

Do underground workspaces impact workers health?

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Impact statement

Urbanisation has increased dramatically in the last century, with no signs of this trend fading. By 2050, two-thirds of the world's population is expected to live in cities. The development of underground spaces for everyday urban functions is seen as a strategic effort towards more sustainable urbanisation. Singapore, a densely populated city-state in South-East Asia, is one such country that wants to maximise its use of underground space to free up surface land for people-centric uses. The Draft Master Plan by the Urban Redevelopment Authority in Singapore is considering developing underground spaces for transport, storage, pedestrian links, shopping malls, workspaces and industrial facilities, underground in Singapore. As these proposed developments would lead to people spending increased amounts of time in underground environments, especially for those working in underground workspaces, this dissertation aimed to understand the potential negative health effects of working in underground workspaces in Singapore. Our research could serve as a case to raise awareness of workplace health in Singapore, for those working in under and aboveground workspaces. Based on our studies, an overview is provided regarding the relevance for society, policymakers, and researchers. In addition, a description of the dissemination of research findings is provided.

Relevance for policymakers and society

As governments and policymakers in land-scarce cities seek sustainable solutions to efficiently use land resources, the development of underground space is increasingly viewed as an important component of such efforts. In this dissertation, we explored if working in underground spaces was associated with negative impacts on health-related quality of life, psychological distress, 'perceived sleep quality' and 'sleep efficiency', when compared with workers in comparable job types and work environments in aboveground workspaces. The key findings from this dissertation are that our studies revealed no differences in the health parameters studied between workers in under and aboveground workspaces. While the lack of difference in the studied health parameters is a positive finding for policymakers considering expanding their cities use of underground workspaces, the studies revealed high levels of psychological distress, poor sleep quality, and burden of NCD risk factors, regardless of working in under or aboveground workspaces.

According to the studies presented in this dissertation, working in underground workspaces may not negatively impact health but indoor environmental quality needs to be

improved in all workspaces. Dissatisfaction with environmental parameters in the workspace was associated with psychological distress and worse 'perceived sleep quality', revealing the important role that indoor environmental parameters have on health. Occupational assessments should monitor indoor environmental parameters, both subjectively and objectively, in order to identify environmental issues and promote worker's health. Workplace design should include engineers, architects, and health professionals in the development of health-promoting workplaces which take a holistic approach to designing the workplace environment.

This dissertation provides insights into the poor sleep health of workers in Singapore. High levels of poor sleep quality were consistently reported over three timepoints, while worker's daily sleep duration was less than six hours. We also revealed that worker's sleep was associated with their health-related quality of life. These findings suggest the need for workplace policies that address sleep impairment and promote sleep health. Collaboration between employers, policymakers and Singapore's Health Promotion Board is needed to develop and implement sleep-related workplace interventions such as educational programs on sleep hygiene and fatigue management.

Relevance for future research

In this dissertation, we explored whether some potential negative health effects were associated with working in underground workspaces, additionally, we examined the factor structure of a subjective assessment of sleep, the association between sleep and health-related quality of life, and examined what workplace factors were associated with psychological distress, 'perceived sleep quality' and 'sleep efficiency'. For each part of the thesis, we will briefly look into the relevance for future research.

In the first part of the thesis, we provided the rationale for the cohort study's creation, detailed information on the study methods used, and a comparison of baseline characteristics of participants in the cohort study. This part of the thesis is valuable for future research as it provides researchers with additional insight and detailed study methods that often can't be fully described in research papers. Cohort profile papers, such as the paper in the first part of the dissertation, are also a useful means of informing the field of your efforts, and a way to generate collaborations with researchers studying the impact of underground spaces on health. This part of the thesis also reports that lighting levels were similar in under and aboveground workspaces, which may seem somewhat counterintuitive but lighting levels in both under and aboveground workspaces were much lower than the recommended levels for workspaces in Singapore. Investigators need to develop on this research with interventional studies that can

control or manipulate the lighting levels in workspaces, to get a greater understanding of its impact on worker's health. Finally, in this part of the thesis, we demonstrated the significantly higher prevalence of overweight and obesity by using a Body Mass Index (BMI) cut-off point of ≥ 23 , which is recommended for use in Asian populations, to define participants as overweight or obese, when compared to the BMI cut-off point of ≥ 25 , which is most commonly used. We suggest that future research in Singapore should use the BMI cut-off point that has been previously recommended for the local population, in order to more accurately inform and trigger policy action.

In the second part of the thesis, we examined whether working underground was associated with health-related quality of life, the relationship between sleep and health-related quality of life, and the factor structure of the Pittsburgh Sleep Quality Index (PSQI). We demonstrated that working underground was not associated with workers' health-related quality of life. Previous research has reported a relationship between sleep and health-related quality of life, which this part of the thesis built upon by demonstrating this relationship, for the first time, among a working population in Singapore. Considering their relationship, sleep hygiene education in workplaces in Singapore has the potential to improve both the quality and quantity of worker's sleep and may also help improve worker's health-related quality of life. Therefore, future research should examine the effects of sleep health interventions in workspaces in Singapore, and do so in a longitudinal manner. Additionally, in a longitudinal design, future researchers may be better able to understand the bidirectional relationship between sleep and health-related quality of life.

The second part of this thesis also examines the factor structure of the PSQI. We demonstrate that the sleep assessment tool is composed of two factors (perceived sleep quality and sleep efficiency) in a working population in Singapore. This is highly relevant for future sleep research among working populations in Singapore, as we demonstrate that the two-factor model of the PSQI may be a more adequate means to evaluate sleep quality in working populations in Singapore over the single-factor model. Such an approach may better identify workers experiencing sleep impairment that would otherwise go undetected with the unidimensional use of the PSQI and pure dichotomization of the scale into "good" and "poor" sleepers. By considering distinct dimensional structures of sleep quality, future clinical studies are more likely to uncover individualized protocols for the management of sleep problems.

In the third part of this thesis, we demonstrated that working in underground workspaces was not associated with psychological distress, 'perceived sleep quality' or 'sleep efficiency'. Considering that the light levels did not differ between under and aboveground

workspaces, this may have resulted in the lack of difference in the health parameters studied in this dissertation. Future research should examine more optimally lit work environments, both under and aboveground to further develop our understanding of the potential health effects of underground workspaces. Also, to develop more concrete findings, research on the effects of underground spaces should be conducted over a longer period as it's possible that any negative effects may need a longer time period to develop.

We demonstrated that there was a relationship between subjectively assessed light quality, with both, psychological distress and 'perceived sleep quality'. Future research should build upon this by examining the role of workplace lighting on workers' sleep quality and psychological health. This research should entail both objective and subjective assessment of workplace lighting, and objective measures of lighting should include multiple aspects of lighting, including colour, spectrum, timing and duration of exposure, and how each may impact worker's health. Not only light, but also air quality, noise and thermal comfort were associated with psychological distress, highlighting the importance to consider how a broad range of indoor environmental parameters may potentially influence worker's mental health. Future research should objectively measure these environmental signals to better unravel the relationships between indoor environmental parameters and psychological distress, and do so in a longitudinal manner.

Dissemination

To optimise knowledge utilisation and social impact, study findings have been and will be published in international peer-reviewed journals (e.g. *Epidemiology and Health*, *International Journal of Environmental Research and Public Health*, and *Building and Environment*). Four of the five studies included in this thesis have been published, one manuscript is currently under review. Next to that, study findings were disseminated via oral and poster presentations at relevant national and international conferences (e.g. *Future Health*, and the 32nd Annual Conference of the European Health Psychology Society). Lastly, the findings from this study were reported to the members of the Ministry for National Development in Singapore as well as the senior management of the companies enrolled in the study.