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Indoor air quality and thermal comfort in elderly care centers

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ABSTRACT

This study explored environmental variables and buildings characteristics in 22 elderly care centers (ECCs) in Portugal. Indoor environmental parameters were measured twice for a total of 141 sampling sites. Each site was assessed for PM_{10}, $PM_{2.5}$, total volatile organic compounds (TVOC), formaldehyde, CO, CO_2, total bacteria and fungi. Thermal comfort (TC) parameters were measured according to ISO 7730:2005 and a building characterization was performed. The overall $PM_{2.5}$ mean concentration of the 22 ECC was above international reference levels in summer and winter seasons. TVOC, bacteria, CO and CO_2 showed significantly higher indoor levels compared to outdoor, in both seasons. Indoor PM_{10}, TVOC, bacteria and CO_2 present significant differences between seasons. TVOC, bacteria and CO_2 show significant variation between ECC rooms and 4% of fungi samples were positive for pathogenic *Aspergillus species*. The winter predicted mean vote (PMV) index showed a 'slightly cool' thermal sensation scale which may potentiate respiratory tract infections. The predicted percent of dissatisfied people (PPD) and PMV indices show significant differences by season. The building variables 'Insulation', 'Heating Ventilation' and 'Windows frames' were significantly associated to chemical, biological and TC parameters. 'Bacteria', 'Fungi', 'Temperature', Relative Humidity', and 'PPD index' are the mostly affected by building characteristics. Insulating ceilings, walls, and

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windows could improve winter season TC, providing health benefits to ECC residents.

1. Introduction

According to the United Nations estimates, the total number of people aged 65 years and older was 506 million in 2008 and is anticipated to double to 1.3 billion by 2040, accounting for the 14 percent of total global population. By 2050, Europe will continue to be the world's oldest region with its elder population increasing more than fivefold from 40 million to 219 million (Bentayeb et al., 2013). These demographic changes result in new patterns of morbidity and mortality, such as the increasing number of patients simultaneously affected by different chronic diseases. Healthcare organizations throughout the world have an increasing concern about how to cope with a quickly aging population (Caley and Sidhu, 2011). This trend explains the increasing demand of long-term care services (Damiani et al., 2009) such as elderly care centers (ECCs). Furthermore, considering that persons who are 65 years or older often spend a considerable portion of their lives indoors it is clear that the possibility that adverse indoor climate can influence their health status cannot be ignored.

As levels of outdoor air pollution have been reported to decrease in many areas, indoor air quality (IAQ) has increasingly gained importance. It is estimated that in developed countries people spend 80% to 90% of their day indoor (Kembel et al., 2012), and this figure is likely to be higher in elderly. This prolonged exposure to indoor air pollutants of this age-group – even at low concentrations – may induce health damage more likely than occasional exposure to outdoor pollutants (Corsi et al., 2012). In addition to IAQ, also thermal comfort (TC) is a key factor that might affect comfort, health, and occupants' performance (Mendes et al., 2013). Thermal comfort is influenced by a range of environmental and individual factors, both objective and subjective, including air temperature, the temperature of the surrounding surfaces, the air movement, the relative humidity, and the rate of air exchange (ventilation) (Ormandy and Ezratty, 2012).

Living in a ECC may induce exposure to chemical compounds through their release from building materials, household furnishings, and a wide range of consumer products (Spengler and Adamkiewicz, 2009). Furthermore, indoor habitat has been found to harbor microbial taxa not commonly found outdoors, and it has been reported that air temperature and relative humidity, as well as the source of ventilation air and occupant density, can influence the abundance and transmission of some pathogenic microbes (Kembel et al., 2012). Inadequate air-conditioning systems, low ventilation rate, and overcrowding can increase these risks (Wan et al., 2011).

Fine particulate matter, with diameter 2.5 μm or less ($PM_{2.5}$), can penetrate deeply into lung tissue and be associated with reduced lung function in children and adults, lung inflammation, respiratory symptoms, adverse cardiovascular effects, and increased prevalence of chronic obstructive pulmonary disease (COPD) (Wang et al., 2006). $PM_{2.5}$ exposure can also cause oxidative stress to human DNA (Sørensen et al., 2003). The quality of indoor climate is affected equally by the building equipment and operation and maintenance. However, critical conditions may originate from the buildings themselves, or actions of the occupants or operation and maintenance of the buildings (Seppänen et al., 2004). Although housing standard is important for indoor climate, knowledge on different aspects of individual daily behavior patterns, especially those related to thermoregulatory behavior and home heating habits, is a critical piece of information (Bokenes et al., 2011). In general elderly energy expenditure decreases with increasing age because of a reduction in basal metabolic rate and also because elderly tend to be less active (Antunes et al., 2005). Due to this mechanism, elder population has an average comfort zone/thermal neutrality (where the body is able to maintain a balance between heat production and heat loss) higher than the general population (25 °C in summer and 23 °C in winter) (Hwang and Chen, 2010; Schellen et al., 2010), and is more sensitive to respiratory infections in the winter (Ormandy and Ezratty, 2012; Mourtzoukou and Falagas, 2007) and heat-related mortality