Enabling Elderly: Age-Related Biological Changes and Designing for Independence

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Abstract: The world population prospects indicate a progressively increasing number of elderly persons, such that 15.9% of the world population will be above 65 years of age by the year 2050 according to the projected population prospects of the world by UN report, 2019. Elderly services, health-care facilities, inclusive built-environments and housing for elderly will be of demand in near future. A need to understand ageing process and associated functional decline is established in order to design for the increasingly growing elderly population. The current study aims to review existing literature about ageing, age-related biological changes, and associated functional decline in elderly persons and to identify design guidelines for application in residential-environments, to enable elderly for independent living. The present study bridges two domains of knowledge, namely health and design. The study provides an easy reference of design guidelines, as a response to age-related challenges and associated functional decline in elderly persons.

Key Words **- Ageing process, Age-related biological changes, residential design for elderly, inclusive design, ageing in place.**

I. INTRODUCTION

Good health, psychological and emotional well-being, living independently, and ageing in place with dignity, are sought after by most elderly. The world is ageing at a faster pace than ever before. Improved medical facilities and decrease in death rates have considerably increased the longevity of human life. It has been predicted that the number of people over the age of 65 years, would be representing 15.9% of the world's population by the year 2050 and 22.6% by the year 2100, as per world population prospects (2019), by the United Nations. This indicates that every one person in five, will be a senior citizen by 2100. This demographic shift calls for a high demand for elderly services, health-care facilities, inclusive built-environments and housing for elderly people.

Built-environments should be designed to enable the elderly to live without fear of dependency. Residential-environments, particularly play a major role in physical and psychological well-being of the elderly. Kahana (2003) stated the importance of person and environment fit (P-E fit), as a major predictor for residential satisfaction and in enabling the elderly to live an independent life in community settings. In a contrary situation, where a lack of person-environment congruence, was conceptualized by Kahana & Kahana (1996), that elderly persons will be prone to chronic stress, that is likely to cause adverse health issues. The person-environment fit theory was studied by Lawton (1980), who stated that, a barrier-free environment design with more attention to functional abilities of the elderly persons, by having the environment accommodate the individual, rather than an individual adjusting to the environment will increase the functional abilities in them. The current study attempts to understand the 'person', in this case the elderly, who is prone to various age-related biological changes, leading to functional decline and how these aspects can be addressed with design of the residential-environment to enable them to live independently.

The present study is two-fold. The first, is a literature review, conducted to understand age-related biological changes and associated functional decline in elderly persons. The second part of the study aims to identify guidelines for designing residential-environments for elderly persons, with an emphasis on dealing for age-related biological changes and functional decline. Together, the study bridges two domains of knowledge, namely health (Person) and design (Environment) and how to design residential spaces for elderly persons in order to live independently, by achieving a congruence between these two domains.

II. METHODS OF STUDY

A scoping review of literature was conducted for the current study. The key words, ageing, ageing process, age-related biological/physiological changes, residential design for elderly, inclusive design, ageing in place, falls-prevention in elderly and interior design for elderly, were used to search related scientific papers using Google Scholar. 47 published research papers were identified initially for the study. After exclusion on basis of relevance to the topic, 32 research papers were finally selected for the study.

III. DEFINITION OF AGEING

According to the World Health Organization (WHO) report on Ageing and Health (2015), biological ageing is associated with the gradual accumulation of a wide variety of molecular and cellular damage, which leads to gradual risk of many diseases, and a general decline in the capacity of the individual, ultimately resulting in death. Some studies referred to ageing as an increase in molecular disorder resulting in deteriorating physical and mental systems [6, 7]. Some stated that physical ageing was related to permanent physical changes, and chronological ageing occurs when a person has lived a designated number of years [8, 9]. Lawlor (2008) defined ageing as the time when a person is unable to independently perform certain basic, personal, routine functions- referred to as 'activities of daily living'.

The World Health Organization and most countries refer to 65 years and above as a legal old age. Aged persons have been sub-divided into three categories depending on a person's chronological age for clinical and research purposes. young-old age (65-74), the old-old ages (75-84) and the oldest-old ages (85 years and above) [8]. However, for the current study, physical ageing has been considered rather than chronological ageing.

IV. AGE-RELATED BIOLOGICAL CHANGES IN ELDERLY PERSONS

Ageing is associated with a gradual deterioration in various systems of the human body like the skeletal, muscular, respiratory, and nervous systems making elderly persons vulnerable to chronic degenerative diseases like strokes, arthritis, hypertension, cancer, degenerative bone/joint diseases, coronary artery disease, etc. [11]. In most cases, the biological changes are cumulative with the individual experiencing more than one of these conditions which increase progressively.

Early signs of ageing are noticed to have 25–30% decreased strength, 18-20% decreased flexibility and Balance disorders that are known to cause falls in one-third persons in the age group of 65-74 years old, each year. Perception of senses like vision, smell, hearing, touch and taste decline with age. Frailty sets in by the 70 years age making elderly persons more vulnerable to environmental stressors [7]. Ageing is associated with multiple chronic degenerative diseases which may lead to either sensory loss or physical impairments that limit mobility, impair cognition, or reduce the ability to perform activities of daily living, ultimately leading to dependency [12].

V. CHALLENGES DUE TO AGEING MUSCULOSKELETAL SYSTEM

5.1. Impaired Mobility:

Physiological changes related to poor muscle strength, reduced body mass and posture problems, declining bone and joints health, reduced range of motion and flexibility contribute to mobility issues in the elderly. In some cases, neurological deterioration is also associated with mobility issues [13]. Some studies observed changes in gait such as reduced stride length & walking speed, upper-lower extremity synchrony, arm swing amplitude and being more attentive to guarding their gait than being vigilant about environmental hazards as major predictors for falls in the elderly persons. In some cases, sedentary lifestyle contributed to muscle weakness leading to loss of balance confidence and mobility issues [13].

5.2. Frailty:

Frailty is a status of extreme vulnerability to endogenous and exogenous stressors exposing the individual to a higher risk of negative health-related outcomes [14]. In simple terms, the word 'Frail', refers to people, who are weak, vulnerable and have poor health outcomes. Frailty is associated with deterioration of physiological function, which leads to decreased ability to complete the activities of daily living [15]. Frail persons have decreased mobility, strength and responsiveness to external and internal stressors, low levels of physical activity, weight loss and lower self-perceived health and well-being [8].

5.3. Issues with reach and hand grip:

The structure of the body changes with age. The overall height is reduced due to shortened torso and spine in the elderly leading to arm reach issues Arthritis affects 50% to 80% of elders and is a major contributor to issues with hand grip in the elderly persons [13]. Joint pain, stiffness and reduced flexibility not only contribute to reaching issues and decline in hand grip, but also affect the performance of the activities of daily living (ADLs) in the elderly, eventually leading to dependency [13].

VI. CHALLENGES DUE TO AGEING RESPIRATORY SYSTEM

Ageing causes structural changes in thoracic cage, that effects the lung volume. Though the total lung capacity remains unchanged, lung function reduces with ageing [16]. The oxygen consumption decreases by approximately 1% per year in people aged over 30 years [17]. Weaker respiratory muscle strength is associated with decreased cough strength [17,18]. Cough cannot adequately remove a foreign material and this contributes to the increase in the incidence of aspiratory pneumonia in elderly persons [17, 19]. Low immunity in elderly makes them vulnerable to many respiratory infections [18].

VII. CHALLENGES DUE TO AGEING NERVOUS SYSTEM

7.1. Deterioration of Vision:

The symptoms of an ageing eye are most often observed as early as at age of 40 years. Presbyopia is a condition that occurs due to stiffening of the eye lens and the near focus of the eye is disturbed such that the person has difficulty seeing objects closer to him. The hardened lens causes the eye to focus light behind the retina rather than on it when looking at close objects [20]. The near point focus is around 10 cm at age 20, compared to 100 cm at age 70 [13].

Pupillary miosis is an age-related condition where the pupil becomes smaller and allows less light to enter the eye. People with this condition require higher levels of illumination to see clearly. A 60-year old with normal vision needs twice the illumination to see sharply as a 20-year old [20].

Another age-related challenge with vision is associated with changes in vitreous humor. The light entering the eye scatters within the eye due to this condition, making older people sensitive to glare and increases the time taken to adapt to changes in illumination levels. Elderly people face difficulty when they move between spaces with sharp difference in illumination levels. Decreased rod-mediated dark adaption in elderly may also lead to night vision problems [20].

Reduced Visual Acuity is common in elderly. The ageing eye provides very low resolution, poor colour vision and poor stereopsis (perception of depth). Visual acuity of elderly is often around 20:100 to 20:150 at age 90 whereas, legal blind bench mark is 20:200 [9]. It becomes difficult to adjust to rapidly changing visual stimuli and to perceive motion at low illumination [13].

Increased density of eye lens diminishes colour perception, especially in the violet-blue-green portion of the spectrum. It is easy for an older person to identify colours in the yellow-red portion of the spectrum as compared to the range of cool colours [20]. Retinopathy is another condition affecting most elderly persons, especially those who are diabetic. Retinopathy causes partial or complete loss of vision [9].

7.2. Decline of tactile sensation:

The sense of touch declines progressively with ageing. As people age, tactile sensation on hands and feet decreases, making it difficult for the person to judge if the body has made full contact with a surface such as when the person is sitting, he may not be able to sense if he is fully seated. The same may be experienced while judging sensation of touch on small surfaces for example, when an elevator button is pressed, the person has difficulty to sense if the key is depressed or not. Sensitivity to touch, pressure, and vibration starts declining by age of 50 years old in most cases and progresses with age[13].

7.3. Decline of sense of hearing:

Presbycusis is a most common age-related sensorineural hearing loss affecting 60% of people aged 55 years or older to some extent and 20% of people aged over 80 years require a hearing aid [13]. People affected by presbycusis initially compromise with their ability to hear high frequency sounds eventually leading to difficulty with hearing low frequency sounds.

Talking louder than usual, mumbling or unclear speech and confusion are the common symptoms of hearing impairment in the elderly. The individual's ability to understand conversations, particularly in noisy situations is compromised. Hearing impairment tends to isolate elders from their family, friends and the wider environment eventually leading to loneliness and trauma [12].

7.4. Balance Inability:

Ageing is associated with poorer sense of balance. Newton, 2003 stated that both Static balance and Dynamic coordination are compromised with age. Static balance addresses sitting posture or being still while standing. Dynamic coordination is when a person is moving and negotiating the physical environment.

Balance depends on three factors: Vision, Vestibular system of the inner ear and Proprioception. Vision helps in providing information about the environment, the vestibular system of the inner ear provides information about the movement of the body in a space and proprioception (also known as kinaesthesia) is the feedback from receptors in the body about the surfaces with which the body is in contact [23]. The three factors that are related to balance are compromised with age in most cases.

Age-related vestibular loss is a great concern for elderly as the vestibular system provides signals of self-motion, important for gaze and postural control, and signals of travelled distance for spatial orientation especially in the dark. Vestibular loss thus leads to balance disorders and falls in the elderly [23].

7.5. Dizziness:

Dizziness is another very common condition in elderly that hinders with their quality of life. Instability, loss of balance, light-headedness, rotational sensation, tendency to fall, environmental spinning sensation, disorientation, confusion, fear and blacking out are the common symptoms of Dizziness [24].

Dizziness is caused due to mismatch between the visual receptors and the somatosensory receptors [25]. Visual receptors help in providing stable retinal image of the surroundings and the somatosensory receptors that provide information regarding gravity, position and motion of muscles and joints. Four types of dizziness were identified by the classic study of Drachman and Hart, 1972. Vertigo, presyncope, disequilibrium, and light-headedness.

Vertigo is an illusion of false motion between the person and outside world [27]. Presyncope is a perception that the person is about to fall but there is no actual loss of consciousness. Light-headedness is a feeling of emptiness and a mild sensation in the head usually accompanied by nausea, anxiety and confusion. Disequilibrium is a sensation of losing one's balance without a feeling of illusionary movement or an impending loss of consciousness. Disequilibrium occurs due to disruption in the interaction between sensory inputs and motor output. The ability of the nervous system to process sensory inputs and control the postural reflexes declines with ageing. Elderly are most prone to it in unfamiliar surroundings, uneven ground and in poorly lit spaces.

Cardiovascular disease was identified as the most common cause for dizziness in the elderly. Conditions like, peripheral vestibular disease, psychiatric illness like depression, drug effect, neurological disease, impaired vision, metabolic or endocrine conditions, and locomotive diseases also could cause dizziness to some extent in elderly persons [24].

7.6. Decline of Cognitive skills:

Cognition is defined as the mental action or process of acquiring knowledge and understanding through thought, experience and the senses. Cognitive changes like reduced focus, reduced memory, difficulty with conceptual reasoning, decline in processing speed, are a normal process of ageing [10].

The working memory (short-term memory) is responsible for temporarily holding information available and processing it. Ageing has an impact on the working memory such that the time taken to process information is much longer in elderly people when compared to their younger counterparts [28]. For example, the ability to remember and use relevant information while in the middle of a task declines with ageing. Fewer chunks of information are held in the working memory at any given time which makes multi-tasking difficult for the elderly persons.

Prospective memory is the ability to remember to do something after a certain lapsed time. Semantic memory is a type of long-term memory involving the capacity to recall words, concepts or numbers, etc. Semantic memory is rarely affected in elderly except for people suffering from Alzheimer's disease which is a pathological condition [28]. Procedural memory is a type of implicit and long-term memory and is concerned with how to carry out tasks learned in the past. Memory with respect to performing routine tasks and those concerned with automatic behaviour remains largely intact with ageing but the task may require more attention and time [29].

The ability to attend a task and process information regarding that does not change with ageing in most cases. However, the ability to switch between tasks is reduced as a people age. It becomes increasingly difficult for elderly people to ignore information unrelated to the task at hand causing shifts in attention and slowed down processing of information [13].

Spatial cognition addresses the ability to navigate and stay oriented in a space. Spatial cognitive abilities deteriorate with age and it is difficult for older persons to figure out where they are located in a particular space based on other cues [14]. Ageing has less impact

on visuospatial perception, image maintenance and image scanning. Whereas, Image generation, rotation and metric properties processing are impaired with age [29, 30].

VIII. GUIDELINES FOR DESIGNING RESIDENTIAL SPACES FOR ELDERLY

Table I, has been used for easy reference of design guidelines against age-related biological changes and associated functional decline. The design solutions provided in response to particular functional challenges, faced by elderly persons, can be adopted universally in practice, as most age-related challenges are cumulative and progressive in nature.

Table 1. Age-related biological changes, associated symptoms and functional decline, and design guidelines for residential spaces.

S.No.	**Age-Related Biological Changes**	**Associated Symptoms and Functional decline**	**Design Guidelines for residential spaces**
8.1	**Changes in skeletal system and related disease/concerns**		
8.1.1	Structural changes in skeletal system like shortened Torso and Spine height.	Impaired range of motion specially the upper body and balance inability.	→ Design for easy reach. Vertical reach of 580mm to 1625 mm while standing and 250mm to 910 mm in sitting position, horizontal surface reach of 900mm to 1060mm sideways and 600mm forward reach. → Counter-tops, wash basins, sinks and other work surfaces should be installed at a maximum height of 850mm from ground level. → Falls-prevention strategies like non-slip, textured flooring in wetness prone areas, good lighting, clutter-free spaces, avoiding or marking level differences and barriers in circulation spaces will help to prevent fractures from falls and accidents. → Slopes for ramps should be in the range of 1:12 and 1:20 ideally. → Uneven flooring and uncovered walkways have to be avoided and connecting spaces should be planned with most direct routes.
8.1.2	Reduced bone density.	Frailty and vulnerability to fractures	
8.1.3	Wearing of cartilage in joints	Pain, stiffness and mobility issues like inability to climb stairs	
8.1.4	Osteoporosis	Weak skeletal system, making bones more susceptible to fractures.	
8.1.5	Osteoarthritis and degenerative joint disease	Joint pains, stiffness and reduced flexibility. Particularly affects the hip and knee joints. Issues with reach and hand grip significantly impacting their ability to perform activities of daily living.	
8.2	**Changes in muscular system and related disease/concerns**		
8.2.1	Poor Muscle Strength	Frailty, poor hand grip and reach problems	→ Seating has to be provided in places where physical exertion is involved, like at the entrance foyer, bathroom, kitchen, etc. → Activities like cooking, bathing, dishwashing, etc., where the person may not have stamina to stand for a long time, should be designed to have provision for sitting also. → Easy to operate hard ware should be provided for door handles, window controls, faucets and cupboards to help better grip for people who are frail. → Grab bars should be provided along all circulation paths, toilets and bedrooms, etc. → Furniture should be designed such that it provides sufficient support for the person while getting up and moving around. → Recliners should be avoided since they require upper body strength and an ability to grip firmly or require leg strength to push the footrest down.
8.2.2	Loss of flexibility	Impaired Mobility, Balance Inability, loss of Upper – lower extremity synchrony.	
8.2.3	Loss of Muscle Mass	Frailty, vulnerability to accidents and falls.	

			→ Taller seating is required for elderly. Recommended seat height is 520mm from ground level.
8.3	**Changes in respiratory system and related disease/concerns**		
8.3.1	Reduced lung volume	Decreased ability to perform physical activity, fatigue and low stamina.	→ House should be of the right size and should be designed for easy maintenance by a person with less stamina. → Seating should be provided in intervals of 10 meters, in case long walking paths cannot be avoided in design. → Ramps should not be longer than 9M between landings. → Stairs with more than 10 steps per flight should be avoided. Riser height should not be more than 150mm in height. → Optimum use of natural lighting and good ventilation enhance well-being of elderly persons suffering from respiratory issues and frequent illness.
8.3.2	Reduced Lung Function.		
8.3.3	Weaker Respiratory Muscle strength	More incidence of coughing and feeling of mildness.	
8.3.4	Vulnerability to Respiratory Infections	Frequent illness	
8.4	**Changes in nervous system and related disease/concerns**		
8.4.1	**Sensory Impairment (Impaired Vision, Decline of Tactile and Auditory systems)**		
8.4.1.1	Presbyopia (Near Vision)	Worsening ability to focus on closer objects and difficulty reading small print.	→ Larger size of letters and high contrast between the background and foreground provides good legibility in case of signage design.
8.4.1.2	Slower Light/Dark Adaptation	Takes longer to adjust to sharp difference in illumination levels (indoor to outdoor lighting levels and vice versa). Decreased rod-mediated dark adaptation may lead to night vision problems in most elderly.	→ Abrupt changes in lighting levels should be avoided. Transition lighting levels could be used to bridge sharp difference in lighting levels of two spaces. → Two-way light switches which are accessible near both the entry and exit of a room will help avoid accidents at night. → Light control switch at an easy reach from the bed is recommended in bedroom. → Radium tapes/paint may be used for marking doors, corners of the room, edges of furniture for indicating walking paths in the dark, to avoid accidents.
8.4.1.3	Vitreous humor (transparent gelatinous tissue filling formation behind the eye lens)	Creates light scattering within the eye, making the person sensitive to glare. This also results in slower adaptation to changes in illumination levels	→ Should avoid glare and glossy finishes as much as possible. → Indirect lighting where the light source does not disturb direct vision is recommended.
8.4.1.4	Reduced Visual Acuity	Lowered resolution in sight and difficulty to adjust to rapidly changing visual stimuli and to perceive motion in low illumination.	→ Optimised use of natural lighting and increase in the levels of task and ambient light is recommended. → Multiple sources of light should be used and designers should aim at providing uniform lighting.
8.4.1.5	Retinopathy	Complete or partial loss of vision	→ Textural changes in flooring can help as a form of wayfinding.
8.4.1.6	Increased density of Eye Lens (thickening or yellowing of the eye lens)	Poor Colour Vision. Colour vision diminishes especially in the violet-blue-green portion of the spectrum. Elderly have better colour vision in red-	→ Colours of adjoining surfaces should be in contrast to each other so that it is easy to identify sharp edges and obstacles. A contrast of at least two levels in a 10-level grey scale is recommended.

		orange part of the spectrum.	→ Contrast colours have to be used for sign boards and house numbers, etc. for better legibility.
8.4.1.7	Poor Stereopsis	Poor perception of depth	→ Contrasting colours or patterns may be created between floors, walls, tabletops, and other adjoining surfaces for easy recognition of depth to avoid accidents. → Non-uniform lighting that forms shadows on the flooring or a flooring with varying shades could confuse an elderly who is likely to perceive the darker shade/shadow as a level difference and may cause falls or accidents.
8.4.1.8	Age-related pupillary miosis	Reduced size of pupil allows less light to enter the eye and the person will need more light than normal to see clearly	→ Uniform lighting and multiple sources of lighting is recommended. → An older person needs twice as much light as a younger counterpart to see clearly. Anything below 107 Lux levels can be a hazard to the elderly.
8.4.1.9	Decline of Tactile Sensation	Perception of touch, pressure and vibration declines, especially in hands and feet.	→ Textured rather than smooth surfaces supplement touch sensation.
8.4.1.10	Presbycusis	Hearing impairment, mumbling and speaking louder than necessary. The person's ability to understand conversation in noisy situations is compromised. Hearing impairment may cause isolation from friends and family leading to loneliness and trauma.	→ Noise reduction strategies like acoustical flooring should be adopted. → Designers should eliminate annoying background noises by separating conversation areas from TV and other entertainment areas. → Furniture should be arranged in order to avoid frustration due to being cut off from a conversation. At least one seating should be at 90-degree angle or face-to-face.
8.4.1.11	Decline of sense of smell	Unable to or delayed detection of odour	→ Gas stoves should be avoided and fire extinguisher should be provided within easy reach in the kitchen. → Adequate ventilation directly above cook tops, remove cooking odours, vapours and smoke. A minimum of 100 CFM ducting capacity is recommended for kitchen exhaust system.
8.4.2	**Balance, Dizziness and Mobility Disorders**		
8.4.2.1	Vertigo	Causes Dizziness with an illusion of false motion between the person and outside world.	→ Grab bars should be installed near bed, toilets and along the wall in circulation spaces. → Grab bars should be installed near places where a person is expected to stand for a long time while performing a task. → Seating facility should be provided with easy access in all rooms. → Strongly patterned flooring should be avoided since it may be confusing or can cause a sense of movement in persons suffering with vertigo and vestibular loss. → Since dizziness occurs while suddenly getting up from lying position, grab bars must be provided for support along the wall near the bed. → Handrails should be provided on both sides of staircase or ramp.
8.4.2.2	Vestibular Loss	Balance disorders and falls due to deteriorated sense of self-motion important for gaze and postural control. Decreased spatial orientation especially in the dark.	
8.4.2.3	Presyncope	Causes Dizziness with a perception that the person is about to fall but there is no actual loss of consciousness.	
8.4.2.4	Light-headedness	Causes Dizziness with a feeling of a mild sensation in the head usually	

		accompanied by nausea, anxiety and confusion.	
8.4.2.5	Disequilibrium	Causes Dizziness with a sensation of losing one's balance without a feeling of illusionary movement or an impending loss of consciousness.	
8.4.2.6	Psychiatric diseases	Depression and other psychiatric diseases could lead to dizziness and loss of balance confidence.	→ Open-floor plans, big and low sill level windows that provide views of the outdoor activities while seated or while lying on bed help elderly persons to connect with people in the house and the outside world. → Furniture should be arranged such that it can give access to someone on wheelchair to join conversations with family members at any time. → Optimum use of daylighting and proper ventilation can boost psychological well-being of an elderly person.
8.4.3	**Changes in Cognitive Skills**		
8.4.3.1	Decline of Working Memory	Reduced ability to recollect information in the middle of a task and difficulty with multi-tasking.	→ Coding systems like colour, size, shape, texture, etc could be used to ease the issue. A Case-in-point, of colour coding entrance doors in neighbourhoods with identical units help in easy identification of one's home. → Providing a prompt tied to the task, for example, a buzzer to switch off the oven or installation of automatic switch-off systems wherever possible will help persons with loss of prospective memory. → Well organised interiors such that it is easy for the person to locate things without much hassle will help improve task performance time. → The design of cabinetry and storage spaces should be well organised, easy to locate and identify, and be within easy reach.
8.4.3.2	Decline of Prospective Memory	Difficulty in remembering something after a certain lapsed time.	
8.4.3.3	Semantic Memory is largely unaffected.	Reduced capacity to recall words, concepts or numbers.	
8.4.3.4	Slower Procedural Memory	Delayed performance of routine work or tasks related to following certain procedures.	
8.4.3.5	Decreased Attention	The ability to orient attention from completing one task to the other is slowed down.	
8.4.3.6	Decreased Spatial Cognition	The ability to navigate and stay oriented in a space deteriorates.	
8.5	**Other age-related disease/concerns**		
8.5.1	Cardiovascular Diseases	Physical activities like walking long distances or walking uphill may become difficult. Cardiovascular disease is one of the leading reasons for causing dizziness in the elderly.	→ Seating should be provided in intervals of 10 Meters, in case long walking paths cannot be avoided. → Ramps should not be longer than 9M between landings. → Stairs with more than 10 steps per flight should be avoided. Riser height should not be more than 150mm in height.
8.5.2	Locomotive Syndrome: Lumber, hip and knee osteoarthritis and spinal canal stenosis and osteoarthritis are associated with	Problems with bending forward, frequent falls, mobility issues, balance inability, pain, muscle weakness and reduced walking speed.	→ Larger circulation spaces have to be designed for easy movement. → Unnecessary movements back and forth in spaces like kitchen, laundry and bathrooms should be avoided. → Grab bars should be provided in functionally active spaces.

	locomotive syndrome.		
8.5.3	Diabetes	Certain diabetic medication could cause dizziness	→ Strategies indicated for persons suffering from dizziness maybe adopted.
8.5.4	Urinary Incontinence (Over-active Bladder)	Strong and sudden Urge to urinate. Frequent visits to bathroom.	→ Direct un-obstructed route to toilet from bed should be planned. → Well-lit and clutter-free path to toilet is required. → Furniture that is difficult to get out of or manoeuvre around should be avoided.
References for Design Guidelines: [4, 9-11, 31, 32].			

IX. CONCLUSION

Designing home-environments to accommodate specific needs of the elderly, will enable them to live independently. Home-environments should be designed to accommodate elderly with their challenges, rather than them adjusting to the environment. Designers shall aim to establish a congruence between the person and his environment to enable him to live independently. The present study provides easy reference for designers and professionals of related domains for designing residential environments for the aged.

Ample research is available in the area of designing health-care facilities and institutions for the elderly. However, research in the area of residential design for elderly, especially for those living independently in community settings is very limited. Future studies can also focus on residential design for elderly persons suffering from chronic degenerative diseases like Parkinson's disease and Alzheimer's disease, since research in this area is meagre. This being a vast area of study, the current article was limited to an overview of the subject. However, it leaves a good scope for future research to identify areas of concern for a more focused study.

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