these sites were invited to participate in the study via worksite posters and emails. Workers aged ≥21 years who could speak English and worked for at least four hours per day at their assigned workplace were eligible. We excluded participants who were pregnant at the time of recruitment. A total of 516 workers were screened, of whom 464 were eligible, and recruited into the study. Of 464 workers at baseline (A1), 424 (91.4%) were followed-up at three months (A2), and 334 (72.0%) after 12 months (A3). Figure 1 shows the selection of study sites and participants and their follow-up at 3 months and 12 months. Data collection for this study was conducted from August 2017 to March 2018. Among the 334 adults who completed the three assessments, 5 were excluded due to missing or incomplete data, resulting in 329 adults and a total of 978 observations included in the final analysis.

2.2 Study variables and measurements

2.2.1 Outcome measure

The outcome measure, psychological distress was measured using the 12-item General Health Questionnaire (GHQ-12). The GHQ-12 asks whether the respondent has experienced a particular symptom or behaviour recently; and includes questions on mood, emotions, self-worth and worries during the previous four weeks. Responses range over a 4-point scale, from “less than usual” to “much more than usual”, and the original GHQ scoring method (0-0-1-1) was applied [28]. The GHQ-12 has acceptable psychometric properties to screen for minor psychological distress in occupational studies [29]. Based on previous research from Singapore, a GHQ-12 score of ≥2 was used to categorize participants with psychological distress [30].

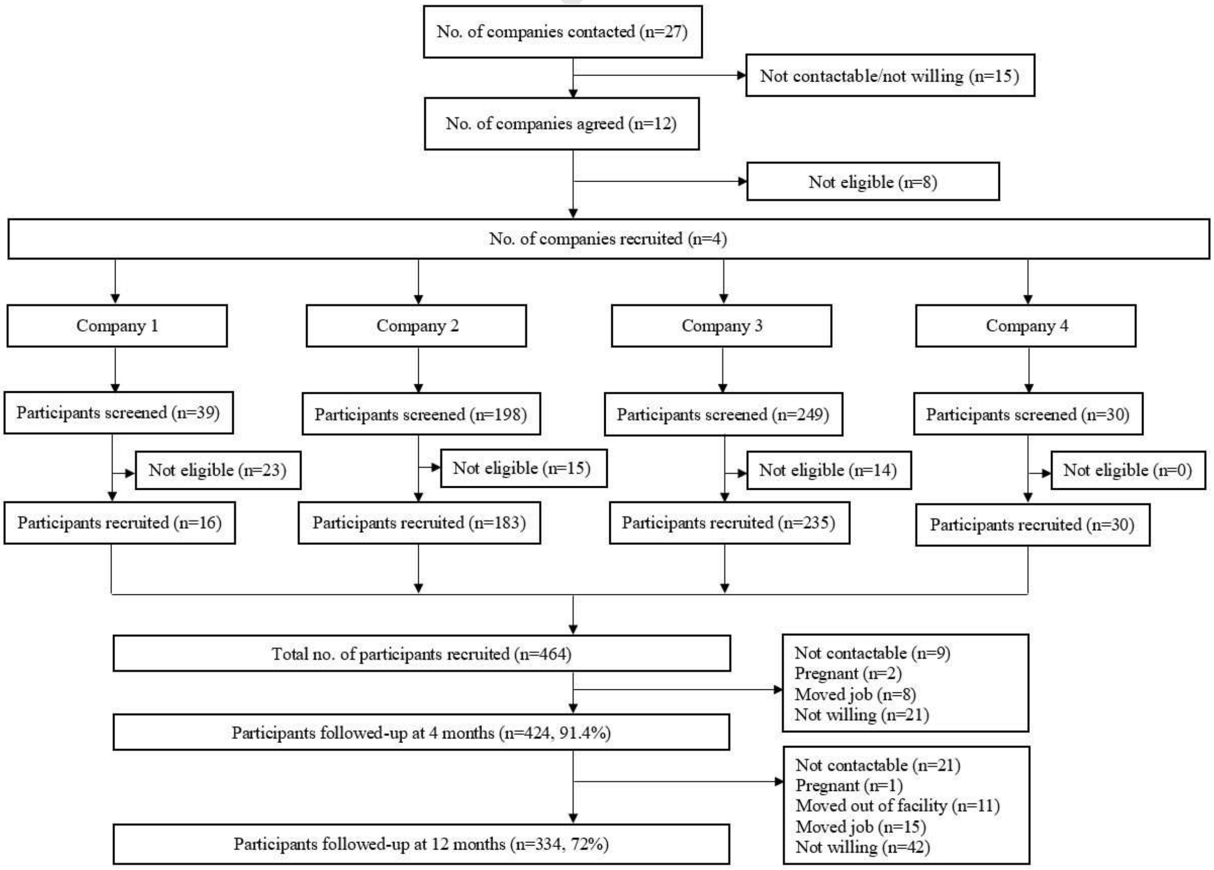

Fig. 1. Participant enrolment and follow-up flowchart.

2.2.2 Independent variables

Work location: Participants worked in underground and aboveground workspaces (0=aboveground; 1=underground). Underground workspaces were defined as work environments that are below the street level, while aboveground workspaces were on or above the street level. Underground workspaces did not contain a window view of the outdoor environment, while workers in aboveground workspaces varied in their distance and view of a window. Individuals in underground workspaces worked comparable job types (administration, control room and workshop) to those in aboveground workspaces.

Work-related characteristics: Questions assessed the number of years employed in the current company, daily working hours, shift worker (0=no, 1=yes) and occupation type (1= office, 2=control room, or 3=workshop). For the occupation type variable, the office category consisted of desk-based workers who were admin personnel and managers, control room consisted of traffic controllers who were also desk-based workers, while workshop consisted of engineers and technicians.

Perceived indoor environmental quality: Perceived indoor environmental quality (IEQ) of air, temperature, noise, and light were measured using the OFFICAIR questionnaire [31]. The OFFICAIR is a standardized questionnaire with established reliability and validity that has been used in several European countries [32]. Responses were reported on a seven-point Linkert scale: 1 (unsatisfactory) to 7 (satisfactory). Responses were reverse coded for the analysis so that a higher score equated to higher dissatisfaction.

2.2.3 Covariates:

2.2.3.1 Socio-demographic characteristics

Socio-demographic characteristics included age, gender (0=male; 1=female), ethnicity (0=Chinese, 1=Malay, 2=Indian, 3=others), and education (0=primary and secondary, 1=pre-university, 2= university degree and above).

2.2.3.2 Health and lifestyle factors

Physical activity was measured using the Global Physical Activity Questionnaire [33], which measures activity levels in three domains namely, work, travel, and leisure. A metabolic equivalent (MET) value of four was assigned for moderate physical activities and a MET value of eight for vigorous physical activities. The duration (in minutes) of an activity performed in each of the three domains was multiplied by its MET value, and these were summed to obtain the total MET-min/week. Individuals were categorized into three groups based on their total MET-min/week (0=low activity [<600 MET-min/week], 1=moderate activity [600-2999 MET-min/week], 2=high activity [≥3000 MET-min/week]). Self-reported chronic conditions were assessed using questions on the history of various chronic medical conditions including diabetes, heart disease, stroke, high cholesterol, hypertension, chronic kidney disease, peripheral vascular disease, asthma, allergy, and mental disorders were collected and used to categorize multi-morbidity in participants (0=none, 1=≥ 1 conditions). The Pittsburgh Sleep Quality Index (PSQI) was used to measure sleep quality in the previous month [34]. It has 19 self-rated items, which are grouped into seven subscales: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medications, and daytime dysfunction. The sum of scores for these seven components provides a global score (ranges from 0 to 21), with “0” indicating no difficulty and “21” indicating severe difficulties in all areas. Participants with a PSQI global score >5 were categorized as having poor sleep quality (0=good sleep quality, 1=>5 poor sleep quality).

2.3 Light measurement

An optic spectrometer (AvaSpec-ULS2048L StarLine Versatile Fiber-optic Spectrometer) was used to obtain readings of illuminance (lux) at participants’ eye level at their work desks/spaces. Measurements were taken for a period of 10 minutes on a random workday during the baseline assessment. Individual readings were obtained for participants with individual workspaces (i.e., specific work desks, cubicles, or work stations), whereas 5-10 readings (depending on the size of the workspace) were taken for participants in shared workspaces. The average of those readings was then assigned to participants working in those workspaces.

2.3 Statistical analysis

Continuous variables (daily working hours, perceived IEQ) were summarised using means (± SD) and categorical variables (gender, age category, ethnicity, education, physical activity, sleep quality, co-morbidity, stress at work, occupational type, duration of employment, shift work status, work location) using frequencies and percentages. Normality of the continuous variables was tested by the Shapiro-Wilk test, and if skewed, then median and inter-quartile range were given for those variables. Pearson’s chi-square test was used to compare crude proportions between those with and without psychological distress. Student’s t-test was used to compare the difference in means between two groups for normally distributed variables and Wilcoxon rank-sum test was used for skewed variables. The prevalence of psychological distress was calculated per assessment. The numerator for prevalence was the number of workers with psychological distress. Similarly, unadjusted means of IEQ parameters over time are compared using repeated measures ANOVA separately for work location and psychological distress.

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To assess the association between perceived IEQ scores and working underground with psychological distress, we performed a generalised estimating equations (GEE) with repeated measures using logit link and an exchangeable correlation structure. For IEQ parameters, analyses were conducted for combined (aboveground and underground) workspace location, then separately for aboveground and underground workspaces, adjusted for socio-demographic (age, gender, educational attainment, marital status, and ethnicity), health and lifestyle (physical activity, comorbidity, and sleep quality), and work-related factors (shift work, occupation type, stress at work, work location, and years at company). We tested for interaction or effect modification by including cross-product terms representing products of workspaces by perceived IEQ. The cross-product interactions were also checked and considered significant if $p<0.05$. However, a separate model was fitted for work-related parameters by adjusting socio-demographic, health and lifestyle factors. GEE was employed to consider the dependency of repeated observation on the same subjects over time. Results for the GEE models were expressed as adjusted odds ratios (aORs) for psychological distress with 95% confidence intervals (CIs) using robust standard errors. Only data that was recorded at each timepoint was included in the GEE analysis. Due to logistical reasons, lux data from the spectrometer was only recorded at one timepoint in the study. hence lux data was excluded from the GEE analysis. All statistical tests were two-sided and p-value <0.05 were considered to be statistically significant, and analyses were conducted using Stata software (version 14.2, StataCorp, College Station, TX, USA).

2.4 Sensitivity analyses

We conducted a sensitivity analysis to examine the robustness of the reported associations. We repeated the analysis with the main effects model using an autoregressive correlation structure to allow for possible correlations between assessments for overall workspaces.

2.5 Ethics approval

The study was approved by the Institutional Review Board of Nanyang Technological University (IRB-2015-11-028). Informed consent written consent was obtained from all study participants prior to the commencement of data collection.

3. Results

3.1 Baseline characteristics

Table 1 presents the baseline characteristics of the study participants. The mean age of study participants was 39.8 years (±11.1). The majority of participants were male (77.8%), of Chinese ethnicity (65.7%), had at least post-secondary education (64.6%) and worked AG (66.9%).

There was no significant difference between participants working in above and underground workplaces in terms of age, ethnicity or education. The only demographic difference between groups was based on gender. Female participants were less likely to be working in underground workplaces, with females making up 13.8% of workers in underground workplaces compared to 26.4% of aboveground workplaces. There was no difference in health and lifestyle factors between underground and aboveground participants. Underground workers were more likely to be a shift worker compared to those working aboveground. Participants working underground reported working 42 minutes longer per day than those working aboveground.

The overall prevalence of psychological distress was 21.9% (95%CI: 17.5% to 26.7%) at baseline, 26.1% (95%CI: 21.5% to 31.2%) and 21.9% (95%CI: 17.5% to 26.7%) at 3 and 12 months follow-up, while 7.4% of participants presented as cases of psychological distress at all three assessments. The crude prevalence of psychological distress by health, lifestyle and work-related factors over time is presented in Table 2. The distribution of psychological distress over time did not vary significantly by participants' characteristics.

Table 1

Baseline characteristics of study participants, N=329

Variables	N (%) N=329	Aboveground N=220	Underground N=109	p-value
Socio-demographic factors				
Age (years)				0.576
21-30	92 (28.0)	65 (29.6)	27 (24.8)	
31-40	95 (28.9)	64 (29.1)	31 (28.4)	
>40	142 (43.2)	91 (41.4)	51 (46.8)	
Gender				**0.010**
Male	256 (77.8)	162 (73.6)	94 (86.2)	
Female	73 (22.2)	58 (26.4)	15 (13.8)	
Education				0.897
Primary and secondary	34 (10.3)	22 (10)	12 (11.0)	
Pre-college	178 (54.1)	118 (53.6)	60 (50.1)	
College and above	117 (35.6)	80 (36.36)	37 (33.9)	
Ethnicity				0.603
Chinese	216 (65.7)	142 (64.6)	74 (67.9)	
Malay	60 (18.2)	44 (20.0)	16 (14.7)	
Indian	39 (11.9)	26 (11.82)	13 (11.9)	
Others[a]	14 (4.3)	8 (3.6)	6 (5.5)	
Health and lifestyle factors				
Physical activity[b]				0.780
Low	73 (22.2)	51 (23.2)	22 (22.2)	
Moderate	145 (44.1)	97 (44.1)	48 (44.0)	
High	111 (33.7)	72 (33.6)	39 (35.8)	
Comorbidity				0.532
No morbidity	204 (62.0)	139 (63.2)	65 (59.6)	
≥1 morbidity	125 (38.0)	81 (36.8)	44 (40.4)	
Sleep quality				
Good sleep quality (PSQI<5)	191 (58.1)	127 (57.7)	64 (58.7)	0.864
Poor sleep quality (PSQI≥5)	138 (42.0)	93 (42.3)	45 (41.3)	
Work-related factors				
Occupation type				0.683
Office staff	159 (48.3)	110 (50)	49 (44.9)	
Control room staff	98 (29.8)	63 (28.6)	35 (32.1)	
Workshop staff	72 (21.9)	47 (21.4)	25 (22.9)	
Shift work				**0.022**
No	218 (66.3)	155 (70.4)	63 (57.8)	
Yes	111 (33.7)	65 (29.6)	46 (42.2)	
Years working at company[c]	4.0 (1.0-8.0)	1 (1.0-7.5)	4 (1-10)	0.124
Daily working hours[d]	8.6 (1.4)	8.4 (1.0)	9.1 (1.8)	**<0.001**
Light[d] (lux)	121.9 (74.4)	124.0 (81.4)	117.3 (55.9)	0.463

[a] Includes mixed ethnicities, Indonesians, Pakistanis and Filipinos

[b] Physical activity: low activity=<600 MET-min/week, moderate activity=600-2999 MET-min/week, high activity =≥3000 MET-min/week.

[c] Median and inter-quartile range (IQR) reported for non-normally distributed variable

[d] Mean and standard deviation (SD) reported for normally distributed variable
[!] Student t-test for normally distributed continuous variables, the Wilcoxon rank-sum test for non-normally distributed continuous variables, and the Pearson chi-square test for categorical variables. PSQI, Pittsburgh Sleep Quality Index

Table 2
Crude prevalence of psychological distress by health, lifestyle and work-related factors, N=329

	Baseline	At 3-months follow-up	At 12-months follow-up	p-value[!]
	n (%)	n (%)	n (%)	
Overall prevalence	72 (21.9)	86 (26.1)	72 (21.9)	0.160
Health and lifestyle factors				
Low physical activity	16 (21.9)	32 (33.7)	28 (26.2)	0.218
>=1 comorbidity	32 (25.6)	35 (28.7)	35 (27.1)	0.862
Poor sleep quality (PSQI>=5)	46 (33.3)	56 (39.2)	47 (37.3)	0.587
Work-related factors				
Shift workers	30 (27.0)	31 (27.7)	17 (16.2)	0.085
Workspace location				
Aboveground	50 (22.7)	54 (23.9)	48 (21.5)	0.839
Underground	22 (20.2)	33 (30.8)	24 (22.6)	0.542
Occupation type				
Office staff	36 (22.6)	42 (26.4)	41 (25.8)	0.707
Control room staff	24 (24.5)	26 (26.5)	16 (16.3)	0.194
Workshop staff	12 (16.7)	18 (25.0)	15 (20.8)	0.469
Continuous variables				
Years working at company (median, IQR)	4.0 (2.0-8.5)	4.6 (2.3-9.8)	5 (3.1-7.9)	0.246
Daily working hours (mean ± SD)	8.9 (1.4)	8.9 (1.5)	8.7 (1.2)	0.496

[!] Side-by-side crude comparisons were made to check any trend in psychological distress. Chi-squae test for categorical variables, ANOVA for normally distributed variables, and Kruskal-Wallis H test for non-normal variables. IQR: inter-quartile range; SD, standard deviation; PSQI, Pittsburgh Sleep Quality Index.

3.2. Change in perceived IEQ over time by work location and psychological distress status

Table 3 shows unadjusted mean scores and standard deviation of perceived indoor environment quality (IEQ) stratified by work location and psychological distress status. Mean scores of dissatisfaction with air quality, noise level, and light quality significantly increased ($p<0.05$) over time in aboveground workspaces, while in underground workspaces, only mean scores for dissatisfaction with light quality increased ($p<0.05$) over time. None of the IEQ parameters showed any significant trend among participants with psychological distress. However, mean scores of dissatisfaction with noise level and light quality significantly increased ($p<0.05$) over time among respondents without psychological distress.

Table 3
Unadjusted mean and standard deviation (SD) scores of perceived indoor environment quality (IEQ) stratified by work location and psychological distress status. (N = 329)

	Baseline	At 3-months follow-up	At 12-months follow-up	p-value
Aboveground				
Air quality	3.6(1.3)	3.7(1.4)	3.8(1.3)	**0.028**
Temp comfort	3.5(1.4)	3.5(1.4)	3.6(1.3)	0.356
Noise level	3.5(1.4)	3.6(1.3)	3.8(1.4)	**0.012**
Light quality	3.0(1.2)	3.4(1.3)	3.6(1.2)	**<0.001**
Underground				
Air quality	3.6(1.3)	3.7(1.3)	3.7(1.3)	0.366
Temp comfort	3.2(1.3)	3.5(1.3)	3.3(1.2)	0.086
Noise level	3.2(1.3)	3.4(1.3)	3.3(1.4)	0.596
Light quality	3.1(1.2)	3.4(1.2)	3.6(1.3)	**0.003**
With psychological distress				
Air quality	4.1(1.2)	4.1(1.4)	4.2(1.2)	0.222
Temp comfort	3.7(1.5)	3.9(1.3)	4.0(1.2)	0.322
Noise level	3.9(1.4)	3.8(1.5)	4.2(1.5)	0.055
Light quality	3.4(1.1)	3.7(1.4)	3.8(1.1)	0.395
Without psychological distress				
Air quality	3.5(1.3)	3.5(1.3)	3.6(1.3)	0.331
Temp comfort	3.3(1.3)	3.4(1.4)	3.4(1.3)	0.288
Noise level	3.3(1.4)	3.4(1.3)	3.5(1.4)	**0.040**
Light quality	2.9(1.2)	3.3(1.2)	3.6(1.3)	**<0.001**

3.3. Comparing perceived IEQ by work location and psychological distress status

The means and standard deviations of perceived IEQ values stratified by above and underground workspaces, and by cases and non-case of psychological distress are provided in Table S1 of the supplementary materials. In assessments 1 and 2, there was no difference between workers in above and underground workspaces in terms of perceived IEQ. However, in assessment 3, there was a significant difference in perceived temperature and noise between the groups, with aboveground workers reporting higher (worse) scores on these parameters. Means of perceived IEQ scores of cases of psychological distress were consistently higher (worse) compared to non-cases across each assessment.

3.4. Association between workplace factors and psychological distress

The results from the GEE analysis assessing the association between workplace factors and psychological distress are shown in Table 4. In the multivariate analysis, working underground was not associated with psychological distress after adjusting for potential confounders (aOR: 0.96, 95% CI 0.60-1.52). Longer working hours (aOR: 1.28, 95% CI 1.08-1.51)were associated with a higher odds of psychological distress after adjusting for potential confounders.

Table 4
Unadjusted and adjusted odds ratios (OR) with 95% confidence interval (CI) of psychological distress and work-related factors (N=329)

	Unadjusted OR			Adjusted OR		
Variables	OR	95% CI	p-value	OR	95% CI	p-value
Work location						
Aboveground (ref)	1	--	--	1	--	--
Underground	1.10	0.73 - 1.66	0.649	0.96	0.60 - 1.52	0.750
Occupation type						
Office staff (ref)	1	--	--	1	--	--
Control room staff	0.87	0.55 - 1.37	0.549	0.72	0.35 - 1.48	0.375
Workshop staff	0.79	0.47 - 1.34	0.384	1.10	0.58 - 2.07	0.773
Years working at the company						
Less than 4 years (ref)	1	--	--	1	--	--
4 years or more	1.25	0.89 - 1.75	0.207	1.37	0.91 - 2.06	0.127
Daily working hours	**1.18**	**1.04 - 1.35**	**0.012**	**1.28**	**1.08 - 1.51**	**0.004**
Shift work						
No (ref)	1	--	--	1	--	--
Yes	1.12	0.76 - 1.65	0.584	1.13	0.61 - 2.08	0.699

OR: odds ratio; CI: confidence interval; ref: reference category
Multivariable analysis was adjusted for demographic characteristics (age, gender, educational attainment, ethnicity), health and lifestyle factors (physical activity, comorbidity, sleep quality) and season.

3.5. Association between perceived IEQ and psychological distress

Table 5 presents odds ratios for psychological distress before and after adjustment for potential confounders stratified by workspace location. Adjustments for confounders made little difference in the odds ratios. A 1-unit decrease in perceived air quality (OR: 1.24, 95% CI: 1.09–1.41), temperature comfort (OR: 1.26, 95% CI: 1.10–1.43), noise level (OR: 1.21, 95% CI: 1.09–1.37), and lighting (OR: 1.18, 95% CI: 1.05–1.33) was significantly associated with psychological distress. A significant interaction was observed between the perceived air quality and workplace location. In aboveground workplaces, the estimated prevalence of psychological distress was significantly associated with noise level (OR: 1.24, 95% CI: 1.09–1.43) and temperature comfort (OR: 1.19, 95% CI: 1.02–1.38) in the workplace. However, in underground workplaces, perceived air quality (OR: 1.62, 95% CI: 1.26–2.18); temperature comfort (OR: 1.49, 95% CI: 1.12–1.97); and perceived light quality (OR: 1.37, 95% CI: 1.07–1.77) were significantly associated with the psychological distress.

Table 5
Unadjusted and adjusted odds ratios (OR) with 95% confidence interval (CI) of psychological distress associated with 1-unit decrease in perceived indoor environment quality (IEQ) parameters stratified by workplace location (N=329)

	Variables	Unadjusted OR			Adjusted OR[a]			P-value for interaction[b]
		OR	95% CI	p-value	OR	95% CI	p-value	
AG + UG	Air quality	**1.24**	**1.10-1.40**	**<0.001**	**1.24**	**1.09-1.41**	**0.001**	**0.016**
	Temp comfort	**1.21**	**1.08-1.37**	**0.002**	**1.26**	**1.10-1.43**	**0.001**	0.099
	Noise level	**1.25**	**1.12-1.41**	**<0.001**	**1.21**	**1.09-1.37**	**0.001**	0.858
	Light quality	**1.17**	**1.05-1.30**	**0.005**	**1.18**	**1.05-1.33**	**0.006**	0.306
	Workplace location[c]	1.12	0.75-1.69	0.581	0.96	0.60-1.51	0.858	-------
AG	Air quality	1.13	0.98-1.31	0.104	1.14	0.98-1.33	0.093	-------
	Temp comfort	**1.17**	**1.02-1.34**	**0.029**	**1.19**	**1.02-1.38**	**0.029**	-------
	Noise level	**1.28**	**1.12-1.47**	**<0.001**	**1.24**	**1.09-1.43**	**0.002**	-------
	Light quality	1.13	0.99-1.29	0.057	1.12	0.97-1.28	0.114	-------
UG	Air quality	**1.57**	**1.26-1.95**	**<0.001**	**1.62**	**1.26-2.08**	**<0.001**	-------
	Temp comfort	**1.35**	**1.06-1.72**	**0.016**	**1.49**	**1.12-1.97**	**0.006**	-------
	Noise level	1.24	0.99-1.55	0.057	1.22	0.97-1.55	0.090	-------
	Light quality	**1.22**	**1.00-1.47**	**0.043**	**1.37**	**1.07-1.77**	**0.013**	-------

AG: aboveground workspaces; UG; underground workspaces
[a] Adjusted for demographic characteristics (age, gender, educational attainment, ethnicity), health and lifestyle (physical activity, comorbidity, sleep quality), work factors (work hours in a day, shift work, work type, years at company) and season.
[b] P-value for interaction between workplace location (aboveground and underground) and perceived IEQ scores
[c] AG workplaces as the reference category

3.6. Sensitivity analysis

Results of the sensitivity analyses showed that using the correlation structure of autoregressive in place of exchangeable correlation structure in GEE modeling were similar as the autoregressive correlation structure made little difference in the effect estimates (see Table S2, Supplementary Materials).

4. Discussion

4.1. Main findings and study summary

To our knowledge, this is the first study to estimate and compare the prevalence of psychological distress in aboveground and underground workspaces with repeated measures over time. In addition, this study assessed the association between perceived IEQ parameters and work-related factors with psychological distress over time. Our findings indicate that working in workplaces that are underground was not associated with a higher odds of psychological distress when compared to those in comparable job types in aboveground workplaces. We found a significant association between dissatisfaction with indoor air quality, temperature, noise and lighting in the workplace with psychological distress, after adjusting for a range of potential confounders, including socio-demographic, health, lifestyle and workplace factors. We observed that the association between perceived air quality and psychological distress was modified by workplace location, suggesting that perceived air quality has a stronger effect on psychological distress in underground workers compared to those aboveground. Longer working hours was the only work-related factor associated with psychological distress. The overall prevalence of psychological distress was 21.9%, 26.1%, and 21.9%, at baseline, 3 and 12-month follow-up, respectively. The prevalence rates observed in this study are in line with previous research in the working and general adult population in Singapore, with reported rates ranging from 20.2%-21.7% [35-37].

4.2. Underground and aboveground workers show similar levels of psychological distress

There was no significant difference in the levels of psychological distress between workers in under and aboveground workspaces, which is somewhat surprising given that previous research examining the mental health of individuals working in underground spaces has reported a high prevalence of depressive symptoms and anxiety among this population [15-17, 38]. However, these reports have been limited to the study of miners and train drivers [15-17, 38], and is lacking for other occupations. There is also a lack of studies comparing similar occupations working in above and underground workspaces, thus limiting the interpretations of the impacts of underground workspaces *per se.* In fact, several aboveground spaces lack environmental qualities like direct and indirect sunlight exposure and connection to outdoor spaces (e.g. natural landscapes), which have been shown to be associated with occupational stress, depressed mood and anxiety [39]. Hence, the elements that make underground spaces so particular in terms of impact on physical and mental health are somewhat similar to a vast amount of aboveground workplaces nowadays. This similarity is demonstrated by the lack of difference observed in the under and aboveground workplaces in terms of both the objectively measured light intensity at baseline, and the subjective assessment of workplace lighting across each of the three assessments. Occupants of aboveground workspaces may have been limited in their view and exposure to windows due to the height of their cubicle or seating arrangement, and the occupants also had the possibility to use shutters and blinds which would further restrict views of the outside environment and reduce natural light entering their workspace. Similarities in IEQ parameters may potentially explain why we did not find a difference in levels of psychological distress between the groups. Furthermore, while dissatisfaction with lighting was a predictor of psychological distress in the univariate and multivariate analyses, satisfaction with workplace lighting did not differ between above and underground workers.

4.3. Longer working hours associated with psychological distress

The GEE model indicates that other than the IEQ parameters, experiencing stress at work and longer working hours were also associated with psychological distress. The association between longer working hours and psychological distress is in line with prior research [40-43]. This may be of additional concern in Singapore as the national average working week for a full-time worker in 2019 is 45 hours [44], which is 10 and 5 hours longer per week than the average full-time worker in the US and the EU respectively [45, 46]. The average daily working hours of this sample was 8.6 hours, which is similar to the national average in Singapore [44]. Previous research has highlighted that shift work is usually related to poor mental health outcomes[47], however, this finding was not observed in our sample of workers.

4.4. Perceived IEQ relates to psychological distress in all workspace environments

While previous studies have reported a relationship between IEQ and sleep quality [48], musculoskeletal disorders [49], sick building syndrome [50-52], sensorial symptoms [53] and performance at work [54] this study demonstrated that perceived IEQ parameters, namely air quality, thermal comfort, noise and lighting in the workplace were associated with psychological distress. While air quality has long been known to impact our physical health, its effect on our mental health has only recently come to fore [55-57]. A recent exploratory study using a dataset with more than 150 million individuals from the US and Denmark reported a significant association between air pollution exposure and the risk of neuropsychiatric disorders [55]. The literature on workplace thermal comfort and psychological distress is limited. However, a correlation between greater thermal comfort and lower levels of anxiety has been reported in a study among nurses [58]. In line with other workplace studies, our study found an association between dissatisfaction with workplace noise and psychological distress [59, 60]. A population-based study in Germany involving 15,010 participants reported that noise annoyance was associated with an increased prevalence of depression and anxiety [59], while a workplace study involving 2,368 blue-collar workers similarly reported that noise exposure and noise annoyance was associated with psychological distress [60]. In terms of the association between IEQ parameters and mental health, the most well studied and understood relationship is that between light and mental health. This relationship is based in neural networks that translate retinal light stimuli into neural and hormonal outputs in a biological system that coordinates physiological and behavioral rhythms [61, 62]. It is now known that alterations in normal biological rhythms via unusual light signals (lack of natural sunlight during daytime and exposure to light pollution at night) have significant impacts not only for seasonal affective disorder [63], but also for unipolar depression and other mood affections [64-66]. A field study with office employees during winter reported that repeated bright-light exposure improved vitality and reduced depressive symptoms in non-depressive workers. The effects were similar for individuals with and without seasonal variation of depressive symptomatology [67].

Strengths, limitations and potential implications

This study has a number of strengths. First, the study included a relatively large sample size for a workplace cohort study. Secondly, we included employees from offices, workshops, and control rooms, thus advancing the generalisability of findings to occupational groups sharing similar work environments. Thirdly, we accounted for a large number of confounders in the analysis. Nonetheless, limitations of the study need to be considered too. Firstly, there was a 28% loss to follow-up at 12 months, however, attrition is a common issue in workplace studies. The loss to follow-up in this study was mainly due to staff turnover and a lack of time owing to work commitments or work shifts. Comparable rates of attrition have been observed in other workplace studies with repeated measures in Asia [68-71]. Secondly, the study still has the limitation of a cross-sectional study that cannot confirm causation, furthermore, we cannot delineate whether sub-standard environmental parameters caused psychological distress or whether being a worker experiencing psychological distress led to more negative perceptions about the environmental parameters in the workplace. However, this study provides good evidence for future experimental studies. Thirdly, we collected self-reported data which is subject to reporting bias, though most of the questionnaires have been validated and been extensively used in epidemiological studies. Lastly, due to logistical issues, we were unable to conduct objective environmental measures at each timepoint, and thus are unaware of how the environmental parameters within the workplaces may have changed over time.

In this study, worse perceived IEQ parameters were associated with psychological distress reinforcing the importance to consider all IEQ parameters that may potentially influence an individual's mental health. Future studies should objectively measure these environmental signals to better elucidate the relationships between IEQ and psychological distress, and do so in a longitudinal manner. We highlight the need for an integrative approach to workplace design which should include engineers, architects, psychologists and health professionals in the development of health-promoting workplaces which take a holistic approach to designing the workplace environment.

Conclusion

There was no difference in psychological distress between individuals working in above and underground workspaces. However, the prevalence of psychological distress in this sample of workers remained high and consistent over a 12-month period. A decrease in perceived indoor air quality, temperature, noise and lighting in the workplace was associated with a higher odds of psychological distress. In underground workplaces, a decrease in perceived indoor air quality, temperature comfort, and satisfaction with lighting was associated with a higher odds of psychological distress, while in aboveground workplaces noise dissatisfaction and temperature discomfort were associated with a higher odds of psychological distress. As worse perceived IEQ was associated with psychological distress, healthy building policies that improve IEQ may lead to a lower prevalence of psychological distress among workers. Future studies are needed to examine the relationship between objective measures of IEQ and psychological distress and the impact of healthy building policies and improved IEQ on psychological distress.

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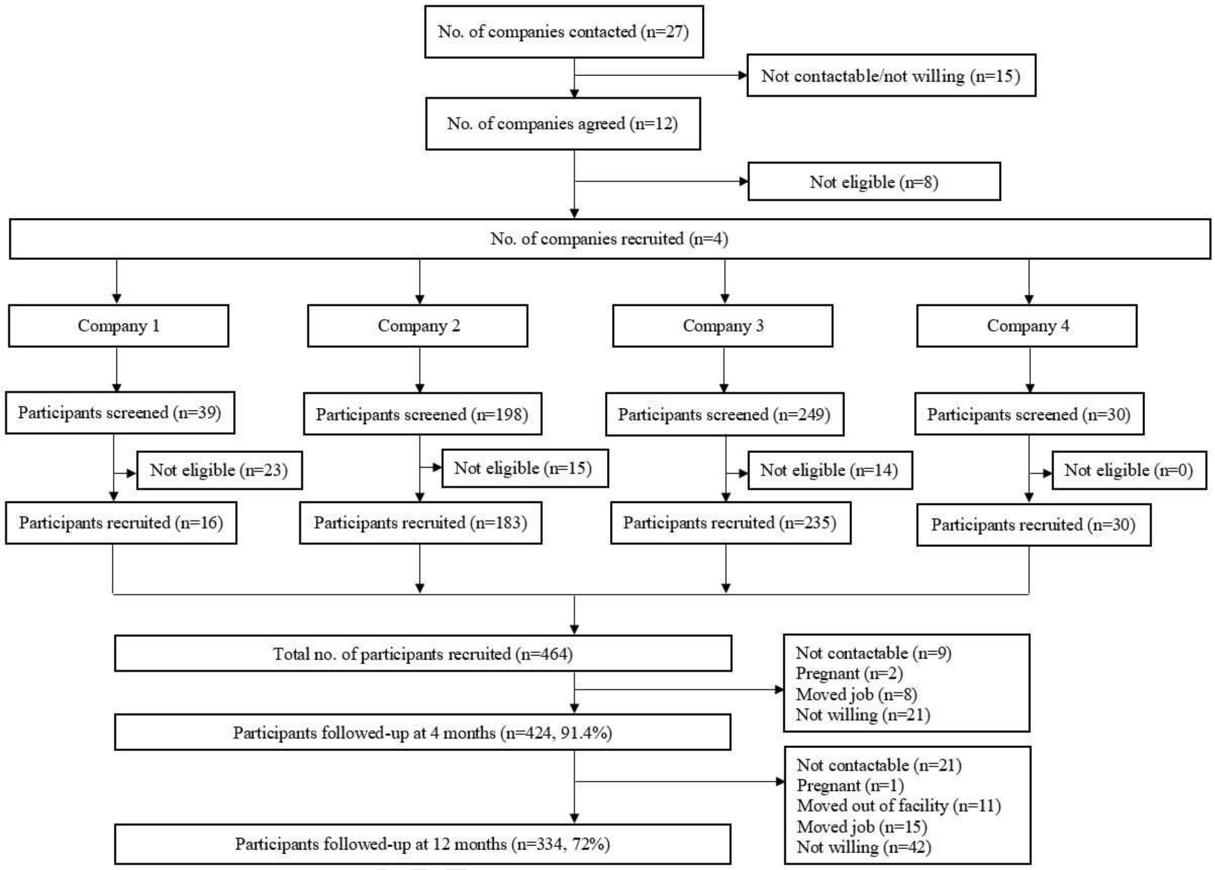

Fig. 1. Participant enrolment and follow-up flowchart.

Highlights

- There was no association between working underground and psychological distress
- Perceived IEQ in the workplace was associated with psychological distress
- Stress at work and longer working hours were associated with psychological distress

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: