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Indoor Environmental Quality in Residential Care Facilities: A Scoping Review with Design Focus

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Abstract

Elderly adults experience physical and cognitive deterioration, which makes them more dependent on others for their daily needs. It is not always possible to provide adequate care in their own homes, emphasizing the crucial need for qualified residential care facilities (RCFs). Given that elderly spend most of their time indoors, it's crucial to provide a good indoor environment quality (IEQ) at RCF. Using the PRISMA scoping review approach, this study seeks to review the body of knowledge about IEQ elements of RCFs. A keyword search yielded 1044 possible papers; however, after removing irrelevant articles and duplications, only 94 papers remained to be reviewed. A snowball search was used to add 32 papers, and finally 126 papers were included in this paper.

Keywords: *Design for elderly, elderly care, indoor environmental comfort, indoor environmental quality, residential care facility.*

Kurumsal Yaşlı Bakım Alanlarında İç Mekân Çevre Kalitesi: Tasarım Odaklı Araştırma Makalesi

Öz

Yaşlı bireylerin fiziksel ve bilişsel işlevlerinin azalması, yaşamlarını başkalarına bağımlı olarak sürdürmeye neden olmaktadır. Bireylerin evlerinde sürekli bakım sağlamaya uygun koşullar bulunmadığında yaşlı kurumsal bakım alanların acil ihtiyacı karşılamaktadır. Yaşlı bireyler zamanlarının çoğunu iç mekanlarda geçirdikleri için, tesislerin yeterli iç ortam kalitesini sağlaması hayati önem taşır. Bu makalede, tesislerin iç mekân çevre kalitesi ile ilgili var olan literatürün incelenmesi amaçlanmaktadır. Makalede PRISMA kapsam belirleme yaklaşımı benimsenmiştir. Belirlenen anahtar kelimeler ile yapılan arama sonucunda 1044 potansiyel makale tespit edilmiştir, ancak kapsam dışı makaleler ve tekrarlar elendikten sonra geriye analiz edilecek 94 makale kalmıştır. Kartopu yöntemi ile 32 adet makale eklenmiş olup, toplamda 126 adet makale araştırmaya dahil edilmiştir. Elde edilen sonuclara göre; gürültü kontrolü için izolasyon uygulanması ve bölgeleme yapılmasının, günışığı kullanımını arttırırken, kamaşmaya karşı kolay kullanımlı kontrol seçeneklerinin tercih edilmesinin, doğal havalandırmanın etkin şekilde kullanımına ek olarak kullanıcıların kolay kontrol edebileceği HVAC sistemlerinin kullanımının kurumsal yaşlı bakım alanlarında iç mekân çevre kalitesinin iyileştirilmesine katkıda bulunduğunu göstermektedir.

Anahtar Kelimeler: *Yaşlılar için tasarım, yaşlı bakım, iç mekân çevre konforu, iç mekân çevre kalitesi, yaşlı kurumsal bakım alanları.*

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1. Introduction

Associated with aging, elderly adults undergo physical and cognitive functioning declines that result in increased frailty, sensory loss, and mental competence deterioration (Hegde & Rhodes, 2010). Thus, as people age, they become more environmentally gentle and live a passive lifestyle (Wang, 2020). Unsuitable or inaccessible spatial arrangements endanger the elderly and make their lives even more passive. Though aging in place—living in their homes—for as long as possible is the preferred lifestyle both for the elderly and government policies (Darton et al., 2011; Victoria Maria et al., 2018), it is generally very difficult to supply proper care and services in their homes.

As the elderly population arises and their needs vary, a corresponding need for residential care facilities that support special care and supporting services (such as healthcare, recreational activities, transportation, eating, bathing, and memory care) develops (Wang, 2020a; Yuan et al., 2019). This need is not regional but global, and in the grand scheme of things, many different names are given to these facilities that provide these elderly care services (such as residential care facility, senior living facilities, assisted living facilities, nursing homes, homes for the aged, elderly house, attention homes, retirement homes, skilled nursing facilities, long-term care facilities, intermediate care facilities, geriatric rehabilitation centers, etc.). As their names change, so do the types of care they give (such as rehabilitation, professional eldercare, high-quality medical care, nursing care, etc.) also vary. All those different names and their differences in terms of service are not that clear due to the need for a flexible level of care (Yuan et al., 2019). In this study, all forms of eldercare institutions are referred to as "residential care facilities (RCF)" for the sake of simplicity.

Indoor environmental conditions that satisfy its occupants' comfort requirements have a direct impact on their health, performance, and wellbeing(Šujanová et al., 2019; Tao et al., 2020; Wong et al., 2014). The findings identified the general effects of noise, lighting, thermal conditions, and air quality as the most important factors of the interior environment. Generally, these factors are named "Indoor Environmental Quality" (IEQ), which includes acoustics, lighting, thermal environment, and indoor air quality (Nimlyat et al., 2015; Wong et al., 2014). When IEQ is insufficient, it can negatively influence elderly people's wellbeing and quality of life because they spend 17 hours indoors on average (Pinto et al., 2019; Tao et al., 2020). However, studies on IEQ do not adequately address or incorporate elderly profiles into international standards (Wu et al., 2019). The existing theoretical and empirical literature on RCFs focused on several aspects, including physical health (Mei et al., 2013; M et al., 2020; Pérez-Ros et al., 2019; Robinovitch et al., 2013; Toraman & Yıldırım, 2010), mental health (Hallit et al., 2020; Lapp et al., 2019; Tseng et al., 2020; Zhang et al., 2019), and social support (Carlson & Bengtsson, 2014; Cheng et al., 2011; Drageset et al., 2011; Tao et al., 2018). However, less attention has been directed toward the design of IEQ aspects in RCFs that are significantly effective in improving the elderly's life quality (Pinto et al., 2019; Tao et al., 2020). In this paper, a scoping review of the literature on indoor environmental design aspects for RCFs is reported. The primary goal is to present a summary of the most recent evidence on IEQ in RCFs and design recommendations to meet the particular needs of the elderly. The secondary purpose is to identify any existing gaps in the evidence and provide guidance on where new research is needed to strengthen it.

2. Material and Method

The PRISMA scoping review approach was adopted following the PRISMA ScR checklist in this study. Scoping reviews synthesize a body of literature and map key concepts, characteristics, sources, policies, practices, current research, and evidence. Scoping reviews, unlike systematic reviews, do not assess the quality of papers but provide a detailed summary, highlight research gaps, outline research agendas, and provide recommendations (Sav et al., 2017). A scoping review aims to explore the breadth and depth of available literature on a broad topic area, while a systematic review has a focused research question that aims to answer a specific research question. Scoping reviews have become increasingly popular and widely accepted for (Pollock et al., 2021) fields that have not been reviewed comprehensively before (Arksey et al., 2005; Mays et al., 2001).. The methodological framework for scoping reviews established by Arksey and O'Malley was used in this study, which was carried out in five stages (Arksey & O'Malley, 2005) as given below:

Stage 1- Identifying the research questions: The following research questions were formulated: "How do the elderly's spatial requirements differ from adults?", "How do current standards, regulations, and applications reflect these requirements?" and "How can designers provide better IEQ in RCFs for the elderly?"

Stage 2- Identifying relevant studies: Identifying relevant studies: The authors classified sub-categories and compiled a list of relevant keywords. The terminology used for elderly facilities, user profiles, and IEQ differs significantly, so keywords are categorized according to main and subfields in order to perform an effective review. The set of keywords (Figure 1) that are found to be relevant were grouped as a set (facility name+ user profile+ IEQ component) during the literature search (Figure 2). Keywords were distributed according to the authors' proficiency, and authors screened the results' titles and abstracts for inclusion and exclusion criteria with the given sets of keywords.

All authors searched the Scopus and Web of Science databases between September 2020 and September 2021.These databases were selected since they include a variety of disciplines and a broad range of publications within the research field.

Facility name	User Profile	IEQ
•Senior living facility	•Older adult	•**Indoor Environmental Quality**
•Attention home	•Aged adult	•Indoor environmental comfort
•Nursing home	•Older people	•Indoor environmental control
•Residential care home	•Seniors	•Interior Comfort
•Retirement home	•Residents	•Physical environment
•Residential care facility	•Elderly	•**Indoor Air Quality**
•Elderly house		•Humidity
•Assisted living facilities		•**Thermal comfort**
•Group Homes		•**Acoustics**
•Homes for the aged		•Sound(scape)
•Intermediate care facilities		•Noise
•Skilled nursing facilities		•**Lighting**
•Long-term care homes		•Visual comfort
		•Lighting
		•Daylight

Figure 1: List of keywords

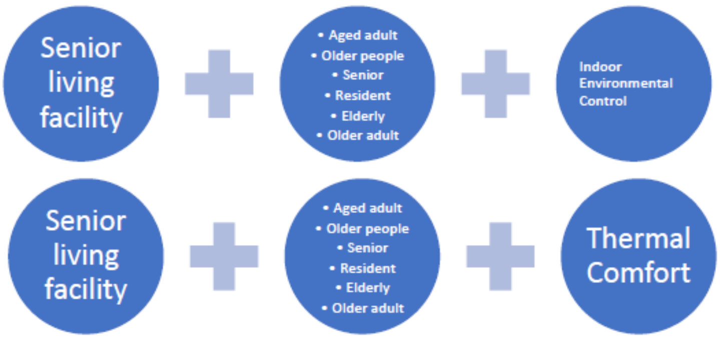

Figure 2: Two example keyword sets that are used during literature search

Step 3- Study Selection: The first author developed the search strategy, while inclusion and exclusion criteria were determined by all three authors. The search procedure was concentrated on searching for keyword combinations given in Figure 2. Only peer reviewed journal articles that were published after 2000, written in English, involved elderly participants, focused on at least one of the IEQ aspects from a spatial (architectural or interior design) perspective, and used elderly care facilities as a setting were included. Papers were excluded if they focused on medical treatments, did not address the elderly, did not deal with any architectural or IEQ design components, or used private houses as a setting. To ensure an inclusive body of literature on the field from various perspectives, both quantitative and qualitative studies, as well as mixed method studies, were included. The complete list of inclusion and exclusion criteria can be seen in Figure 3.

Inclusion Criteria	Written in English
	Published in peer-reviewed journals
	Published after January 1st,2000
	Must have at least one IEQ component that is being evaluated
	Should be conducted in residential care facilities
	population should be older adults (60 or higher)
Exclusion Criteria	studies that do not deal with architectural or interior design components
	medicine focused (medical treatments, psychology, rehabilitation etc) studies
	private houses
	studies that do not include any of the IEQ (lighting, acoustics, thermal comfort and indoor air quality) topics

Figure 3: Inclusion and exclusion criteria applied to select papers

Step 4- Charting the data: Titles and abstracts were read, and articles that met all the criteria proceeded for further screening while the others were categorized as “excluded” or “unsure”.

In the second phase, all three authors assessed the abstracts of each paper that was classified as "unsure" and discussed its eligibility until they reached consensus. Duplicates and articles without full-text access were removed during this phase, and 94 articles were assessed for eligibility. Finally, references from the selected sources were screened for additional relevant articles by the snowball method. The snowball method, also known as snowball sampling or snowballing, is a technique used in research to find additional relevant articles or studies beyond those identified through the initial database search. Through snowball method, 32 studies were found relevant, and eventually 126 articles were included in the study.

In the third phase, selected papers were read in full text, and data was extracted using a data-charting form according to the following: authors, year of publication, country, method used, study population, facility type, IEQ parameters, and key findings. All authors reviewed the papers and continuously updated the data-charting form.

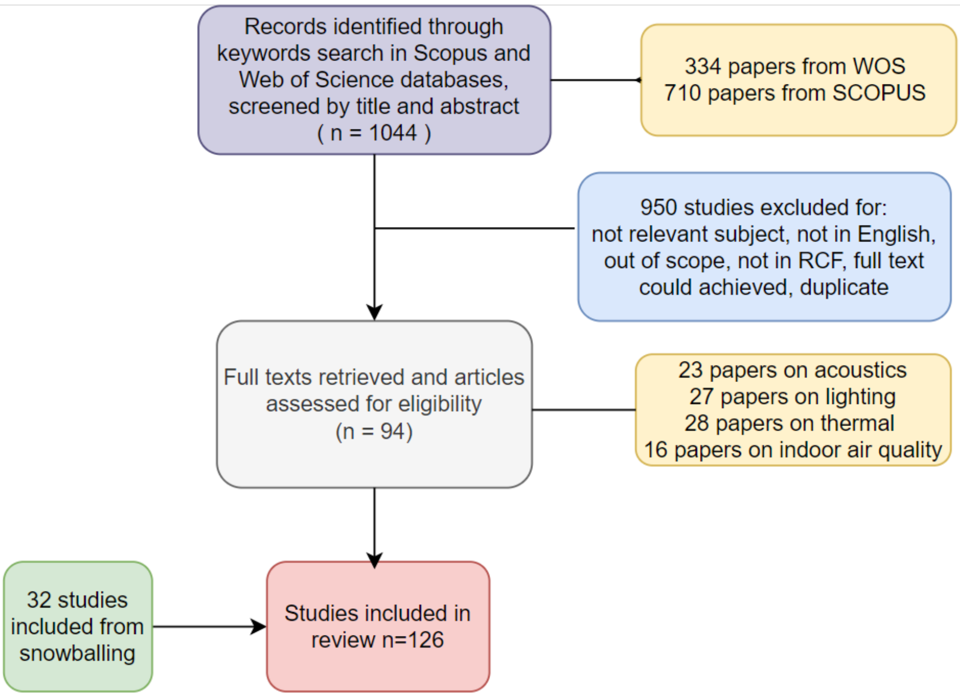

Figure 4: Scoping review phases

Stage 5- Summarizing and Reporting the Results: The studies that were retained for detailed study were grouped according to IEQ aspects; 44 papers in lighting, 39 papers in acoustics, 27 papers in thermal, and 16 papers in IAQ. Lighting is evaluated and reported by the first author, while the second author evaluated thermal comfort& IAQ and the third author evaluates acoustics studies. The remarkable outcomes and highlights of the studies for each IEQ aspect were discussed separately by each author according to the workload distribution that is given above.

The paper was organized into 5 main sections; (a) acoustics; (b) lighting; (c) thermal comfort; (d) indoor air quality; and (e) IEQ in general. Each parameter was discussed with reference to the literature, and final recommendations were made. In the discussion part, a general evaluation, literature gaps, and recommendations regarding RCF facilities are presented.

3. Findings and Discussion

3.1. Acoustics

In this section, acoustic literature findings have been presented, along with the two most common metrics (BNL and RT), and finally, acoustic recommendations and gaps of the field have been provided.

3.1.1. Importance of Acoustics and Sources of Discomfort

Since different groups of people with various disabilities and levels of sensitivity live in RCFs, the acoustic environment gains more importance. Understanding speech in a noisy environment is more difficult for elderly people than for young adults due to hearing loss. When compared with young adults, the elderly need a quieter environment to concentrate and hear other people talking (Harris & Reitz, 1985; Peng et al., 2018; Sloane et al., 2003). However, the acoustic environment of RCF is often disregarded, and specific standards are often missing, which may lead to noisy and unpleasant sound environments for the users (Aletta et al., 2017). Previous studies on the acoustic environment of RCF have mostly focused on perception (Devos et al., 2019; Harris & Reitz, 1985; van den Bosch et al., 2016, 2018) privacy and belonging (Devos et al., 2019; Thomas et al., 2020). Yet, the quality of the acoustic environment is also crucial, both for residents and the staff, who are spending a considerable amount of time indoors (Van Hecke et al., 2019). Poor acoustic conditions in RCFs have a negative impact on residents' and staff's well-being and comfort (Thomas et al., 2018) and lead to barriers in speech communication that decrease the life quality of the elderly. Furthermore, acoustic discomfort brings many psychological difficulties for the elderly, such as low self-esteem, autism, irritability, and stress, but it also impairs elderly people's relationships (Harris & Reitz, 1985; Ventry & Weinstein, 1982).

The talking sounds of nursing staff, squeaking food and medication carts, nursing stations, roommates, television and radio usage, mechanical noise, electronic devices such as air conditioners, electric fans, heaters, electric fires, kitchen facilities, TV, and announcement speakers can be listed as the noise sources in RCF's (Henshaw & Guyet al., 2015; Mui et al., 2008; Thomas et al., 2020; Wong et al., 2014; Xie et al., 2020; Zhao et al., 2020). Besides, the sound of medical appliances and turned on televisions in both communal areas and shared bedrooms, regardless if there is an audience or not, seemed to be a noise source to residents (Zhao et al., 2020). Most of the residents in RCF's are quite sensitive to certain noise and consequently their behaviors are affected negatively by those noises, such as feeling unpleasant, unsafe (Henshaw & Guyet al., 2015; Hsieh et al., 2012; Neikrug & Ancoli-Israel, 2010; Wong et al., 2014; Zhao et al., 2020) or residents woke up at night due to noise disturbance (Zhao et al., 2020). Additionally, unwanted noise can result in physical injuries such as increasing the risk of falling for elderly residents (Leung et al., 2013). Thus, a comfortable acoustic environment influences the well-being of residents and hampers their independence and social interactions.

3.1.2. Background Noise Level (BNL)

BNL is of utmost importance, and there is often a sound pressure limit for acoustic comfort. Sound levels above 50 dB(A) have been linked to annoyance, disturbed sleep, delirium, blood pressure elevations, tachycardia, and possibly ischemic heart disease in healthy populations (Berglund et al., 1995; *GB 50340-2016 Code for Design of Residential Building for the Aged*, 2016). There are several standards and studies on the level of background noise in RCFs. Suggestions vary depending on the function of the building, time of the day, origin of country, and organization (Table 1). For instance, recommended BNL values for the elderly in residential buildings are 40 dBA (daytime) in living rooms and 45 dBA as the maximum limit; however, common rooms and dining rooms are not considered in the study (*GB 50340-2016 Code for Design of Residential Building for the Aged*, 2016; Peng et al., 2018). On the other hand, the World Health Organization (WHO) has established sound level standards for schools and industrial, commercial, shopping, and traffic areas, however, no such standards exist for RCFs. WHO only mentioned that background noise levels in most rooms should not exceed 35 dBA where patients are being treated or observed, and during nighttime peaks should not exceed 40 dB (Schwela, 2001; Xie et al., 2020). Also, the Hong Kong Planning Department stipulates that peak hour noise should be below 55 dBA in the neighborhoods surrounding RCFs (Tao et al., 2020). The Environmental Protection Agency (EPA) in the United States and some other studies (Berglund et al., 1995; Bharathan et al., 2007; Schwela, 2001; The U.S. Environmental Protection Agency Office of Noise Abatement and Control, 1974) recommended that BNL should not exceed 45 dB in nursing homes in daytime hours. In addition, for nighttime, the above-mentioned international standards suggest 20–35 dBA, whereas the EPA suggests a maximum of 35 dBA for sound intensity. Despite that, a number of studies on acoustic comfort in RCFs highlight that background noise levels in RCFs are mostly above the threshold (Devos et al., 2020; van den Bosch et al., 2016; Xie et al., 2020).

Table 1. Background noise level suggestion comparison

	For Elderly Room		**Common Areas**		**Non-specified**	
	Recommended	**Maximum Threshold**	**Recommended**	**Maximum Threshold**	**Recommended**	**Maximum Threshold**
China 2016 (*GB 50340-2016 Code for Design of Residential Building for the Aged*, 2016; Peng et al., 2018)	40 dBA (daytime)	45 dBA	Not considered	-	-	-
(Schwela, 2001; Xie et al., 2020)	-	35 dBA	-	40 dBA (night time)		
(Tao et al., 2020)	-	-	-	-	-	55 dBA
(Berglund et al., 1995; Bharathan et al., 2007; The U.S. Environmental Protection Agency Office of Noise Abatement and Control, 1974)	45 dBA (daytime), 20-35 dBA (nighttime)	35 dBA (night time	-	-	-	-

3.1.3. Reverberation Time (RT)

Reverberation time (RT) measurements of RCFs range from 0.44s to 1.54s (Devos et al., 2020; van den Bosch et al., 2016; Xie et al., 2020) and are 0.55s on average in resident's rooms (Thomas et al., 2018). For instance, in a study that was conducted in five bedroom and nursing areas in Chongqing, China, that the measurements show that RT for bedrooms was 0.44s-0.68s and the nursing stations were 0.63s- 1.54s (Xie et al., 2020). Braam (2006) suggests that reverberation time (RT) in nursing homes should be between 0.4s- 0.7s, and rooms meant for speech require a short reverberation time; a value of 0.5s is suitable for small rooms(Peng et al., 2018). When RT exceeds 0.5 in spaces for speaking, speech intelligibility decreases and acoustical defects such as echoes arise (K. B. Ginn, 1980).

3.1.4. Evaluation and Recommendations for Acoustics

In order to provide acoustical comfort while maintaining speech privacy and sound transmission class ratings between rooms and corridors, design recommendations should be applied (Razavi, 2012). For example, resident room walls should have an STC rating of 45 (optimal), and HVAC systems should have sound attenuation that does not exceed the noise criteria (NC) of 25 STC in bedrooms and 35 STC in amenity places (Benbow, 2018). Some basic precautions may be the most effective measure to reduce noise; such as closing the door (Connell, 2004) or physical separation of residents from each other (also called acoustical separation) (Thomas et al., 2020). During room design, it is recommended to prevent usage of the shared wall by the TV in one room and the headboard in the other room to eliminate transmission of noise through walls. Aside from potential noise sources that can be replaced if possible, soundproof materials can be applied around the noise source if this is not possible. Closing the undercut door, installing a quiet vent silencer, and installing an acoustic curtain or more absorptive materials on the ceiling (such as acoustical tile or absorbing baffles) and floor (such as rubber flooring or carpeting) are the most common techniques for maintaining speech privacy (Gustavsson et al., 2017; Razavi, 2012; Thomas et al., 2018).

Reviewed studies on acoustic comfort were mainly focused on the noise level and reverberation time of the rooms where the elderly sleep, live, and socialize. These two parameters can give very clear and accurate preliminary information about the acoustic comfort of a place, but in some special places, more detailed studies can be done by considering user profiles. Aside from the Lombard slope, the ratio of speech levels to background noise level has only been studied in Devos et al.'s study (2020) in related studies. The Lombard effect is a phenomenon where talkers increase their vocal effort in response to louder noise levels to maintain appropriate conditions for verbal conversation in dining facilities. Since elderly complain about BNL and a lack of verbal communication, spaces should be evaluated by considering the Lombard effect and Lombard slope.

Acoustic problems in RCFs are primarily concerned with noise sources as well as BNL and RT characteristics. However, studies on speech intelligibility must be expanded to assure acoustic comfort. Finally, it is important in RCF material selection since the material used must be durable and easy to clean, yet a material with these features has reflective properties rather than acoustical absorption. Thus, employing reflective materials increases BNL and RT while decreasing speech intelligibility. As a result, material selection in such areas is more challenging compared to other spaces, and the goal should be to produce innovative materials that are sustainable and fulfill these criteria. If more modeling and optimization studies are carried out on material selection, it will be easier to provide acoustic comfort and intelligibility in RCF's.

3.2. Lighting

The findings from the lighting literature, as well as glare, recommended illumination levels, daylight, and finally lighting-related problems with their solutions have all been provided in this part.

3.2.1. Importance of lighting and preventing glare

As people age, they suffer from visual impairments, declined visual performances, optical changes, and visual diseases (such as cataracts, glaucoma, macular degeneration, etc.) (Shikder et al., 2012; Tural & Tural, 2014). Aging eyes require more illuminance to compensate for their deteriorating vision(Leung et al., 2016). For instance, an average 60 year-old eye needs three times more light than an average 20 year-old eye to complete the same task(de Lepeleire et al., 2007; Sinoo et al., 2011). Furthermore, aging can impair adaptation to dark and depth perception; thus, when moving from a bright room to a darker area, an elderly person cannot fully see the environment for a minute or more (de Lepeleire et al., 2007). Dimly perceived visual environments, blurred vision, and adaptation reductions can be associated with an increased risk of fall (De Lepeleire et al., 2007; Hegde & Rhodes, 2010; Leung et al., 2016; Sinoo et al., 2011) and falls account for nearly 71% of causes of severe injury, disability, and accidental death in the elderly (Joseph et al., 2016; Moore et al., 2011; Sagha Zadeh et al., 2018; Shikder et al., 2012).

Providing a good visual environment is not limited to quantity of light alone; quality is equally important. Glare is a physical discomfort caused by too much (artificial or natural) light or contrast in the field of view, which impairs users' ability to see their surroundings (Brawley, 2009; Jakubiec & Reinhart et al., 2011; Tural & Tural, 2014). Elderly people are more sensitive to glare, and their recovery time from glare effects is longer than that of younger adults, which can increase their risk of falling. Besides, some elderly people suffer from frequent nighttime toilet usage, which requires waking up during the night, walking to the toilet, and going back to bed to sleep. This pattern can repeat two or more times in a night, which ends up reducing the time and quality of sleep(White et al., 2013). If the room is too bright, it causes discomfort and makes returning to sleep more difficult, resulting in a tendency to sleep during the day (Lee et al., 2009a; Leung et al., 2020). If it is below the requirements, then going to the toilet can be quite risky in terms of falls and injuries (Lee et al., 2009b).

3.2.2. Illumination Levels

To provide a sufficient, elderly-friendly, and fall-preventing interior, adequate illuminance levels on workplanes should be provided. Lighting standards and codes represent the recommended illuminance values for specific functions (Aalto University School of Science and Technology Department of Electronics Lighting Unit, 2010) considering healthy eyes; however, elderly people require higher light levels, therefore adapted standards should be applied to RCFs (de Lepeleire et al., 2007; Kunduraci, 2017; Leung et al., 2016). There are contradictions in the existing recommended illuminance levels for the elderly (Table 2). For instance, recommended illuminance levels in the Adapted Standard (which is the adapted version of the European standard EN 12464-1 that deals with indoor work places) increased standard illuminance levels by 55%. To exemplify, for entrance halls, it was 200 lux in EN 12464 and increased to 310 lux in the Adapted Standard, while general lighting in rooms ranges from 100 lux to 155 lux, and table-chair lighting is from 500 lux to 775 lux (de Lepeleire et al., 2007). Likewise, IESNA's "Lighting and the Visual Environment for Senior Living" standard suggests a minimum of 320 lux (30 fc) for general areas and 538 lux (50 fc) for specific task areas (Brawley, 2009; Hegde & Rhodes, 2010). Moreover, in a post-occupancy evaluation study in Hong Kong, results indicate that for bedrooms 268-300 lux, for common areas 260-300 lux, and for bathrooms 350-530 lux are preferred by elderly (Leung et al., 2014). Though all these values are similar, in Turner et al.'s study it was suggested that "128-320 lx; 184-460 lx; 256-640 lx; 400-1000 lx; 536-1340 lx; and 656-1640 lx would be insufficient in 45, 55, 65, 75, 85 and 95 year old adults, respectively" (Sinoo et al., 2011; Turner et al., 2010). All the illuminance levels mentioned are higher than the thresholds of existing standards and guidelines, and these level differences point to the need for increased illuminance levels in RCFs (Sinoo et al., 2011).

Table 2. Illuminance level comparison

	For Elderly Room		**Common Areas**		**Non-specified Recommendation**
	Living Area	Bathroom	General	Task Lighting	
(de Lepeleire et al., 2007)	-	-	-	-	Increased standard illuminance levels by 55%
(Brawley, 2009; Hegde & Rhodes, 2010)	-	-	320 lux (30 fc)	538 lux (50 fc)	-
(Leung et al., 2014)	268-300 lux	350 -230 lux	260-300 lux	-	-
(Sinoo et al., 2011; Turner, Van Someren, et al., 2010)	-				Insufficient illuminance levels for different age ranges:
	-				128-320 lux for 45 years
	-				184-460 lux for 55 years
	-				256-640 lux for 65 years
	-				400-1000 lux for 75 years
					536-1340 lux for 85 years
					656-1640 lux for 95 years

3.2.3. Daylight

Daylight has long been associated with human health, well-being, mood, and sleep quality, with its variations in length of exposure, duration, quantity, and spectral composition (Altomonte, 2008; Brawley, 2009; Gharaveis et al., 2016; Mobley et al., 2017; Philips, 2004). Studies highlight that well-evidenced daylight may help to maximize treatment efficiency, reduce perceived pain, stress (Gharaveis et al., 2016; Nioi et al., 2017) and symptoms of depression (Brawley, 2009; Figueiro et al., 2019), increase melatonin, and improve sleep quality (Brawley, 2001, 2009; Gharaveis et al., 2016; Konis et al., 2018; Wang, 2020b; White et al., 2013). Daylight's photobiological (non-vision) effects, such as stimulating circadian rhythm and vitamin D synthesis, are also quite significant (Brawley, 2009; Ellis et al., 2013). With passing years, the circadian clock begins to weaken, and when the circadian rhythm slides out of sync, it leads to disrupted sleep/wake rhythms, melatonin, and cortisol hormone releases (Ellis et al., 2013; Lee et al., 2009b; Sinoo et al., 2011). Besides loss of cognitive ability, depression caused by seasonal affective disorder (SAD) occurs (White et al., 2013). The elderly who spent time in rooms with insufficient daylight described the environment as the "waiting room of death" (Van Hecke et al., 2019). Thus, elderly should be exposed to sufficient daylight throughout the day for their well-being, good sleep, and increasing alertness(Neikrug & Ancoli-Israel, 2010). Despite this, research shows that the elderly in developed countries are only exposed to the sun for 20-120 minutes per day (Sinoo et al., 2011). The studies show that daylight exposure is even more reduced when living in a RCF(Olsen et al., 2016). A study by Ancoli-Israel and colleagues reported that "4% of the elderly were not exposed to daylight at all, and 47% were never exposed to light greater than 1000 lux"(Neikrug & Ancoli-Israel, 2010). On average, elderly people living in RCFs received an average of only 9 minutes of daylight exposure during a day (Brawley, 2009). To compensate for daylight, artificial lighting is being used, but typical artificial lighting does not contain the spectral distribution to which circadian rhythm is sensitive (Brawley, 2009).

3.2.4. Evaluation and recommendations for lighting

A good combination of artificial and natural lighting contributes to active aging and a fulfilling lifestyle (Brawley, 2009). To increase daylight availability, windows should be clearly designed to exclude low-elevation sunlight and glare. Besides, positioning windows at the ends of corridors might cause silhouetting effects(Torrington et al., 2007). When circumstances allow, other daylighting strategies such as skylights, roof windows, or light pipes can be used (Sinoo et al., 2011).

When daylight is insufficient, it should be compensated by artificial lighting to provide the required illuminance levels constantly, and using lighting sensors could both provide control and energy savings (Brawley, 2009; Leung et al., 2019). Lighting switches with sensors that keep illuminance levels above threshold levels while preventing glare could be used (Leung et al., 2019; Sinoo et al., 2011; Torrington et al., 2007). The recommended color temperature of light is neutral white (5000 K), however, the elderly's preference can differ both personally and culturally (Leung et al., 2014). In Wang's study, the same questionnaire was conducted in two RCFs in the USA and China, and results show that Chinese elderly prefer warm colors for lighting compared to elderly in the USA (Wang, 2020c). Similarly, in European RCFs warm white was preferred (3000K) (Sinoo et al., 2011) and high color temperatures (above 6500 K) are found unpleasant. To trigger circadian rhythm with artificial lighting and suit the varying demands of elderly people LED lamps with changing color temperatures could be used (Ellis et al., 2013).

Using light colors for ceilings (reflectance values of 80 and above), walls (65-85%) and floors (30-40%) with indirect distribution of light can provide a bright and spacious space (Brawley, 2009). Especially in wet spaces, high illuminance levels with indirect light distribution, and mate surfaces rather than shiny surfaces must be used for visual comfort (Torrington et al., 2007). Lamps with high color rendering values (80 and above) should be used for color distinction (Brawley, 2009). Glare from natural and artificial light should be avoided, and night lights should be bright and easy to use (Leung et al., 2016; Mobley et al., 2017; Wong et al., 2014).

Lighting studies examined the subject from several perspectives and with diverse characteristics, such as artificial lighting, daylighting, lighting's effect on wellbeing, mood, psychology, and lighting quality.

When the distribution is evaluated, it is evident that the majority of the research concentrated on the quantity of light, such as illuminance and luminance, with only a few daylight metrics receiving attention. This could be due to the fact that there are still many unknowns about vision loss. Age-related vision impairments are fairly frequent and usually begin around the age of 40 and worsen around the age of 60 (Robertson et al., 2010). Because these changes do not happen overnight, the emergence of vision-related disorders in the elderly must be studied further.

One of the major energy consumers is artificial lighting, although, oddly, research on lighting in RCFs rarely mention this issue. This could be attributed to the complexity and uniqueness of RCFs' duty of providing 7/24 optimum visual comfort for the elderly.

3.3. Thermal Comfort

This section presents scholarly findings on thermal comfort, as well as the thermal sensitivity of the elderly, adaptive thermal strategies, and HVAC systems. Finally, thermal comfort recommendations were provided.

3.3.1. Importance of thermal comfort and thermal sensitivity of elderly

Thermal comfort is an important parameter of indoor environmental quality, which is affected by physical, physiological, psychological, and other factors such as age, gender, metabolism, and clothing insulation (Djongyang et al., 2010). Besides behavioral actions such as changing clothing, activity level, posture or location, providing natural ventilation can influence thermal comfort (ASHRAE Handbook Committee, 2001).

Older people's thermal comfort may differ from that of younger individuals since they are more sensitive to the thermal environment due to a reduced metabolic rate (Hoof et al., 2017; Schellen et al., 2010; Tao et al., 2020; Yang et al., 2016). The thermal sensation of the elderly varies depending on the season, with the sensitivity level being higher in the winter (Tao et al., 2020). However, there are discussions on thermal comfort for the elderly. Fanger suggested the neutral temperature, which was defined as the comfort temperature of the occupants, did not differ between elderly and young people (Fanger, 1970) while Mendes et al. (2017) stated that the 20–24°C, which is assumed as a comfort zone, is not warm enough and that 25.3°C was selected as the optimal temperature for sedentary elderly (Mendes et al., 2017). Similar to Mendes et al (2017), Wang et al. (2020) the results show that the thermal neutral temperature predicted by the PMV method is 2.7°C lower than the findings(Wang et al., 2020). A significant number of studies have examined the finding that elderly people prefer an environment approximately 2C° warmer than youngsters (Hoof & Hensenet al., 2006) (Wang et al., 2018).

The thermal environment of the elderly is associated with increased vulnerability and risk to their mental and physical well-being. They may not perceive the changes in the thermal environment, which can cause a potential threat to their health such as heatstroke, major adverse cardiovascular events, and acute kidney injury (Meade et al., 2020). Similarly, thermal discomfort conditions may cause the agitation of dementia residents in RCF, and agitation may be reduced by limiting the range of indoor air temperature variations (Tartarini, Cooper, Fleming, et al., 2017).

3.3.2. Adaptive thermal strategies

In order to provide thermal comfort, occupants have a natural tendency to adjust to changing conditions through behavioral and psychological adaptation, which is referred to as adaptive thermal comfort models (Law, 2013). Occupants' behavior and their developed strategies such as clothing insulation, use of ceiling and portable fans, and window opening practices can be mentioned as adaptive strategies widely used by residents and they are significant for the elderly to provide thermal comfort (Cena, Spotila & Ryan, 1988). Specifically, during summer, changing clothing and opening windows are found as the two most used adaptive strategies (Jiao et al., 2017). Tao et al. (2020) have highlighted that while adjusting clothes is a major strategy, usage of an electric fan and window opening are the two other common strategies among RCF residents (Tao et al., 2020). Multiple studies have stated that layered clothing is an effective and preferable strategy among elderly people (Jiao et al., 2017; Tao et al., 2020; Tartarini et al., 2018). In harsh weather conditions such as in winter, older people may wear seven pieces of clothing to regulate their thermal balance (Tang et al., 2020). In the winter some other adaptive strategies such as mechanical heating and taking a hot bath are used, while in the summer mechanical cooling and electric fans are the major strategies for the elderly (Jiao et al., 2017). Interestingly, despite the changes in climatic conditions in different countries, the same adaptation strategies were developed by the elderly.

3.3.3. HVAC systems

HVAC systems can be mentioned as the most common technological adaptation strategy for thermal comfort (Tartarini et al., 2017). When controlling windows to provide natural ventilation is not sufficient, HVAC systems are necessary to ensure the thermal comfort of the elderly. However, it is not always preferred by the elderly, particularly during the summer, when older people prefer natural ventilation over HVAC systems (Tartarini et al., 2017). One of the reasons for preferring natural ventilation was economic status. Interestingly, the elderly’s preferences and actions regarding HVAC systems were associated with their economic status, and the elderly with low income prefer natural ventilation instead of HVAC (Tsoulou et al., 2020). The other reason is related to the control of HVAC systems. Generally, HVAC systems are operated by caregivers, staff (Walker et al., 2016) and the thermal environment of the elderly is controlled by nurses and staff (Yang et al., 2016). Thus, residents highlighted that they preferred making their own choice for their room’s indoor environment because staff could sometimes misunderstand their preferences, which caused dissatisfaction with thermal comfort (Cleary et al., 2019). Similar to this, thermal discomfort situations can develop when staff impose their own preferences to control temperature (such as opening windows or turning on air conditioners without consulting residents). On the other hand, older individuals are less accustomed to technology and are not taught how to operate air conditioning unit remote controls, making them unable to meddle.

3.3.4. Evaluation and recommendations for thermal comfort

Although the elderly try to obtain their thermal comfort through individual adaptive strategies, the implementation of technological solutions such as HVAC can enhance thermal comfort without the need for adaptive strategies (van Hoof et al., 2019). To provide efficient use of HVAC systems, training staff members and the elderly in terms of air conditioning units can be helpful (Wu et al., 2019). In addition to that, understanding the needs of the elderly and their habits is significant. Though these behaviors, habits, and strategies may differ by region, season, person, or other climatic factors, they must be envisaged in the design process, and both staff and residents should be trained. Also, there must be specific comfort regulations for the elderly that can be modified for all regions and climates.

Thermal comfort research can be divided into three categories: determining the parameters to assure thermal comfort, the causes and effects of comfort and discomfort, and techniques to minimize these impacts on the aged. Most research looked at all thermal comfort factors together, however some of them were particularly interested on skin comfort factors. The causes of thermal comfort or discomfort in the elderly are essentially connected to their thermal environment sensitivity and perception, which are both extremely diverse. Therefore, it is still necessary to look at individual preferences in research that concentrate on the thermal discomfort of the elderly under various climatic circumstances. Considering that natural ventilation is currently favoured and energy economy is a top priority, adaptive thermal comfort techniques for RCF buildings should be carefully considered.

3.4. Indoor Air Quality

The findings from indoor air quality's influence on health problems and the most common pollutants are discussed in this section, along with literature gaps and recommendations for improving IAQ.

3.4.1. Importance of Indoor Air Quality (IAQ) and pollutants

The indoor air quality where people spend a substantial part of their life is a significant determinant of healthy life and people’s well-being. The air pollutants lead to a broad range of health problems and may even be fatal, especially in elderly people (World Health Organization (WHO), 2010). Indoor air pollutants are caused by a variety of sources, including occupant activities and other biological sources, the combustion of substances for heating or fuel, and emissions from building components (Jones, 1999). Allergens, asbestos, CO, CO_2, volatile organic compounds (VOCs), particles (PM10), microorganisms, pollens, and fungi were mentioned as major indoor pollutants and emission sources for buildings (Spengler & Sexton, 1983).

There is a special concern for older adults' indoor chemical and pollutant exposures since they spend most of their time indoors and are exposed to indoor chemicals and pollutants for long periods of time (Tao et al., 2020). Especially the elderly, who are over 80 years old and living in poorly ventilated nursing homes, can have adverse health outcomes for their respiratory system, even at moderate air pollutant concentrations (Belo et al., 2019; Bentayeb et al., 2015; Maio et al., 2015; Simoni et al., 2003). TVOC (total volatile organic compound) exposure and respiratory infection have a significant relationship (Belo et al., 2019), and higher levels of carbon dioxide can cause breathlessness and coughing in the elderly (Belo et al., 2019). It has been stated that there is a strong relation between indoor pollutants and health outcomes such as wheezing, breathlessness, coughing, phlegm, asthma, COPD, and lung cancer (Simoni et al., 2003). It has also been observed that air flow decreases the risk of transmission of COVID-19, one of the deadliest epidemics of recent years. According to the recent study that interrogated the relationship between air flow and COVID-19 infection risk, ventilation, infiltration, and behavior were determined as the most important components for indoor air quality under the pandemic conditions (Browning et al., 2019).

Indoor air quality is affected by the presence of air suspended particles (PM2.5, PM10), VOCs (volatile organic compounds), SVOCs (semivolatile organic compounds), and bacterial and fungal concentrations (Almeida-Silva et al., 2014; Madureira et al., 2015; Mendes et al., 2013, 2016). When the chemical characterization of air suspended particles is examined indoors, it is discovered that PM10 average concentrations in living rooms are higher than in bedrooms due to the occupation for dust re-suspension (Almeida-Silva et al., 2014). Similarly, when SVOCs were measured, it was seen that five times more SVOC was found in corridors compared to bedrooms and living rooms (Arnold et al., 2018). In terms of bacterial and fungal concentrations when indoors and outdoors were compared, as might be expected, indoor concentrations were higher than outdoor concentrations due to occupancy or resuspension (e.g., from carpet) (Madureira et al., 2015; Mendes et al., 2013).

3.4.2. Evaluation and recommendations for ındoor air quality

Occupancy, building envelope, ventilation schedule, climate condition, and room layout are the parameters that can influence the indoor pollutants' concentration (Serrano-Jiménez et al., 2020). The poor ventilation in the buildings can be mentioned as one of the pollutant factors (Almeida-Silva et al., 2014) and it can be modulated by natural ventilation (Almeida-Silva et al., 2015; Bentayeb et al., 2015). The highest CO_2 concentrations have been measured mainly in the bedroom (during sleeping periods), where residents spend most of their time (Serrano-Jiménez et al., 2020). As a result, exposure must be limited by taking precautions, such as providing natural ventilation, using RCF building materials, and controlling VOC sources. It is also recommended to collect periodic samples and investigate the chemical or pollutant concentration in RCF on a regular basis. The staff and building occupants can be trained about the indoor air quality.

Indoor air quality and thermal comfort are investigated simultaneously in some articles since the two topics are connected and both are required to offer a neutral environment. However, compared to other IEQ factors, the quantity of IAQ studies in RCF is small. Choosing the wrong indoor material can harm IAQ and be harmful to senior citizens' health. Studies focusing on indoor air quality should concentrate on modernized indoor materials because the market for building materials is relatively broad and new materials are welcome.

4. Conclusion

The systematic review starts by looking into all IEQ components (acoustics, lighting, thermal comfort, and indoor air quality) for elderly needs, with a specific focus on RCFs. There are many perspectives and issues to look for, and IEQ and its components are cogent factors of elderly satisfaction. Because

IEQ components are affected by a variety of elements (including environmental, personal, cultural, and operational aspects), this study sought to present a comprehensive method that takes all into account. Despite great efforts, more work remains to be done. To expand the literature on IEQ and provide elderly friendly interiors, it is critical to take a user-centered design approach that entails understanding the needs, preferences, and limitations of the elderly population and applying this knowledge to creating functional, comfortable, and safe spaces. Architects and designers can obtain significant insights into the needs and preferences of the elderly by incorporating them in the design process, leading to superior design outcomes. Furthermore, incorporating technology into interior design can considerably improve the living experience of the elderly. For example, smart lighting systems can be implemented to help control illumination levels and improve visibility. Voice-activated assistants, fall detection systems, and home monitoring systems are examples of assistive technology that can be used to promote safety and well-being. Another critical topic that must be addressed is the provision of flexible design solutions for the elderly in order to accommodate their changing demands and preferences. To accommodate changes in mobility and living situations, for example, adjustable lighting systems, flexible seating arrangements, and adaptable storage solutions can be used. These design solutions might assist elderly individuals in maintaining their independence and gaining control over their living spacesFinally, in order to enhance environmental sustainability and reduce energy costs, sustainable design principles can be implemented into interior design for the elderly. Energy-efficient lighting, passive solar design, and green building materials, for example, can assist decrease the environmental impact of buildings and promote sustainability.

A framework has been constructed to identify the significance of IEQ for the elderly, existing problems, recommendations, and gaps in the literature. The authors feel that designing places to meet the needs of the elderly can improve their quality of life and contribute to safe and comfortable aging. In addition to this evaluation, the study intends to offer baseline data for RCF facility designers, researchers, and management by emphasizing issues and outlining suggestions to enhance IEQ in senior living facilities.

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Author Contribution and Conflict of Interest Declaration Information

All authors contributed equally to the article. There is no conflict of interest.

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