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FUNGAL CONTAMINATION, ERGONOMIC ASSESSMENT AND TEMPERATURE COMFORT AT NURSING HOMES

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ABSTRACT

Objective: The caregivers and the elderly in the nursing homes may be exposed to various health risk from their surroundings. This study assessed fungal contamination, musculoskeletal disorders (MSDs) and thermal comfort in the nursing homes in Bangi, Selangor, Malaysia.

Method: A total of 10 nursing homes were involved in the study and the parameters for assessment were selected to address the issues raised by the occupants. Indoor air quality monitor was used to measure temperature and carbon dioxide (CO_2) and open plate method were used to determine the average total colony count of fungi. Thermal comfort through temperature, relative humidity and air velocity were measured. The risk level and prevalence of MSDs among a number of 33 caregivers was obtained using Rapid Entire Body Assessment (REBA) and standardized Nordic questionnaire.

Result: Fungal contamination assessment found that the average total colony count of fungi isolated at the two nursing homes was 488.38 ppm and 470.67 ppm respectively with three genera of fungi identified; Aspergillus sp., Cladosporium sp. and Penicillium sp. There was significant association between temperature and CO_2 with fungal growth. The results of ergonomics assessment of MSDs shows the prevalence of MSDs was high at lower back (66.7%) and shoulder (60.6%) with the risk factors from lifting, carrying, pulling and repositioning of the elderly. REBA assessment conducted on caregivers found that 51.52% caregivers were exposed to high risk, 30.30% of them were at medium risk and 18.18% of them exposed to very high risk of developing MSDs. As for thermal comfort, temperature, relative humidity and air flow rate measurements did not comply with the standard of ASHRAE 55.

Conclusion: On-site monitoring and survey conducted were able to provide baseline to improve the health and welfare of the occupants of the nursing homes.

Keywords: *Indoor air quality, musculoskeletal disorders, thermal comfort, caregivers*

1. Introduction

Nursing homes are occupied by the elderly and caregivers at all times and they are exposed to multiple health hazards. Depending on the age and condition of the building, the indoor air quality may affect the thermal comfort of the occupants (Al horr et al, 2016; Cao et al, 2021). Poor indoor air quality may create health hazard such as fungal contamination and may cause allergy and infection. The condition of the indoor environment with other features such as poor maintenance, improper house structure or activities by inhabitants cause “Sick Building Syndrome” (SBS) where the occupants may experience unhealthy condition

resulting from time spent inside the building (Zhang et al, 2021).

Apart from that, the caregivers were also exposed to ergonomic factors. Long exposure to ergonomics factors lead to the development of musculoskeletal disorders (MSDs) around the susceptible body parts such as neck, shoulder, hand/wrist, back area, knee and ankle. Manual handling of patients such as lifting and moving patient are the contributory factors to developing MSDs (Chung et al., 2013; Sharan et al., 2012). Shoulder pain, backache, knee pain and joint strains are commonly reported among full-time caregivers because they had to deal with manual handling and physical force on daily basis (Iridiastadi et al, 2016).

Thermal comfort refers to a building's comfortable temperature for its occupants (Djamila, Chu, & Kumaresan, 2013). Due to loss of their thermoregulatory regulation, an aged population of around 65 years and older is at a greater risk of being impacted by thermal stress (Guergiva, 2011; Millyard et al, 2021). Susceptible group like the elderly may experience heat stress and heat strain, which can cause mild condition like rash or cramps to potentially life-threatening condition like heat-stroke. This study would like to assess these common concerns in the environment of the nursing homes to improve the health, safety and welfare of all the residents and the caregivers.

2. Materials and Method

A total of 10 nursing homes were involved in this study. Two nursing homes were experiencing fungal problems and were further assessed with fungal contamination. As for musculoskeletal disorder, the participants were the caregivers from all ten nursing homes where they handle and assist the elderly everyday. Three nursing homes were assessed for thermal comfort due to discomfort complaints among the occupants. This study had received UiTM ethics approval (Ref no: REC/309/17).

2.1 Assessment of Fungal Contamination

The methods used for fungal assessment were the enumeration of fungal growth on Potato Dextrose Agar (PDA) and walkthrough inspection. PDA was prepared before sampling. The bacterial growth is inhibit using PDA to allow fungi colony emerge after incubation (Ramos & Stephens, 2014). The agar was prepared by added 39 g of PDA powder into 1 liter of distilled water. The solution was stirred using the hot plate prior to heated by microwave for three minutes until all powder were dissolved. The heating process was repeated for three times. The solution was autoclaved for three hours at 121^{o}C before it being transferred into petri dish.

Sampling was made at two nursing homes (labeled as A and B). The viable indoor airborne fungi samples were collected using an open plate method. Plates were placed at five different points depending on the total floor area of the nursing homes (DOSH, 2010).

Sampling points were the bedroom, the bathroom, the kitchen, the living room, and the elderly resting area. Each plate was placed for 20 minutes and the plates were then kept immediately in a cool box. Meanwhile, indoor air quality monitoring was measured through the level of carbon dioxide, relative humidity and temperature in the same sampling areas at the nursing homes using Q-Track Indoor Air Quality Monitor. All petri dish filled with PDA were incubated inside a laboratory refrigerator at 22^{o}C for 3 to 5 days for fungal colony to grow before being enumerated.

2.2 Assessment of Musculoskeletal Disorders among Caregivers

A number of ten nursing care homes were selected for assessment with a total number of 33 caregivers as participants. The caregivers had at least one year of working experience and had no current injuries. Interview session, observation and recording, and evaluation of whole body postures took place with the participants. A brief survey was conducted for all caregivers to obtain their demographic information, risk factors and to record the prevalence of MSDs among them.

There were two tools used along the interview session which were the self-constructed questionnaire and standardized Nordic questionnaire. Standardized Nordic questionnaire was used to record prevalence rate of MSDs. The tasks of each caregiver were observed to provide scores of their body postures. REBA worksheet was used as a tool for evaluating whole body postures. Final score of REBA assessment was used to determine the level of risk of MSDs for each caregiver.

2.3 Assessment of Thermal Comfort

Three nursing homes were selected based on the micro climate area and complaints regarding the thermal comfort of the buildings. The data collection procedures involved for this assessment were observation, interview session and measurement of indoor thermal variables. Data for the building characteristic was gathered through the walk-through survey.

The observation were made on age of the building, type of building construction and ventilation system. Thermal comfort questionnaire survey was carried out by face-to-face interview. Meanwhile, indoor thermal variables were measured accordance to American Society of Heating, Refrigerating and Air- Conditioning Engineers (ASHRAE) 55 Standard including temperature (Ta=ambient temperature; Tg=glass transition temperature), relative humidity and air velocity.

The sampling points were located more than 1 meter from the walls, windows, doors and any heating system available in the building. The equipment used to measure thermal parameters was Wet- bulb Globe Temperature (WBGT) and anemometer to measure air velocity.

2.4. Data Analysis

Fungal identification analysis on colony growth was used to identify the common indoor fungi in nursing homes. Statistical Package for the Social Sciences (SPSS) software version 22 was used to find the statistical significant of all variables. The mean difference between indoor air quality parameter with total fungi count was analysed by the Mean-difference test. Pearson correlation test was applied to determine the relationship between indoor air quality parameters and total fungi count.

Chi-square test was used to determine the significant difference between tasks of caregivers with the prevalence of MSDs. REBA worksheet was used to determine the level of risk of MSDs. Meanwhile, paired T-test was used to compare the air quality data of the rooms in the nursing homes.

3. Results and discussion

3.1 Identification of Fungal Species

At nursing home A, the bedrooms were identified with 439 colonies (Penicillium sp, Aspergillus sp.), living room with 39 colonies (Penicillium sp. and Aspergillus sp.), toilets with 345 colonies (Penicillium sp., Aspergillus sp., and Cladosporium sp.), office area with 12 colonies (Penicillium sp., and Cladosporium sp.) and kitchen area with 15 colonies (Penicillium sp. and Cladosporium sp.). The total colony count of fungi at nursing home A was 835 cfu/m^3. As for nursing home B, the bedrooms were identified with 402 colonies (Penicillium sp, Aspergillus sp.), living room with 50 colonies (Penicillium sp., and Cladosporium sp.), toilets with 397 colonies (Penicillium sp., Aspergillus sp., and Cladosporium sp.), office and kitchen both with 34 colonies (Penicillium sp.) in each area. The total colony count of fungi identified at nursing home B was 917 cfu/m^3.

The high number of colonies in toilets was largely attributed to the humidity inside the area, which promotes fungal growth especially Penicillium, Aspergillus and Cladosporium species. At both nursing homes, the toilets were attached to the bedrooms. Spores from this particular mold produce mycotoxins that are toxic to humans if inhaled, eaten, or touched. Many activities took place in bedrooms including resting, praying and sleeping that could pose health risk condition such as hypersensitivity, pneumonitis, rhinitis and allergic fungal sinusitis (Rajasekar & Balasubramaniam, 2011).

3.2 Analysis of Indoor Air Quality

Figure 1 shows the temperature readings taken at the two nursing homes. The temperature readings were taken during the mid-day where the daytime temperatures is normally the highest. This is probably related to the problems with environmental conditions either inside or outside the buildings (Cao et al, 2021; Zhang et al, 2021).

The climatic factor of high temperatures and humidity and heavy rainfall in South East Asia countries also play its role for relatively higher indoor temperature. Ventilation brings in fresh air from outside and distributes the air throughout the structure. Building ventilation's goal is to provide healthy air for breathing by diluting pollutants in

the building with clean air and providing a set airflow rate to change the air at a set rate. Ventilation is also utilised to regulate odours, confinement, and temperature. Possible exposure toward contaminants and hygienic and cleanliness condi-tion of buildings are heightened with inadequate ventilation (Bentayeb et al, 2015).

Figure 2 shows the concentrations of carbon dioxide in the two nursing homes taken from 11.00 am until 12.24 pm with the interval of 2 minutes. Measurement of carbon dioxide in both building shows that the concentration of carbon dioxide at nursing home A and B were safe for the occupants.

Although low concentrations and short exposure durations of CO_2 do not pose a serious health risk, but this indicate a low ventilation level and possible air contamination with other pollutants (Pathirana et al, 2017). If the concentration of CO_2 violates the acceptable limit, eye and throat irritation, fatigue and headaches can occur. Therefore, ventilation system of the buildings need to be evaluated and changes to the structure should be made if required (Avaltroni et al, 2015).

3.3 Indoor Air Quality Parameters and Total Colony Count of Fungi

In this study, correlation test was used to analyse the relationship between temperature and total colony count of fungi, and relationship between carbon dioxide and total colony count of fungi in both nursing homes (Table 1).

There is weak significant correlation between temperature and total colony count of fungi in nursing home A. This indicate changes in temperature in the building not affecting the growth of the fungi. There was positive correlation between carbon dioxide and the colony count. This highlight carbon dioxide level may influence the fungal growth (p=0.02).

There was a negative correlation between temperature and fungal growth in nursing home B which indicate that increase in temperature will reduce the growth of fungi. However, the relationship is not significant at the p is more than 0.05 (p=0.60). Positive correlation was found between carbon dioxide level and the total colony count of fungi but the relationship was not statistically significant (p=0.68).

This study concurs with the review by Hiwar et al, 2021 in hospital environment that total fungi were not significantly correlated with temperature, relative humidity or CO_2 level. Future study should look at the coupled mechanisms that underpin the Indoor Air Quality parameters that govern microbe dispersion, survival, and deposition in real-world settings.

Table 1. Correlation test of temperature and carbon dioxide towards total colony count of fungi

Variables	Nursing home A		Nursing home B	
	Correlation Coefficient (r)	p-value	Correlation Coefficient (r)	p-value
Total colony count	835 CFU/m^3		917 cfu/m^3	
Temperature (^{0}C)	0.275	0.06	-0.080	0.60
CO_2 (ppm)	0.341	0.02*	0.063	0.68

*significant at p-value 0.05

3.4. Prevalence of Musculoskeletal Disorders (MSDs)

Figure 3 shows the prevalence of MSDs among the caregivers at the nursing homes. The prevalence of MSDs was highest for lower back (69.7 %) and shoulder (60.6%). Force is applied on shoulders that are used for lifting and lower back pain is felt owed to the effect of the loads forced on the muscle and joints during lifting and upsetting the backbone curve and spine (Kulkarni & Darsana, 2013).

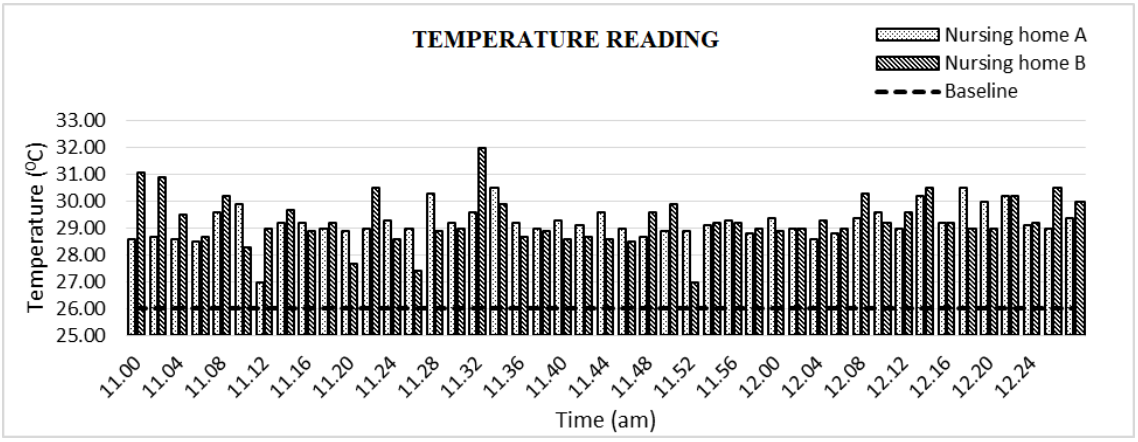

Figure 1. Temperature level at nursing home A and B

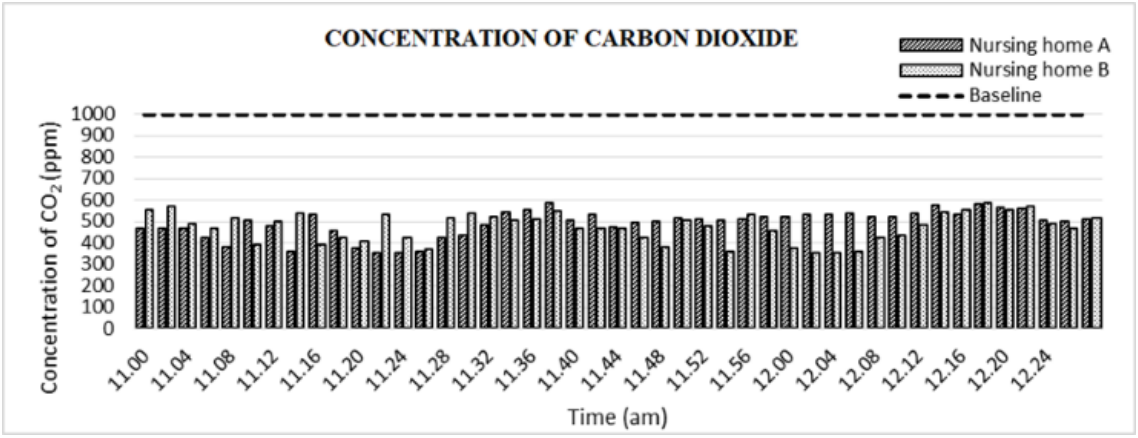

Figure 2. Concentration of carbon dioxide (CO_2) in nursing homes

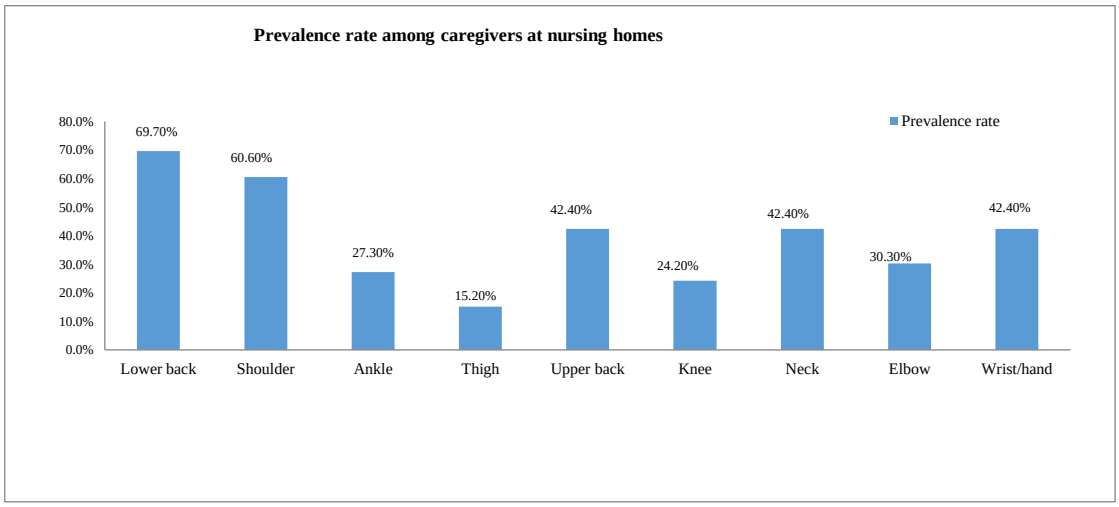

Figure 3: Prevalence rate of caregivers at nursing care homes

Meanwhile, the lowest prevalence of MSDs is at the thigh (15.2%) due to lesser use of the muscle and less force applied at the area. The availability of lifting devices used such as lifting beds can reduce the force and use of energy at certain muscles (Koppelaar et al., 2011). Safe work practice performed during handling of the elderly also influenced the prevalence rate between body parts (Rutkowski & Velez, 2016).

3.5. Job Risk Factors of the MSDs

Table 2 shows the statistical difference between risk factors of MSDs at workplace and prevalence of MSDs among caregivers. Most of the risk factors show significant association with prevalence at difference body parts. Chi-square test proved that workplace, working experience, tasks like carrying, pulling and repositioning has significant difference with lower back, ankle, upper back, neck, elbow and wrist or hand.

According to Li et al. (2004), the availability of lifting devices with limited manoeuvrable space became a barrier for any caregivers who wanted to execute the activity with lifting devices, which can cause discomfort to the body and indirectly influence the prevalence rate among workers. The purpose of the REBA assessment was to show that lifting is one of the contributing variables to MSD development.

3.6. Evaluation of Whole Body Postures by using REBA Worksheet

REBA assessment was conducted to assess the awkward postures of the most difficult task reported by caregivers (Table 3). Most of the caregivers (51.52%) were at “high risk” because the posture scores were within 8-10 scores with another 18.18% of the caregivers were at “very high risk” and the rest were with “medium risk”.

The findings were similar with a study by Mahdavi et al. (2013) where the majority of the caregivers were exposed to high risk of MSDs. These results explained that further investigation and change of body postures needs to be implemented. Otherwise, caregivers may experience torn ligaments, muscle strains and other soft tissues problem especially on shoulder area due to awkward postures for long period (Sharan et al., 2012).

3.7. Assessment of Thermal Comfort

Nursing home A have been operated for seven years, while nursing home B has been in operation for eight years. Both nursing homes are semi-detached single-storey houses. There are 10 bedrooms and one living room in nursing home A, while 7 bedrooms with one living room in nursing home B. All the windows at nursing home A was casement window type with tinted and sliding doors.

The nursing home B had a window with fixed glass blades and single wooden door. Mechanical ventilation system was used in both nursing homes. The air-conditioning (AC) was used in all bedrooms while living rooms were only equiped with ceiling fans and natural ventilations. At nursing home B, three bedrooms were installed with AC and the rest were using ceiling fans. The AC were normally turned on during the mid-day when it is the hottest and at night before the occupants went to bed for 2-3 hours.

The questionnaire was used to obtain data for symptoms of illness due to thermal comfort in both nursing homes. They were asked about health symptoms experienced and shown in Figure 4. Symptoms of illness experienced by the elderly were cough (25.0%) followed by skin rash (22.8%), and dry mouth (21.4%). The elderly in both nursing homes had symptoms of illness due to the uncomfortable environment and surrounding. When their thermal environment was hotter or colder than usual, they claimed to feel ill. According to Mendes et al. (2013) and Hoof et al. (2010), the elderly's quality of life is influenced by their thermal environment because they have low body thermoregulation, which makes it difficult for their bodies to adapt to the temperature of their surroundings.

Table 4 and Table 5 shows the average reading for air temperature (Ta), globe temperature (Tg), relative humidity (RH) and air flow indoor thermal environment over a duration of 9 hours. The data collection for indoor thermal variables were from the living rooms and the bedrooms. The temperatures in the living room and the bedroom of nursing home A ($p<0.05$) was significantly difference (Table 4).

Table 2. Risk factors associated with the prevalence of MSDs at the workplace

Risk Factor	P-value								
	Lower back	Shoulder	Ankle	Thigh	Upper back	Knee	Neck	Elbow	Wrist/hand
Working experience	0.031*	0.714	0.174	0.861	0.161	0.167	0.631	0.196	0.007*
Lifting	0.397	0.999	0.642	0.999	0.670	0.999	0.999	0.646	0.999
Carrying	0.999	0.999	0.394	0.999	0.047*	0.366	0.416	0.673	0.238
Pulling	0.433	0.999	0.690	0.133	0.033*	0.999	0.160	0.433	0.716
Reposition	0.461	0.999	0.263	0.625	0.472	0.431	0.015*	0.050*	0.999

*significant at p-value 0.05

Table 3. REBA score of difficult tasks performed by caregivers

Job risk factors	REBA score					
	1 (negligible risk)	2-3 (low risk)	4-7 (medium risk)	8-10 (high risk)	>11 (very high risk)	Total (n=33)
Lifting	-	-	6	13	3	22
Carrying	-	-	2	4	1	7
Repositioning	-	-	2	-	2	4
Total (n=33)	-	-	10	17	6	33
Percentage of caregiver (%)	0	0	30.30	51.52	18.18	100

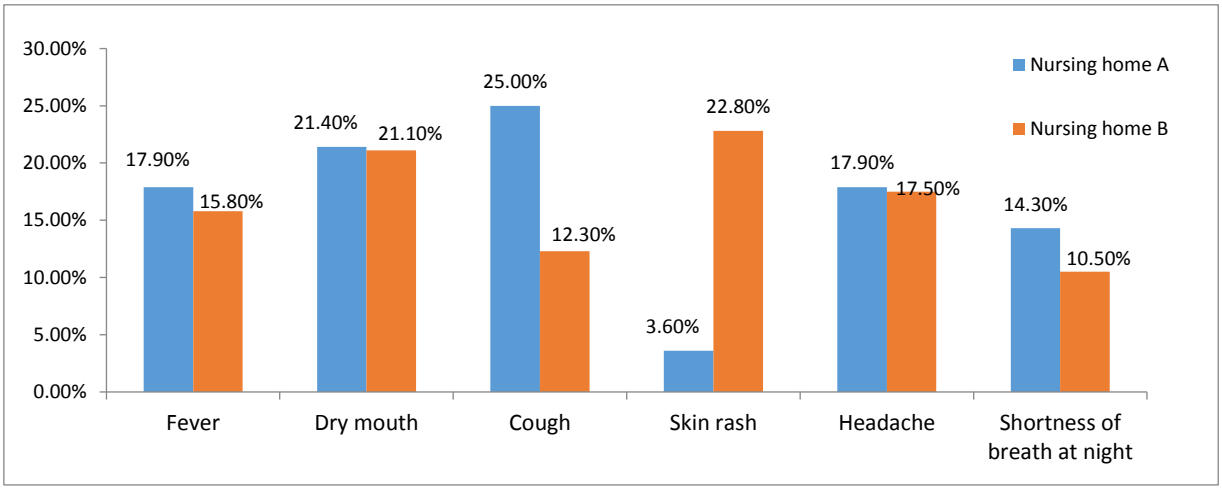

Figure 4. The health effects of poor thermal comfort

Table 4. Distribution of indoor thermal variable at nursing home A

Parameter	Sampling points		Std. Deviation	Std. Error Mean	Sig. (2-tailed)
	Living room	Bedroom			
Ta (°C)	29.8	29.3	0.211	0.0486	0.000*
Tg (°C)	29.7	29.2	0.833	0.191	0.016*
RH (%)	74.9	75.4	1.073	0.246	0.070
Air flow (m/s)	0.25	0.25	0.0577	0.0132	1.000

Table 5. Distribution of indoor thermal variable at nursing home B

Parameter	Sampling points		Std. Deviation	Std. Error	Sig. (2-tailed)
	Living room	Bedroom		Mean	
Ta (°C)	30.7	30.1	0.112	0.025	0.000*
Tg (°C)	30.6	30.0	0.291	0.066	0.000*
RH (%)	75.4	76.3	1.100	0.252	0.002*
Air flow (m/s)	0.27	0.26	0.031	0.007	0.163

Mendes et al. (2013) concurs with this finding that there was a significant difference for different type of rooms at nursing homes. In Table 5, there was also significant different between the temperatures in living room and bedroom of nursing home B ($p<0.05$).

Readings for indoor thermal variables at both nursing homes did not comply with standard of ASHRAE 55 which exceeded the limit range (19-28oC). The indoor thermal environment at both nursing homes was influenced by the factors environment surrounding. The nursing home A was located away from busy roads and had its own microclimate consisting of green space. The nursing home B was located by the busy roadside especially during the time people commutes to work (8.00 am to 10.00 am) and (4.30 pm to 8.00 pm). These local factors may also contribute to the occurences of symptoms of illness.

If at least 80% of the inhabitants are unlikely to object to the ambient state, the comfort zone is considered adequate, implying that the majority are between -0.5 and 0.5 on the comfort scale (ASHRAE 55, 2004). The range of indoor air temperature changes can be decreased to lessen discomfort and agitation in the elderly, and aged care providers should ensure that nursing homes have a thermally appropriate atmosphere to improve the comfort and well-being of all occupants (Tartarini et al, 2017).

5. Conclusion

The assessment of fungal contamination, thermal comfort and ergonomics show that the occupants of nursing homes were exposed to potential health risk. It can be concluded that the common species of fungi presence at nursing homes are Penicillium sp., Aspergillus sp., and Cladosporium sp. The growth of fungi was due to the favourable temper-ature and adequacy of CO_2 at these nursing homes.

The study also indicated that the prevalence rate of MSDs among caregivers is high especially for lower back pain and shoulder area. The contribution factors were lifting, carrying, pulling and repositioning of the elderly. REBA assessment also shows the relationship between the job risk factors with the prevalence of MSDs where majority of the caregivers were exposed to high risk and very high risk of MSDs. Apart from that, the occupants of nursing homes were exposed to poor thermal comfort since the findings stated the violation of temperature, relative humidity and air velocity with ASHRAE 55 standard. The situation may lead to

health problems such as fever, dry mouth, cough, skin rash, headache and shortness of breath at night. Therefore, hy-giene and safe work practice are recommended to overcome and reduce the implications of fungi growth and the ergonomics issues in the nursing homes for the health and welfare of the both the elderly and the caregivers.

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Conflicts of Interest

The author declares no conflict of interest.

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