

**Design Guidelines for the Development of Mobility Products for  
Older Users**

by

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## Abstract

Mobility limitations in the growing US older adult population lead to negative functional consequences such as falls and increased functional decline. When these factors combine with the existing changes in the aging process, such as sensory and physical decline, the older adult becomes susceptible to decreased functional capability, limiting their opportunity to remain personally independent. Participation in regular physical activity can maintain or improve many of these functional changes; however, participation levels are currently low. Identified barriers to activity suggest that the application of accommodations to the products, activities, and lifestyle choices has been shown to be beneficial in promoting activity in the older adult. Unfortunately, the product offerings doing so have been difficult to access in the at-home setting. Through the application of product design, many of these accommodations can be included into the products that offer beneficial movements within the preferred lifestyle of the older adult through product modifications and enhancements to the characteristics of the activity products they use. These accommodations are synthesized into a collection of design guidelines that promote mobility to the aging process in three areas, Lifestyle, Mobility, and Ergonomics. When applied to the product design process, designers may be able to promote mobility among the older adult population through improved design solutions that account for the barriers to physical activity.

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## List of Abbreviations

AARP Association of American Retired Persons

ACSM American College of Sports Medicine

ADL Activities of Daily Living

AHA American Heart Association

BAPS Biomechanical Ankle Platform System

CAD Computer Aided Design

CNS Central Nervous System

COG Center of Gravity

COM Center of Mass

FITT Frequency, Intensity, Time, Type

IADL Instrumental Activities of Daily Living

IDSA Industrial Design Society of America

IP Interphalangeal Joint

MTP Metatarsophalangeal Joint

NIA National Institute on Aging

NIH National Institute of Health

POG Product Opportunity Gap

QOL Quality of Life

ROM Range of Motion

SET Social Trends, Economic Forces, Technological Advances

SI Sacroiliac Joint

VOG Value Opportunity Gap

W3C World Wide Web Consortium

WHO World Health Organization

2-D Two Dimensional

3-D Three Dimensional

## **Chapter 1 Problem Identification**

The population in the U.S. experienced a boost after the end of World War II. The return of those who served transitioned the population into a period of economic abundance, transitioning the country from an agricultural existence into a continued industrial growth. Improvements in medicine such as vaccinations and prescription drugs have allowed the eradication of disease and the improvement of general health, which have improved life expectancy. The increase in life expectancy brings with it the increase in the time spent in the retirement years. Whereas just a few decades ago, the extension of the family was limited to the immediate area, the transition into the suburbs and the following of careers has spread the family circle over the country. While technology allows for communication, hands-on roles of supplementary care are no longer guarantees in later life with the geographic spreading of family. Their career and family creation roles now occupy time that recently was more available for aging relatives.

Within this same period of growth, the roles of individual age groups has begun to transition from views on the appropriateness of physical activities of women to those of older individuals. No longer are Victorian-style views of the lady widely held by society as a whole as technology has spread the speed of information and its ability to shape public view from months to moments. While current society may hold different belief systems, the increase in the older population raised within previous societal norms may carry with it views that older adults are to follow a take-it-easy approach to retirement. Additionally, many groups, such as women, were raised in an area where activity was not appropriate for ladies, and lack the exposure to previous participation. This creates situations where confidence in the interaction with the environment may become compromised.

The general impact of products post World War II cannot be overlooked as factories transitioned from war production activities into hubs of products that fueled the transition into the suburbs. People began to have their lives enhanced by improved abilities through thoughtfully designed products that allowed for the transition into leisure time activities of other product and technological advances. Leisure time could now be filled with TV and later the internet in this simplified life, lessening the need to perform activities that fueled our daily lives just decades earlier. Individuals can have their lives enhanced through well designed interactions.

## **1.1 Problem Statement**

*“No one is too old to enjoy the benefits of regular physical activity. Of special interest to older adults is evidence that muscle strengthening exercises can reduce the risk of falling and fracturing bones and can improve the ability to live independently” (2000)- US Surgeon General*

The U.S. population is growing older. This increase in our older adult population has raised concerns surrounding their wellbeing and personal independence. Falls are a known problem for older adults, often leading to increased morbidity in this population. Examination of the reasons for falls among older adults indicates the need to maintain mobility and strength as they age. This study seeks to reduce the risk of falling among older adults by improving mobility through improved, accommodated physical activity product interactions.

A survey conducted by the American Association of Retired Persons (AARP) found that 90% percent of the older adults desired to maintain independence at home rather than in assisted facilities (2012). Individual abilities are required to accomplish essential tasks without outside assistance. Diminishing abilities to accurately and safely interact with the surrounding environment and products compromise this goal. Problems climbing stairs, navigating grocery stores, and rising from toilets are essential activities of daily living (ADL) that require functional levels of mobility. When individuals can no longer self-sustain their independence, outside assistance is necessary. The costs associated with staffing and financing the growing older population with personal care make this difficult.

It is estimated one in three older adults over age 65 in the U.S. fall annually, yet only half of these incidents are reported to the medical community (Falls-Older Adult: CDC, 2015). After a fall that results in hip fracture, it has been shown that 50% of people will never regain their previous level of functioning, and one in five die within 3 months (Yardley, Donovan-Hall, Francis, & Todd, 2006, p. early binder). Awareness of the potential consequences associated with falls creates a fear of falling among older adults. Fear of falling creates a barrier to activity participation by self-choice because of anxiety and belief that injuries sustained during activity may jeopardize their ability to maintain personal independence and how they are perceived socially (Finbarr, Hart, Spector, Doyle, & Harari, 2005, p. 285; Rhodes, et al., 1999, p. 406). Activity avoidance creates patterns of disuse leading to a sedentary lifestyle. Fear of falling and low physical activity rates among older adults increase the rate of decline in body system capabilities. Reductions in abilities from injuries sustained are complicated by slower recovery processes that accompany even healthy aging individuals. Recovery times are exacerbated by sedentary lifestyles filled with disuse. Accumulation of pathologies caused by poorly functioning body systems force healthier systems to adapt through a process of compensation, in both functional health and mobility. Eventually body systems are overcome and can no longer adapt through compensation. This transitions the individual into a disability state to the extent that the systems have failed, requiring outside assistance and loss of independence.

The ability to remain mobile requires strength in the abilities of the physical and sensory systems to interpret the environment through feed-forward interpretive systems. Feed-forward systems such as vision are necessary to accurately interpret the surroundings; when done safely, they act to produce movement to be accomplished in a safe coordinated fashion to avoid falls (Heasley, Buckley, Scally, Twigg, & Elliot, 2005). There has been minimal effort to provide in-home products for older adults that seek to address the maintenance and improvement of the body systems necessary to produce mobility through physical activity. Dysfunction within the kinetic chain can adversely affect the intended movements that occur during the gait cycle, the pattern of forward movements that occur from the strike of the heel until the return to that position (Rose D. J., 2010). Products designed for older adults to improve their mobility are minimal,

with few product solutions appearing to address the adoption stage of activity. The adoption stage of activity participation is comprised of a segment of the older population who can benefit most from activity participation.

Personal independence that avoids assisted living and involves remaining at home is desired by older adults (Daley & Spinks, 2000, p. 2). However, the ability to pursue this way of life requires abilities to, at minimum, perform activities of daily living (ADL) that include mobility and interactions with the environment. To move about must also include the confidence or self-efficacy to do so without the fear of falling or injury. Unfortunately, avoidance and limited participation in activity increase the risk to fall by escalating the rate of body system deterioration. Compromised systems can negatively affect the performance of kinetic coordination during mobility without access to maintenance and improvement methods. However, the ability for older adults to interact with products that are both accommodative to aging human factors and promote mobility needs are minimally accessible within current design solutions.

## **1.2 Need for Study**

Physical activity is widely supported historically as being beneficial to overall health. Adoption of activity participation in older age has not always been thought to be appropriate. The emergence of evidence suggesting the adaptive capability of training body systems in older adults through activity participation is similar to gains that can be achieved by younger adults (Daley & Spinks, 2000, p. 8); however, problems implementing participation and retention in activity among older adults has become an area in need of designed solutions. The ability for older adults to have available mobility promotion at limited cost has been problematic. Older adults are further distanced from participation at an individual level through activity apprehension and biological decline. Adopting patterns of sedentary behavior and disuse of body systems increases the rate of decline, which is most evident in the function of the lower body. Adoption of these patterns is also linked to increased falls risk (Carter, Kannus, & Khan, 2001). These behaviors put them further from safe starting levels, limiting the selection of traditional activities. Problems in lower body ability to maintain adequate levels of strength and coordination with the sensory system necessary to produce mobility require appropriate



movements to positively affect changes (Daley & Spinks, 2000, p. 6). The limited solutions, participation, and retention of older adults in activities that promote personal independence through mobility requires design guidance in order to appropriately design possible design solutions.

Many programs have been made available to older adults to participate in. Threshold of entry is lowest among walking, leading to its high rate of prescription. Many of the available solutions fail to understand the barriers present to the older adult user (Seefeldt, Malina, & Clark, 2002, p. 146); additionally, many older adults would prefer to participate in activity outside of a class setting. When combined with travel, financial, and health barriers that have been identified, the current state of solutions may provide the necessary metrics to demonstrate change; however, they have demonstrated limited success on participation metrics as adherence rates for three decades have remained at about 50% (Seefeldt, et al., 2002, p. 146). By addressing designs to incorporate the lifestyle needs of the older adult user, overall participation may be improved through improved designs that focus on the product interactions that can potentially lead to improved mobility performance and activity participation.

In addition to limited access, the activity apprehension has been seen as a barrier even when views about activity are favorable (Rhodes, et al., 1999, p. 402). Reducing the apprehension and overcoming barriers has been favorably shown in individuals possessing higher levels self-confidence, especially when beginning a new program (Burbank & Riebe, 2002, p. 47; Rhodes, et al., 1999, p. 406). The continued building of self-efficacy in activity among both sexes of older adults has been tied to both higher overall retention and participation rates when the opportunity to participate on a regular basis is available (Burbank & Riebe, 2002, p. 46). The need to include the ability to promote beneficial movement activities that reduce user apprehension and build self-confidence are needed.

The variety of personal capabilities among the older population requires additional considerations, especially in activity promotion. It has been suggested when designing activity programs for older adults, that providing accommodations can encourage participation (Jones & Rose, 2005). These are areas of sensitivity that acknowledge the

variable functional abilities needed when creating programs for older adults. However, these efforts have focused on the programs, not on the products that are interacted with. The selection of the products is left to the expertise of an instructor. Because of costs associated with the growth in the older population, it will become increasingly difficult to provide individual guidance on product selection. The demand for products to satisfy the user needs of the older adult in self-guided exercise will be necessary.

Accommodation required through product design for older adults needs to apply human factors considerations. The decline in the physical systems of the older adult have been addressed by designers such as Pirkel through transgenerational design principles, along with other user-centered and human factors design approaches. These focus on the sensitivity required to design products utilized by all users, especially the older adult with physical limitations, as a component of good design; the gap between personal demands and capabilities can be decreased through application of controls with technology, surroundings, and behavioral adjustments (Pirkel & Babic, 1988; Kroemer, 2006, p. 129). The application of principles such as these appears to be lacking in the equipment choices available to older adults. The declines in the physical and sensory functions of older adults requires the application of properly designed product interactions that can accommodate these declines in an effort to improve product use, especially those that promote mobility activities.

There is a need to study the possible new approaches that can improve the access to activity for the older adult. Additional needs include identifying ways to limit the apprehension to activity through improved self-efficacy and adaptability to progressively build these beneficial traits, by studying how the design of programs for older adults can be formatted to accommodate lifestyle considerations such as individual home use with improved product interactions by identifying ergonomic design principles applied to the losses that occur to the required movements of the lower body that affect older adult mobility. By studying how to accommodate the needs of older adults within their current lifestyle, activity, and ergonomic needs, the ability to improve design solutions necessary to improve the training needs required to promote mobility.

### **1.3 Objectives of Study**

The objective of this study is to create a set of design guidelines to aid in the development of physical activity products that improve the interaction and use of mobility products that are designed for older adults over age 50, through increased accessible use in their living environment. This was achieved through answering the following objectives:

- What are the problems with the physical activity product interactions that older adults currently encounter?
- What guidance would benefit designers to improve the interactions of older adults utilizing activity devices for mobility?
- How are the activities that benefit mobility in older adults currently offered?
- What is needed in mobility promotion for older adults?

### **1.4 Assumptions**

The use of physical activity is the preferred, non-surgical form of maintaining mobility.

The focus on the use of the lower body of the older adult is the ideal place to focus for mobility.

The definition of older adult is fifty years of age and older.

The older adult is capable of self-training safely to improve mobility.

The techniques for improving movement and strength among older adults suggested by field experts is reliable.

The thesis assumes that older adults desire the ability to maintain their mobility in an effort to remain independent.

The thesis assumes that product design can be employed to improve the interaction between older adults and physical activity products.

The thesis assumes that the views held by older individuals in the Southeastern region of the U.S. provide a similar representation of those regarding mobility as elsewhere in the U.S.

## **1.5 Scope and Limits**

The research conducted on the design products for the promotion of mobility among the older adult was conducted in an academic setting that created a set of goals that were constrained by elements unique to the study.

### **1.5.1 Scope**

The project scope focused on the promotion of mobility as it relates to older adults. The identification of causes that limit mobility included falls reduction and functionally limiting physical and sensory impacts in the lower body region. The focus of the proposed solutions were conceptual designs in the development stage of the design process. Current research included on mobility in the aging process is included in the development of design guidelines for product designers.

### **1.5.2 Limits**

The number of older individual and field experts will be limited by their proximity to the immediate surrounding areas of the research location. The views of those that choose through voluntary participation to provide their opinions and thoughts to the research will be included. The movement factors that are currently viewed to be modifiable through participation in physical activity by older adults will be limited to those that focus on the source of falls, imbalance, and mobility that have been suggested through existing and ongoing research. Because of the speed of current research findings, the information provided from research studies on movements, activity participation, and their influence on the older adult was limited to the knowledge and beliefs at the time of the study.

## **1.6 Procedures and Methods**

The research procedures conducted was divided into two categories, the development and the application. The development stage procedures researched the existing state of devices, opinions, and knowledge available to promote the mobility of the older adult. The research gathered the information from existing literature, user interviews, and

observations to produce a general understanding of the problems as they exist. The product research guided the development of conceptual design solutions in the form of illustrations and physical sketch models to test the research findings through the use of design reviews.

The procedures of the application phase refined the gaps and opportunities for improvement discovered during the research and product research phases to produce a set of design guidelines that sought to refine the gaps that were seen to be present in the delivery of mobility products for older adults. The design guidelines were applied to the development of a proposed solution to demonstrate the proposed process.

### **1.6.1 Development of Research for the Mobility Needs of Older Adults in Activity**

Talked with medical professionals to determine user needs; talked with potential users of mobility and/or physical activity products; conducted written research book, journal, and internet research to identify current state of information through review; identified two groups of influential stakeholders in the design process: 1. Targeted User: defined as individuals  $\leq 50$  years of age chronologically, referred to in study as “Older Adults”, and 2. “Field Experts”: defined as (a.) individuals or groups that have direct interaction with “Older Adults” in their occupational capacity, and/or (b) individuals that have professional training in topics that relate to the health, wellbeing, and movement of individuals

### **1.6.2 Development of Concepts to Determine Activity Focus Direction**

Tested the initial sketch model within two identified influential stakeholders groups: 1. targeted user population, and 2. targeted field experts within the medical community to determine validity through observations and questionnaires

### **1.6.3 Conceptual Development, Validation, and Refinement in a Design Cycle**

Created ideas in the following forms: concept sketches, renderings, sketch models, mechanical feasibility models; refined concepts through review to assess strengths and weaknesses of directions and review current written information; sections, materials, suggestions, and findings were summarized for use in the development of guidelines

### **1.6.4 Guideline Creation**

Created a set of guidelines that applies research into an organized approach; proposed guidelines are sought to be used by designers when applied to the design of mobility product for older adults by those designing solutions

### **1.6.5 Guideline Application**

Documented of the product concept utilizing the design criterion from the previous research and development review

### **1.6.6 Guideline Testing and Review**

Validated the final design through review of initially identified influential stakeholders; target user trials in a controlled environment; determined if the current process is useful and accurate; outlined the benefits of the product; suggested areas for improvements, and potential directions future research and development

## **1.7 Anticipated Outcome**

The anticipated outcome of the study is the development of a set of design guidelines to aid the creation of mobility products for older adults. Application of the guidelines will be demonstrated by a potential conceptual solution. The potential solution of the guidelines will focus on improving the user interactions with physical activity products that focus on the lower body movements used in activities for older adults. The effectiveness of the guidelines will be reviewed through the application of the guides demonstrated in a potential design solution concept. The findings of the research will be

synthesized into a thesis. The guidelines developed will have the possibility of being utilized by designers in the future who are seeking guidance on how to create mobility activity solutions for older adults.

## **1.8 Definition of Terms**

### **Accommodation**

1. in Transgenerational Design: provision for enhancement or modification provided in the design of products or services that include older adult users which is satisfied through four areas of consideration: (1) legibility, (2) accessibility, (3) adaptability, and (4) compatibility (Pirkl J. J., 1994, p. 104)
2. in Physical Activity Program Design for Older Adults: the performance of exercises and activities to the best of the abilities of the older adult, but to never push themselves to a point of overexertion, pain, or beyond a level that they consider to be safe; this applies to the current time activity occurs, and the current state of the individuals physical functioning condition; application of modifications that make allow for these current abilities to be provided for including seating or reduced challenges (Jones & Rose, 2005, p. 136)

### **Balance**

Controlling the body's Center of Mass with respect to the base of support, whether the individual is stationary or moving (Rose D. J., 2010, p. 4)

### **Challenge**

In older adults, the selection of activities or exercises that need to task, but not exceed, an individual's intrinsic capabilities (e.g., strength, cognition, sensorimotor ability); the level of task can be altered by changing the task demands (seated, standing, or moving; single or multiple task) or the environmental demands (surface type, lighting, visual flow) (Jones & Rose, 2005)

### **Closed Kinetic Chain**

Motion that occurs when the distal portion of the extremity is weight bearing or otherwise fixed (Starkey & Ryan, 1996)

### **Center of Gravity**

The midpoint or center of the weight of a body or object. In the standing adult human the center of gravity is in the middle of the pelvic cavity, between the symphysis pubis and the umbilicus

### **Center of Mass**

The point at which all of the mass of the body is concentrated in terms of the forces that act on the body and the body's motion (Rose D. J., 2010, p. 4)

**Dynamic Balance**

The ability to anticipate and react to changes in balance as the body moves through space

**Endurance**

The ability to persist in physical activity or to resist muscular fatigue (ACSM, 2001, p. 376)

**Extrinsic**

Arising from outside of the body or away from the body part being described (Starkey & Ryan, 1996)

**Feed-forward**

Vision is used to anticipate changes in the environment and prepare the motor system in advance of action (Rose D. J., 2010)

**Flexibility**

Range of motion about a joint, dependent on the condition of the surrounding structures

**Frequency**

The number of times a repetition of activity occurs over a tracked period of time; this can be measured in repetitions of a movement, the amount of times in a session, or measure of activities in a week

**Functional Relevance**

In older adults, the encouragement of selecting exercises that simulate the movements of everyday activities that are to be performed in environments similar to those regularly encountered daily by program participants (Jones & Rose, 2005, p. 136)

**Gait Cycle**

The representation of walking that is measured as the time between the first contact of the heel of one foot with the ground and the next heel-ground contact with the same foot (Rose D. J., 2010)

**Intensity**

Marked tension; great activity; often used simply to denote a measure of the degree or amount of some quality; the degree or extent of the perceived difficulty expressed in the completion of a task

**Intrinsic Muscle**

Group of muscle that is located within or positioned deeper in a structure

**Kinetic Chain**

The position and movement of one joint influences the position and movement of another joint (Starkey & Ryan, 1996)



**Lifestyle**

Characteristics of daily living activities that include social interactions, preferences, comforts, and habits that comprise our individual lives

**Mobility**

The ability for an individual to personally move freely through their current environment with little to no assistance by possessing a physical functional capacity to act

**Movement**

Process of actions or activities that are performed by an individual using their body

**Older Adult**

An individual of any gender, ethnicity group, or state of physical function who is chronologically age 50 or older

**Open Kinetic Chain**

Motion that occurs when the distal portion of the extremity is non-weight bearing (Starkey & Ryan, 1996)

**Overload**

For a tissue or organ to improve its function, it must be exposed to a load to which it is not normally accustomed. Repeated exposure is associated with an adaptation by the tissue or organ that leads to improved functional capacity (American College of Sports Medicine, 2001)

**Physiological**

Consisting of the normal function of an organism; pertaining to physiology; normal; not pathologic

**Plantar Fascia**

Deep fascia of the sole of the foot; includes a thick central part, the plantar aponeurosis, covering the central compartment of the sole of the foot, and thinner medial and lateral parts covering the flexor hallucis and flexor digit minimi muscles (compartments), respectively.; inflammation pain that is felt especially first thing in the morning (overnight rest with the foot in plantarflexion allows the fascia to contract) or on weight-bearing exercise: a dull pain felt along the sole of the foot

**Postural Control**

The act of maintaining, achieving, or restoring a state of balance during a stance or position or activity; this is achieved through either a reactive or predictive change that occurs under either a fixed or changed base of support

**Postural Sway**

The constant displacement and correction of the center of gravity within the base of support

**Power**

The rate at which work is done; the strength or force that is exerted or which is capable of being exerted

**Progressive Training**

The adaptation of increasing difficulty levels; in older adults this can include chair based, supported, and weight bearing stances

**Proprioception**

The internal sense and awareness of stimuli that relate to the posture, movement, or position of the body and/or its limbs as they relate to a position in space during movements and seeking equilibrium

**Psychological**

Relating to the mind and its processes; relating to psychology

**Reaction Time**

The time required for a subject to initiate a prearranged response to a defined stimulus

**Sarcopenia**

The degenerative loss of skeletal muscle mass that is associated with aging; the process can begin gradually as early in age as thirty

**Self-Efficacy**

Individual's belief in her or his capacity to execute the behaviors or actions necessary to produce specific performance attainments; a reflection of the confidence in the ability to exert control over one's own motivation, behavior, and social environment

**Sensory Input**

The source of sensation or response of the senses (vision, touch, hearing, etc.) to inbound stimuli

**Specificity**

Training effects derived from physical activity are specific to the type of exercise and muscles involved (American College of Sports Medicine, 2001, p. 376)

**Strength**

The ability to generate force at a given speed or velocity of movement (American College of Sports Medicine, 2001)

**Step Length**

The distance between 2 successive placements of the same foot, consisting of 2 step lengths

**Time**

A measure of duration;

In activity, the duration spent participating;

In barriers, the limits to the duration available for including additional activities or events into daily life

**Transgenerational Design**

The practice of making products and environments compatible with those physical and sensory impairments associated with human aging and which limit major activities of daily living; products and environments that accommodate, and appeal to, the widest spectrum of those who would use them, including the young, the old, the able, the disabled, without penalty to any group

**Type**

A specific version or variation of an activity, exercise, or movement pattern

## **Chapter 2 Literature Review**

The identification of the factors that define an older adult will be explored to understand the lifestyle and social roles that are present. These needs and desires form the barriers and opportunities that can frame solutions and hindrances to interventions. Strategies employed by designers and business will be explored to draw connections to the opportunities the unanswered barriers can have to creating value for the older adult.

The ability to create value for an older adult to become mobile requires an understanding of the science and technology that drives the ability to do so. Physiological, anatomical, and biomechanical understanding of the underlying processes that produce balance and mobility through walking is necessary to determine intervention possibilities. These possibilities include the understanding of programs that have shown promise and success to produce positive physical activity outcomes to determine if there are areas to further examine for solution potential.

Finally, the abilities of the older adult will be explored to identify the ability to utilize and interact with potential solutions of value. The requirements to satisfy the interactive needs based on size and fit will be explored to determine the role that properly considered user needs can have on devices for the population. What else can be explored as potential directions from what has not worked?

### **2.1 Defining the “Older User”**

No study aimed at understanding the older adult can proceed without defining the term as it relates to this research. There are many ways that age is defined. The form that is most recognizable, chronological age, represents the expression of a number in regards to the years the individual has been alive; other forms, such as biological age or functional age, attempt to represent the status of the body function as the age determinant (Jones & Rose, 2005, p. 6). In this way, a 50 year old individual through

poor body function and other impairments may have a body that functions as a 100 year old individual, with the converse of the example being possible also. For the general understandability, chronological age will be the form of representing age. However, another age question remains undefined: what chronological age will represent “older adult”?

Reviewing studies and most literature, 65 years of age represents a widely followed demarcation of chronological age applied to represent the older adult. Several approaches have suggested targeting age 50 as a transition into the roles of an older adult with preventative reasons as their reasoning. As early as 1996, the World Health Organization (WHO) suggested the adoption of targeting information on beneficial physical activity to adults with age 50 as the demarcation (Chodzko-Zajko, 1997). This was seen as the point in the aging process where the benefits of physical activity participation have the most relevant means of minimizing, avoiding, and/or reversing many of the physical, psychological, and social hazards that may present themselves in the aging process (Chodzko-Zajko, 1997). The use of the functional needs of activity promotion for special considerations are presented by a joint effort between the American Heart Association (AHA) and the American College of Sports Medicine (ACSM). The recommendations are targeted at all older adults age 65 and older, as well as those individuals age 50-64 years of age with chronic needs or functional limitations (Nelson, et al., 2007). The recommendations presented by the AHA/ACSM include 50 year old individuals if they are functionally older than their chronological ages presents them to be. These functional limitations are caused by a variety of reasons that can be present on a temporary basis such as surgical recovery, and those that are more permanent effects caused by certain health conditions. Although the majority of individuals receiving home health care are older adults, there are many younger individuals that experience functional limitations that hinder their capabilities in the same way the aging process hinders the older adult (Gardner-Bonneau, 2011, p. 753). The inclusion of those who are younger and those who are functionally limited by these organizations highlights the importance of a time horizon. By increasing the participation over a longer time horizon, the potential for greater benefit can be achieved.

The other area that is highlighted by the recommendations is the self-diagnosis needed identifying oneself as being either a falls-risk or functionally limited. This suggests that individuals are willing to acknowledge that they are prone to fall, or they are limited in their abilities to remain independent.

In summary, the pure definition of when someone becomes “older” and stops being “younger” has no clear delineation (Kroemer, 2006). While most research studies reviewed present the older concept at 65 years of age, this study will represent the concepts of aging towards the older adult at the age of 50 to promote both the preventative and functional potential of the information.

## **2.2 Falls Reduction**

The presence of falls negatively impacts the older adult. The ability to maintain individual independence largely revolves around the ability for an individual to maintain a sufficient amount of mobility in order to complete activities that are associated with daily living, such as travel, cleaning, and eating. The greatest negative impact to maintaining mobility in older adults is falls, the leading cause of injury requiring hospitalization among older adults; this risk increases as individuals age (Carter, Kannus, & Khan, 2001, p. 428; Li, et al., 2006, p. 1192). Injuries resulting from these falls commonly effect the hips, wrist, and skull through fractures, impact sites on the body commonly associated. The impact to older adult is extremely problematic and costly. Among older adults, 30% of individuals over 65 years of age fall at least once a year, with about half of those individuals doing so recurrently (Carter, Kannus, & Khan, 2001, p. 428; Yardley, Donovan-Hall, Francis, & Todd, 2006, p. 508). Along with potential injury, the financial cost of these falls increases the impact on older adults with an estimated cost of over \$10 billion annually in the United States alone (Carter, et al., 2001, p. 428). Regrettably, the costs of falls appear to run further among the older adult then just financially and injuries; they affect the psyche.

In addition to actual injuries, the effects of potential falls has led to the observation of a concept of the fear of falling. The fear of falling is a mental or internal belief that the individual will experience the negative consequences associated with the actual act of

falling, even if they have not done so. The development of this fear could come from personal experience of the pain or embarrassment associated with a fall, functional capacity declines that affect personal abilities, or possibly peers who have gone through such an event (Finbarr, Hart, Spector, Doyle, & Harari, 2005, p. 281). Regardless of the source, the consequences of developing a fear of falling among older adults are negative to wellbeing. These consequences have been observed by researchers as including reduction in activities and mobility, increased anxiety and depression, reduced social contact, and an increase in medication and health services sought (Carter, et al., 2001, p. 428; Yardley, et al., 2006, p. 508). Because the goal of the research is to improve the mobility older adult, the fear of falling on the older adult should be sought to be overcome in the development of an intervention.

To develop interventions, the sources of the fall should be addressed; many studies and investigations have looked to discover the source of falls that are prevalent among older adults. One particular study discovering 130 potential sources (Carter, et al., 2001, p. 429). Because many of these factors are complexly intertwined with one another, the researchers further explain that these sources can be simplified for examination into general categories. These two categories are, “intrinsic, host factors (increased personal liability to fall) and extrinsic, environmental factors (increased opportunity to fall)” (Carter, et al., 2001, p. 429).

The first category of falls research will address the extrinsic and environmental sources of falls among older adults. The location the falls occur suggest that the majority occur outside of the home (Li, et al., 2006, p. 1192). This is significant because many programs involving education and prevention are focused on modifying the home environment as part of a falls risk reduction strategy. At times these in-home modification and other similar fall prevention programs are implemented post-fall, a time that has been seen to be too late in many circumstances because of associated injuries (Yardley, Donovan-Hall, Francis, & Todd, 2006, p. 508). It cannot be suggested that these programs should be halted, because they do potentially assist in the reduction of falls, but the diversity of the outside environment cannot all be modified to suit individuals. An older adult who seeks personal independence will require the means to safely navigate his or her

surrounding environments; these external environments interactions should be examined. Accommodations should be provided to allow for the modification of how the older adult responds to those external interactions in an effort to reduce the potential falling incidents outside the home. The internal response of the older adult to the external outside environment must be established to understand the interpretation of the outside world, and the effects it has on the response taken by the individual.

The remainder of the research will focus on those factors categorized as host factors, those originating within the individual, that are associated with falling; these become the focus of the research because they are potentially modifiable within the scope of the research. They are potentially modifiable through preventive measures undertaken by the individual through personal choices. These self-directed choices can positively affect their outcome. Although the identification of a singular source appears beyond the current scope of science, there are factors that appear to be positively correlated with individuals who do not experience falls.

Increasing the personal liability to fall includes the decline of physical features associated with aging including muscle strength, mass, and power. It has been stated that falls in older, nonclinical community-dwelling adults are associated with the factors such as lower extremity weakness, increases in reaction time, and postural instability (Shaw, Witzke, & Winters, 2001, p. 304; Kell, Bell, & Quinney, 2001, p. 864). Flexibility plays a significant role in the increased risk for falls (Williams, 2001, p. 516).

Positive factors reducing falls risk include the participation in physical activity on a routine basis as a part of their daily activities as they age as an attempt to limit the functional declines of the aging process (American College of Sports Medicine, 2001; Daley & Spinks, 2000, p. 3; American College of Sports Medicine, 2001). The benefits that body systems can potentially receive depend on the styles and intensity of the activity performed. The performance of activities are thought to be a component of the beneficial link between reduction rates and participation in activity. The activity benefits are localized and specific to the body systems focused on during the training (ACSM, 2001). Therefore, to further understand how to overcome falls, it is necessary to



understand the composition and science of falls through understanding balance and mobility, as well as the aging process effects on the body.

### **2.3 Barriers to Physical Activity among Older Adults**

No single barrier nor specific combination of barriers perceived or real act on whether or not an older adult participates in physical activity; rather, the combinations of the barriers put forth below encompass the general challenges and characteristics that have been reported by both older adults, and those who study the population when presenting physical activity to the older adult population. Because of their presence, it has been suggested that the barriers should be explored (Daley & Spinks, 2000, p. 2). Identifying these barriers, physical, environmental, and others, along with the attributes contributing to non-adherence is necessary to develop solutions for physical activity adoption among older adults (Rhodes, et al., 1999, p. 398; Rhodes, et al., 1999, p. 404; Corbin & Metal-Corbin, 1990, p. 46). Barrier identification in the design process of products offered to a user population has an objective. “The objective [for designers] is to uncover why the error occurred in the first place, so that corrective action can be taken” (Cuffaro, et al., 2013, p. 132). By understanding the presented barriers and the suggestions of the medical community as to the potential corrective measures to address them, product designers can more easily implement corrective features to their designs that satisfy these needs.

From the standpoint of the designer, it is necessary to create a level of empathy for the challenges design solutions may face when presented to older adults for use and interaction. Highlighting the need for understanding, Pirkel and Babic suggest that by gaining empathy for the older adult, this “segment of the population will be accommodated through a conscious effort on the part of the designers to eliminate those potential barriers which have, for too long, deprived many of the aged their freedom and dignity” (1988, p. 11).

Although barriers can be identified, it should be noted that not all barriers will be amenable to modification; however, they require acknowledgment and understanding in order to create design guidance relating to the challenges faced by the user. The barriers

identified through the research are categorized into personal characteristics, program related factors, and socio-environmental factors for individual identification.

### **2.3.1 Personal Characteristics Barriers**

“The most consistent demographic factors that are negatively associated with exercise participation by older adults include being female, being in an ethnic minority group, older age (especially those age 85 years old or older), rural residence, and low socioeconomic status” (Jones & Rose, 2005, p. 112; Rhodes, et al., 1999, p. 399). The inclusion of older females not participating in activity is of importance. It is estimated that within the expanding older population, especially the “older, old”, the gender distribution is estimated to occur at a ratio of 2.36 older women to every 1 older man over age 85 (Rhodes, et al., 1999, p. 398). This information highlights that lower participation can be expected at higher rates the older we get because the composition of the population is more associated with low participation rates.

While gender and ethnic roles are not modifiable, understanding that financial restrictions and limited access to possible interventions are negative barriers that can be modified through thoughtful design is worth noting. The perceptions of barriers by older individuals that may not physically exist can negatively affect the chance of older adult activity participation, even when their individual attitudes towards activity are favorable (Rhodes, et al., 1999, p. 406). Beyond simply falling within a demographic category, the mindset of the older individual appears to have a tremendous impact on the participation of the older adult. Characteristics of this mindset include fear of falling, low activity self-efficacy, and motivation (Burbank & Riebe, 2002; Rhodes, et al., 1999). The ability to create a perception within older adults that there are not barriers or to limit the impact of these potential barriers present should be understood by designers in the development process. The perception of barriers on the personal level requires identification.

The vast majority of personal barriers to physical activity appear to lie within the perception of personal abilities and the perception of the role of the older individual within society. These areas include not wanting to look feeble, weak, or over-the-hill by

others, both in their immediate circles with friends and family, and externally within society. This internalized perception is especially true of the fear of falling. The individuals avoid activities to not only to avoid physical ramifications, such as injury or loss of independence, but to also avoid the impacts of social consequences, self-image, and self-consequences, through the embarrassment of being seen to lose control (Yardley, et al., 2006, p. 509).

At the self-perception level, commonly cited barriers have been reported as, “fear of falling or suffering an exercise-related injury such as a heart attack, lack of self-motivation or willpower, psychological distress (e.g., depression and anxiety), low exercise self-efficacy, and lack of knowledge or experience with activity” (Jones & Rose, 2005, p. 113). Paradoxically, many of these barriers would be positively amended with activity participation. The list suggests a theme of lack of belief among older adults in their self-ability combined with a varying knowledge base of what activities and movements to consider. Many older adults do not trust their physical abilities, reducing their activity self-confidence through a belief that injury from a fall can be avoided by simply abstaining from all physical activity they feel puts them in a dangerous situation; if they possessed the knowledge that appropriate physical activity could improve factors, motivation to participate could increase, and they could potentially live a more independent lifestyle.

This limited knowledge base of activity was exemplified in a study by Yardley, et al that, “almost all our participants were previously unaware of the benefits of strength and balance training exercises, a method of falls prevention that they welcomed because it was viewed as promoting independent activity” (Yardley, et al., 2006, p. 515). This finding demonstrates the power and willingness of the older individual to make the decisions and connections on their own if afforded proper self-direction. Rather than be told what to do, they have the choice to decide, and are provided with the information to act. This is a shift from intervention strategies and programs that focus on “hazard reduction” to a focus of “improving balance” and “increasing confidence and freedom in movement”; this has been suggested as a potential anxiety and apprehension reducing

strategy (Yardley, et al., 2006, p. 515). If they wish to maintain or improve strength and balance, they have the information to choose their own self-image.

Looking at the population reveals that subsections of older adults may be more prone to possessing negative personal beliefs. It is important to remember that older adults, especially older women, may hold more negative attitudes and beliefs about physical activity than younger adults because of inexperience, misconceptions, and stereotypes (Jones & Rose, 2005, p. 113; Rhodes, et al., 1999, p. 399). Commonly cited barriers to physical activity by older adults, especially older women, include fear of falling or suffering an exercise-related injury such as a heart attack, lack of self-motivation or willpower, psychological distress (e.g., depression and anxiety), low exercise self-efficacy, and lack of knowledge or experience with activity (Jones & Rose, 2005, p. 113). It appears that clarity in the messaging to older adults requires a combined approach of confidence building and realistic health outcome expectations. Limited knowledge combined with worries about the repercussions of injury contribute to an apprehension to participation. It appears that designs presented would benefit from visually appearing both safe and understandable as to their purpose and benefit. Presenting solutions that reduce apprehension may allow for a transition to belief in their abilities as tasks are safely completed, and therefore should be considered. Limited knowledge of health benefits gained from activity participation in later life assists to increase the rate of functional decline in older adults. Understanding that general activity and movement knowledge may be limited is also an important design consideration for promotion. Regardless of gender, focused designs that informed on the benefits that older individuals felt they could attain through participation provided with a stated purpose may benefit their willingness to participate, assisting motivation.

Subsections of the older population are further explored by Saxon and Etten as they describe the role that ethnic and cultural roles play in activity avoidance. They have found that many health care givers and providers have failed to identify the roles that cultural and ethnic belief systems may have on the trust that older adults have reporting issues. “For example, in some instances there may be a fear of reporting illness or participating in health screening for fear of some negative consequences to self or

family” (Saxon & Etten, 2002, p. 321). The role that outside perception negatively influences individual in this case refer to the perception individuals fear might be held if they report an issue. The older adult may be left questioning themselves when reporting negative health status information to their family, Could this be the episode for which my family transitions the individual from independence to an assisted facility?

The older adult is seen to have many perceptual barriers that can limit their participation in physical activity. Improvements to activity delivery designs should recognize the positive impact that making interventions that promote self-confidence in participation appear to be beneficial for improving adoption. Limiting the perception of injury and providing knowledge necessary to participate appear to be desirable attributes in overcoming barriers, especially among subsections of the population such as older women. Many of these perceptions are based on the overall health status of the individual, and their role in the shaping of the perceptions must be examined.

**2.3.1.1 Personal health barriers.** Health-related factors also affect exercise participation. The reduction in participation appears to be a combination of the physical symptoms associated with body system deterioration, as well as the ability to treat these accompanying symptoms through intervention.

The effects of pain and the extent of the conditions present seem to have a lot to do with participation. Illuminating the scope of the costs, both financially and physically:

*“Chronic pain...typically defined as pain lasting more than three to six months, it affects 100 million U.S. adults, according to a 2011 report from the National Academy of Sciences’ Institute of Medicine. It is the leading reason people go to doctors, and it costs the nation upwards of \$635 billion a year- more than cancer, heart disease, and diabetes combined” (Foreman, 2014, p. 4).*

Chronic pain seems to have multiple sources of cause, and impacts the participation in physical activity among older adults. The biological aging process leads to the deterioration of body systems at variable rates among the older adult. The negative effects of the deterioration of health and the effects that accompany the loss have been shown to be strong indicators of minimizing the participation of physical activity among older adults (Jones & Rose, 2005, p. 112; Rhodes, et al., 1999, p. 400; Daley & Spinks, 2000, p. 3; Rhodes, et al., 1999). The effects of the deterioration that have shown the

greatest negative impact have been the pain and discomfort that are side effects of symptoms of many of the aging reductions and conditions present in the aging.

Many older adults limit their activity participation because they report that they have a chronic condition that keeps them from participating; however, the existence of chronic conditions among older adults is not an isolated issue. It has been reported that as many as 65% of adults 65 years of age and older have two or more chronic conditions, with only 16% possessing none (Partnership for Solutions, 2002). When compared against society as a whole, it has been observed that the elderly have twice as many disabilities and 4 times as many physical limitations as people less than 65 years of age, requiring the need for the health and mobility of the elderly to be maintained (Daley & Spinks, 2000, p. 2). Although ongoing participation is sought, the delivery of the designs appear to be limited if the adoption continues to suffer. A gained understanding of limiting physical and sensory considerations should be developed in order to provide greater inclusive solutions for the older adult population.

As it was previously mentioned, the other effect of physical deterioration is the impact that the ability to intervene these associated symptoms has on health, and the process of achieving beneficial intervention. The ability for older adults to receive treatment for their chronic issues also can have an effect on individuals seeking out treatment for future issues. “For some older adults it is so difficult to obtain adequate treatment for illness that they may have a sense of futility about seeking services for health promotion or disease prevention” (Saxon & Etten, 2002, p. 321). The futility can be based off of financial cost, transportation, or lack of knowledge, characteristics that can be viewed as access limitations. Many of these barriers seem to be intertwined with one another.

It has additionally been observed that older individuals are likely to not take that action to engage in physical activity unless they see a pressing need to act or do so, such as reducing falls risk (Yardley, et al., 2006, p. 515). Because of this lack of pressing need to take action against risk factors, several studies have been showing that the functional limitations are being shown to be a barrier to older adults participating in activity (Rhodes, et al., 1999, p. 400). The functional limitations seem to revolve around movement confidence and limitations that occur in the lower body; these are the same

areas that individuals lose ground on with mechanics of mobility. The lack of pressing need seems to revolve around a societal view of treatment for negative health conditions rather than a proactive preventive approach (Saxon & Etten, 2002, p. 321). Factors such as proactivity to participate among older adults, mentioned in the Yardley and Saxon examples, were previously mentioned as a concern in the physical activity guidelines section of the literature. The individuals seem to lack the guidance of benefits produced through activity participation prior to incidence occurring to limit their independence. They are instead acting later, after the fact, when the gains are potentially lessened because of injury or ability. It continues to appear that proactive control should be given to the older adult to affect the potential for change.

To further complicate the preventative intervention, the recommendation of the medical health screen prior to engaging in physical activity further acts as a barrier to physical activity among older adults. “In no group is exercise perceived as more dangerous than the older segment of our population” (Burbank & Riebe, 2002, p. 32). Although the idea of the medical health screen is to insure that an individual is physically capable of safely entering into a physical activity program, the very process of the investigation has undesired consequences. As it has been stated previously, older adults are sensitive to social perceptions of physical inadequacy. The very nature of the health screen partly is to determine an individual’s physical ability. The potential for negative results can drive older individuals away since it has been shown that they are likely to avoid intervention until deemed necessary. It has additionally been suggested that the suggestion that a physical exam is necessary gives the impression that physical activity is a dangerous endeavor for the older adult to pursue.

The management of pain and discomfort exemplifies the seeking of treatment rather than prevention through activity. It has been reported in a recent study that pain and discomfort were in the top five for barriers to activity among older adults (Jones & Rose, 2005, p. 112). While there are certainly situations such as surgical recovery where pain management and rest are justified, many of the most common sources of pain and discomfort can be positively amended through activity by avoiding deterioration caused by disuse. Arthritis, for instance, is a commonly reported ailment among older adults

resulting in painful inflamed joints. Physical activity performed at moderate levels has been shown to be able to alleviate many of the symptoms of arthritis by helping to reduce the fluid buildup that can occur in the joints (Whitbourne, 1985). “Exercise also can help prevent chronic pain; for women 65 and older in one 2011 Norwegian study, the prevalence of chronic pain was 21% to 38% lower among exercisers” (Foreman, 2014, p. 4). The avoidance of medication in this case can minimize the negative effects of unintended drug interactions that are a common source for falls among older adults. Not only can physical costs be reduced, but the financial costs associated with the purchase of medications could be as well.

The need to understand that medical conditions are likely present in the older adult creates the need to provide ways to provide adaptability to activity design solutions. This is needed because the literature suggests that avoidance of activity is more problematic to the older individual wishing to remain mobile than adapting their personal ability to potential design solutions. In order to provide the activity solutions, understanding how the older adult views their time is necessary.

**2.3.1.2 Personal time barriers.** The final personal barrier to physical activity is the element of time. Even though older adults have favorable views towards exercise, it has a low priority among older adults during leisure time (Rhodes, et al., 1999, p. 402; Tokarski, 2004). Because of this, lack of time is the most frequently cited barrier to physical activity by adults in general (Jones & Rose, 2005, p. 113). This is exemplified in another study among both genders of older adults; 58% of those aged 65 and over could think of nothing which would induce them to increase their exercise behavior (Rhodes, et al., 1999, p. 403). The problem seems to lie more within self-motivation than not having adequate amounts of time. This is presented by studies that show that even among those who regularly exercise that lack of time and motivation are seen as a barriers among all (Rhodes, et al., 1999, p. 405). Solutions that can minimize the occupation of time should be explored for programs that should be beneficial. The activity guidelines that were presented by the organizations which focused on older adult activity levels which considered the accumulation of activity in short bouts throughout the day may be referred to as being potentially beneficial.



### **2.3.2 Program Related Barriers**

Program-related factors that act as barriers to older adult activity adoption include the structure, format, complexity, intensity, convenience, and costs, both financial and psychological, associated with the activity. It has been shown that the majority of older adults prefer moderate-intensity activities instead of more vigorous ones, especially those activities that reduce their chances of experiencing vertigo (Jones & Rose, 2005, p. 113; Rhodes, et al., 1999, p. 406; Mazzeo & Tanaka, 2001, p. 812). This preferred level of intensity can be seen in the type of activities that generally rank highly among older adults in participation rates, as they tend to be less competitive. Walking and gardening for instance are highly adopted and participated in relative to other activities. As has been stated by Mazzeo and Tanaka, activity choices that minimize injury risk and provide enjoyment should lead to higher participation and adherence rates (2001, p. 813).

In addition to the intensity of the activities that are participated in, the format of the program plays a significant role in the adoption and adherence of physical activity among the older adult (Rose D. J., 2015, p. 23). The formats can include formal group classes, supervised activity, as well as self-led initiatives.

From a safety and instructional aspect, the inclusion of a supervisor to monitor activity would be preferred. An instructor who is educated in the needs of both activity as well as aging considerations allows for the possibility for intervention during participation. Correcting form, selecting activities, monitoring attendance, and providing medical response are just some of the benefits that instructor inclusion is capable of providing. However, the financial cost of this approach is becoming increasingly unfeasible with the already growing older adult population simultaneously living longer lives. This is especially true for one-on-one instruction outside of a group setting or provided to the aging in their living environment. Because of these emerging factors, many are beginning to suggest a different course of intervention in regards to older adult activity. Moving away from structured supervised activity, and instead an approach that incorporates activity into daily life has been suggested (Mazzeo & Tanaka, 2001, p. 813).

Although the inclusion of a supervisor can lead to intervention in technique or health concern, it does not come without challenges. The inclusion of multiple older individuals adds difficulty to instructors because teaching a group of older adults is generally more challenging as it requires accommodating a wide range of abilities and medical concerns (Jones & Rose, 2005, p. 138). Essentially, the inclusion of the supervisor's expertise is no guarantee that individual concerns of the older adult can be addressed with just their presence (Burbank & Riebe, 2002). The impact of a growing older population creates the potential for overcrowding in many of these offered monitored activity classes. As the number of individuals an instructor has to interact with and monitor increases, there is a corresponding drop in quality of supervision available to the instructor and observation.

From a structure and format framework, many activities and programs are designed in a supervised, group settings for older adults. They attempt to intervene with technique, knowledge, and social support with a supervisor. While well intentioned, it appears that older adults though do not desire to seek this framework for physical activity, and these programs are financially costly, as many are not covered by health insurance (Burbank & Riebe, 2002, p. 34). With the increase in the possibilities of being economically tied to a fixed income in later life and losing health insurance through retirement, having individuals pay out-of-pocket is increasingly unlikely to cover programs that are not subsidized in some fashion. This explains from a financial aspect the heavy promotion of low-cost activities such as walking (Rhodes, et al., 1999, p. 400). It has been found that approximately two thirds of older women and men, regardless of current physical activity levels and race or ethnicity, prefer physical activities that can be undertaken outside a formal class or group setting (Jones & Rose, 2005, p. 113). This is exemplified by the finding that adherence to supervised home-based programs is typically higher than adherence to class or group programs (Jones & Rose, 2005, p. 113). This could build on the previously discussed personal barriers to activity in section 2.3.1 above that individuals in this age group do not wish to appear inept in front of others. Additional benefits gained through convenience and financial costs savings could add to the reasons why older adults prefer these activities outside of a class setting.

It has been suggested that the activity should avoid being a structured supervised approach and should rather be incorporated into daily life (Mazzeo & Tanaka, 2001, p. 813). With this approach, many of the previously mentioned barriers such as social perception and lacking time to participate could be potentially reduced. Providing a daily life solution could further place the motivation for action on the older individual, through self-directed intervention. However, many interventions that focus on balance and mobility continue to try to force the supervised, class format. It appears the potential inexperience and lacking knowledge with physical activity among older adults might be the guiding force behind the continued attempts at this approach. Unfortunately, it appears that the older adult is choosing to not prefer that group framework.

While the experience may be lacking, putting the older adult at risk of injury from improper technique, it appears that older adults do not prefer high intensity activities that would put them at risk. Rather they have a preference for light to moderate activity that causes less chance of vertigo (Rhodes, et al., 1999). In addition to being preferred by the older end user, moderate activity is likely to be a more pleasurable experience that limits the possibility for injury (Mazzeo & Tanaka, 2001). Many of the program barriers could be reduced by looking at what the older users are willing to do in regards to physical activity, and tailoring the design of products and solutions in that manner. In this way, potential design solutions could promote activity by limiting the intensity level in a manner that allows for self-direction, which has previously shown to be an approach to building self-confidence; the inclusion of lower intensity solutions could potentially further the building of activity self-efficacy.

Beyond the personal barriers within the older adult, other barriers have been identified to be additionally influential to the participation in physical activity. The final areas of barriers involve the impact that social and environmental issues have on the older adult. These areas also have an interrelated effect on the program designs and how the individuals view themselves as they participate having been previously described.

### **2.3.3 Social and Environmental Barriers**

Socio-environmental barriers involve the interactions between the older adults and their surroundings. These surroundings include the social connections they possess with others such as family, friends, and professionals as well as their connections to the environment they inhabit; because of the interactions of the two factors they are viewed together as a group.

The social barriers of the group revolve around the interactions older adults have with the individuals in their lives as they age. These individuals include typical relationships held between family and friends, but also includes the wider cast of relationships held with the medical community and society. It has been shown that positive social support towards activity that can be gained from these groups is positively associated with exercise adoption and maintenance, especially among older women (Jones & Rose, 2005, p. 113; Rhodes, et al., 1999, p. 407). Regrettably, it appears that the encouragement to participate in physical activity among older adults is lacking because of the circumstances that surround the aging process, creating one of the top five reported barriers to activity (Rhodes, et al., 1999, p. 407; Jones & Rose, 2005, p. 114).

It should be noted that many older adults, particularly women, do not have a history of activity participation or have a knowledge of proper physical activity implementation (Rhodes, et al., 1999, p. 400). Aiding to limit participation, many older adults yield to the assumption and attitude that physical activity is a youthful endeavor, and that participation by older adults is socially inappropriate (Seefeldt, et al., 2002, pp. 146-147; Corbin & Metal-Corbin, 1990). Because of this lack of experience and knowledge base, older individuals are increasingly in need of the external stimulus of encouragement and support to initiate a physical activity program into their daily routines. However, the transition into older age leads to changes in the social roles that individuals have maintained in life both in their personal lives and within society. This causes the social network of the aging to become more limited than in younger populations.

The loss of loved ones and the increasing trend of separation as family moves for work impacts the availability for older adults to access this support internally from their own

support systems as social isolation becomes a very real possibility. As an example of personal loss and change in social roles, older women who have not remarried have been shown to live more than 24 years alone when widowed (1989, p. 13). Whether it is developed freely or against their will, the establishment of new roles in life adds stress to the older adult as they adjust, such as outliving savings or entering nursing care because of insufficient family assistance (Navasky & O'Connor, November 21, 2006).

With the loss of peer and family support, many older adults are influenced by default by the opinions of their doctors or physicians and other external sources of social support. Unfortunately, it has been reported that many doctors do not spend enough time, only 3 to 5 minutes of council, or inform their patients of the benefits of exercise (Rhodes, et al., 1999, p. 407). Tokarski goes even further, stating “that many older persons would start a physical exercise program if their physician recommended it” (2004, p. 100). There is a lack of prescribing physical activity when individuals are healthy at any age, with physicians sometimes taking the approaches of “take it easy” and reliance on prescription drugs with their dealings with older adults (1989, p. 16). Through these examples of potential interactions experienced with the medical community, it is evident that there is minimal effort to take a proactive stance as a collective in regards to older adult’s activity.

While the medical community does have a role, it is not all on them to deliver the information. Governments at all levels appear to have difficulty in providing the necessary information to the aging as well. Many times older adults are not informed of available options in their community (Jones & Rose, 2005, p. 33). As shown in the various revisions of activity guidelines portrayed earlier in the review, the messages are inconsistent, sometimes lacking tested methods, which may put weary doctors and communities in a position of not informing patients and residents because of the litigious culture of the United States (Jones & Rose, 2005, p. 33). It appears that simplifying the activities, knowledge, and encouragement could streamline the application of activity among older adults. This could lead to limiting the apprehension of older adults and those with influential support to participate in such programs.

The second half of this group of barriers relates to the environmental factors that can impact participation among older adults. Even with an adequate base of social support to participate in physical activity, older adults are challenged by the physical access to such programs and interventions created by their physical surroundings. Physical environmental factors such as the travel distance required for exercise, climate and weather, neighborhood safety, and availability of facilities for physical activity (e.g., parks, walking and jogging paths) could also affect physical activity by older adults (Jones & Rose, 2005, p. 114). These factors can include aging in both city and rural environments while effecting geographic regions with varying levels depending on the seasons of the year. For habitual activity to occur, access should seek to be available regardless of these environmental barriers.

Transportation can limit an individual from attending age appropriate programs and can be magnified if the individual resides rurally, increasing travel time. Many older adults are unable to safely drive on their own, and can be limited further if their community does not offer a public transit system; therefore, transportation for some older adults becomes a very real barrier to activity (Saxon & Etten, 2002, p. 321). Even with accessible transportation, functional abilities must allow for the safe entry and exit of these transportation mediums, creating a barrier.

Climate and weather represent additional barriers to the participation in physical activities and hobbies. This is especially true of those activities that occur outside the home, such as common low cost leisure activities such as walking or gardening (Rhodes, et al., 1999, p. 400), even when the health of the older individual is good. Climate can impact the safe participation in activities both indoors and out because of the components of temperature and humidity. When extremes in climate occur, in the form of heat, cold, humidity, or a combination of these elements, stress introduced to the body can become dangerous, affecting activity participation if left uncontrolled (Bernard, 2001, p. 216; Corbin & Metal-Corbin, 1990). For instance, best practices are encouraged to be employed by instructors when air temperatures fall below 50 degrees Fahrenheit in cold environments (Bernard, 2001, p. 216); it is recommended that moderate activity should be avoided for older adults in particular when ambient air

temperatures exceed 82 degrees Fahrenheit (28 degrees Celsius) (Jones & Rose, 2005, p. 146). Unfortunately, in both cases the suggestions are to be followed by instructors, a secondary option source that many older adults are unable to access.

The ability to provide the encouragement to participate in activity among the older adult population appears to have a high level of influence, especially the input from the medical community. Limiting travel considerations appears to have a great impact to not only the access in an environmental consideration, but limiting travel could afford older adults more time for participation in all activities. The range of environmental components such as heat, cold, and humidity should be controlled when possible. If these components are present and beyond control, physical activity should be avoided or delayed. The ability to control environmental components while providing simplified access appears to be a beneficial goal out of potential future solutions aimed at older adults. It is fortunate that many living situations provide for the ability to control these barriers, and should be considered in the future solutions.

#### **2.4 SET Factors, Creating Value**

The presence and range of barriers to physical activity for older adults represents information that can be interpreted as potential opportunities for the design of products, services, or programs to overcome through different intervention strategies. “People use products to improve their experience while doing tasks” (Cagan & Vogel, 2002, p. 5). These areas are frequently presented to designers through market research, customer feedback, and surveys. However, sometimes these needs remain unmet, or unidentified, requiring a different approach to uncover potential new directions. When barriers are constantly reported, there must be an investigation as to the source(s) and cause(s) of these conditions. One or more factors critical to the desired function of physical activity among older adults must be misunderstood or missing all together for the continued reporting of the presence of barriers.

Understanding this, designers seek to unite the identification of the problem source, the barriers, with the presentation of a desired user solution. This can be achieved by investigating the product-service relationship. Cagan and Vogel explain the product and

service relationship as an understanding of the “experience that the end customer wants, and then translating that understanding into a product or service that enhances a particular interaction with objects, environments, and/or other people” (Cagan & Vogel, 2002, p. 7). In the case of older adults, these wants include what the older adult seeks from personal independence and mobility, and those features that can help facilitate these results provided from the medical and research communities. Thus understanding the service to be offered also includes the awareness of the channels and stakeholders involved in the process. Defining the roles, needs, and dislikes of each group can lead to the development of potential design solutions that can achieve these efficiencies born of information collaboration (Stickdorn & Schneider, 2011, pp. 111-113).

The customer wants expressed into a product or service also include a decision process that represents a series of trade-offs. The product or service is not only competing against the offerings within its own industry, but the offerings of other industries that offer trade-offs through substitute products and offerings (Kim & Mauborgne, 2001, p. 4). Kim and Mauborgne describe the process of the trade-off through an example of going to dinner; the decisions on whether to drive and pay for parking or to take a taxi represent the substitute industries that influence going to dinner in the city (Kim & Mauborgne, 2001, p. 4). Exploring the deficiencies presented as barriers among older adult activity participation, many of these goals appear to not being satisfied.

In the case of activity participation, trade-offs include time, knowledge, access, finances, and perception. The lack of participation in physical activity among older adults is facing these trade-offs. As an example, to avoid appearing inept, the older adult is trading-off potential embarrassment from limitations of ability for preservation of social perception. Overcoming these barriers requires understanding the relationships that each trade-off has on the older individual.

Identification of the potential for missing solutions is the initial step that occurs. There appears to be a link that the various barriers researched regarding physical activity avoidance and lack of participation among older adults exists with minimum product solutions offered to address these issues. If these products were in place, it is assumed that their presence or ineffectiveness would have been noted. The examination for the



potential to create improvements to the product category for this segment of the market. “A product opportunity exists when there is a gap between what is currently on the market and the possibility for new or significantly improved products that result from emerging trends” (Cagan & Vogel, 2002, p. 9). The gap that is present is identified as the product opportunity gap (POG). Within the examination of older adults, this gap appears to lie in the offerings that promote mobility activities.

The product opportunity gap is defined as a product that successfully fills and meets the conscious and unconscious expectations of

consumers that is perceived as useful, usable, and desirable (Cagan & Vogel, 2002, p. 9). To satisfy the characteristics found in the products, certain areas of need should be identified to provide information necessary to make those items available for the user to experience. The method utilized by Cagan and Vogel is the SET Factors identification process. As Cagan and Vogel explain the SET Factors directly, they state:

*This SET of factors generates opportunities for producing new products that can have an effect on the way people live their lives at any given moment. The goal is to create products and services by identifying an emerging trend and to match that trend with the right technology and understanding of the purchasing dynamics (Cagan & Vogel, 2002, p. 11).*

The SET factors are a collection of observations of existing conditions or the presence of markers in the marketplace that represent areas for design opportunities. Three areas are seen as the source of many of the directions for new growth. They are represented by the trends in Social, Economic, and Technological which translate into the given

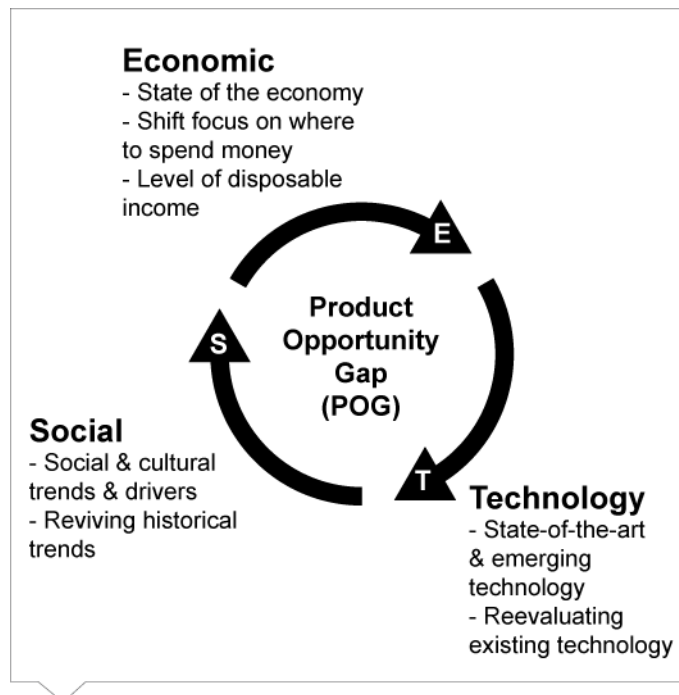


Figure 2.1 Product Opportunity Gap (POG). The Product Opportunity Gap is comprised Social, Economic, & Technological Factors (SET Factors). The older adult activity market can be examined on the barriers present to complete this qualitative analysis of unmet needs. (Cagan & Vogel, 2002)

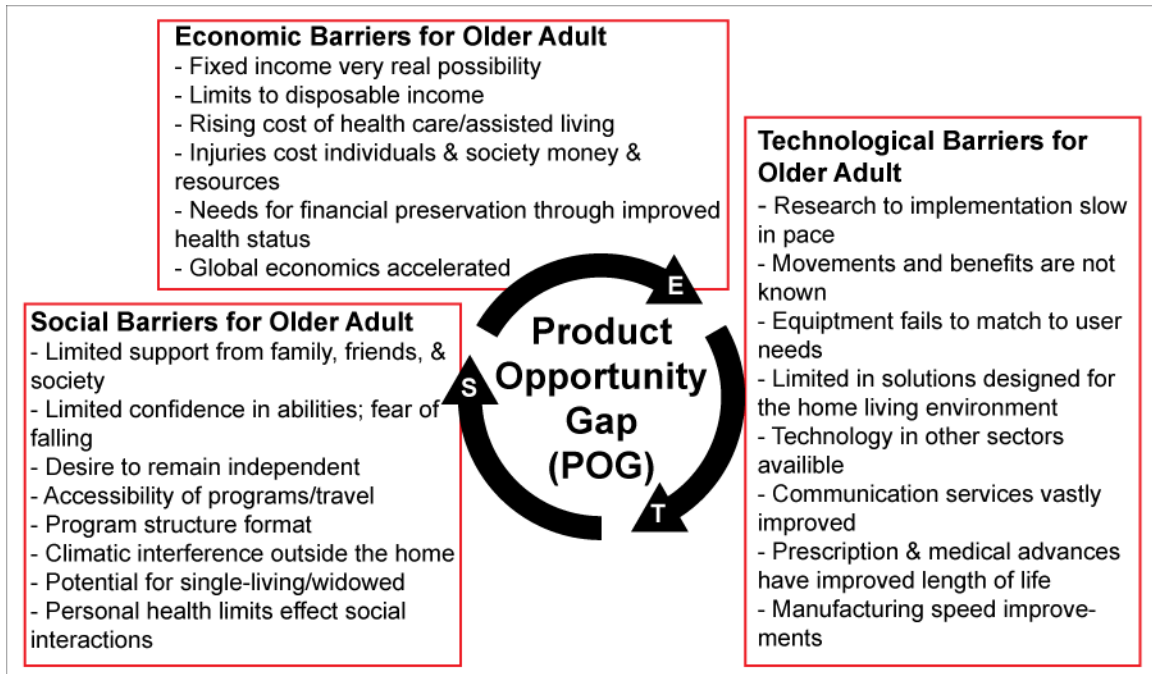


Figure 2.2 POG Identified through Barriers to Activity in Older Adults: The POG is applied on the 3 levels to the barriers that have been listed limiting older adult participation. The similarities between these characteristics allow for this assumption to be made

opportunities within a market. It should also be noted that the SET Factors identify POGs for a targeted user group, and that target may not be you (Cagan & Vogel, 2002, p. 12). The presentation of the elements is the acronym SET factors, visually demonstrated with Figure 2.1. The characteristics of the three trends are individually identified below.

The SET Factors appear to have the ability to link the issues that are currently expressed as barriers to activity among older adults. The barriers presented categories that negatively affect participation in the current approaches with the aging. By creating this relationship within an identification process suggested in the design field, the translation of the barriers into potential product opportunities for designers may become more visible, and is illustrated in Figure 2.2.

### 2.4.1 Social Trends Identification

The creation of value within the model structure seeks to identify current social trends (S) within the given potential market. “Social and cultural interaction” should be sought and identified to satisfy this category of factors within the intended object (Cagan &

Vogel, 2002, p. 10). The areas they discuss to look for inspiration include entertainment, health issues, family and work patterns, print materials, and products with success in other fields.

The social trends that exist within the older adult barriers to physical activity are identified by many of the areas suggested by Cagan and Vogel as potential for new product category exploration. At the family level, the distance created by career-based income patterns has led to the geographic spreading of families, limiting the social support system for the older adult. The extension of life for the aging through improved medicine has brought about health issues that include increased falls, and changed social roles as individual's age. Additional exploration is necessary to identify successful products, services, and strategies in other fields, as well as the potential associated trade-offs as mentioned by Kim and Mauborgne.

#### **2.4.2 Economic Forces Identification**

The economic forces (E) identification requires the examination of the possible financial deficits that are in place, and those that have the potential to make a positive impact caused by financial inefficiencies. "The economic factors focus on excess income that people perceive they have, or that they expect to have, to give them purchasing power" (Cagan & Vogel, 2002, p. 10). These economic factors guide the choices people make in purchasing the products that influence their lives. They go on further suggesting the marketing of the products should also be examined as to identify in addition to the source of the income, who ultimately is buying the products, and who they are buying the products for (Cagan & Vogel, 2002, p. 10). This was also suggested earlier by Stickdorn and Schneider; the need to gather information from the stakeholders of the entire product or service may include those outside of the direct use of the offering.

These economic factors can all be influenced on a large macro scale, such as the financial health of global and government economies, and how the consumer confidence is reacting with spending patterns relative to those conditions. These economic factors can also be influenced at micro levels with the influence of fixed income, retirement

income and investments, and other financial factors that are realized at a more individual level by the older adults.

The economic barriers previously noted as present among older adults towards physical activity participation demonstrated many of the economic opportunities for new product development in both macro and micro levels. The lengthening of lives through better medicine has elongated the time horizon that personal finances are required to support. Government policies have introduced uncertainty to the availability of macro level fixed income such as social security, financial market collapse, and uncertain health incentive programs aimed at older adults. This effects the spending power of the aging at the micro level when personal investments lose value, out-of-pocket medical expenditures, and consumer staples cost more to purchase. Both levels of economic conditions play a role which affects the disposable income available to make discretionary purchases. The strain on the finances of the older adult can require additional work into the retirement years, if retirement is possible at all. When viewed as a whole, this can effect gas prices to travel, plane tickets for visits, and the ability to spend money on healthier food options, and health services. All of these factors can negatively impact the availability of physical activity for older adults at the economic level.

### **2.4.3 Technological Advances Identification**

The final input to the identification of potentially successful and missing product innovation through the creation of customer value revolves around the identification of the technological advances (T) that impact the potential market. Designers should “focus on direct and imagined results from new scientific discoveries in corporate, military, and university research and the implied capabilities stemming from that research....new material and manufacturing advances, electrical and mechanical innovations, aerospace and military technologies, film and sports entertainment technologies, and micro-and bio-technologies” (Cagan & Vogel, 2002, p. 11).

Many of the technologic advances can be seen as potentially impactful for the older adult in regards to physical activity. Technologic advances in the field of athletic

function has grown as the science of movement is more fully understood. These advances are typically introduced into practice at the elite user level; many more still appear to occur at the research level such as those discovered in academia. The transfer of the technological knowledge has been identified as problematic as to its effectiveness and speed transfer to the older adult user. Additionally, many advances have not been adapted to the needs older adult user. These advances have had a current focus on the elite user, such as the athlete. If these elite features can be formatted into formats that include older adult considerations, it may be possible to overcome many of the challenges and barriers that have been identified thus far among the older adult population.

Many of the conditions that are required from the market suggest that an unmet need according to the application of the SET Factors have been described in the older adult population thus far. The desire for a reduction in the falls occurring in the older adult population exists. The desire for older adults to participate in physical activity exists within the medical community. What does not exist is a method of addressing the barriers that satisfies both the needs of the medical community and the needs within the older adult population. The existing barriers at the personal, social, and environmental levels are evidence of this disconnect between physical activity participation and ongoing adoption.

Although identification of these opportunities is necessary, so too is the identification of the processes that can lead to these potentially beneficial changes from physical activity. To provide design solutions and guidance, it is necessary to further understand the changes that occur in the aging process. Additionally, the further understanding of the role improved product interactions can have on the implementation of design solutions. The role of the aging process will be identified first, to provide information about the necessary movements and design considerations in the current literature on mobility.

## **2.5 Technology and Science of Physical Activity and Mobility**

Identifying the barriers to physical activity indicates that there is a potential market segment of older adults that is currently underserved with the approaches that are

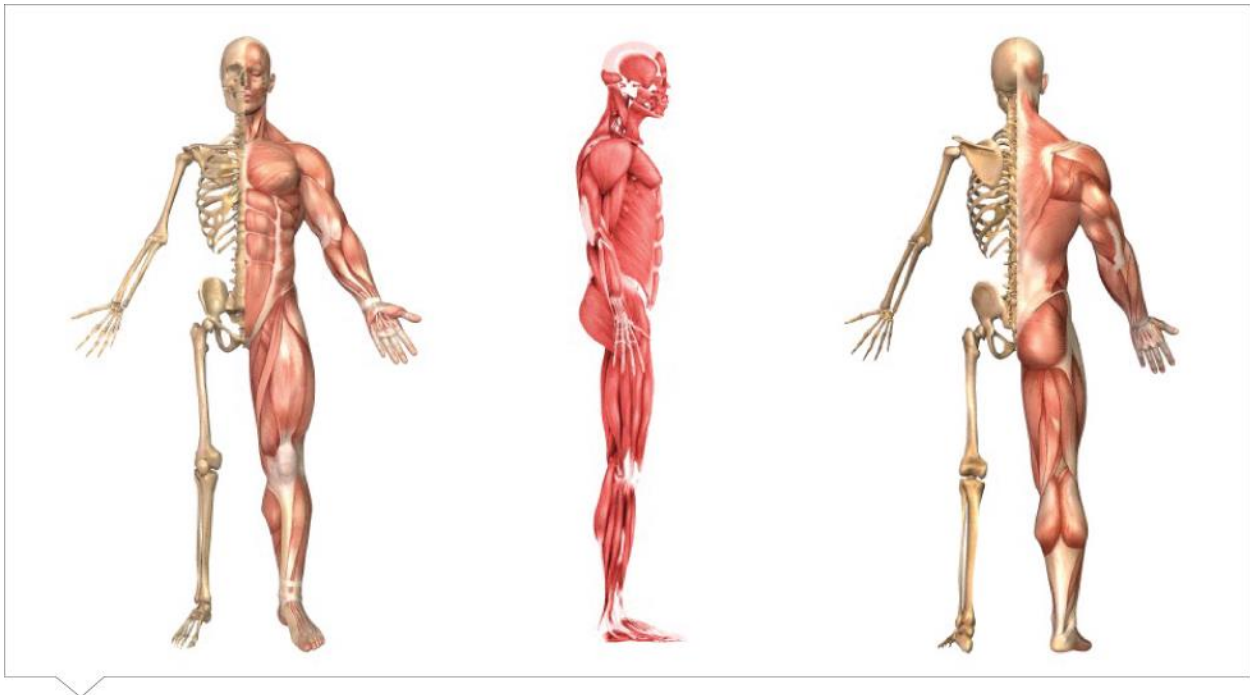
currently offered creating a POG. To gain a complete understanding of the challenges that both the older individual and providers currently face, examination of the mechanical components of mobility and balance is necessary. The process of building understanding of the body will include an exploration of the anatomy, biomechanics of mobility, and the communication inputs to these systems as they relate to the aging process in the older adult.

The components reviewed begin with the general anatomy and physiology of the lower body. Regions examined include the components of the lower limbs, the foot, ankle, knee, and hip; the components of the lower lumbar spine are also examined. The identification of the structures and their corresponding abilities will provide the foundation for understanding the support necessary for dynamic movement.

The movements that comprise daily activity such as walking and mobility will be examined at their component level through understanding the relationships formed in biomechanics. The biomechanics of the anatomical components will provide an understanding of the process of providing basic balance, and how the components evolve to provide greater ranges of dynamic movement through mobility. This will identify the relationships and coordination of body systems necessary to produce the chain of movements encountered through walking and other similar moves.

Lastly, the inputs needed to interpret the environment and the responses the body must make to navigate even simple daily tasks will be examined. These input systems include the sensory information received from areas such as vision. In addition to providing understanding of how the systems communicate the needs of the environments to the needs of the individual, the changes that potentially interfere with these feedback loop actions will be explored.

## 2.6 Anatomy and Physiology



*Figure 2.3 Collection of the Muscles & Bones of the Human Body: The illustration above displays the wide range of support structures offered by the bones, & the muscular system that they support.*

To fully begin to understand the role of the components that allow for mobility, the identification of the structures is required. The structures of the lower body and lower limbs provide the support for the actions encountered during mobility. The individual components that require further exploration include the foot, ankles, knee, hip and lower lumbar spine; the bones, muscles, joints, and other range of motion features will be explored to provide an understanding of the general region. The further exploration of the roles and responsibilities will follow.

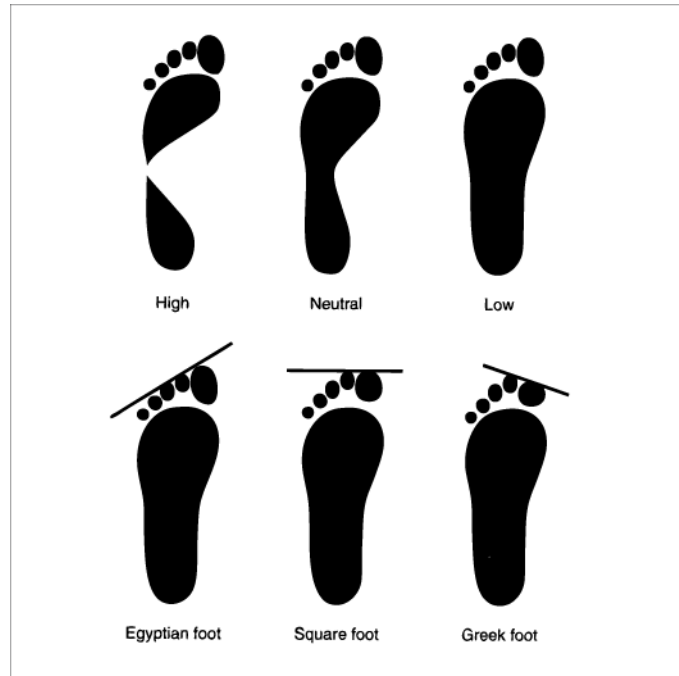
It should also be noted that, during the exploration and identification of the anatomy and the structures, many features are interrelated or have shared roles. The detail of structures may fall into one of the regions for general discussion and identification, but it does not mean that the structure is exclusive in function to that region or body part.

### **2.6.1 Foot**

The lowest point or most distal of the limbs to be examined, the foot represents a collection of 26 bones and more than 100 ligaments and tendons; the structure of the foot is very similar to the hand, but is stronger because of the weight bearing nature of its mechanics. Structurally, the foot provides two important functions, weight support and mechanical leverage (Starkey & Ryan, 1996, p. 47). The weight bearing and mechanical leveraging can be seen in action during the gait cycle, as the foot serves as the contact point for the body. Many of the features and functions occurring in the foot are shared or have relationships with the surrounding structures such as the ankle and lower leg that are present in some conditions that disrupt function (Starkey & Ryan, 1996, p. 47).



**2.6.1.1 Bones.** The skeleton of the foot is comprised of three bone groups, the bones of the tarsus, the bones of the metatarsus, and the phalanges (Marieb & Hoehn, 2013, p. 241; Moore, 1980). The foot can be segmented further into three zones, the forefoot, midfoot, and hindfoot. The forefoot, formed by the five metatarsals and 14 phalanges, acting as a lever during the toe-off phase of the gait cycle (Starkey & Ryan, 1996, p.



*Figure 2.4 Arch & Toe Styles: The collection of 3 foot impressions on the top show the contact made based on the degree of arch in the foot. The bottom represents the form the toes can commonly take on as characteristics to their shape inside of footwear. (Kreighbaum & Smith, 1996)*

47). Each toe is formed by three phalanges, with the exception of the great toe, which is formed by only two bones (Starkey & Ryan, 1996, p. 47). The midfoot is composed of the navicular, three cuneiforms, and cuboid; this unit provides the shock-absorption region during movement (Starkey & Ryan, 1996, p. 47). The last of the three zones of the foot, the hindfoot, is formed by two bones, the calcaneus and the talus; this zone is responsible for providing stability during the heel-strike phase of gait as well as a lever arm during plantarflexion of the foot (Starkey & Ryan, 1996, p. 47).

The segmentation of the foot allows it to remain pliable, which enables the foot to adapt to uneven ground surfaces (Marieb & Hoehn, 2013, p. 241). The structural support of the segmented bones of the foot that allows the pliability of the bones of the foot is maintained through the shape and structure of the arches, and is provided muscular action by muscles intrinsic in the foot and those originating in the lower leg (Starkey & Ryan, 1996, p. 47). The arches of the foot are comprised of three units, the medial longitudinal, the lateral longitudinal, and the transversal arches (Starkey & Ryan, 1996;

Moore, 1980). The arranging of interlocking shapes of bones, ligaments, and pull from tendons when activated during muscle activity. The spring and give provided through the stretching of the tendons and ligaments provides energy economy to walking and running (Marieb & Hoehn, 2013, p. 242).

The bones and connective tissues of the arches take on a half dome shape when formed in this manner, translating half of the body's weight to the heads of the metatarsals and the other half to the heel bones (Marieb & Hoehn, 2013, p. 242). This shape with the relationships to the weight forces applied to each of these areas of the foot play a role in the kinetic relationships occurring in gait activities.

**2.6.1.2 Range of motion.** The joints in the foot are all synovial (Marieb & Hoehn, 2013, p. 261). The primary function of the phalanges is to provide the hinge action during flexion and extension (Starkey & Ryan, 1996; Moore, 1980). The greatest range of motion (ROM) occurring in the foot is provided by the first metatarsophalangeal (MTP) joint. The first MTP joint provides flexion of 35-45°, and 75-85° of extension (Starkey & Ryan, 1996, p. 69). The range of motion for the remaining MTP joints progressively decline with each lateral joint segment in subsequent toes moving outward from the first MTP. This range of motion is demonstrated during the gait cycle, as the sole of the foot transfers from a relative flat position in mid stance into the toe off stage that propels the body forward.

Adjacent tarsals at the synovial joints of the intertarsal joint allow for inversion and eversion (Marieb & Hoehn, 2013, p. 255). The synovial joints of the tarsometatarsal joints are formed by the articulations of the tarsals and metatarsals, which allow for a gliding of the metatarsals (Marieb & Hoehn, 2013, p. 255). The articulation of the metatarsal and proximal phalanx bones form the synovial MTP joints; the movements of the joints include diarthrotic, biaxial, flexion, extension, abduction, adduction, circumduction of the great toe (Marieb & Hoehn, 2013, p. 255). The adjacent phalanges of the synovial interphalangeal (toe) joints hinge to allow for the movements of diarthrotic, uniaxial, flexion, extension of the toes (Marieb & Hoehn, 2013, p. 255).

**2.6.1.3 Muscles.** The intrinsic muscles of the foot originate and directly influence only the motions of the foot and toes; intrinsic muscles help to flex, extend, abduct, and adduct the toes, which helps provide stability and propulsion during the gait cycle, especially as they act on the movements of the toes and the arches (Starkey & Ryan, 1996; Marieb & Hoehn, 2013, p. 376). With additional help from other structures, these muscles assist the supporting of the arches, especially the longitudinal arch, during walking and other ground force activities (Marieb & Hoehn, 2013, p. 376; Starkey & Ryan, 1996, p. 51; Starkey & Ryan, 1996). The intrinsic muscles acting on the foot are comprised of four layers: superficial, middle, deep, and interosseous layers (Marieb & Hoehn, 2013, p. 376; Starkey & Ryan, 1996, p. 51; Starkey & Ryan, 1996). Many of the intrinsic muscles would be considered small in size.

Extrinsic muscles acting on the foot originate in the lower leg, and also act on the ankle. Extrinsic muscles that cross the subtalar joints effect the position of the foot (Moore, 1980, p. 51; Starkey & Ryan, 1996; Starkey & Ryan, 1996). The extrinsic muscles are comprised of three muscles group compartments: the posterior, anterior, and lateral compartments (Marieb & Hoehn, 2013, p. 370). The foot is provided two groups of movement, and the ankle a third by these compartments; the intertarsal joints are able to invert and evert and the toes are able to flex and extend (Marieb & Hoehn, 2013, p. 370; Moore, 1980, p. 511). The flexing assists the plantarflexion of the region during gait (Starkey & Ryan, 1996, p. 51). The group of muscles in the anterior extensor compartment primarily act as toe extensors and dorsiflexors of the ankle as well as making contributions affecting the position of the foot (Marieb & Hoehn, 2013, p. 370; Starkey & Ryan, 1996, p. 51). The dorsiflexion movement prevents the toes from dropping during gait, a potential source of tripping which can ultimately lead to falls if accurate response is not taken.

## **2.6.2 Ankle and Lower Leg**

Serving as the junction of the foot and leg, the ankle is the transfer point of the weight of the body as it is distributed to the structures of the foot such as the arches. The distribution of these forces provides a transfer point during gait cycle activities, where generation and absorption of movement forces is necessary. Distally, the ankle shares a

mechanical relationship with the foot, and proximally with the knee (Starkey & Ryan, 1996, p. 86). This relationship with the foot, along with the functional abilities of the movements in the ankle, make the ankle prone to injuries such as sprains. Chronic ankle instability is a severe form of this type of injury pattern. The frequency of sprains in the ankle region makes it a common source of compensating movement patterns that are experienced during walking gait and general mobility (Starkey & Ryan, 1996, pp. 86, 88; Moore, 1980, p. 580).

**2.6.2.1 Bones.** The tibia and the fibula run parallel with one another, providing the support for the structures of the lower leg; distally the foot and ankle creating the ankle mortise, and proximally the knee (Marieb & Hoehn, 2013, p. 238; Starkey & Ryan, 1996, p. 86). The tibia transfers the load and weight of the body forces received from the femur as it transmits them to the foot, as it also allows ROM for the ankle mortise during walking and running; this makes the tibia second only to the femur in strength and size of bones located in the body (Marieb & Hoehn, 2013, p. 239; Starkey & Ryan, 1996, p. 86). The fibula is described as a thin bone that does not play a role in weight bearing functions, but it does provide multiple insertion sites for many muscles occurring in the ankle and lower leg region (Marieb & Hoehn, 2013, p. 239; Starkey & Ryan, 1996, p. 86).

**2.6.2.2 Range of motion.** Movement distally occurring in the lower leg takes place at the ankle. The form and shape of the bones allows the ankle region to create movement in a full range of directional movement, which is limited by the characteristics of the bones forming the joints. For example, the shape of the heads of the tibia and fibula act as rigid stops to the movement distally occurring at the talus bone of the foot at the ankle (Marieb & Hoehn, 2013, p. 239). The tibia, also known as the “shinbone”, proximally articulates with the femur to form the knee joint, while the fibula plays no role at that joint (Marieb & Hoehn, 2013, p. 239). The articulation of the tibia and fibula with the talus at the synovial ankle joint produce the following movements: diarthrotic, uniaxial, dorsiflexion, and plantar flexion of the foot (Marieb & Hoehn, 2013, p. 255). The articulation occurring at the interior tibiofibular is created by

the tibia and fibula, which gives slightly during dorsiflexion (Marieb & Hoehn, 2013, p. 255).

**2.6.2.3 Muscles.** In the ankle region, the muscles act on both the foot distally, as well as the knee proximally. The three compartments of muscles, posterior, lateral, and anterior compartments, provide the movements of plantar flexion and dorsiflexion, inversion and eversion of the foot. The anterior compartment muscles provide dorsiflexion to the ankle, which prevents the foot from dropping during gait, which, if that occurred, could promote tripping (Marieb & Hoehn, 2013, p. 370; Starkey & Ryan, 1996, p. 90). This would be caused by the muscles' inability to provide the pull upward on the toes and foot to prevent the foot drop in situations such as stair climbing or obstacle avoidance. The lateral compartment muscles provide several functions; these roles include plantar flexion and eversion of the foot, as well as contributing to the lateral stability of the ankle and lateral longitudinal arch in the foot (Marieb & Hoehn, 2013, p. 370; Starkey & Ryan, 1996, p. 90).

The posterior compartment as a whole provides the plantar flexion of the foot and ankle, the powerful action that propels the gait cycle. The posterior compartment is comprised of two layers, the superficial and deep layers (Moore, 1980; Starkey & Ryan, 1996). The posterior superficial muscles include the most powerful group in the region, the triceps surae, which is comprised of the gastrocnemius, soleus, and plantaris muscles (Moore, 1980). The triceps surae represent the prime movers of the ankle during plantar flexion and assist in the extension of the knee (Moore, 1980). The primary movement of the ankle allows for movements such as standing on tip toes during ballet, to running and walking movements (Marieb & Hoehn, 2013, p. 370). The plantar flexion appears to be of great significance to the abilities in the gait cycle process. The plantar flexion provides the velocity to the walking movement which is commonly translated as walking speed through the "spring-to-the-step" provided to the great toe during the push-off in the gait cycle (Moore, 1980). Since walking speed slows in the aging process, preservation of its capabilities would be of interest in functional activities.

### **2.6.3 Knee and Thigh**

The knee interacts distally with the tibia and fibula of the lower leg, and proximally with the femur of the upper leg. The union at this point forms the knee joint, which represents the largest joint in the human body. The relationship transfers the weight of the body through to the lower leg and ultimately the foot. The movement the joint provides the knee along with the connective tissues providing its support makes the knee a common site for ligament tears that require surgery (Moore, 1980).

**2.6.3.1 Bones.** The femur is the largest, longest, and strongest bone in the body which accepts applied forces the equivalent of two tons a square inch; the femur is also the only bone of the thigh, and represents about a quarter of an individual's height (Marieb & Hoehn, 2013, p. 238). The arrangement of the femur as it leaves the hip courses its path medially to form the knee; this allows for better balance to be exhibited as the knee is closer to the body's center of gravity (Marieb & Hoehn, 2013, p. 238). The femur exhibits shapes of its distally and proximally located ends that form joints at their sites. Distally, the femur forms a concaved and curved surface that forms the knee at the patellar surface. Although the femur is a strong bone, the neck of the head of the femur that forms the ball and socket joint with the hip is the weakest point of the bone, making it a common sight of fracture with falls (Marieb & Hoehn, 2013, p. 238). In addition to fractures in the ball and socket, older adults commonly face the possibility of a total hip replacement of this feature through the application of artificial components that replicate the ball and socket function.

**2.6.3.2 Range of motion.** The femur proximally articulates with the hip bone (Marieb & Hoehn, 2013, p. 238). The smooth patellar surface on the distally occurring femur is the site for the articulation with the patella, or kneecap (Marieb & Hoehn, 2013, p. 238). The two synovial joints, femoropateller and tibiofemoral, provide articulation of the patella and fibula with the femur (Marieb & Hoehn, 2013, p. 255). Movements exhibited by the joints here include the following: diarthrotic, biaxial, flexion, extension of leg, some rotation allowed in the flexed position (Marieb & Hoehn, 2013, p. 255). The superior tibiofibular synovial joint articulates the tibia and fibula, allowing for the gliding of the fibula (Marieb & Hoehn, 2013, p. 255).

**2.6.3.3 Muscles.** The muscles acting on the knee are members of some of the largest muscle groups in the body. Muscles acting on the knee also have relationships to the movements of other regions of the leg, such as the thigh and hip, and are linked to the path the muscles take as to the joint movements. Although other types of movement occur at the knee joint, the primary movements are flexion and extension. The strength and tone of the muscles acting on the knee joint, especially the quadriceps, are very important to the overall stability of the joint (Marieb & Hoehn, 2013, p. 365). The muscle groups located in the thigh providing movements to the upper leg can be sectioned into those located in the anterior, posterior, and medial compartments (Marieb & Hoehn, 2013, p. 363).

The majority of the muscles of the anterior compartment that provide extension at the knee are members of the quadriceps group (Marieb & Hoehn, 2013, p. 365). The sole extensor of the knee is the quadriceps femoris muscle located in the anterior section of the thigh (Marieb & Hoehn, 2013, p. 363). The quadriceps provide the powerful knee extensor movements that are used in climbing, running, jumping, and rising from a seated position (Marieb & Hoehn, 2013, p. 365). Especially in walking movements in gait, these muscles in the quadriceps provide the acceleration of the lower limbs.

The majority of the muscles of the posterior compartment that provide flexion at the knee are members of the hamstrings group (Marieb & Hoehn, 2013, p. 369). Knee flexion is provided by the biceps femoris, semitendinosus, and semimembranosus muscles located in the hamstrings group (Marieb & Hoehn, 2013, p. 363). The role the hamstrings play to the joint they act on is largely determined to which joint, the knee or hip, is in the fixed position as the joint is extended (Marieb & Hoehn, 2013, p. 369). Hamstrings will flex the knee, for example, when the hip is extended. During walking activities viewed in the gait cycle, the hamstring muscles as a group provide the opposite action that the quadriceps provide; in this case, the hamstrings look to decelerate the movements occurring in the lower limbs, as they prepare the body to accept the weight bearing stage.

The popliteal muscle has a position that crosses the knee, and a role that makes it difficult to classify; the muscle assists the knee joint to unlock from extension in

preparation for flexion during the weight bearing phase experienced during walking gait in the transition from weight acceptance segment of the cycle in preparation for the swing phase (Marieb & Hoehn, 2013, p. 363; Starkey & Ryan, 1996).

#### **2.6.4 Pelvis and Hip**

The transition between the axial lower back segments, and the appendicular segments of the lower limbs occurs at the pelvic girdle, is supported by some of the strongest ligaments in the body (Marieb & Hoehn, 2013, p. 234). The strength of the ligaments allow for the maintenance of upright posture. The sacrum and the coccyx represent the lowest two regions of the vertebral column in the pelvis and hip region. Differences in the structure of the pelvis between men and women include the structure of the female pelvis exhibiting less strength of the bone, differing tilt angles, and a broader and rounded appearance (Marieb & Hoehn, 2013, p. 237). These changes in angles especially affect women that have been pregnant, as the body releases chemicals that interact with connective tissues in the regions, allowing for the passage of the child in the region. There is also some thought that these tilt angles may have an effect on the mechanics of the gait cycle in different genders.

**2.6.4.1 Bones.** The pelvis is a deep, basin-like shape created by the formation of the hip bones, coccyx, and sacrum (Marieb & Hoehn, 2013, p. 238). The false pelvis is actually part of the abdomen as it is formed by the lumbar vertebrae posteriorly, and the alae of the ilia laterally (Marieb & Hoehn, 2013, p. 238).

The pelvic girdle, or hip girdle, attaches the lower limbs to the axial skeleton, transmitting the full weight of the upper body to the lower limbs (Marieb & Hoehn, 2013, p. 234). The pelvic girdle is formed by the sacrum (axial skeleton) and a pair of hip bones, called coxal bones (Marieb & Hoehn, 2013, p. 234). The center of gravity of the body lies about 1 cm posterior to the sacral promontory within the vertebrae of the sacrum (Marieb & Hoehn, 2013, p. 222). The coccyx, or tailbone, provides nearly no support or role at all (Marieb & Hoehn, 2013, p. 224).



**2.6.4.2 Range of motion.** The hip bone and femur articulate at the synovial ball-and-socket joint at the coxal or hip joint (Marieb & Hoehn, 2013, p. 255). The planes and movements exhibited here include the following: diarthrotic, multiaxial, flexion, extension, abduction, adduction, rotation, circumduction of the thigh (Marieb & Hoehn, 2013, p. 255). The sacrum articulates with the hip bones that are located in the pelvis (Marieb & Hoehn, 2013, p. 218).

**2.6.4.3 Muscles.** As no muscles directly act on the hip itself, the relationships and insertions of the muscles of the thigh, pelvis, and lumbar spine contribute to the movements experienced at the hip. These muscle relationships at the hip include the previously discussed compartments of the thigh muscles as well as the anterior, medial, and posterior muscles originating in the pelvis and spine (Marieb & Hoehn, 2013, p. 363). Because of the design of the joint acting here, the ball and socket joint allows for motion in multiple planes at the hip. This is even more important during weight-bearing upright activities because of the COG of the body occurring in this region. The strength of these muscles is necessary to accurately place and control the COG as movement becomes of influence.

In addition to the anterior quadriceps and posterior hamstrings relationships in the thigh, the muscles of the medial compartment of the thigh contribute to the movement abilities and patterns the ball and socket hip joint (Marieb & Hoehn, 2013, p. 363). The large majority of movements occurring at the hip joint are accomplished by the thigh muscles that are anchored to the pelvic girdle (Marieb & Hoehn, 2013, p. 363). However, additional relationships with the axial spinal column occur that influence postural control and the COG.

The anterior compartment of the thigh, with the quadriceps, provide the ability to flex the thigh at the hip joint (Marieb & Hoehn, 2013, p. 365). The majority of the hip flexors path passes in front of the hip joint as they travel towards the thigh (Marieb & Hoehn, 2013, p. 363). However, the quadriceps also provide a level padding for the hip joint through the size of the mass that is present in an individual on the lateral aspect of the thigh; this feature comes into play during laterally occurring falls as an individual falls to the side (Marieb & Hoehn, 2013, p. 365). This padding protects not only the bones of

the pelvis and hip, but the previously mentioned weak point of the femoral head that forms the ball for the socket joint in the region.

The posterior compartment of the thigh, which includes the hamstrings, primarily act to extend the thigh in movements that occur at the hip (Marieb & Hoehn, 2013, p. 369).

The medial compartment muscles provide adduction of the hip joint as they press on the thighs (Marieb & Hoehn, 2013, p. 365). The insertion relationships in the pelvis and femur provide the important movements that are necessary when the tilting of the pelvis occurs, such as walking, when fixing the hip is necessary during knee flexion with the foot off the ground (Marieb & Hoehn, 2013, p. 365). Abduction is provided to the hip joint by the laterally occurring gluteus medius and gluteus minimus, as they abduct the thigh (Marieb & Hoehn, 2013, p. 363). The abduction and adduction of these muscles is important to walking as shifting the trunk side to side, as well as balancing the weight of the body over the grounded limb (Marieb & Hoehn, 2013, p. 363). This is the placement of the COG over the grounded limb that will be further demonstrated in section 2.7 below.

### **2.6.5 Lumbar Spine**

The lumbar spine represents the lowest four regions of the spinal column. The location of the lumbar spine serves as the cut-off point between the upper and lower body, with the lumbar spine and the previously discussed components of the lower limbs representing the lower half of the body.

Located between the lower region of the rib cage and the pelvis, the axial lumbar spine is the transfer to the lower limbs represented by the previously mentioned segments of the lower leg. The curvatures of the spine increase the resilience and flexibility of the spinal column as they transfer the weight of the upper body to the lower body and provide the transfer of movement (Marieb & Hoehn, 2013, p. 218).

**2.6.5.1 Bones.** The lumbar region is composed of five lumbar vertebrae and their connective tissues (Marieb & Hoehn, 2013, p. 218). Although the vertebrae bones share similar shape characteristics, the proportions that are displayed by the body of the

bones in the lumbar region are massive when compared to those in the thoracic and cervical spine (Marieb & Hoehn, 2013, p. 223). The bulk provided by this additional size shows the role in the supportive nature of this group of vertebrae.

**2.6.5.2 Range of motion.** Movements allowed by the region include flexion and extension and some lateral flexion; rotation is prevented as the orientations of the facets of the lumbar vertebrae lock together, which contributes to stability of the lumbar spine (Marieb & Hoehn, 2013, p. 223). The rotation of this region allows for the corresponding interactions with the lower limbs starting in the hip and pelvis to allow for the rotational movement needs in the gait cycle.

**2.6.5.3 Muscles.** The muscles occurring in this region are commonly referred to as core muscles, those which perform the role of assisting in the posture of the individual. The four muscles of the anterior and lateral abdominal wall help promote the lateral flexion and of the vertebral column (Marieb & Hoehn, 2013, p. 342). These four flat muscles are flat, and strap-like in appearance, characteristics that are layered one on top of another to create the structure and support of the wall (Marieb & Hoehn, 2013, p. 342). The muscle support is provided in the same manner that plywood achieves its strength, by the alternating of the direction of the fibers. The horizontal fibers of the deep lying transversus abdominis is opposed by the fiber direction of rectus abdominis, which allows for the sit up action and pelvic stabilization; the internal oblique with its angular fiber direction in the upward and medial direction is opposed by the direction of fibers in the external oblique, which run downward and medially as it aids the muscles of the back in rotating the trunk and lateral flexion (Marieb & Hoehn, 2013, p. 342).

The flexors of the thigh are the iliopsoas, the tensor fasciae latae, and the rectus femoris, with assistance from the abductors of the medial thigh compartment (Marieb & Hoehn, 2013, p. 363). The iliopsoas is a composite of two muscles, iliacus and psoas major; they have origins on the pelvis or spine and assist in the flexing of the trunk on the thigh as well as laterally flexing the vertebral column (Marieb & Hoehn, 2013, p. 363).

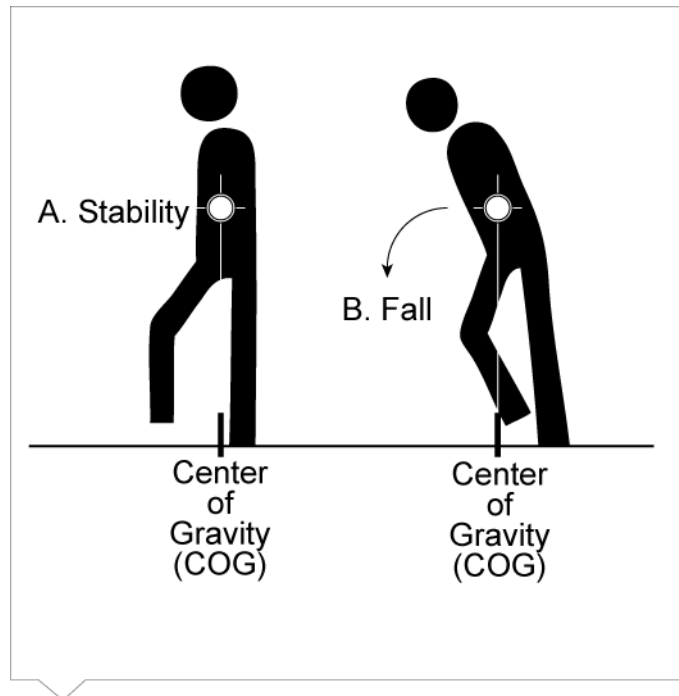
With a basic understanding of the individual components in the human anatomy of the lower body, a greater understanding of the roles that each component play is achieved.

The limits of each joint can begin to allow designers to understand physical limits their designs must consider if the corresponding body region is designed to be used. The groupings of muscles and their movement roles that include their directions of muscular influence lay the foundation for how to best develop these features. While the individual components have these characteristics, the movement process provides additional responsibilities and formations of relationships that require further understanding. By gaining this understanding of the movements, the development that optimizes the improvement of the factors that would improve the mobility function of older adults could be improved from the standpoint of the designer.

## **2.7 Biomechanics of Balance and Mobility**

From a physical standpoint, the ability to reduce falls lies with the ability of individuals to control their balance and mobility as it relates to their postural stability in an environment. Older adults “exhibit a unique set of behaviors brought about by the gradual decrease in their sensory functions” (Pirkl J. J., 1994, p. 57). To understand the dynamic processes that control an individual’s ability to maintain an upright posture, defining several terms as well as examining the biomechanics of standing and movement are necessary to understand how someone may become at risk for falls.

The first concept addressed is Center of Mass (COM). Rose defines Center of Mass as, “the point at which all of the mass of the body is concentrated in terms of the forces that act on the body and the body’s motion” (2010, p. 4). The establishment of the COM can be as simple as maintaining COM within the base of support while standing, or as complex as reestablishing COM with each step taken during walking. The process of accomplishing this is



*Figure 2.5 Influence of Center of Gravity on Falling. (A.) Stability is demonstrated as the COG is centralized. (B.) Falling is promoted when the COG is extended beyond the body of control. (Pirkl J. J., 1994, p. 59)*

the familiar term balance. Balance is defined as “controlling the body’s Center of Mass with respect to the base of support, whether we are stationary or moving” (Rose D. J., 2010, p. 4). The various muscles groups of the body in conjunction with sensory inputs received are constantly processed by the body and adjusted against the destabilizing force of gravity to control the position of the COM (Brownstein & Bronner, 1997, p. 207). The balance process occurs in both static situations such as merely standing, or dynamically as we move through our environment walking or running; the COM is constantly adjusted to maintain a vertical upright standing position.

Now that the relationship between center of mass establishment and balance has been established, the means employed by the body to effect the change must be defined. The movement of COM occurs through the posture of the body. The location of the COM is relative to our posture, which is defined as “the biomechanical alignment of each of our body parts as well as the orientation of the body to the environment” (Rose D. J., 2010, p. 4). Good posture is then deemed critical to maintaining good balance because it more appropriately aligns the body’s COG. Because individuals not only stand statically, but

they also move dynamically, the strategies that are employed by the body need to be examined because the source of many falls has been shown to occur in these dynamic activities (Li, et al., 2006). To modify the COM through a change in posture requires an input that suggests that a change may be necessary; additional decisions from the input must comprehend the extent of the change necessary. Figure 2.6 demonstrates the balance between the input, and the response of the body posture. These planning decisions lead to postural control strategies that incorporate the extent of the change necessary.

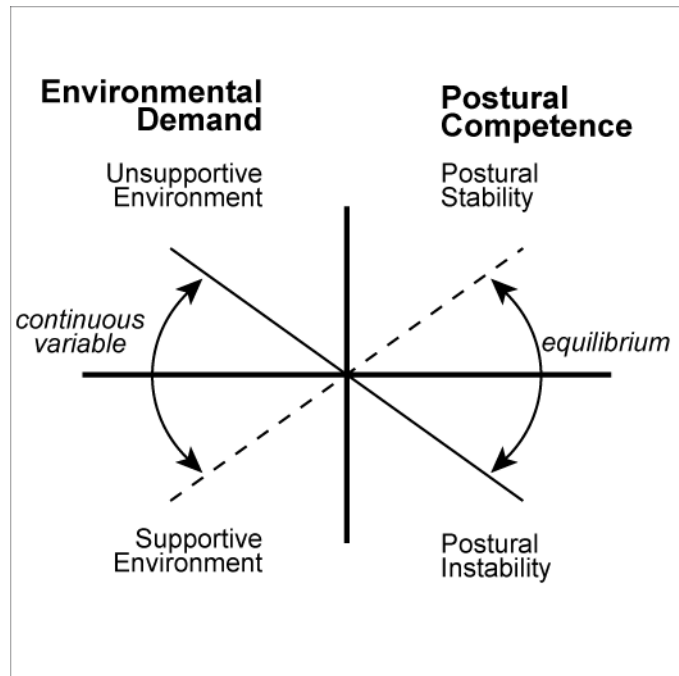


Figure 2.6 Postural Competence. The interpretation of the surrounding environment, and the choices made to those, effect the posture. (Pirkl J. J., 1994, p. 49)

The decisions that lead to the selection of the postural control strategies employed are based off of an individual's ability to either plan or react to the environment in order to maintain balance. Anticipatory postural control refers to those actions that can be planned in advance (Rose D. J., 2010, p. 4). These actions include avoiding seen obstacles as we move about an environment; it also assists individuals as they transition between different surface types and path openings such as loose gravel and narrow walkways. When a quick response is required to a change to their posture, a reactive postural control is utilized. Reactive postural control is defined as actions that cannot be planned in advance due to the unexpected nature of an event, such as an unexpected bump in a crowd or an unseen hole in the ground (Rose D. J., 2010, p. 4). The ability to successfully accomplish these strategies as an individual ages is required for even the most basic of daily activity tasks if older adults wish to maintain independence as they age, especially those occurring outside the home where environmental controls are limited.

The postural strategies previously described are built on the concept of the confidence or abilities an individual possesses within stability limits and ultimately the size of the sway envelope. The maximum distance that an individual is able or willing to lean in any direction without changing the base of support is the premise of the concept of stability limits (Rose D. J., 2010, p. 5). The key is “willing and able” when considering an older adult’s stability limits. If confidence, ability, or a combination of both is lacking presence within an individual, he or she is likely to have to modify the base of support. The zone that the path of the body’s movement during quiet standing travels defines the individual’s sway envelope (Rose D. J., 2010, p. 5). Older adults generally have a smaller sway envelope as they begin developing balance issues, which have been shown to increase falls risk.

When viewed together, these concepts highlight the conditions that can negatively impact the older adult’s ability to safely control these areas. Along with other factors that are beyond the scope of this research, weakness in the ankle muscles, limited range of motion about the ankle joint, and fear of falling have all been identified as negative impacts to the ability for an older adult to maintain proper biomechanics (Rose D. J., 2010, p. 5; Brownstein & Bronner, 1997). Falls risk is especially increased when these negative impact factors act on the individual’s movement in the lateral and backward directions (Rose D. J., 2010, p. 5; Brownstein & Bronner, 1997).

When going beyond basic static standing and balancing skills, when transitioning to dynamic movement, the concept of mobility is introduced. Mobility is defined as an individual’s ability to move functionally independently and safely from one place to another (Rose D. J., 2010; Daley & Spinks, 2000, p. 1). As it is described, mobility is essential to daily activity tasks that are essential to older adults wishing to remain independent without help from others, as well as being necessary for higher complicated tasks such as physical activity. It should be further noted that while understanding the basics of the biomechanics of posture and postural controls are necessary, the majority of falls occur during a dynamic activity (Brownstein & Bronner, 1997, p. 320). This suggests that attention to designs should consider the needs of dynamic movements in an effort to reduce falls, as well as provide for mobility and independence during

activities of daily living because all of these require dynamic activity ability to safely complete.

### **2.7.1 Postural Control Strategies**

As movement is dynamic and a source of falling, the understanding of the choices that describe postural strategies that control body sway and have been biomechanically observed is necessary. The maintenance of posture through the postural control strategies represents the starting point for understanding the processes that influence the ability to maintain an upright posture. Controlling posture is required first before increasingly difficult control of balance can occur. The choices have been shown as a collection of three progressively complex postural control strategies; from simplest to complex they are ankle, hip, and stepping strategies. The strategies demonstrate the choices that are made in an effort to maintain the proper vertical posture by an individual, ideally with the least effort put forth.

Ankle strategy is defined as the postural control strategy in which the body moves as a single entity about the ankle joints (Rose D. J., 2010, p. 6). The body is moved in the same direction about the ankle joint, being supported by the strength of the muscles of the ankle region. The ankle strategy requires a level of strength in the smaller muscles that surround the ankle region. This strategy can be seen most often in static standing or recovering from minor nudges. Because the strength of the muscles controlling the ankle region are supporting the body as it extends the COM away from the center, this strategy can be seen as weaker because of the relative strength of the muscles of the area.

The hip strategy is the postural control strategy in which the upper and lower body move in opposite directions as a result of the hip muscles being activated to control balance (Rose D. J., 2010, p. 6). This strategy is often utilized when an individual is reaching out for an object located away from the body such as when housewares are located in an above-the-counter cabinet.



The step strategy is the postural control strategy used when the COM is displaced beyond the maximal stability limits or sway is too great to use a hip strategy effectively with the new base of support to be established as a requirement (Rose D. J., 2010, p. 7). This strategy is essentially the body's last resort to maintain vertical posture. A step strategy could be used by an individual who for example has been nudged in a group within a crowded environment. If the force of the nudge is great causing the COM to be shifted, the need to step in order to compensate for the new location of the COM would be necessary to maintain an upright position or the individual would face the possibility of falling.

The deficiencies that can negatively impact these postural strategies highlight areas of concern for older adults as it relates to falls risk. The main drivers of these limitations revolve around strength, range of motion, neurological, and sensation deficiencies of the lower body region, from the feet to the hips regions. The modifiable accelerant of these factors from a physiological area appears to be physical inactivity, also known as a sedentary lifestyle. A sedentary lifestyle is characterized by limited participation in activities. The lack of participation in activities then result in the disuse of body systems which lead to the accelerated declines in functional abilities. The atrophy of muscles in both overall size and strength is an example of a type of decline which is particularly negative to the functional performance of older adults. It is also noted that that rates at which individuals have or do not have sensory deficiencies affects the rate of the postural stepping choices as well. The sensory deficiencies can include for example limited vision that can affect these stepping choices (Heasley, Buckley, Scally, Twigg, & Elliot, 2005, p. 3584; Finbarr, Hart, Spector, Doyle, & Harari, 2005, p. 285; Campbell, et al., 2005, p. 1).

When these components of standing posture and mobility are compromised, the risk for falls is increased while the individual's opportunity to remain personally independent is reduced. This occurs because an individual's ability to cope with a disturbance in their physical environment has exceeded their personal capabilities. While it is clear that the diversity of the individual systems controlling the larger systems of balance and mobility varies in the older adult population, the ability to focus on the improvement of these

areas that can be improved or maintained can be looked at as previously suggested. To reduce this imbalance between ability and action, an individual should improve his or her capabilities to do so. The vehicle that has shown promise from a preventative training standpoint is physical activity. To produce physical activity, especially in the lower body regions effecting mobility, the understanding of the movement

process is necessary. The movement is guided by the relationships in the kinetic chain.

### 2.7.2 Kinetic Chain

Understanding the gait cycle is necessary to understand mobility. Building on the previous section, the processes that act on balance statically are now required to act dynamically through the movement of the limbs. Successful locomotion requires the ability to integrate the movements of the upper and lower body under control (Rose D. J., 2010). The relationships that form from these movements create kinetic chains of movement, and is illustrated in Figure 2.7.

The articulations of the toes, foot, ankle, knee, hip, pelvis, and spine compose a kinetic chain through which gait occurs (Starkey & Ryan, 1996). The relationships established by the positioning of one joint influences the positioning and movement of the subsequent joints. Two forms of kinetic chain movement relationships exhibit this behavior. Closed kinetic chains occur under weight bearing movement “when distal joint relationships affect the joint proximal to its position” (Starkey & Ryan, 1996). An open kinetic chain occurs in a non-weight bearing position. The open kinetic chain is formed

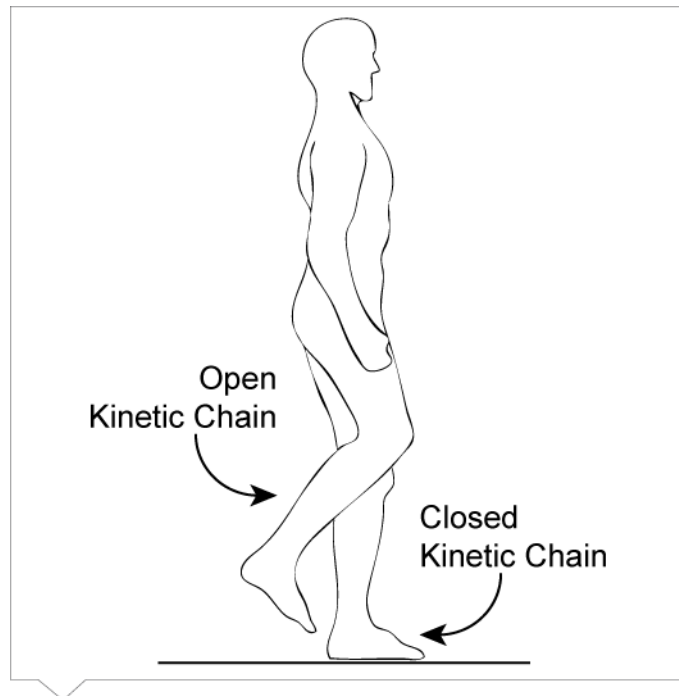


Figure 2.7 Kinetic Chain: The weight-bearing limb represents the Closed Kinetic Chain. The non-weight-bearing limb represents the Open Kinetic Chain (Starkey & Ryan, 1996)

when “the proximal joint influences the position of the joint distal to its location” (Starkey & Ryan, 1996). In both kinetic chains, the relationship of one part of the chain effects what the next part of the chain does.

The interdependent relationship between regions highlights the potential of a negative influence that dysfunction to the kinetic chain can have. An example of a temporary alteration to the kinetic chain showing the adaptation required to the movement pattern is a sprained ankle, a commonly occurring injury. The pain affects the mobility of the ankle joint, creating the need to alter the normal movement pattern, causing a limping movement during gait. The foot, knee, hip, and spine alter their normal movement to compensate for the dysfunction of the ankle in the kinetic chain. In this example, the compensation of each related section of the chain has to make up for the role the ankle would normally provide.

If it is not a serious injury, a temporary dysfunction may not affect an individual greatly over a short period of time. However, it has been suggested that an abnormal gait caused by improper or irregular biomechanics that occur in the lower extremities can potentially cause injury because of the redistribution of forces to other joint surfaces (Starkey & Ryan, 1996). The redistribution causes systems to operate beyond their intended role, and when prolonged over time, this can lead to potential injury along with the mentioned irregular mechanics. All of these forces cause inefficient use which can tax systems at a higher rate, reducing the endurance, for instance, in the movement.

To further understand the negative impact adaptation can have to movement patterns within the kinetic chain, some of the basic movements should be explored, especially mobility as it relates to the older adult. The basic importance that mobility provides to the personal independence sought by older adults highlights the negative role that dysfunction in the kinetic chain can exhibit for the older adult; mobility requires the kinetic relationships found in the gait cycle to function as efficiently as possible to reduce the complications and compensations that inefficiencies can potentially cause.

### **2.7.3 Gait Cycle**

Walking can be measured and expressed as a collection of activities that are repeated with each step we take; this is measured through the term gait cycle. The gait cycle is the time between the first contact of the heel with the ground and the next heel-ground contact with the same foot (Rose D. J., 2010). The muscles that provide the movement during the individual tasks during the gait cycle require a preservation of strength to preserve the quality of the gait cycle patterns, as well as reduce the risk of falls among older adults (Rose D. J., 2010). The preservation of strength is an efficiency that reduces compensation in movements in the kinetic chain.

Providing the strength and forward movement, several of the important muscles for gait include the hip extensors, knee extensors, plantar flexors, and dorsiflexors (Rose D. J., 2010). In addition to the knee and hip, the function of the lower leg in the foot and ankle participates in this activity. As the gait activity is an upright postural movement, the lateral stability strength during walking is reliant on strong hip abductor muscles. This helps maintain the COG and COM to provide this activity. Along with sufficient muscular strength, the overall composition of the gait cycle requires three additional major attributes to achieve the normal gait pattern: (1) an adequate range of motion, (2) appropriate muscle timing and coordination, and (3) unimpaired sensory inputs as provided by the visual, somatosensory, and vestibular systems (Rose D. J., 2010). These attributes of gait are provided for by the (1) capability of the joints involved, (2) the efficiency of the kinetic chain, and (3) inputs received for interpretation and distributed as commands to action as a part of the feedback loop within the individual.

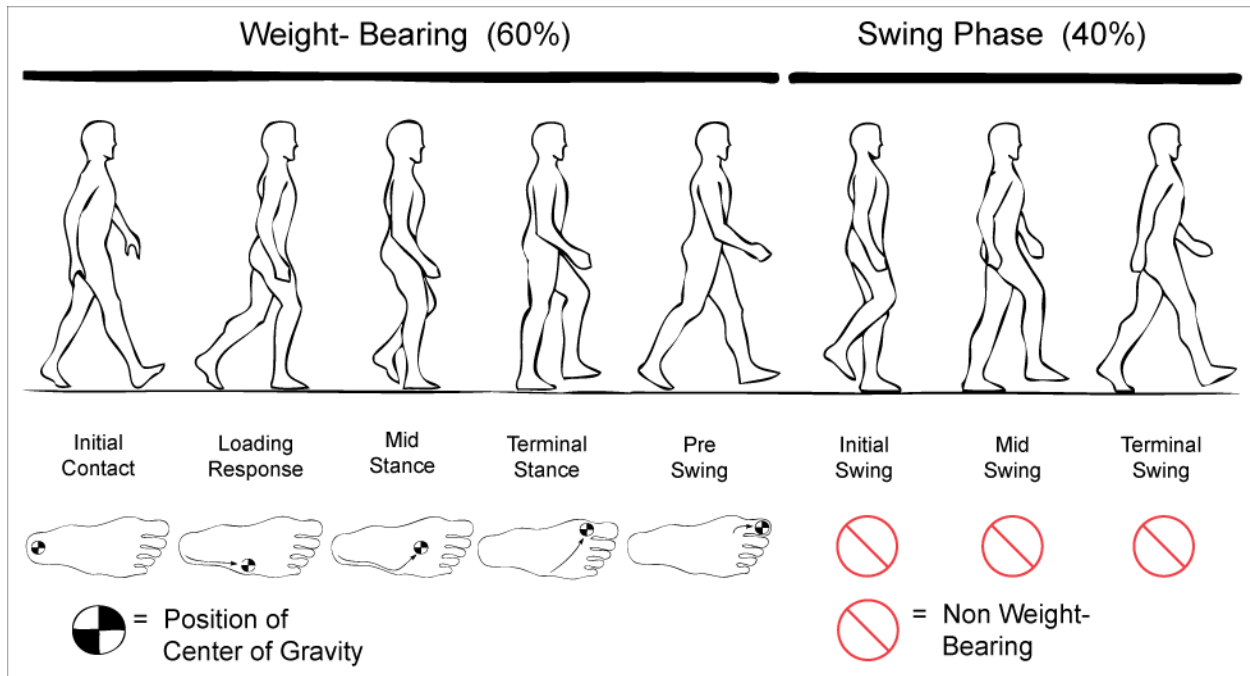


Figure 2.8 Gait Cycle Phases: The gait cycle is comprised of two phases, (1) Weight-Bearing & (2) Swing Phases. The positioning of the Center of Gravity (COG) is identified when present in the Weight-Bearing phase, and when it is not present in the Swing Phase. (Starkey & Ryan, 1996)

There are three major tasks that must occur during the gait cycle, (1) weight acceptance, (2) single-limb support, and (3) limb advancement (Rose D. J., 2010, p. 179). Because of these tasks, the general overall gait cycle can be divided into two distinct phases for individual analysis; the two phases are the stance phase and the swing phase, and each will be individually examined for detail.

**2.7.3.1 Stance phase in gait cycle.** Representing approximately 60% of the cycle time when walking at a preferred speed, the stance phase is initiated when the foot first contacts the ground (Rose D. J., 2010; Starkey & Ryan, 1996). The stance phase is comprised of five periods in the duration of the gait cycle: initial contact, loading response, mid stance, terminal stance, and pre swing (Starkey & Ryan, 1996). The individual periods share similar contributions and can be grouped further into three tasks within the gait cycle: weight acceptance, single-limb support, and advancing the limb (Rose D. J., 2010).

The first individual period of the stance phase is initial contact with the ground. Initial contact begins when the heel strikes the ground on one side, while on the opposite foot,

the toe-off period is completing (Starkey & Ryan, 1996). The initial contact is followed by the loading response period, which lasts until the opposite limb has left the ground, ending double-support of the limbs (Starkey & Ryan, 1996).

Initial contact and the loading response periods are weight acceptance tasks in the gait cycle that require adequate muscle strength to successfully achieve. These tasks require the chain of events to include good limb stability from the hip extensors; the forces generated by the body's weight require proper knee flexion control from the quadriceps as the heel-strike motion provides forward-transfer of COG through the dorsiflexors as the cycle prepares for limb loading (Rose D. J., 2010).

The mid stance period shifts to a single limb of support. The forward movement of the body weight from the previous loading period transfers the COG directly over the foot (Starkey & Ryan, 1996). The single-limb task supports the entire body weight as the center of gravity passes over the foot during the terminal period of the gait cycle.

The key muscles that provide support for the weight of the body and the maintenance of posture include the hip abductors that stabilize the hip and pelvis as well as the trunk muscles that maintain the upright position (Rose D. J., 2010). The forward progression of COG is provided from the quadriceps, and the plantar flexors act to control the movement of the tibia during mid and terminal stance (Rose D. J., 2010).

The final period of the stance phase is the pre-swing. The pre-swing is the second of the double-stance postures in the gait cycle. The phase begins with the initial contact of the opposite limb, and ends with the toe-off phase as the knee is tasked to begin to flex in an effort to advance the limbs forward (Rose D. J., 2010; Starkey & Ryan, 1996). The weight-bearing forces have shifted to the big toe, loading the limb towards push-off. This transitions the stance phase of the gait cycle into the swing phase.

**2.7.3.2 Swing phase of the gait cycle.** The swing phase of the gait cycle is a non-weight bearing, open kinetic chain period that represents approximately 40% of the gait cycle when walking at a preferred speed (Rose D. J., 2010; Starkey & Ryan, 1996). The swing phase is comprised of three periods in the duration of the gait cycle: initial swing, mid swing, and terminal swing (Starkey & Ryan, 1996). The task that is to be achieved

during the swing phase is to advance the limb forward to complete the swing phase. The initial swing period begins as the toes leave the ground; this period goes until the knee has reached a maximum range of flexion to provide the toes clearance (Rose D. J., 2010). This also marks the length of the step which is related to the distance the limb was advanced. The second period, mid-swing, finishes with the tibia in a vertical position perpendicular to the ground (Starkey & Ryan, 1996). The swing phase concludes with terminal swing period with the initial contact of the heel to repeat the process.

The large muscle groups are the primary contributors to the swing phase; those playing a role include the hip flexors, knee flexors, dorsiflexors, quadriceps, and hamstrings (Rose D. J., 2010).

While describing the gait cycle in a perfect situation of execution, it has to be mentioned that older adults are likely not to experience a perfect execution of this process. For designers to promote mobility through guidance, the effect of the aging process on this activity needs to be explored to identify the areas of concern and focus for potential design solutions to consider.

**2.7.3.3 Age associated changes in the gait cycle.** When younger adults are compared to even healthy older adults, clear differences are present (Rose D. J., 2010). The underlying cause of this is unclear, yet there are factors that may be potentially significant for positively amending them. The most reported difference is gait speed, which is attributed to a decrease in the length of the stride, not the cadence of the steps (Rose D. J., 2010). This could potentially have some connections to the limited flexibility of individuals as they age. Another possible connection to the shorter step length can be caused by a perceived fear of falling, in which the older individual shortens their step length to reduce their perceived ability to fall; the shorten step also has been shown to include an increase in the double support phase of the gait cycle, suggesting the belief in lateral balance may be reduced in the aging (Finbarr, Hart, Spector, Doyle, & Harari, 2005). As the process of the kinetic chain shows, this one change has measured consequences in the other aspects of the gait movement, as the coordination and timing that has been exhibited throughout life becomes altered.

Because the cadence or rhythm of the steps taken by individuals during the gait cycle remains unique to them and unchanged as they age, the shortening of the step length can potentially have unforeseen consequences as they age, and negatively alter the coordination of the kinetic activity they have performed throughout their lives.

The other changes to the lower body that can potentially impact the gait cycle when present include reduced rotation of the hips, knees, and ankles, increased double-support time, and a more flat-footed ground contact in the stance phase prior to toe-off (Rose D. J., 2010). As a result of the kinetic chain of gait altering, older adults demonstrate patterns of compensation during mobility tasks. Additional adaptations that are seen include reduced knee flexion and cautious weight transfer (Rose D. J., 2010); in an effort to reduce the likelihood of tripping, older adults have been observed to slow their gait speed as they are approaching obstacles (Rose D. J., 2010). This cautious nature can be readily seen among older adults. The adaptations discussed thus far are physical, but sensory system changes have also been noted to adversely affect older adult gait, especially vision.

As the review of basic biomechanics and posture highlighted, there is a need for the sensory system of the body to provide these feed-forward inputs from the surrounding environment to aide in the ability to make decisions and how to react to the environment. As the effectiveness of vision and other sensory inputs diminish, the quality of the information the body has to respond to also diminishes. The sensory systems like vision that assist the body in preparing the motor functions for the changes in the environment are referred to as feed-forward inputs (Rose D. J., 2010). Reductions in a feed-forward visual input, among other sensory deficits, can impact gait speed because of the additional processing time required for the body to decide as to what action to take. Also, the quality of the visual information may be limited in an aging adult because of conditions occurring in the eye such as cataracts, which can cloud the vision. The quality of the information received appears to be a design consideration that designers should invest time understanding to ensure interactions are communicating the intended messages for action.



Additional sensory inputs from the proprioception receptors and vestibular system has been shown to impact gait through the information about limb position in critical movements during gait (Rose D. J., 2010; Daley & Spinks, 2000, p. 6). The proprioceptive system, such as those found in the lower limbs like the ankle, provides limb positioning information; reductions in the number and quality of the receptors combined with the posture and balance control offered by the ankle would contribute to gait dysfunction in older adults (Daley & Spinks, 2000, p. 6). While this occurs, the vestibular system helps steady the head to assist the visual information received by the eyes by stabilizing the head during movement. As the kinetic chain relationships have shown, the reduction of the ability to locate the foot in space would have cumulative effects as the relationships in the chain are effected by the information received from the other.

The impacts from reduced function from the body systems may vary from individual, to individual, and in severity and presence in the same manner. The addition of these deficiencies leads to increased opportunities for negative consequences to companion these deficits, especially if these factors are not readily practiced or performed as is the case among many older adults. Further exploration of these factors will highlight prevalence tendencies which will assist in the design process as factors to consider among the older individual.

## **2.8 The Aging Process Effects on the Individual**

As the exploration of movement and mobility has highlighted, the initiation of movement as well as the reactions necessary to adapt to an individual's environment are influenced by the cycle of interpretation from the inputs and the effects of the outputs. The surrounding environment is read by the body through a group of processes; these then translate the information they process in order to determine the proper intervention or action. The group of systems that communicate with one another unfortunately biologically degrade among the older adult population, with a varying rates, within varying body systems. The result is a variability in the aging process, which appears to be highly individualized. This variability complicates the design process, but is necessary in order to understand the needs of the older adult. These areas have an

impact on the mobility of the individual because of the declines within several areas. As the composition of the receptors of this information degenerate, balance and mobility are negatively impacted among older adults at several levels: the sensory, motor function, and central processing body systems (Pirkl J. J., 1994, p. 58; Rose D. J., 2010; Daley & Spinks, 2000).

The following individual sections will attempt to highlight factors that have been suggested throughout the literature as significant in the aging process in general so that they are acknowledged, as well as those that directly impact mobility. As with other topics on aging, some of the factors are currently determined to be non-modifiable, but their presence requires attention.

### **2.8.1 Sensory Function Decline**

The sensory functions are the body systems that interact with the inputs of the environment that guide the decisions that the body responds to. It is thought that sensory deficits may contribute to an increase of 35-40% in falls among those over age 60 (Williams, 2001, p. 516). These sensory systems include the sense of sight, touch, sound, taste, and smell. The collection of these systems are responsible for the feed-forward interpretation needed to produce balance and movements in the previous sections. The incidence of the sensory deficits and threshold of perception required for many stimuli increase with the aging process. The study focus of the sensory systems will be on those that have demonstrated higher rates of influence on falls, mobility, and independence among older adults, the sensory systems of vision and touch.

**2.8.1.1 Vision decline.** The sense of vision has a tremendous impact on the ability for an individual to interpret their surrounding environment. Because of this relationship Brownstein and Bonner suggest that vision is the most important input source to the maintenance of balance that is negatively associated with falls risk as it degrades (1997, p. 320). Several aspects can be present to negatively impact sight. Vision exhibits well documented changes in aging which include: (1) spatial frequency sensitivity, (2) peripheral vision, (3) glare sensitivity, (4) dark adaptation, (5) depth perception, and (6) contrast sensitivity (Jones & Rose, 2005; Pirkl & Babic, 1988).

## Collection of Vision Changes Affected by Aging Process



Normal Color Vision



Cataracts



Glaucoma



Diabetic Eye Disease



Age-Related Macular Degeneration (AMD)

Figure 2.9 Effects of Vision Changes in Aging Process. The image on the left represents an example of Normal Vision. The collection to the right illustrates the negative effects each has on the older adults ability to accurately interpret visual information. (Rose D. J., 2010, p. 12)

Increased light is necessary to see an object because of decreased contrast sensitivity (Jones & Rose, 2005, p. 49; Kroemer, 2006). With the compromising of this input source, the body can misinterpret the visual information and choose the improper response, potentially leading to falls (Finbarr, et al., 2005, p. 281). While not all individuals will experience these conditions that in many cases are unmodifiable, the sensitivity to their existence is required to prepare for interventions and solutions. The need to accurately disseminate information from the surrounding environment must occur if a response is expected. An example can be seen in the compromised dark adaption abilities; these can lead to difficulty in negotiating obstacles, maintaining balance, and mobility (Jones & Rose, 2005, p. 49).

Vertigo is the condition in which the hallucination of movement occurs; the disorientation that can occur from the misinterpretation of busy patterns or the surrounding visual information as it is perceived by the individual creates a situation that mimics visual information that is generally received during movement (Pirkl & Babic, 1988; Mazzeo & Tanaka, 2001, p. 812). Because of the misinterpretation of the

input, inappropriate adjustments may be made to compensate for information of the surrounding environment that is inaccurate. Situations such as these can lead to potential injury if the capabilities to recover are not present within the older individual.

**2.8.1.2 Touch decline.** The next sense of importance to lower body mobility is the sense of touch. While the use of the hands is often more commonly associated with touch sensitivity, the sense of touch in the feet and ankles particularly are important to mobility, walking, and other movement activities that are weight bearing. The ability for older adults to detect vibration, especially in the feet and ankles, is diminished with age, making it increasingly difficult for older adults to develop an understanding of joint position (Carter, Kannus, & Khan, 2001, p. 428.; Saxon & Etten, 2002, p. 303). The understanding of the position of the body and limbs in space is referred to as proprioception. Diminishing abilities in proprioception negatively affect the body from effectively and accurately establishing a consistent base of support when an individual moves about their environment. As was stated earlier, this condition of decline in the quality of the mechanoreceptors that assist in the accumulation of proprioceptive information required to place the body has been seen to diminish in the ankles and feet. The detection ability is hindered further through the use of improper footwear that reduces the senses even further because of masking vibration detection abilities in the lower extremities (Jones & Rose, 2005, p. 48).

Sense of touch can also be lessened by areas and conditions on the surface of the skin. The presence of thick skin, calluses, bunions, cracked feet, wounds, and deformities in the feet can also be found to complicate the touch sensitivity required in weight bearing activity (Ciavarelli, 2008). Vibration masking can be a result of many of these influences on the skin surface as is the case with thickened skin, or through regional physical pain, as caused by the presence of wounds or bunions.

Compassion from designers for sensory system abilities among older adults and how it impacts their ability accurately interpret the products and environment needs to be established in potential design solutions. Although variable in extent and manifestation, these issues can be challenging the use of products through reductions of the quality of

the information that the individual receives from the interactions. The ability to incorporate sensory information more clearly should be sought.

### 2.8.2 Motor Function Decline

Skeletal muscle is of interest in the study of the older adult because of the movement that is made possible when the muscles contract and exert a force on the bones and connective tissues

that support them (Whitbourne, 1985, p. 20). Musculoskeletal changes occur on three levels that contribute individually to an individual's ability to timely and safely accomplish tasks:

muscle strength, muscle endurance, and muscle power (Kell, Bell, & Quinney, 2001, p. 365; Hurley, 1988, p. 13; Deschenes, 2004, pp. 810-813; Hurley, 1988, p. 13). From a physical standpoint, the components of this system offer the most obvious abilities for modifications through physical activity by improving muscular strength and flexibility through a range of motions (Pirkl J. J., 1994, p. 59; Daley & Spinks, 2000, p. 8). In addition to the strength of the muscle present is the need for individuals to possess a level of muscular endurance and power. In all cases, an acceleration of the deterioration of these systems occurs within the practice of a disuse and a sedentary lifestyle.

**2.8.2.1 Muscular strength decline.** With muscular strength, studies have repeatedly found a decline in lean muscle mass, and overall strength in the musculoskeletal system of elderly adults (Carter, Kannus, & Khan, 2001, p. 429; Pescatello, 1999, p. 319; Xu, Li, & Hong, 2006, p. 53). The deterioration of the muscle mass that affects the musculoskeletal system is a condition known as sarcopenia

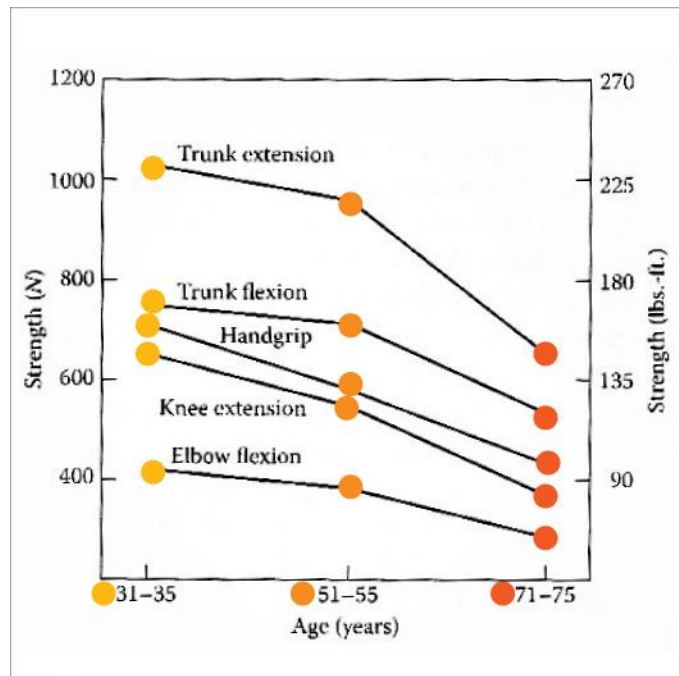


Figure 2.10 Muscular Decline Comparison between Different Age Groups: The figure illustrated the rate of progressive decline in muscular function over time. This change accelerates in later years. (Allread & Israelski, 2011, p. 122)

(Deschenes, 2004, p. 809). Sarcopenia is connected to the decreasing in the overall size in mass and strength of the skeletal muscle fibers of the body in aging; the reduction of muscular strength is largely attributed to the loss of the overall muscle mass, with the size of the muscle mass decreasing by 40 to 50% between the ages of 25 to 80 (Burbank & Riebe, 2002, p. 6). Because of this link between size and strength, the tracking of muscle mass is frequently reported in studies as a measure regarding older adult's functional ability.

Although it affects skeletal muscles located throughout the body, loss of strength and mass in the muscles of the legs are more pronounced than in the hands and arms (Whitbourne, 1985, p. 21; Daley & Spinks, 2000, p. 3). The decreasing of the quality of the muscles of particular regions like the legs appear to have greater impacts on areas of life and mobility among older adults. This reduction affects the performance of the movements associated with the kinetic chain, mobility, and walking locomotion, all which are critical to personal independence maintenance in older age.

For instance, Xu et al observed that balance “is influenced by strength in the muscles that control the ankle, knee, and hip, which are used in postural movements and gait” (2006, p. 53). Additionally, “the loss of strength in the dorsiflexors muscles is associated with falls and with difficulty in performing certain activities of daily living” (Xu, Li, & Hong, 2006, p. 53). These regions are important to the performance that can be achieved during gait and mobility. Designers should note that these areas of the lower body appear to be of significance for the maintenance and development of beneficial strength in older adults seeking mobility.

Support for the body through posture is necessary from the muscular strength influenced by the lower core, pelvic region, and lower extremities to maintain proper alignment of the posture of the body (Hurley, 1988, p. 13). When these supporting muscles weaken, the slumping can produce poor alignment, making it more difficult for the body to maintain COG, as well as introducing compensatory kinetic movements. The ability to maintain proper posture has previously been discussed as important to balance and postural control in section 2.7. The muscle weakness that occurs in the lower body and elsewhere in the aging process of the musculoskeletal system occurs in

several manners, not just in the strength of the muscle. Another muscular weakness that can be seen among older adults of both genders includes muscular endurance.

**2.8.2.2 Muscular endurance decline.** Muscular endurance effects the duration the individual can perform the tasks with the muscles in question without fatigue (Hurley, 1988, p. 13; Deschenes, 2004, p. 813). The muscles requiring endurance in older adults include important regions such as the muscles in the back, abdomen, and quadriceps (Hurley, 1988, p. 13). The loss of muscular endurance in older adults can limit the time spent in activities. In addition to kinetic activity found in gait, the weight bearing support for the core, for example, is required to establish an upright posture or rise from a recliner require an ability to perform over time. The muscular endurance required for the core effects the amount of time the person can use these muscles without experiencing fatigue. The loss of muscular endurance can force individuals to compromise on even simple tasks, as was reported in one study focusing on women age 55 to 84 years of age; because of a lack of muscular endurance, many of these women reported in the study that they were unable to perform many aspects of household work (Burbank & Riebe, 2002, p. 5).

Tasks such as cleaning, whether for the home or during personal care, require basic levels of ability to complete independent of outside assistance if personal independence is desired. While certain situations and environments will allow compensation for additional breaks to rest, such as a park bench, many other tasks that are required of older adults on a daily basis or in unaccommodating environments do not. Therefore, designers must understand the importance of muscular endurance as it relates to older adult mobility.

**2.8.2.3 Muscular power decline.** The final dimension of muscular output as it relates to musculoskeletal factors is muscular power. Muscular power represents the rate at which work is performed, and is calculated by dividing that work by time (Jones & Rose, 2005, p. 44). The reduction in muscular power can be related to the changing of the type and quality of the skeletal muscle fibers remaining available during the aging process as it occurs. The reduction of the number and size of the muscle fibers is more apparent in the fast-twitch or Type II fibers; these fibers are responsible for the

explosive, short-duration movements such as lifting a heavy object or sprinting (Burbank & Riebe, 2002, p. 6; Whitbourne, 1985, p. 21). These are also muscle actions that assist in reactive forces that act on the body, such as recovery movements to tripping, or jumping out of the way of a speeding car as you walk along a street, Or avoiding a fall (Deschenes, 2004, p. 810).

These aging factors combine to reduce force production, and reduce contraction speed which translates into the loss of ability to move against forces quickly. Muscular power contractions are not strictly for athletic movements like a sprint; similar movements are required in daily life. Rising from a seated posture, such as a toilet or chair, or recovering from a trip necessitate the ability for an individual to generate muscle power (Deschenes, 2004, p. 810). The muscles make it possible for the adult to perform actions required at home, at work, and during recreational activities. Some of these actions involve strength, others endurance, and many especially require muscular coordination (Whitbourne, 1985, p. 24). The importance of muscular power to the completion of daily activities is heightened as it is increasingly difficult to develop muscular power with age, even more than muscular strength. This highlights the reasons the medical community stress the importance the role physical activity plays in the aging process. Ongoing participation can maintain for longer periods the necessary dimensions needed in daily life like having the ability to create muscular power to get out of a car.

The importance of the effects of dynamic muscle movement is essential from what has been shown with the mechanics of mobility. The decrease in the quality of the muscles as individual's age demonstrates the need to maintain the ability to walk and get around an environment. This was shown in the study on activity and tai chi conducted by Xu et al, as well as mentioned by Whitbourne; they both described that this need for muscular power is very important for older adults as they need to possess a level of high speed muscle contraction which is required by them during function in daily activities, such as walking at a normal speed and responding in a timely manner to disturbance (Xu, et al., 2006, p. 53; Whitbourne, 1985, p. 21.). The ability to create movements that can stimulate the generation of muscular power should be explored. Further, the movement



motions that provide the creation of reaction time and explosiveness in muscles should be explored by designers.

**2.8.2.4 Joints, flexibility, and range of motion decline.** The quality of motor function expressed by the joints in a body region is controlled by the flexibility ability of the muscles. Grandjean (1988) remarks that the ability for a muscle to produce output through work during muscle contraction increases with its length is a demonstration of the importance of ROM has on muscle segments (Grandjean, p. 1). The longer the muscle is able to stretch, the greater potential it has to produce strength. However, the aging process is associated with a progressive loss of flexibility in the sedentary adult. The loss of flexibility limits the length the muscle can extend, limiting its potential. For an example of the potential impact of lost flexibility, the loss of 7% of flexibility is associated with every decade of life that an individual chooses to be sedentary (Jones & Rose, 2005, p. 38). The loss of ROM in older age can be echoed further by the findings “that flexibility decreases with age, 20% to 30% between 30 to 70 years of age” (Kell, Bell, & Quinney, 2001, p. 869). The negative implications of decline in ROM of joints are further inactivity and ultimately immobilization. Influential factors that negatively affect the flexibility of persons include disuse, deterioration of joint structures, and degeneration of collagen fibers; the deterioration of joint flexibility appears to accelerate after age 65 (Williams, 2001, p. 516). The deterioration of joint structures and fibers include the ligaments and other connective tissues responsible for interacting with skeletal muscles and bones. The maintenance of the rigidity of the ligaments needs to stay in place to help stabilize and protect the joints from excessive motion during dynamic activities (ACSM, 2001, p. 381). Range of motion declines in older adults have been seen when both active and passive assessments are measured. The importance of the ability for the skeletal muscle fibers to contract and connective tissues to remain flexible, elastic, and capable of a full range of motion is essential for activities of daily living (ADL). As an example, a recent study “indicated that simply squatting and tying one’s shoe required the largest ROM of all ADL” (Kell, Bell, & Quinney, 2001, p. 870).

Older adults frequently report that joint stiffness and conditions such as arthritis effect their ability to move. This process has been explained regarding the impact life has on the older adult:

*“The joints are subjected to an extreme amount of trauma during life, due partly to constant stresses placed upon them during movement due to weight load in the legs and feet... encountered during everyday activities and during strenuous exercise. Unlike the muscles, the joints do not seem to benefit from their continued and heavy use. Instead, the reparative processes the cellular structures enlist seem to be in and of themselves detrimental (Whitbourne, 1985, p. 31).*

Whitbourne refers to this reparative process as the “wear, tear, and ‘faulty repair’ model”, that can facilitate the buildup of an overgrowth of material on the joint surface which can interfere with normal operation of the joint (Whitbourne, 1985, p. 31).

Because this process effecting the joints will likely be individualized and is not modifiable without surgical intervention, the effects of joint damage is an area that must be accommodated for when possible by designers. It has previously been stated in the literature that providing a gradual introduction of movement may provide benefit to these painful joints by reducing fluid buildup during movement. The ability to provide accommodation can allow for older adults to individualize solutions to their unique needs.

The reduction in the quality of the motor functioning available in older adults may negatively impact factors that are associated with mobility. These reductions include the general strength present in the muscle, the general power that the remaining muscle can generate against a force, and the general longevity of the performance of the muscle present. Accompanying the muscular loss is a diminishing range of motion. This occurs through the reduction of the quality of the motion produced by the joints, as well as the decline in the soft tissue elasticity found in the connective tissues. The combination of these factors greatly reduces the quality of the movement potential for the individual to remain mobile. Efforts should be made to provide stimulus to these factors as they are critical to the movements of the lower body that produce weight bearing mobility required in personal independence in older adults.

### 2.8.3 Central Nervous Decline

The final dimension where declines are seen in the older adult are expressed in the central nervous and central processing functions of the body. The diminishing of the elements in the central processing are responsible for some of the most common disabilities in aging (Jones & Rose, 2005, p. 47). Many of these internal systems are not visible in their physical form, yet the physical actions they are responsible for are visible.

The central nervous system (CNS) collects and processes the raw information input information sent from sensory system areas, and various the motor functions (Pirkl J.

J., 1994, p. 59). “It is widely believed that lowered performance and slower reaction times associated with some aging persons come from neural noise (spontaneous neural activity) and degenerative changes in the central processing system” (Pirkl J. J., 1994, p. 59). Williams suggested that these changes in the central and peripheral nervous systems over time include slowed conduction velocities and reaction times, which drop by 15% by age 70 (2001, p. 516). The result of these changes can be seen in the older adult as they participate in activities in general.

Effects of slowed reaction times are amplified as the task and systems introduced for interpretation involved become increasingly complex. Including complexity to tasks such as mentally adding numbers for a task of solving of a math problem, while simultaneously walking around obstacles requires many decision processes to occur (Rose D. J., 2010). The coordination to perform one task accurately should not take

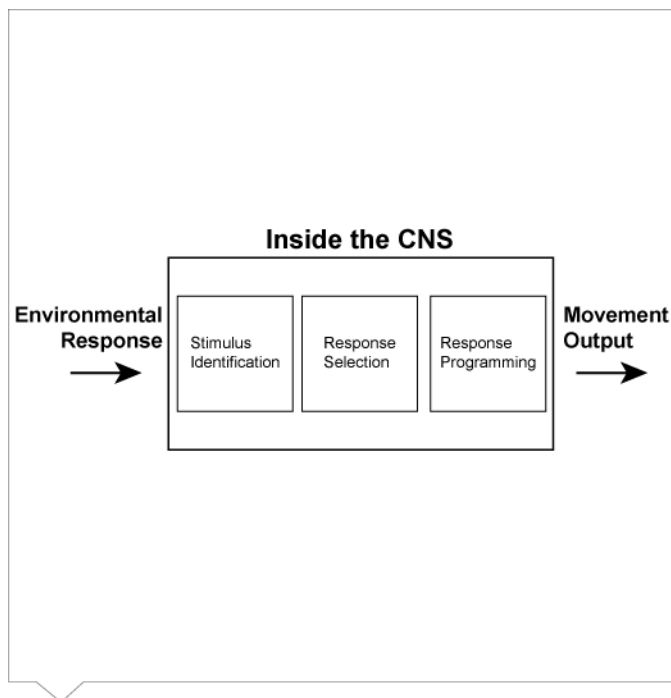


Figure 2.11 CNS Process & Response to Information: The input of information from the surrounding environment is done by the sensory system. The CNS is the transit system for this information that guides response decisions. (Brownstein & Bronner, 1997, p. 317)

away from the performance of another. In the previous example, not accurately adding numbers is not as impactful as not avoiding an obstacle when walking for an older adult; however, the accurate coordination of performance in multiple tasks during daily life activities can negatively impact older adult independence during driving, or walking through crowded areas while reading navigational signage as examples.

Communication occurring through the central processing that is affected with age can include declining proprioception. The proprioceptive system deals with the sense of position, movement, and maintenance of equilibrium, and when effected through impairment, can affect gait and balance (Hurley, 1988, p. 12). Additionally, the reduction in the number and quality of the receptors in the body can add to the internal communication system of the body slowing, ultimately increasing the potential to increase body sway in standing activities (Hurley, 1988; Rose D. J., 2010). Because these input systems are translated into decisions which then travel through the central processing system to influence actions for mobility and balance, a decline in processing and communication systems of the body can negatively impact movement function. As the number of receptors becomes smaller in number, the ability for the body to accurately make decisions also lessens. These changes to the communication system of the body then require an ability for the older adult to practice how to accommodate to the lessening of their abilities. Doing so can potentially assist the postural strategies, balance, and mobility in an older adult, encouraging safe travel through an environment if understood by the designer.

## **2.9 Summary of the Older Adult Body: the Functional Implications**

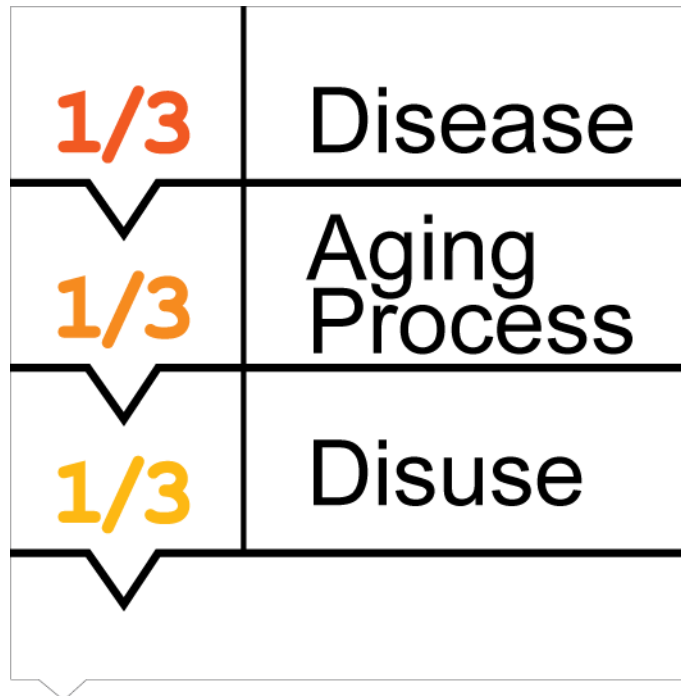
As the input systems that control our balance and mobility performance degrade, the way by which these groups of input systems must be investigated. While genetics, biological, and other non-modifiable justifications for some of the input systems exist, there are many aspects of the body systems that can be effectively managed regardless of genetics. Management can potentially be modified through preventative behavior decisions, and adapting to the unique challenges that individuals will face as they age. Adaptation could include starting an activity in a seated position, and progressing as skills, ability, and self-confidence are established. Unfortunately, many of these changes

to the body systems occur slowly. Because of the ability for humans to adapt, changes sometimes do not show themselves until a jolting awareness of our functional limitations come about as an unyielding environmental demand is unable to be accomplished like it could have been in the past (Pirkl J. J., 1994, p. 41). The rate of slowness of the advance of limitations suggests that many of older individuals may not

readily identify their changing needs, and therefore, designs should seek to proactively implement solutions that can afford for these changes.

Although compensation and adaptations mask some aspects of the aging

process, these same abilities to adapt make it possible to a degree positively modify many of the detriments that are associated with aging. Training for these adaptations include those which are contributing to mobility complications and ultimately falls in older adults. Individuals and designers possess an ability to adjust and overcome these conditions through awareness of the deficits. “Older adults are capable of improving their motor performance with practice combined with physical conditioning” (Brownstein & Bronner, 1997, p. 318). This is furthered by the suggestion that many of the physiological conditions covered in this section are due to a decreased level of activity, and that they can be improved and reversed with proper exercise training (ACSM, 2001, p. 376; Daley & Spinks, 2000, p. 8). The evidence that older adults are capable of adapting their bodies to improve, as well as improving their actions through



*Figure 2.12 The "Thirds" View on the Aging Process: The literature has mentioned that the aging process, along with disease, can limit functions in older adults. The research also suggests the importance of habitual activity participation as a means of maintenance. (Pirkl J. J., 1994)*

practice and participation is very important by itself, but it also brings the attention as to how the older adult is to accomplish the practice and physical conditioning.

The previous discussions on declines in system ability and the components required for mobility in the sections and sub sections of 2.7 and 2.8 above highlighted the potential and likely presence of declined information systems in older adults. While the extent and frequency of the presence can vary, it can be assumed that these factors are likely present. The literature thus far has made ties to the impact of these information processing systems and these physical function systems as they impact independence activities of daily functioning, yet they have not defined what products the older adults are using to create these modifications to their abilities in mobility; nor has the literature covered the product interaction impacts these deficiencies may have on the safe and accurate operation of the physical products.

For example, beyond the physical capacity to participate in activity, the functional limitations also impact the ability for older adults to interact with products, artifacts, and services within their environment. The potentially diminishing ability of vision can demonstrate this concept. The vision deficiencies suggest that products for older adults should allow them to adequately see the edges of a product, reduce the glare off of shiny plastics and materials, and improve the ability to accommodate for contrast sensitivity, illustrating complications older adults may potentially face just for the interpretation of visual cues required for product interaction alone. When other reductions are included, or the severity of the deficiency is amplified, these combinations of factors can reduce the quantity and quality of the information being received. This could be the result of being slowed through the central processing system travel of the information to the muscles or other combinations. Regardless of the deficiency, the reduction of these systems can begin to be appreciated as to the impact to the older adult and the interactions with products are presented.

### **2.10 Studies Showing the Promise of Activity**

The ability to elicit health gains from physical activity participation should not be viewed as the only goal from older adult participation. The positive effects of the

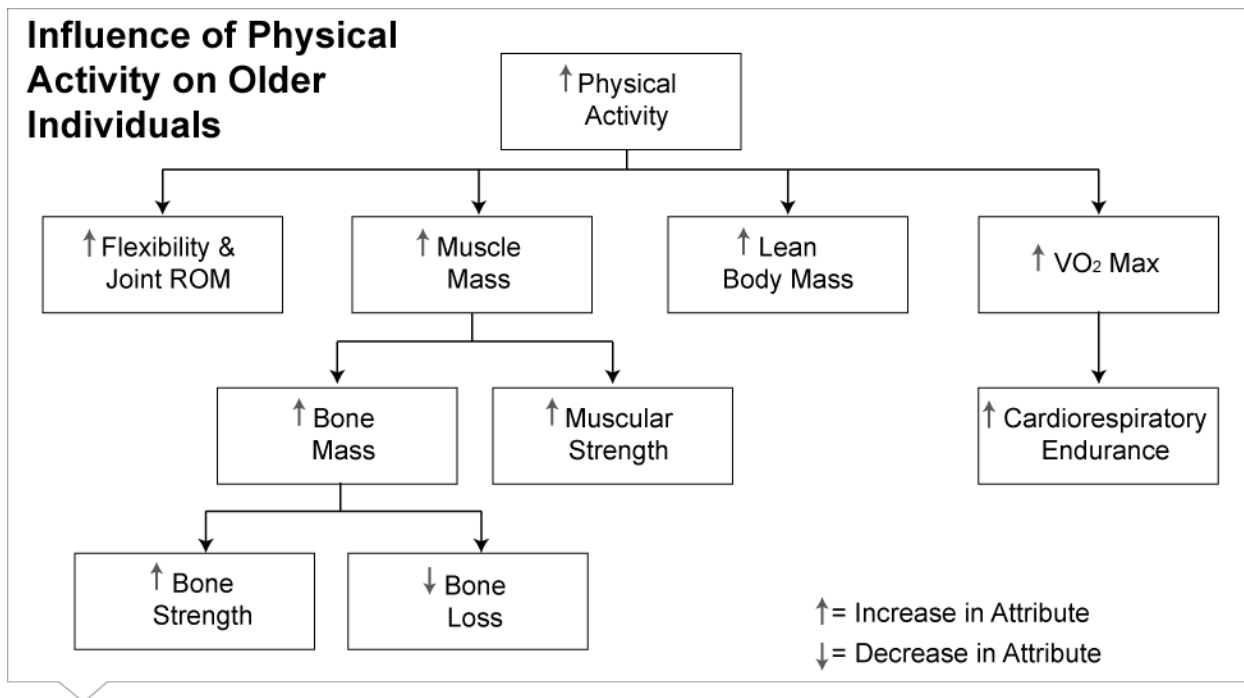


Figure 2.13 Physical Activity Influence on the Older Individual (Brownstein & Bronner, 1997, p. 337)

physical activity, if performed both properly and habitually, can also benefit the specific needs that are required from the systems involved in the gait and mobility functions necessary for personal independence. Exercise is effective in reversing or at least slowing certain age related declines in motor and cognitive performance (Daley & Spinks, 2000, p. 2; Jones & Rose, 2005). When the goal shifts from a fitness focus, to mobility function focus among older adults, a shift in the types of activities and movement forms that can produce the greatest gains occurs.

The movements that are most desirable in the promotion of mobility activity and reducing falls risk include components that represent a collection of diverse activities performed at a low to moderate level of intensity including those that stimulate flexibility, strengthening, and movements along with the reestablishment of COG (Rose D. J., 2015; Rhodes, et al., 1999, p. 408). This differs from traditional focus of younger and healthier adult's activity guidance that is performed at higher intensity and frequency levels in an attempt to alter fitness levels. Achieving these activities can also vary in the activity and movement used that represent activity.

Because of the loss of strength in the population, studies have looked at the ability of resistance training interventions in older adults. Of particular significance is the report that a study was able to Dailey and Spinks suggest that skeletal muscle is perhaps the most responsive to changes in chronic patterns of use (2000). Activities that promote balance with minimal impact and intensity include those that focus on the tai chi movements. These movements are favorable for several reasons for older adults, yet they also have disadvantages. The main advantages lie in the weight-bearing, slow and controlled, movement patterns that are at the heart of the program. Tai chi is described as non-vigorous, gentle, and guided movements that engage the lower extremities in the hip, knee, and ankle in multiple directions (Xu, Li, & Hong, 2006). The ability to move through multiple directions is more aligned with tasks performed in ADL, making tai chi promising. While limbs are moved, stretched, and flexed as you might find in yoga, the tai chi movements are performed in a weight bearing stance, rather than a static holding position as in yoga. While both promote flexibility, the gains in falls reduction in older adults have not been as clear as the gains seen in tai chi (Rose D. J., 2015). The ability to provide breathing focus, movement and limb awareness, as well as a weight-bearing component are very beneficial to the older adult in reducing falls risk.

The graceful nature of the exercise is also a limiting factor to the complete effectiveness as an activity solution. The activities of daily life require not only capable balance, but they require a functional dynamic balance. Because of the kinetic nature of mobility discussed in section 2.7 above, the need to possess muscular power is necessary for activities like running and walking. When compared to individuals who ran as their activity in the study, the tai chi group did not produce the same gains in fast-twitch muscle generation (Xu, et al., 2006). “If you want to improve your ability to balance and walk, try a program that focuses on improving balance while moving, and the ability to step quickly and further” (Fitter International, Inc., 2008), Neil B. Alexander, M.D., professor in the Division of Geriatric Medicine at University of Michigan suggests. The reductions to the flexibility range of joints, the fast twitch skeletal muscle fibers, and the coordination of the sensory systems seem to be the focus of such training, areas that have been shown to limit older adult abilities.



A longitudinal study looking at the inner-city of St. Louis found that those individuals who were interviewed, that individuals who had difficulty walking or other limits to their lower body function were more likely to have deceased during or by the end of the study (American Geriatrics Society (AGS), 2008). The recommendations from the research concluded that, “programs that aim to improve lower body functioning among older African Americans may also extend their lives, and should try to determine the best ways to improve lower body function” (AGS, 2008).

### **2.11 Programs for Falls Reduction Intervention**

No design can take place without first gaining an understanding of the necessary components of exercise to promote benefit in mobility. Because of the potential and likely deficiencies in the functioning of older adults, it has been suggested that special considerations should be taken when designing physical activity programs for this group. These considerations seek to elevate conflicts that can occur both physically through physiological functioning and through psychological means through thoughtful compassion.

The building blocks to initiate a promotion or change in program development starts with defining the goal or outcome desired. With older adults, the focus of the activities shifts from youthful goals that are commonly associated with physical activity, and place the focus on mobility, well-being, and independence. Although the focus of the intended benefit of the activity shifts, the underlying components that represent training must be addressed.

These individual components are overload, specificity, functional relevance, challenge, and accommodation. The individual components can be viewed as a part of one of two groups, the training effect group and adaptability group. Overload and specificity are part of the training effect group. These components require the achievement in a particular fashion to elicit a proper response. The second group of adaptability contains the individual components of functional relevance, challenge, and accommodation. These components are not as strict as to requirements to achieve a goal, yet they are important to the way the older adult reaches the training effect group goals. The

components in the adaptability group seek to make reaching the requirements of the training effects overload and specificity more versatile for the diversity found in the older adult population.

They will be examined individually to understand their significance and determine recommendations for potential design solutions. It is believed that implementing the knowledge of these principles in addition to their understanding is of importance when designing programs mobility for the older adult age group.

### **2.11.1 Specificity**

“The principle of specificity states that the training effects derived from physical activity are specific to the type of exercise and muscles involved” (ACSM, 2001). This reveals that the training effects are going to be site specific, affecting the area that was trained. For example, an episode of training repetitions of leg squats are not going to improve the biceps of the arms; the squats will only improve the strength of the legs. The muscles trained are also going to only be trained through the movement that was undertaken; the increases in strength are going to be specific to the ROM that is trained for (ACSM, 2001, p. 376). Because of the specific isolation of the gains to the movements and muscles utilized occurs, it has been suggested that a well-rounded training program to develop muscular and cardiovascular function should be followed as a general consideration in activity development (ACSM, 2001, p. 376).

The regions of the lower body for older adults have been cited as the sources of many of the deficiencies experienced during the aging process and therefore will have to be focused on by activities to improve mobility according to this principle. Reviewing the areas that are shown to develop weakness and functional limitations should be considered when developing a well-rounded approach that specifically focuses on the mobility considerations.

### **2.11.2 Overload**

“The principle of overload states that for a tissue or organ to improve its function, it must be exposed to a load to which it is not normally accustomed. Repeated exposure is

associated with an adaptation by the tissue or organ that leads to improved functional capacity” (ACSM, 2001). Although the principle applies to individuals regardless of age when it is followed, there is a level of sensitivity that needs to be noted when overload is applied to older adults; further, this sensitivity should also be applied to the remaining principles as they relate to physical activity among older adults. The sensitivity that needs to be employed is in regards to the functional capacity of the older individual, not only as a general status, but especially the functional capacity at the specific time of the physical activity. The variety that can be seen among the population as far as functional capacity can also be various within the same individual depending on the day.

The most common ways to introduce overload to muscles and body systems occurs from a progressive modification or manipulation of the variables of the tasks performed, such as the time and intensity features of the training (Jones & Rose, 2005, p. 136). These factors appear to focus on the variables of the body systems that are being trained, rather than the individual. These variables can also include areas including ROM of the region used, the velocity of the movement, and dynamics used in movements (ACSM, 2001, p. 376). In all cases, the goal is to train the systems to the point of overload so that adaptations can be created to develop a stronger system over time.

While achieving improved function is possible among older adults, the application of the training principles raises issues that are likely present in older adults training. These issues include intensity and retention in the activities designed for promotion. As suggested by the barriers identified in section 2.3 above, older adults prefer moderate intensity activities and retention rates in activity remain low. As for the intensity of the activities performed by older adults, higher levels of intensity in effort are required to create improved conditioning levels (ACSM, 2001, p. 517). This may become increasingly unrealistic to provide because of many of the barriers listed earlier. Because of this, it is recommended that programs place a focus on two measures, (1) time duration of participation and (2) frequency of participation, to promote health-related benefits from activity participation such as a mobility program could provide older adults (ACSM, 2001, p. 517). A focus on these areas can reduce the chances of injury

caused from higher intensity activities, especially if functional concerns existed as they do in many previously sedentary older adults.

The next issue of concern regarding training effects involves user retention. Although both the principles of overload and specificity can improve system function if achieved, the results they produce are not permanent. The ongoing need to continue to train is required to maintain the results (ACSM, 2001, p. 376). This is an important consideration among the older adult population, because of their low retention rates. While creating a positive change to their function is a goal, a secondary goal which is equally important has to be answered, how to promote ongoing participation.

To address this, Jones and Rose have included three additional considerations that have a focus on both the physical limitations that are present and providing an ongoing promotion of activity.

### **2.11.3 Challenge**

Very similar to the principle of overload is the principle of challenge. “Selected activities or exercises need to challenge, but not exceed, an individual’s intrinsic capabilities (e.g., strength, cognition, sensorimotor ability), and the level of challenge can be altered by changing the task demands (seated, standing, or moving; single or multiple task) or the environmental demands (surface type, lighting, visual flow)” (Jones & Rose, 2005, p. 136). The differences in the principles of overload and challenge appear to lie in the intent of the application to the intended body systems. The intent of the application of the overload principle is to challenge the muscles to change or evolve to accept the task performed. The challenge principle, although challenging the recruitment of different muscles based on the change, is more focused on the task difficulties as they relate to the individual, not the system as directly as overload.

Although this principle seeks to encourage a disruption of what is typically encountered frequently by an individual, it should be clearly understood that the testing of one’s capabilities should not exceed them. There is a balance that must be achieved between

exercises that challenge a person enough to produce positive effects and those that place a client at risk of injury (Jones & Rose, 2005, p. 137).

The ingredients that appear to help facilitate the challenge of an activity to an older adult are variety and variability. The challenge of an activity is ultimately controlled by the ability to introduce and control the amounts of variability and variety in the activities performed so as to not extend the functional capacity of the older adult.

To build upon this principle, the mobility factors of an individual will need to be challenged in order to stimulate the response. It appears that adaptability should be a consideration when providing challenge, as older adults can be at various stages of capability for activity participation. When these challenges that are presented within the activities are linked to the next concept, functional relevance, the link to why the individual should participate can be more readily seen.

#### **2.11.4 Functional Relevance**

“The principle of functional relevance encourages selecting exercises that simulate the movements of everyday activities to be performed in environments that are similar to those regularly encountered by program participants” (Jones & Rose, 2005, p. 136). Because the activities are seeking a training response, variables should be sought to be altered as skills are learned or shown to be understood to promote the enhancement of areas to be trained, and ultimately modified.

This can be seen in an example illustrating the concept behind this thought. An older individual can be asked to pick up an object they will encounter in daily activities such as a plastic bag of groceries, and to walk that group of objects across a room, with the bag being placed onto a shelf. In this example, there are many variables that can be altered to stimulate this basic activity. Flooring type (shiny and slick, thick and padded) can mimic weather conditions or environment types that can be potentially encountered outside the home; the weight of the bag can be increased/decreased to change the training effect from strength to more cardiovascular endurance in approach; the sensory

system can be altered through lighting changes or closing the eyes to rely on other sensory inputs.

“Functional relevance is similar to the exercise of specificity, but its focus is on functional activities that simulate movements performed in daily life” (Jones & Rose, 2005, p. 136). This suggests that for the improvement of balance, mobility, and falls risk that those “specific” movements and regions need to be the focus of the training in a presentation approach that can be more easily related to daily life activities as shown in the grocery bag grab example.

Functional relevance finally also seeks to link or make a connection between daily life skillsets and their physical activity counterparts in a more self-realization/discovery method. In this way, self-efficacy is sought to be built within the individual by linking one’s desire to remain independent against one’s abilities to complete tasks that directly impact daily lives and are commonly encountered. Providing the ability for the older adult to control the outcome in this way can gently encourage the achievement of a training effect to areas that are important to their desired outcome, while allowing the older adult to remain personally independent.

#### **2.11.5 Accommodation**

The principle of accommodation states that participants should be encouraged to “perform exercises to the best of their abilities, but to never push themselves to a point of overexertion, pain, or beyond a level that they consider to be safe” (Jones & Rose, 2005, p. 136). Accommodation seeks to consider that “a key to any exercise program for older adults is to accentuate movements they can do rather than to dwell on the activities they cannot do (ACSM, 2001, p. 572). Accommodation attempts to offer a layer of compassion to question the state of the individual’s health and standing at two levels: 1) in the current moment the tasks are being asked of them, and 2) their general state of function.

The initial layer of compassion was addressed in the text. Older adults are likely to experience fluctuating states of health that will require adjustment, or accommodation,

to achieve goals or expectations (Jones & Rose, 2005, p. 137). These fluctuations could be caused by a variety of sources from prescription drug interactions to general health for that given day. A generic practical example applying the principle of accommodation would be, for instance, to modify the daily repetition goal of ten repetitions, with a weight, to a goal of as many as possible without weight as a variation. With the previously discussed activity example, perhaps the repetition goal for the activity was ten repetitions; that day, energy levels are felt to be low, so the accommodation occurs in adjusting the number of desired repetitions and weight carrying element to allow for the reduced energy levels.

A second level of compassion the accommodation principle can convey is a general matching of older user needs through their general state of function. This secondary aspect of the accommodation principle provides the means to accentuate the skills that an individual has, while adjusting operation or interaction to frame the use to the available skill level of the user that could be lower than others. As a generic example of this aspect of the principle, the user could potentially have exceptional hearing for an individual of their age, yet have poor vision. This aspect of the principle suggests that while normal hearing can be expected, a secondary or alternative should be provided to accommodate for the low visual ability to complete the task.

As the principle of accommodation from a physical activity program design perspective modifies or adjusts to safely accept the individual's abilities, the principle of accommodation has another dimension that lies within the area of product design. From a product interaction standpoint, this principle has specifically been acknowledged within a specific design strategy, transgenerational design. To better suit the end user, the text highlights specific considerations within the idea of "accommodation" to help guide the design process to deliver products that can achieve this activity goal among the product offerings made available to older adults.

## **2.12 Design Strategies for Addressing User Needs**

Aging has been shown to be a variable process that impacts individuals at varying levels of severity, and that is benefited through activity participation that can account for

accommodations. Providing assistance to older adults requires an application of understanding the individual. Fortunately, many design strategies exist to translate these user needs into potential design solutions. The strategies applicable to older adult design include a user-centered design approach. The unique considerations that have been identified have made this approach applicable for designers seeking to gain insights from the older population. As a supplement to the user-centered design approach, borrowing insights from specialized design areas can assist the design process. Borrowing additional considerations found in the universal and transgenerational design approaches can help to include a wider range of older adults, as well as those with functional limitations or disabilities. As the literature has shown to this point, the ability to provide adaptations to these types of functional limitations is going to be a necessary design consideration to address. Although there are some differences to the strategies, the ultimate goal of each design strategy focusing on inclusion is to optimize the experience of the user through the application to and considerations of individual design strategies.

**2.12.1 User-centered design.** Focusing on the older adult from a user-centered design approach can be potentially beneficial for the design of mobility products. The aim of the user-centered design approach is to provide design solutions that are based on an empathetic understanding of their needs. There exist a number of approaches to achieve the goals of the user-centered approach of design, yet they can be distilled down to three main design objectives: (1) Gather genuine understanding of the intended user, (2) Translate the learning into conceptual/explorative forms, and (3) Validate the conceptual directions through review/repeat if necessary (Stickdorn & Schneider, 2011; Cagan & Vogel, 2002; Erwin, 2014). By following a design process in this manner, the user and those influential to the use of the product can be involved throughout the design process.

**2.12.1.1 Gathering user information.** The gathering of information on the user identifies the needs determined by use of the product or service (Kelley, 2001; Stickdorn & Schneider, 2011). To this point in the research, this information gathering has included the identification of barriers that have been found to limit the participation in



activity among the older adult. This has been shown to have the potential of identifying a POG in the older adult activity and mobility market. However, full reliance cannot be placed on this data. It will be necessary to communicate with older adults to gain their insights directly (Stickdorn & Schneider, 2011). In this way the validation of the research can occur, and the feelings of the older adult can be more fully understood through direct interaction. This interaction because of the nature of activity will also require the inclusion of the medical and exercise community, as their expertise will be necessary to validate the beneficial nature of movement and activity considerations.

**2.12.1.2 Translating information into concepts.** Translation of the findings into conceptual processes and potential solutions will be necessary. At this point the use of the universal and transgenerational design guidance can be beneficial. The goals of inclusion are important to these areas and they provide basis for additional considerations to consider in the design process. “Conceptual product design focuses on combining several product design perspectives: user-centered design approach, a variety of qualitative and quantitative research and data gathering approaches, and visualization techniques such as sketching, imaging, and prototyping” (Stickdorn & Schneider, 2011, p. 60).

The qualitative approaches may include those that assist in the grouping of themes, images, and other abstract information into groups that are more easily understood and communicated among various groups. These qualitative connections have already show to be favorable to the unaddressed needs to overcome activity barriers as described in section 2.4. Also mentioned earlier, the ability to quantitative learning may be necessary as the various activities are more fully understood, and potential solutions arise. The limits of the knowledge designers would have in regards to the medical and exercise fields necessitates their feedback to quantify the potential expectations that design concepts may have when applied to the older adult market.

**2.12.1.3 Validation of concepts and continued learning.** Validation of the concepts is the next stage of the user-centered approach. The synthesis of the previous research findings can be put through an ongoing validation process that tests the assumptions, providing validation or the need for further refinement of the directions

(Stickdorn & Schneider, 2011; Kelley, 2001). The length of this on-going validation and refinement is constrained by the scope and resources available to allow for this refinement to occur; additionally the overall goal of whether or not the process is going to result in implementation or if the process is explorative in nature also should be considered as factors that affect the extent validation process.

### **2.12.2 Transgenerational Design Considerations**

Transgenerational design is defined as the practice of making products and environments compatible with those physical and sensory impairments associated with human aging and which can limit major activities of daily living (Pirkl J. J., 2015). Because of the similarities that exist between the two, the examination of Universal Design principles will be touched upon to briefly highlight the differences and challenges of the two approaches that have been shown by researchers and peers in the field of design.

The transgenerational design principles were the synthesis of a collaborative research product in the late 1980's that sought to combine the research of the professional fields of industrial design and gerontology to identify the implications that a growing aging population would hold for product design (Pirkl J. , 1994). The research generated a set of guidelines and strategies to consider when designing products that placed an emphasis on sensitivity on the needs of the older adult in the design considerations.

To develop the guidelines, the project utilized the identification of three aspects of aging, physiological, sociological, and psychological, which were aligned with three identified roles of the industrial designer, humanistic, aesthetic, and technological (Pirkl J. , 1994). The researchers utilized ties identified between the two groups of aging and industrial design to focus on the physiological needs of the aging and the humanistic role of the designer. The result was the creation of a set of specific guidelines that focused on the sensory and physical factors of aging that affect the aging adult's ability to utilize products, services, and environments created by industrial designers. The industrial designer could utilize the physiological factors identified to be present in the aging to increase their sensitivity to the key factors during the design process; the sensory and

physical factors included in the specific guidelines to consider are identified as vision, hearing, touch, and movement/mobility.

Transgenerational design has been defined as a design methodology that “considers the needs of all generation of users, ranging from the young to the elderly” (Anders & Fechtner, 1993, p. 10). Anders further defines that the findings of gerontology combined with “a sensitivity to the differing needs of the elderly in a world designed primarily for the middle-aged and healthy adult” (Anders & Fechtner, 1993, p. 10) is the driving force behind the application of transgenerational design in the field of design.

The use of transgenerational design principles can be compared to the use of the principles put forth in the previous section regarding physical activity principles for older adults. The question that has been raised is, “When should something work differently for different groups?” (Anders & Fechtner, 1993, p. 10). The needs of an individual may be challenged either temporarily or prematurely with onset of disease or other form of disability. Although the majority of individuals receiving home health care are older adults, there are many younger individuals that experience functional limitations that hinder their capabilities in the same way the aging process hinders the older adult (Gardner-Bonneau, 2011, p. 753).

Although the transgenerational guidance has a focus on industrial designers, the broad nature of the guidance fails to fully identify the needs of any specific category of product design application. The creator even suggests that the application of the guidance should be tailored to the needs of the project, and applied as necessary within the goals of the project (Pirkl J. J., 1994, p. 25). It should be noted that the creator of the guides does not intend them to be utilized to design a product exclusively designed for the older age group, yet it is believed that segment of the population should be addressed. Pirkl states that “the transgenerational design doctrine rejects, as discriminatory, specialized ‘elderly’ products or devices targeted directly at older customers” (1994, p. 25). While the stance is understandable, the practice of applying the principles does not discriminate if the goal of the product is to assist the user by creating a sensitivity to their needs, with a product or service that has been absent from their life. If the intended user who could gain benefit from the intervention of design happens to be an

older individual, that person is still receiving the necessary attention of their issues. Withholding of needs because the intent is for an older adult would in that way be discriminatory. However, the sensitivity necessary by products to provide the user the proper needs regardless of age does raise questions as to how these needs are met.

This is important because the needs of the research thus far seem to point to a need to further understand the movement considerations of the older adult during activity, especially those that promote mobility among the older population. Further detailed guidance that addresses these needs should be sought to more fully develop guidance for designs that place a direct focus on the mobility and the promotion of mobility among older adults.

### **2.12.3 Universal Design Considerations**

A brief explanation of the strategy of universal design will call attention to some of the key elements that its application aim to include. The foundations of both transgenerational design and universal design share similar background goals. Pirkl acknowledges this as stating “the characteristics of transgenerational design stem from the same roots as ‘universal design’, seeking to shift the priorities of product development from aesthetics to suitability; from sales to service; from discrimination to accommodation” (Pirkl J. J., 1994, p. 25.).

Anders and Fechtner define the design methodology of universal design as the attempt to “meet the needs of all people, and includes those of all ages, physical abilities, sensory abilities, and cognitive skills” (Anders & Fechtner, 1993, p. 10). Although the attention to these concerns is of merit, the lack of concrete guidance makes the strategy of universal design worthwhile on paper and difficult to implement. The range of abilities of every individual makes such a practice difficult; further, the range of design intent of the end solution complicates this process. With further detailed guidance, the designer can apply the understanding that is sought through universal design with a more detailed and strategic approach.

The examples of design strategies discussed above have presented the several approaches that are aimed at the same ultimate goal, providing an understanding to the demands of the individual through investigation of their needs. The first step requires a gathering of knowledge of the problems faced. In this area, user focus can benefit from the ideas behind transgenerational and universal design principles because of their focus on the challenges that have been shown to include considerations of individual needs commonly excluded from the design process including older adults. Next, these problems are translated into an exploration of the potential forms that can answer these problems. Validation through feedback from individuals can reinforce or confirm assumptions. These solutions can then be translated into guides for final solutions that can be implemented. When these needs can be addressed in a manner that seeks to include the widest range of individuals, improved experiences can be provided. The way that designers can provide for these areas for older adults includes the application of human factors that optimize interactions with products and services.

### **2.13 Human Factors, User Needs for Older Adults**

The literature has expressed both the presence of varying levels of function and the need for designed activities to make accommodations for these variables among the older population. In design, these characteristics represent user needs that require considerations within the design development of potential solutions. By doing so, designers can provide accommodation for the users that can be expressed within the design solutions to improve interactions and use. Utilizing existing human factors research can create an outline for requirements provided within the design. In addition to this field of research, the use of findings specifically aimed at providing accommodation of human factors to products from a transgenerational design approach can add further details to the understanding of the older adult user within the field of industrial design. Including accommodations found in these human factors' areas to the desired steps of accommodations to the activity program design can provide a more thoughtful application of design principles to address needs in products for older adults.

Within the organizational strategy, transgenerational design calls attention to the accommodation considerations that should be considered by designers while creating

solutions intended for use by older adults. These accommodative design considerations have their roots in the human factors, ergonomics, and anthropometrics that represent many of the physical function aging process concerns. Cuffaro (2013) defines the human factors as the concept of accommodation has been repeated as it was initially. As it was described in section 2.11.5 above by Rose and Jones, accommodation should be provided as a component in a strategy for designing physical activity programs for older adults. However, the detail of what is required from accommodation within the previous discussion was limited as to what would be required from the devices and products that older adults interact with as selected by trained individuals in physical activity in the older population. This information was especially lacking in self-led product selection considerations for the older adult. This poses a problem to an older adult who is required to purchase or select equipment on their own to supplement their activity participation. Pirkl, however, has provided designers a general collection of considerations that should accompany the design process. Because of the general nature of this guidance, these should be used during the learning and development process, and tailored to fit the unique design challenges that are the goal of the executed direction. These considerations are especially important in two ways: (1) it is structured for designers, and (2) the focus of transgenerational considerations specifically seeks the inclusion of the needs of the older adult.

The four areas of accommodation that should be considered when designing or evaluating settings used by older adults are legibility, accessibility, adaptability, and compatibility (Pirkl J. J., 1994, p. 104). This is especially true with the need to identify guidance for a product or environment to accompany the program design for older adults if it is to allow for self-directed participation as previously examined. The overlap of the concepts allows for the application of these individual concepts to be applied early in the design process and learning to any of the previous areas of accommodation. The goal is to ensure that the choices of the operation are as robust as possible to allow for those with diminished or impaired abilities to utilize the artifact without penalty or stigma.

### 2.13.1 General Human Factors Considerations

The previous accommodative considerations provided specific guidance as to the approaches to consider that can interrelate goals of physical activity program of the older adult and transgenerational design for the product designer. To be fully realized within a product design, they should begin with an understanding of the make-up of the larger characteristics and needs that can be provided for through the application of additional general human factors. The general human factors needs that are to be provided at the beginning of a design direction require an establishment of both the size and intended use of the product, ultimately including its operational demands within the environment; the means of achieving this understanding comes from the application of anthropometric data. The measures will help provide the ranges of users to be analyzed as defined through the market segment, representing a population profile that will assist in the definition of the ranges necessary to provide the greatest accommodative range.

The use allows for starting points of general needs of the sizing requirements of the population of the intended use; the anthropometric size information gives statistical guidance as to the volume of space the body of the individual commonly takes on assisting the designer in translating the anatomical and biomechanical learning into designed application. The consideration for the widest range of users to be accommodated through the design of a product requires the application of the design for

#### Female Data Substitution Considerations

If female user data is unavailable, male data that includes the following conversion guidance can be used as a starting point

- Exertions required of the upper extremities, such as the hand & arm, are about 56% less than the male users capability
- Force exertions of the lower extremities, such as the feet & legs, of the female user are about 64% less than a male users capability
- Force requiring trunk strength of the female user is approximately 66% less than the male users capacity

*Figure 2.14 Anthropometric Data Substitution for Female User: If the ability to locate accurate or complete data of the female population is not possible, the following general guidance can assist the initial considerations process of development. (Allread & Israelski, 2011, p. 116)*

extremes; this provides for the inclusion of both the largest measures representation of the intended users, as well as providing the feature considerations that allow for the smallest measures of the intended users to also be fulfilled (Allread & Israelski, 2011, p. 122). In the case of general design considerations and workspace design, the sizing accommodation that is used to provide the widest range of possible users should at minimum target a range of the 5<sup>th</sup> percentile female to the 95<sup>th</sup>-percentile male (Allread & Israelski, 2011, p. 99 & 123). Data for these groups is readily available, and the largest and smallest statures are represented in a range that excludes the most extreme of each population range.

Although the measurement data provides information of size ranges, there are two points of guidance that designers should be reminded of when translating the anthropometric data into their design application. The first point suggests that while an individual falls in a percentile range for an individual body region, such as a height, the remainder of the measures of body regions of that same individual are not guaranteed to fall into the same percentile range, and may possibly be larger or smaller (Allread & Israelski, 2011, p. 100). The second point suggests that a specific percentile, such as 75<sup>th</sup>-percentile for example, will vary in the proportion between the genders when analyzing the proportions of the individual body segments (Allread & Israelski, 2011, p. 100). This suggests that here to the variability of the user, in this case the size proportions present within a percentile segment, must also be considered in the designs. Ultimately, the size recommendations are to only represent a starting point for the design process, allowing the proportions of the designs to fall more closely to what is needed. This can be refined as the data is applied and assessed against the actual use, user capability, and specific interactions that are ultimately employed.

As the need to include the widest range of older adults of varying capability becomes increasingly necessary, establishing the size range and capabilities of the user with the intended operation of the system defined allows for the establishment of design constraints to look at the possible modifications or enhancements needed to optimize those specific interactions which is the goal of ergonomics (Kroemer, 2006, pp. 160-161; Allread & Israelski, 2011, p. 102).



The following detailed exploration of the individual considerations of both levels, starting with the general guides and following with the specific guides, will elaborate on their individual aims.

### **2.13.2 Adaptability**

An initial general consideration should be made to the adaptability of the offering. Adaptability as a consideration of accommodation in the design of a product intends to reduce the need for customization and modification of a product or environment to manage the needs; the product designs and interactions necessary are already in place from the onset for the user no matter the age or skill range (Pirkl J. J., 1994, p. 108). The concept of adaptability is further expressed through the life-cycle of a product and the user. It should not be a concern if the user is a teenager or an older adult; the same effort through design should be made to allow for the equal use of the product by both age groups.

Application of adaptability has been seen as a desired and necessary plan of action in almost all of the program or activity considerations for older adults to this point in large part because of the variability in the functional abilities. In human factors, this adaptability considers the physical ability and the physical measurement dimensions to allow for the designs implemented to provide the necessary adaptations that allow for personal preference and body size to be established through the adjustability of the system (Allread & Israelski, 2011, p. 124). This is necessary because those sharing the same body sizes do not operate an object the same way or with the same preference as to what is comfortable to them, it is a matter of personal preference that should be in place within the design. This was expressed in the use of anthropometric data, the data serves as a starting point that requires the further application of intent and user profile.

The concern is that many of these adaptations have been implemented by outside intervention rather than existing already in place within a product with an aim of use by the older adult. This of particular concern when the goal of the product is to allow for the older adult to self-led their activity program independently. When products are designed to enable the least able among a user population, they are essentially

“successfully raising the competency level and extending their period of valued independence” (Pirkl J. J., 1994, p. 108). The value of personal independence has been echoed as a reason to pursue mobility promotion among older adults. If activity has the potential to extend this independence, then applying the design consideration of adaptability to the products featuring this intent should more favorably enable the extension of independence.

To accomplish this, design considerations should attempt to discover the needs of the least able and those with functional limitations, as well as how they can be better served through targeted actions that account for their limitations. Looking to provide for the least able should include the movements that are expected during system use such as the reach necessary to interact. The functionality of the joint mobility and body segments used in the movements are combined during reaching movements (Allread & Israelski, 2011, p. 111). Interactions that occur in the reach envelope, the area that users can expect to safely interact with functions and operations required of the device should be considered. Applying the knowledge that the least able require the greatest level of consideration here suggests that the reach envelope should consider the range and abilities of the 5<sup>th</sup>-percentile female in both the vertical and horizontal planes of movement to be afforded access to designed solutions (Allread & Israelski, 2011, p. 111). These interactions should include the controls and adjustments that are necessary to be located within this space.

The capability of functions should include understanding the limits that aging and disuse may have on areas such as strength capabilities.

Adaptability of designs in this way will require the inclusion of the capability of the older user at the extremes (Allread & Israelski, 2011, p. 125). The barriers suggest these should include physical and lifestyle barriers in addition to the training needs that provide beneficial intervention.

### 2.13.3 Legibility

Secondly, legibility as a consideration of accommodation in the design of a product intends to clarify the potential interactions and uses in a manner that is best understood by the end user through the proper use of perception, interpretation, and response. For the user to interact with a product, a set of goals needs to achieve a set of system goals through the human-machine interaction (Pirkl J. J., 1994, p. 105).

A feedback loop between the user and the machine, consisting of three steps, is completed to provide the interactive communication.

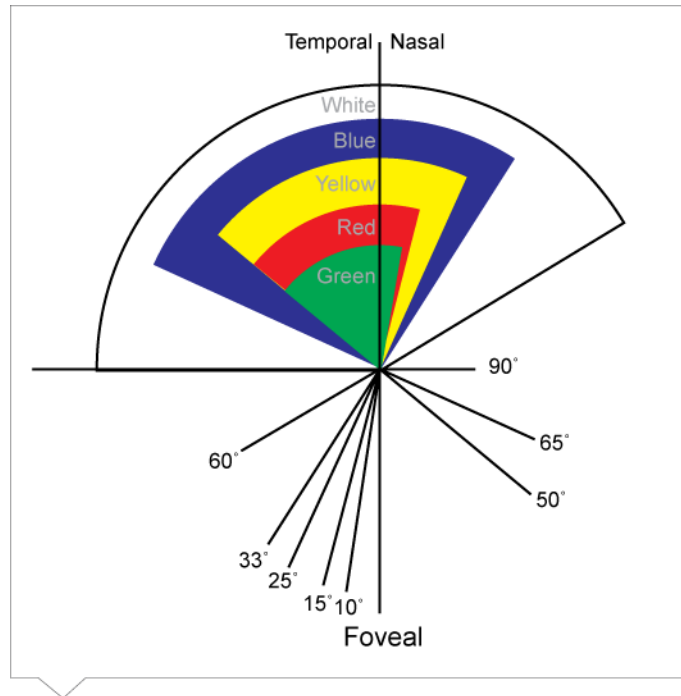


Figure 2.15 Color Vision Accuracy Field: Because of the wavelength of light, each color's accuracy is expressed in a viewing angle as interpreted by the eye. (Woodson, Tillman, & Tillman, 1992, p. 31)

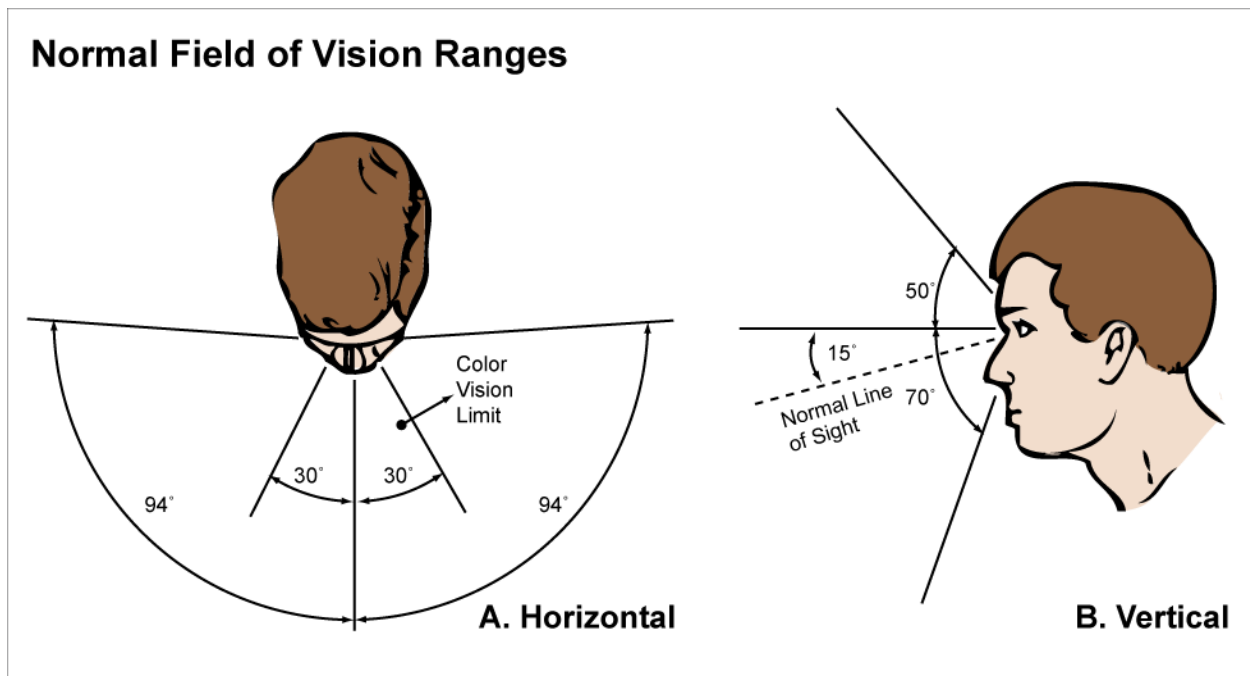


Figure 2.16 Normal Field of Vision: A. The vision field viewed from above allows for a total field of vision of 188 degrees, but only 60 degrees allows for accurate color vision. B. The vision field viewed from the side allows for 120 degrees of viewing. (Woodson, Tillman, & Tillman, 1992, p. 30)

Three factors have been identified as comprising the quality of legibility, perception, interpretation, and response (Pirkl J. J., 1994). These factors translate a shared relationship that should be noted; in the previously discussed sources that also influence balance and mobility in section 2.8 above, sensory (perception), central processing (interpretation), and motor functions (response) were described as subject to decline among the aging population. The declines also vary in extent and total deficits present, complicating the interactions. Because of this decline, the effort put forth to provide for these needs should be addressed to improve collective contributions to the older user's expectations from the product solutions regarding the legibility of the interactions. To assist the communication, the ability to incorporate redundancy in the cuing systems with one or more types of coding (Gardner-Bonneau, 2011, p. 757; Kroemer, 2006, p. 141).

In the design of sports equipment, “the designer’s perspective incorporates three design elements: biomechanics, anthropometrics, and aesthetics” (Kreighbaum & Smith, 1996).

By merging the needs of the various groups of interest, designers may be able to provide the legibility of the demands of these groups into improved solutions.

In the same way the quality of these physical function affect the quality of function in biomechanical movement and daily personal activities, the quality of the factors residing in products that aim to embrace user limitations through feature enhancement potentially improve the quality of the product during use.

#### **2.13.4 Compatibility**

Compatibility as a consideration of accommodation in the design of a product intends to respond to the widest range of individual needs and capabilities through addressing them through the product design and intended interactions process, rather than rely on secondary customization to provide this (Pirkl J. J., 1994, p. 108). As this relates to activities offered to older adults, activity instructors and care providers are asked to provide for the function of the least able by providing progressive compliance to the abilities of the older client. In both the activity promotion and design fields, the means of providing this goal is through providing safety, comfort, convenience, ease of use, and ergonomic fit (Pirkl J. J., 1994, p. 108). Within the older population, considerations as to the abilities present should be included in the compatibility.

In this way, the designs should not try to perform at the extreme edges of the capability of the individual; rather the physical demands of the least able of the intended population should be provided for with only moderate demands on these systems (Allread & Israelski, 2011, p. 123). By minimizing the forces and loads that are asked of the older adults, compatibility needs such as safety, comfort, and ease of use, can be provided for by seeking neutral or relaxed postures during use (Allread & Israelski, 2011, p. 133).

This allows for the accommodations to be included larger percentage ranges of the population of intended use if the functions are critical, to not attempt to disrupt the usability or functionality (Allread & Israelski, 2011, p. 100). Strength Users with

disabilities and functional limits may not differ in ability from those without one on every physical aspect (Allread & Israelski, 2011, p. 122).

The solutions can extend beyond physical use to provide some of these characteristics in the design of older mobility-focused products. Lifestyle needs can be afforded consideration in the application of how conveniently an older adult can travel to participate in an organized class setting compared to how easily they could perform these same activities within comfort of their own living setting.

### **2.13.5 Accessibility**

The final of the four accommodations suggested in transgenerational design relates to the accessibility of the offerings. Accessibility as a component of accommodation goes beyond the location of the interaction being available for the user. Accessibility, as a consideration of accommodation in the design of products for older adults, intends to ensure the designs of products and environments for users, allowing for the proper interaction of all senses and individual needs through appropriate interaction (Pirkl J. J., 1994, p. 107; Gardner-Bonneau, 2011, p. 761). The importance of accessibility in this view is the provision for all user senses. Within the current barriers presented in section 2.3, many of the individual needs required for interaction within activity appear to be lacking a marriage of these individual physical needs with the cognitive mental perception/senses of the older user.

As an example of the senses requiring accessibility attention according to the barriers to activity, limited cognitive function and self-confidence in abilities. The repercussions of injury that can cause a fear of falling appear to be missing in this view of interactions providing for all senses between the user and the activity environment currently available to the older adult. The slowing of the cognitive and decision making process combined with the physical capabilities lessening places more emphasis on the correct decisions being made by the individual, and provided by the system interactions (Gardner-Bonneau, 2011, p. 761). Connections can be made between the fear of falling and the slowing of the cognitive processes; as the confidence reduces, reductions to the motivation to carry out multiple movement operations by the older adult can be seen

(Gardner-Bonneau, 2011, p. 762). The methods and approaches to reduce this apprehension appear minimal as evidenced by the low activity retention rates, and high rates of device abandonment or rejection when used in the home environment by older adults (Gardner-Bonneau, 2011, p. 764).

It has been recommended that to improve the cognitive interactions with products, the information/task asked of the older adult should be reduced into smaller chunks, allowing for the necessary connections to be made between the task and the environment (Gardner-Bonneau, 2011, p. 759). Reducing mental stress when learning a new task or movement could benefit, as the older user has more time to produce an accurate outcome. The reduction of information presented at one time would further reduce this stress. It is recommended that tasks asked of older adults should be limited to four or fewer at a time to assist the short-term memory retention that has been discussed; this is further enhanced by making the tasks based off of event triggers in an act and respond fashion rather than to expect the older individual to respond after a period of time (Gardner-Bonneau, 2011, pp. 760-761). Enlisting the attention on the abilities that do not fully degrade, such as maintaining focus on a singular task or stimulus, the older adult is capable of performance without complications. Placing fewer demands in a more thoughtful pattern of expectation that place understanding to the limits of the capabilities of older users in this way could benefit accessibility to the promotion of mobility among the population.

Allowing for accessibility in this way permits us to easily acquire an object, service, or facility for use; users can move freely and normally throughout an environmental setting without penalty to the choice employed. This includes starting activity participation with limited functional ability in a modified seated position under limited apprehension for injury, and progressively increasing the challenge as skill development allows.

The application of the data is especially necessary for those functions or actions that are critical to the device operation to be identified, accommodating the two group's needs

The aim of identifying these areas of accommodation in design is to condition the empathy necessary to guide designs so that the end products have a higher opportunity

of satisfying user needs. Many of the generalizations can overlap and merge, which at the onset of the design process allows for the greatest range of information to be established, and connections and themes identified for further exploration. As the design process evolves to the refinement of the concept direction, there are further specific considerations that the designers can reference that call attention to conditions or variables that can be present among older adults as well as other age groups. The specific considerations relating to the design goal will require the identification of specific movement considerations that are necessary to fulfill to provide accurate training measures. Many of the specific guidance considerations were covered through understanding the anatomical, biomechanical, and aging process effects and conditions that can potentially exist.

#### **2.14 Building towards Intervention**

While the benefits of physical activity for older adults has been clearly demonstrated through the literature, so too has the inability of the benefits to fully be embraced by this population. The perceptions and beliefs have shown that the gap between application and adoption are disconnected with offerings. Because of the continual failure of the traditional approaches, there is growing sentiment that newer solutions should be sought.

While trusted health organizations seem to have the processes by which individuals can benefit from activity, they have missed with the programs to deliver these solutions by ignoring the views of the older adult. The activity components appear to have a link, with Chozko-Zajko suggesting in an interview that “most scientists would agree that a balanced program of physical activity would include stretching, calisthenics, strength training, and cardiovascular exercise” (ProfessionalPlanets.com, 2007). That has been a consistent theme of suggestion, yet participation is low. The activity components may provide the necessary movements, but the individuals are not performing the movements. The communication of these benefits has not been sufficient.

Implementation of strategies targeting older adults has been suggested to benefit from groups (1) providing a clear strategy to what aspect they wish to address, (2) develop



collaborations, and (3) exchange best practices (National Blueprint on Physical Activity Among Adults Age 50 and Older, 2000, p. 3).

The uniqueness in individual health that has been shown to be present among the older adult poses challenges in the adaptation of solutions. Among those in favor of new approaches is Tokarski (2004); he believes for instance that, “new types of sport activities for the elderly should be developed especially for beginners” (Tokarski, 2004). This is critical because the individuals that are in the greatest need for becoming active have minimal choices that are designed to accommodate their needs and skills. It has further been demonstrated throughout the literature that it is very likely that an older individual may have little experience with how to safely initiate a physical activity program. Burbank and Riebe (2002) echo this belief on user activity experience by stating that providers must “also acknowledge the dynamic nature of exercise and respect the fact that different older adults may be at different stages in the exercise process” (Burbank & Riebe, 2002, p. 49). This explains why Jones and Rose on the guidance of gerontologists suggest that the activity programs for this population should seek to accommodate these functional needs; application of these accommodations can be furthered by product designs that seek to include these accommodations in their designs.

Before the implementation of new approaches can occur, demand must first be accounted for. To achieve new approaches, Tokarski believes that it should be determined:

*...whether there is a demand for a new type of sport for this age group, combining useful and essential activity elements from different sports into a new form. Furthermore, the issue of merging external contents together with sports into an attractive and meaningful activity should also be investigated (Tokarski, 2004)*

This statement suggests that new development should identify existing elements and offerings to see if there are potential connections that can be made to assist the accommodations in a useful way for the older adult, such as functional relevance. The limited participation suggests the demand is present. From a structural standpoint the inclusion of (1) personalization, (2) exercise intensity preference, and (3) purposeful activity have all been suggested as having potential of departing from traditional

approaches that have continued to lead to limited activity results (Seefeldt, et al., 2002, p. 146)

A great place to start for cutting edge activity research applications to borrow new sport insights could be groups known as early adopters and lead users. In physical activity, these early adopters, activities, and equipment can potentially be found in the world of elite and professional athletes where advances are necessary

to optimize performance. This could also satisfy the technology consideration of identifying a product opportunity gap suggested by Cagan and Vogel in section 2.4. The use of technology outside the laboratory

setting and into the free-living situations has been suggested as a path to explore in future studies as a manner of providing compensating devices for failing structural and functional systems in older adults (Seefeldt, et al., 2002, p. 160). The technology does not specifically have to be cutting edge electronics, the technology should simply be viewed as a means of achieving tasks more easily through accommodations provided in the technology implemented.

Perhaps in addition to looking at other areas for activity inspiration, researchers should examine the lifestyle, games, pop culture, and characteristics of older adults for inspiration to ease the transition of physical activity more seamlessly into their daily lives. This approach was suggested in section 2.4 in the discussion about the SET Factors for product opportunity. There, investigating the social aspects of the intended group was seen as a means of uncovering unmet user demand. Uncovering these

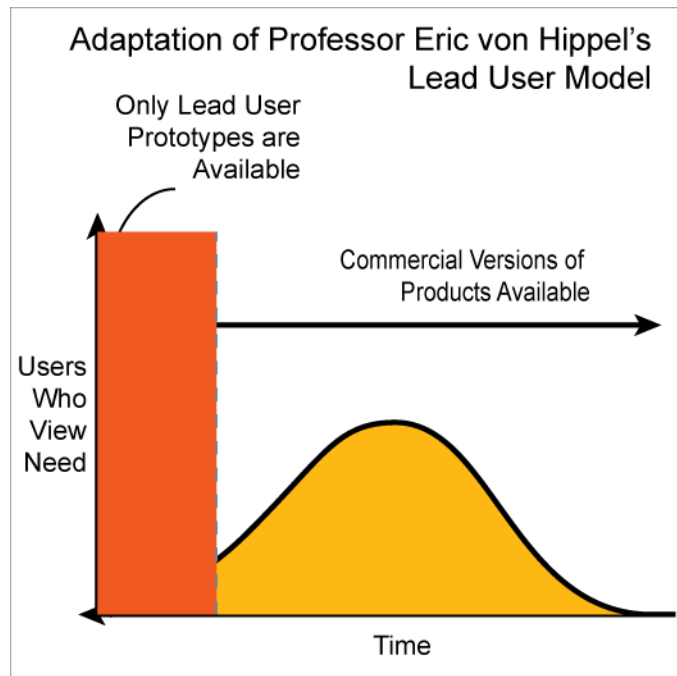


Figure 2.17 Lead User Model: The Lead User is comprised of individuals who feel unmet need is in place in a particular field. Through passion & iteration, these groups accelerate innovation in their area of interest, long before commercial markets exist. (Information About Lead User Research: leaduser.com, 2015)

lifestyle connections can potentially be applied to the activity selection process; it has been stated that:

*“Simple game, exercises, and rhythmic activities should be selected for those whose physical condition and previous experience is lacking. Gradual complexity can be added as improvements are shown in reaction/movement times and coping with more complex demands” (Mature Stuff: Physical Activity for the Older Adult, 1989, p. 126).*

The additional accommodations an approach like this could suggest could relate to both sections 2.11 and 2.13, where providing for all senses and interactions should be followed, especially in older adult activity. Apprehension can lower if familiarity and trust can be developed between the user experience and the product.

Lifestyle of the older adult supports the creation of these newer approaches to have a focus of access that can be easily translated into practice, especially for those at home (Carter, et al., 2001, pp. 434-435). The desire to remain independent includes the environment that older adults want to be in and that is generally at home, in their community. Aging in place in their home was reported by AARP as the location older adults preferred in a recent survey by over 90% of the respondents (AARP, 2012). To provide for this, AARP suggests that accommodations be provided in the home to allow individuals to do that (2012). This includes “The NIA recommends that, in general, older adults gradually progress to at least 30 minutes of moderate to vigorous endurance exercise on most or preferably all days of the week. The 30 minute goal can be accomplished by accumulating time in shorter sessions of at least 10 minutes each” (Jones & Rose, 2005, pp. 197-198).

Regardless of the source of the inspiration of new approaches, the literature has also been clear on the concept of self-efficacy as it relates to older adult activity participation. Means of increasing confidence and reducing apprehension and anxiety have been favorable in the development of self-efficacy (Jones & Rose, 2005, p. 116) . Additionally, activity preference has leaned toward less challenging, less competitive activity pursuits. Armed with this knowledge, developing a new approach that has the potential for both adoption and retention should not deviate from this approach. While the arguments surrounding the lack of effectiveness of low intensity activity exists, there are those who suggest that getting older adults to accumulate activity at higher levels trumps both the

type and intensity because of the gains created by participation (Seefeldt, et al., 2002, p. 146; Mazzeo & Tanaka, 2001, p. 813). Ongoing participation has been clearly linked to higher activity self-efficacy, which can be the gateway to individuals taking on more challenging physical activity pursuits (Burbank & Riebe, 2002). Finally, any activity participation is better than leading a sedentary lifestyle from an overall health standpoint.

The literature has also been clear on the need for low cost, widespread access in order to serve the greatest number of individuals the most cost-effectively. The quality of the program will be deemed ineffective if it cannot be implemented nor adopted. If new programs are to shift from current approaches and embrace the overwhelming growth data, then self-led programs must become an option. Although no one would argue that the most optimal solutions would include the presence of one-on-one supervision, from a cost standpoint it is just not going to be feasible with current technology and health care policies (Burbank & Riebe, 2002). Without insurance-backed financial support, the majority of fixed-income older adults and communities will not be able to afford to bear the cost of such programs.

## **2.15 Summary of the Reviewed Literature**

The exploration of the older adult in the research yielded the identification of the age of those that are sought to be understood as those age 50 and older chronologically. The lowering of the chronological number from 65 years to 50 years of age was to accomplish two goals: (1) greater inclusion and introduction of the potential benefits of physical activity, allowing for a greater time horizon to be established, and (2) greater inclusion of those individuals who may have the presence of a limiting health factor that may be benefited by the inclusion of regular participation.

The literature exemplified the continuing decline in the participation and retention of older adults in activity through the exploration of the barriers. The barriers included personal, social, and environmental conditions that require investigation in the field. The collection of the barriers identified the potential opportunity for new product development based on the SET Factors presented. The barriers identified along with the

later investigation of activity needs among older adults suggest that a potential product category is being underserved or unmet.

The investigation of the aging process yielded that multiple physical and sensory systems degrade at varying rates among individuals. This variability requires designs to allow for users of different functional levels the opportunity to access activity training as equally as possible. Because of declines in ability and functionality, and their subsequent potential negative impacts, the ability to address the declines that effect the lower body region should be investigated. The focus should pay close attention to the attributes and needs of dynamic activities that have the greatest potential for positive impact for time invested by older adults on mobility.

The needs of the programs to influence mobility promotion and activity among older adults must not only account for a training effect, but they should also consider the previously mentioned variability that exists in the older adult through the application of accommodations that can help individuals reach a training effect. In addition to reaching a training effect, the accommodations should seek to promote habitual use, which should also be included in the goal of activity promotion.

To help these interactions take place within the designs of solutions, the accommodations for the aging process should be sought. These should include the diminished role of the sensory and physical functions of the older adult user by seeking to apply both user-centered learning in the field, as well as ergonomic design considerations that exist currently.

The packaging of these learning processes should seek to investigate the potential for new approaches that can assist the older adult in achieving activity participation. The approaches should apply an understanding that apprehension exists within the older population through a combination of functional limitations and their mental view of how this effects them internally and externally. Therefore, the ability to allocate for the development of self-efficacy in activities performed through the progressive development and achievement of activities provided should remain an objective of newer approaches.

The understanding of the physical and mechanical necessities to produce movement provided the sources of many of the necessary aspects of the mobility process. The growing limitations that are experienced by areas located in the lower body highlight the need to provide exploration into providing the stimulus necessary for that individual system.

## **Chapter 3 Considerations of Mobility Product Design**

The favorable connections between physical activity participation among older adults, combined with their low participation rates, warrants further exploration. The product research seeks to answer these areas.

To gain understanding of the user, the initial opportunity observations sought to compare the findings from the literature with current real world practice within the regional constraints of the research regarding older adult participation. The insights gained occurred through observations, interviews, and competitive product analysis to develop potential directions to explore. The initial offerings were validated through a review process to create the final directional focus for the conceptual development.

To further the gaining of knowledge, the findings from the validation process were translated into a procedure of further refinement in the influential product design features section. The refinement cycle procedures focused on the addressing the concerns raised during the previous phase. The concerns raised explored gaining further understanding of user needs during activity participation, possible mechanics, and beneficial movements as applied to the concept design. The method for review of these factors included feedback from field experts to provide validation of the presented concepts as well as recommendations to further refine the direction.

### **3.1 Identify Design Opportunities**

The literature identified the existence of barriers to physical activity among older adults; the literature also identified the presence of these barriers as opportunities left unsatisfied by current offerings. The opportunities left unsatisfied will be examined to gain understanding for the reasons this occurs within the local community, so that these characteristics can be examined and observed.

The areas that require attention include developing a knowledge base of what is being implemented in the community for older adult activity. This will require making assumptions as to where to look to find these programs, such as gyms, community centers, and self-discovery methods that may be available to the older adult. To review these findings, a method of qualitative evaluation will occur. In this way, the value of each area can be evaluated as to its assumptive quality; moreover, this can allow for comparison of the different approaches to develop a wish list of desirable features, as well as considerations that should be avoided. Because of the change in the expectations of the modern consumer, the approach utilized by designers must to evolve to produce products that meet expectations.

### **3.1.1 The Role of Style and Technology**

There is a qualitative approach that seeks to identify why some products enjoy success, while others do not. The qualitative aspects are measured in chart form along two axes that represent the qualities found to be influential. The two factors identified to track are style and technology. Before going forward, the words “style” and “technology” are described to have specific definitions within this qualitative analysis of products and this distinction will be elaborated on below.

Style refers to the “sensory elements that communicate the desired aesthetic and human factors of a product or service; the style must respond to the customer’s expectations while producing an identity within the product” (Cagan & Vogel, 2002, p. 33). In this way, style is not just representative of the “sexiness” of the way the product looks, but it also encompasses the expectations the user. Rather than style being an expression of the look of the product, the style can be more related to way it functions through operation. In this way, the style can be driven by simplified use, improved communication, and operational function, a critical need in the development of older adult products.

Cagan and Vogel next cover the metrics of technology. Technology refers to the “core function that drives the product, the interaction of components that are required to use the product, and the methods and materials used to produce the product” (Cagan & Vogel, 2002, p. 33). Again, the technology expressed in this qualitative way does not



limit the characteristics of the product components to flashy electronics and high tech sensors, though they could be incorporated into a needs of a particular product group. Here, the role of technology can be simply the function of the product. In activity promotion for older adults, this can include the technology that is involved from academia suggesting that certain movements used during activity participation can be more beneficial and efficient in their outcomes than others. Explained further, a product could exhibit “high technology” levels and be manufactured out of foam because it provides a better core function than competitive examples that use expensive, high-cost electronic components to try to serve the same core function to the user.

Because of the chart representing qualitative research, it should be understood that the role here is to gather non-numeric data to help explain and develop a theory about a relationship(s). This allows for the formulation of what is or has happened in the past, in this case competitive activities for older adult activities, in an effort to gather information.

**3.1.1.1 The role of style and technology in older adult products.** The products offered to older adults should seek the same level of delivery if they are to experience successful adoption. The poor levels of retention and adoption seem to suggest that there is a possibility that these desired needs are not fully achieved.

The style offered through the products should create both lifestyle fit, as well as the ergonomic fit to the individual user. While both factors are important to consider among all users, the literature suggesting the changes to both of these metrics among older users may be more pronounced as societal roles change, as well as the capabilities of the individual’s body. These style choices may also be the impact the use has on the living situation, and the ability the user is provided to easily access these offerings. In this way, a solution may appear stylish aesthetically, but fail to provide the user fit to their lifestyle and physical status.

The technological considerations may offer the ability to ease the demands raised by the changes to lifestyle and ergonomics. The ability to mold a technology to adapt to the changes is important, but the change should not be too radical as to intimidate or

impact the individual's self-confidence to attempt to use the product.

Application of best practices may for example be the role technology plays in the features desired by older adults.

### 3.1.2 Visualization of Style and Technology

Products, services, and programs can be visually plotted qualitatively to subjectively plot their features on a two axis map. Where the products and

services land on the map provides a visual tool that can identify how to improve lacking functions and features, and produce greater product value for users.

The Figure 3.2 to the right illustrates the tracking of qualities of style and technology as the axis. The location where the products fall illustrates the qualities they possess. At the conclusion of the observations made through the initial information gathering, assumptions and plotting of the offerings onto the chart can illuminate the current offerings, and allow for the identification of ways to differentiate and improve the products offered to promote activity to older adults.

### 3.2 Initial Opportunity Observations

The establishment of directions to explore was satisfied through two methods, 1. Contextual interviews and observations, and 2. Self-discovery of activity promotion. The first method involved interacting with older adults and stakeholders identified as professionals in fitness and health promotion areas within the community. The second

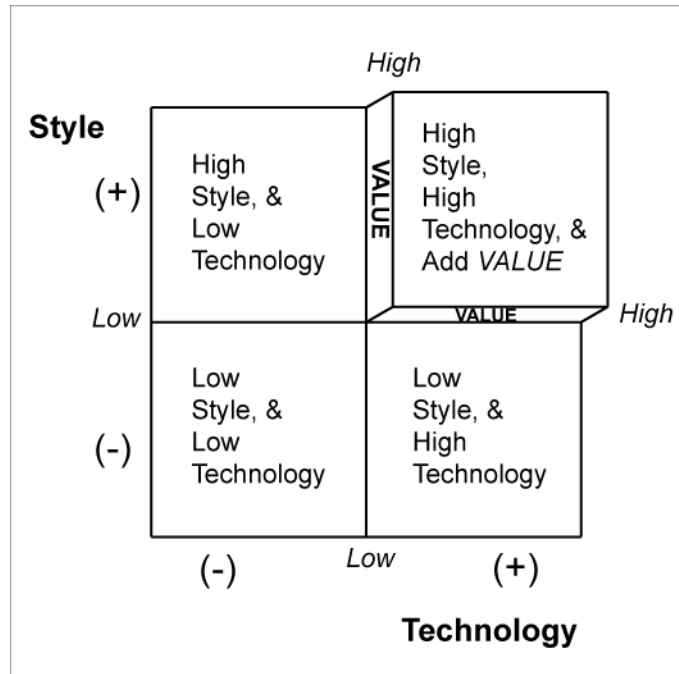


Figure 3.1 Value Chart. The qualitative plotting of the "Style" and "Technology" present in a product represents the amount of or potential for creating "Customer Value". Products developed should seek to move towards the Upper Right to provide the Customer Value. (Cagan & Vogel, 2002)

method relied on the process of self-discovery an older individual could use to identify potential areas of activity promotion that could be implemented by someone wishing to start activity, especially those solutions at home. This was to done to develop a satisfactory level of knowledge about the activity approaches that were currently implemented locally, as well as suggested for home use.

According to Cagan and Vogel, the primary research in the front end of the development of a product requires gathering of qualitative research through informal conversations and observations (Cagan & Vogel, 2002, p. 117). The observations and conversations allow for the gaining of understanding of the social and physical environment surroundings that services examined occur in (Stickdorn & Schneider, 2011, p. 163). Stickdorn and Schneider suggest that the presence of learning in the physical environment of potential use confirms what is being stated by those individuals aligns with what those people actually do in that space (Stickdorn & Schneider, 2011, p. 163). This qualitative research was conducted because of the literature stating that current practices varied from current research.

While conducting the observations and interviews, several themes emerged that relate to the offerings for older adults, and the barriers that the research identified as both gaps and opportunities for these products. Those SET Factors explained earlier illustrated the ability to identify potential opportunities to explore as solution directions for value-adding products and services. Cagan and Vogel describe these themes that emerged as the “Value Opportunity Gap” (VOG) (Cagan & Vogel, 2002); this gap represents the disparity/ability for a product or service to strike an optimum balance between “Style” and “Technology” (Cagan & Vogel, 2002).

The procedures examined the three locations for activity solutions that have been presented, the gymnasium, the community or assisted living center, and the homemade solutions for activity participation. The observations and examples will be documented as well as applied to the qualitative value chart to demonstrate their features, advantages, and disadvantages.

### **3.2.1 Gymnasium Visits**

The initial design research procedure lead to first seeking out current trends in health and fitness through practicing professionals. This was done because of the favorable links to the activity behavior and mobility among older adults, and their potential knowledge they could provide about the subject. After visiting several gyms, it was apparent that the majority of the gyms in the region had younger clientele, with limited to no older clients. There was a gym facility that did have older adult clients, and a member of their training staff who works with older clients offered insights.

Product literature was provided as visual reference to the equipment and movement approaches that were directly available in the facility, as well as optional equipment solutions. The literature also provided terminology to be aware of when seeking out further information on competitive products utilized in the gym industry. The products that were sought out to explore initially were those that would be accessible to a gym, medical, or rehabilitation practitioner in a similar environmental setting.



*Figure 3.2 Gym Visits Observation Examples: The collection of images above represent the observations that included high quality equipment & instruction that comes at a financial cost. The individuals were also seen to be more fit functionally.*

**3.2.1.1 Offerings within the gymnasiums.** A tour of the facility was provided to demonstrate the options that were available to members. Areas were divided into the activity focus. Options included strength (free weights, machines), cardiovascular equipment (elliptical, treadmills, stair-climbing), aquatics, and group training classrooms. Offerings that were available within the gyms were represented in the literature that was provided by the staff.

Utilizing the provided product literature and the observations made onsite through the tour allowed for the initial analysis of the competitive products to occur. The products were reviewed both visually and verbally to determine the qualities that were present. This allowed for the initial placement of these products onto a qualitative map to compare with future visits to other environmental setting offerings.



Figure 3.3 Low Style, High Technology Examples: The provided literature contained devices that are available on the market to provide activities that were seen to reduce falls. These products are seen as targeting users that have capabilities beyond the older user.

Many of the offerings that were identified in the gym setting were found to be expensive, requiring a sufficient level of physical skill to perform. These characteristics were identified by the Value Chart presented earlier in the section as those found within the “High-Technology, Low-Style” region of the qualitative chart. Cagan and Vogel specifically identify products in this category as “requiring a skilled user that is willing to overlook ease of use for performance” (Cagan & Vogel, 2002, p. 44). These represent activity solutions such as those products used by “lead users and early adopters” (Cagan & Vogel, 2002, p. 44). These are not the physical characteristics that appear to be present in the typical older adult, especially those with limited functions.

This could also be a result of the type of outcome that is sought by an athletic function and one that involves daily tasks. Some of the athletic function features place a focus on

short-term outcomes, performing your best in a race or other forms of competition. In this way athletic-style training differs in both purpose and participant abilities from the goals of everyday tasks, especially among older adults with limitations; daily tasks place a need for submaximal efforts carried out throughout the day (Kroemer, 2006, p. 52). However, the physical gains that these products claim to offer through use suggest that there are features and movements that should be identified as beneficial to determine how they can be provided to an individual who has increased functional limitations. Those movements and activities found in the existing athletic-style approaches that can mimic the athletic functions at a level that accepts lower functional ability would be desirable.

### **3.2.2 Community Center Visits**

The second group of professionals sought were the health and fitness practitioners at local community centers and their residents. The community centers included assisted care housing and civic social centers. The centers were sought to understand the approaches and equipment that were utilized with the older adults they interact with daily in an environment more similar to a living environment. These visits allowed for observations and interactions with potential users as well as the staff that interacted with the older individuals on a daily basis.





*Figure 3.4 Community Center Observation Examples: The images above represent the activities occurring in the community center visits. The individuals were seen to participate in lower intensity activities, choosing leisure activities such as games & TV for example.*

Initial observations at these centers showed that the intensity level of activities at these locations was considerably lower than at the gym facilities. They appeared to have higher access and participation in seated activities that utilized their upper body at a higher rate.

While activity levels that are associated with physical fitness were presented at lower levels in these locations, there were many leisure activities that were participated in at higher levels. Many of these activities would be classified as leisure games or entertainment. These leisure activities included playing cards, dominoes, board games, and bingo as example types. These activities took place at tables, such as those for dining, with groups of up to six individuals. This observation was noted as significant because of the potential impact solutions could have if they were able to blend into the lifestyle activities of the older adult. Also, the observation that games were involved in the daily activities lead to seeking the potential of the impact of game-style activities could also play on the transition to activity adoption.



To provide activity to a wider range of individuals, some of the activities offered were modified versions of more familiar activities such as volleyball, baseball, etc. This information confirmed that in the field, facilities were attempting to adapt to the individual needs of those who were limited in their functions. Although accommodations were provided, many of the activities performed failed to focus on the mobility and lower body limiting factors that were highlighted in the literature review.

**3.2.2.1 Offerings within community centers and assisted living facilities.** As the skill level changed, so too did the focus of the activities. A sample of the solutions is shown in Figure 3.5. Rather than the athletic-style outcomes sought, many of these activities appeared to be in place to keep these individuals moving and participating in activity to maintain general health fitness as their purpose.



Figure 3.5 Low Style, Low Technology Examples: These examples provide greater access to the older user capabilities. However, the activities compromise many of the beneficial movements that are necessary for falls reduction & mobility promotion.

*“Products in this quadrant are driven by style. Some companies that live in this quadrant explore the boundary of aesthetic experimentation (lifestyle impact) and usually fail in the application of human factors (ergonomics) and core technology (features)” (Cagan & Vogel, 2002, p. 45).*

When this statement is applied as qualitative measure of what is seen in the program approaches in the living environment, the utilization of the experimentation of modified activity can be seen clearly. While not driven by aesthetic style, these activities are driving by the lifestyle impact of older individual through provisions to their abilities and resources surrounding them. These ‘low-tech’ solutions aim for convincing the individuals through low apprehension activity that appears to have limitations to the gains that are produced, especially those that could assist ADL or mobility.

As it was mentioned, many of the residents participated at higher rates in more leisure activities than those activities that were modified for activity. Looking qualitatively at these approaches as a level of style, a link to the possibility for the higher rates of other activities has been offered by Cagan and Vogel (2002):

*“This cosmetic approach usually fails for the opposite reasons that a high tech product fails. Consumers quickly realize that these products are a compromise and that they rarely perform as anticipated. These companies are often looking for niche markets willing to sacrifice usability for expression alone” (p. 45).*

This suggests that the low participation may be a result of those individuals who wish to abstain from the activities may have some notion or belief that the activity is not of worth to them; the offerings are a compromise of their time and perhaps the perception they feel accompanies participation. It has been stated that a barrier in the lifestyle area of the aging is both their confidence in their abilities in addition to their internalized fears of participation as it relates to perceived functional capacity. Some of these observations were not products but rather programs to make assumptions about; however, it has been suggested that developing a new design in an underserved market requires understanding those processes that are in place in order to make more informed decisions (Erwin, 2014).

### **3.2.3 Homemade Solutions**

The final area that was investigated included the products and services that were made available at home. In addition to simple interventions such as walking, many suggested solutions possess a homemade or repurposed characteristic.

Walking was clearly the most recommended and promoted activity in the area of self-discovery activity promotion. The basic equipment needs and low barrier to entry make walking a highly promoted activity. With limited financial investment, an older adult can undertake a basic walking regimen. With an additional recommended investment, walking can be combined with a tracking feature through the use of a pedometer.

The use of a pedometer allows users the ability to generalize their participation with general accuracy by inputting the height of the user. With this information, a factoring formula can be applied at a rate of 0.4 times the height of the individual to provide an estimation to the step length of the individual. The addition of a tracking function such as a pedometer is desirable because of the ability to track distance performed, rather than simply relying on a time measurement. The benefit of tracking the steps in conjunction with time rather than only measuring time exclusively is based on the intensity effort can be analyzed also. A person could walk for 30 minutes and only travel a short distance, but the same 30 minute walk could be performed with greater effort allowing the person to travel farther.

Because of the tracking function, walking combined with a pedometer allows a simple tracking element that can inform older adults and medical personnel beneficial information for activity participation for general health promotion. Although ease of prescription through step-count goal setting is possible and the financial impact is relatively low, walking alone is not viewed as optimally beneficial and should be supplemented with additional physical elements to create greater opportunity for functional improvement (Rose D. J., 2015, p. 24).

Along with walking, suggestions for additional activities and exercises were found to be promoted to older adults. The goal of the solutions that fall into this category focused on

availability and inexpensive items that could be utilized to perform activities that can promote physical activity. These products looked to overcome barriers that are frequently cited, access through physical availability and through financial feasibility. Many solutions are presented as substitutes for more specialized items; the substitutes are favored in situations where individual's excuses for not having equipment access limits their participation.

As they have been described, the homemade solutions represent the offering of the value proposition of cheap, inexpensive, and available at a low cost. Cagan and Vogel refer to offerings such as this specifically as “functionalism at a low cost”, with the use of “established technologies and minimal styling” (Cagan & Vogel, 2002). These solutions certainly are promoted in this manner for use to increase access, which they are capable of; however, the lack of focus to the full range of perceptions that individuals carry about items such as these limits their continuing adoption and full optimization of human factors.

**3.2.3.1 Offerings within the homemade, repurposed, and in-home approaches.** Repurposed items are suggested for use in some movements. Items that are suggested to be repurposed include but are not limited to canned goods, plastic milk jugs, pillows, and broom sticks. These solutions were diverse and are demonstrated in Figure.

Many of the product offerings observed fell into the Lower Left, with Low Style and Low Technology. Characteristics of these types of products include generic, unrefined, and cheap which, along with availability and user access, represents their suggested use as supplemental aids

From a safety standpoint, many of the offerings suggested fail to account for the potential for complications from using an object in an unintended manner. For example, the use of canned goods as a form of supplemental resistance is promoted when individuals do not have specialized resistance equipment such as a traditional free-weight, resistance band, or free standing machines. These forms of resistance

equipment were intentionally designed to be physically interacted with for this purpose of use with considerations such as size and shape offered.

Canned goods were designed for interactions with hands, but not in this manner.

Canned goods come in various shapes, sizes, and weights with labels that are most often paper based. The larger cans do not offer adequate hand purchase for many to properly handle for long periods. Smaller diameters found on handles and hand tools provide these features more accurately than cans. Also, the introduction of stresses such as sweat can have a negative effect on the adhesives that secure the labels, making it possible for the labels to slip off during this type of activity use. Similar observations can be seen in other items like this such as the milk jugs with similar risks when exposed to unintended, use beyond their designed purpose.

#### **3.2.4 Initial Opportunity Findings**

The groups of products and programs available in the three forms explored highlighted the diversity of the solutions available to older adults seeking physical activity. The individual groups exhibited characteristics of the focus or direction of the offering. For example, the products, programs, and amenities featured at a health club style venue were characterized by newer technology or recent activity education. Features within programs and devices available portrayed higher technology features that were more specialized or exhibited characteristics of specialization. Additionally participants appeared to be more able to participate and interact with these types of products given proper supervision. These features also came at a financial cost and a transportation cost to those seeking to participate. These were observed to be undesirable barriers to solutions seeking to include the widest range of individuals.

Conversely, observations with the community centers had a focus in a very different directional approach. These activities and approaches were lower in impact, intensity, and specialization. General features of health and participation could be seen in the focus, rather than a specialized approach. These approaches might have been limited in developing features needed in the lower body but they did show methods for providing

accommodation for a wide range of functional abilities. By applying this, the director of the center was able to engage individuals in a form of participation.

The community center also revealed an additional insight to the types of activities that were offered. Because these activities were performed with the upper body, it was noted that the low participation levels may be a result of focus being placed by the medical community on lower body activities when the older adult might have greater interest in upper body considerations. It was thought that placing a variable into the design validation process that included an upper body activity could provide the clarification of the assumption that older adults may prefer a focused activity that works on upper body limitations.

While the use of the accommodation was applied to upper body activities, the question was raised why this type of adaptation could not be applied to lower body considerations. Also questioned in the lower body was the possibility of this lower body activity allowing for a passive role of user engagement. As the observations showed individuals playing cards and other games while socializing, it was thought that a more seamless transition could be achieved through this style of passive activity.

### **3.3 Influential Product Design Factors**

The initial observations provided guidance to present potential directions as areas to focus attention on. The potential directions were formulated into a procedure of exploratory and rough, three-dimensional forms referred to by some as a “sketch model” to then be validated by users and stakeholders. Because of the literature suggesting that the participation and retention rates were both low, conformation as to the area focus was examined and tested within a method which included both the potential users and the stakeholders. The insights, suggestions, and objections were noted and utilized as guides to the further refinement of the improvement of devices for older adult mobility interactions.

Following the procedure of involving those with influence to determine the direction, the lower body was chosen to pursue for the remainder of the research. The refinement of the insights was grouped into three procedures of exploratory areas of focus: the

enhancement of activity participation, the exploration of potential mechanisms, and the potential beneficial movements. These were driven through stakeholder review as to refine the activities to avoid causing potential user harm.

### **3.3.1 Sketch Model Directional Development**

These sketch models seek to generate both the qualitative and quantitative research insights from the potential users and stakeholders regarding the potential direction(s) (Cagan & Vogel, 2002; Kelley, 2001; Erwin, 2014). These methods are favored by many design firms and practitioners because of the low cost to produce, and the high value of insight that can be gained. There are several reasons that these model types are thought to produce these insights, including approachability and the tangible nature, allowing more concrete feedback from those that you seek input from.

Materials utilized to create sketch models can “prototype just about anything”, and they can be created from “anything that may be laying” around, according to Tom Kelley, one of the founders of the design firm IDEO (Kelley, 2001, p. 103; Kelley, 2005, p. 47). Heather Riley further suggests that because those who are responding and participating in the learning process to a potential new solution can tell that the product is clearly not existent, that the reservations individuals have to assisting are lowered; ultimately this leads to the participant being forced to creatively think about how his or her idea would work or how to make it work if it had to be implemented (Erwin, 2014, p. 43).

Another of the mentioned benefits to this approach of development relates to the tangible nature of a three-dimensional object. Erwin refers to these sketch models as “build to think” prototypes; the prototype(s) are “low resolution and low fidelity, just enough experience to imagine the concept, without distracting detail and quality craftsmanship that signal a more developed idea” (Erwin, 2014, p. 42). Sometimes abstract concepts or information that is not readily available to a target group, for instance, can be clarified through the ability to manipulate the object and place the abstract into the tangible (Erwin, 2014, p. 43). Turning abstract design concepts aimed at older adults as well as seeking input from the medical community on suggested movements was thought especially benefit from using this form of concept translation.

The ability for people other than the designers to interact with the product through simulated use is an additional benefit. The design process requires the designer to make assumptions of how an object will be interacted with (Boess & Kanis, 2008). The ability to have the actual use or feedback on how the object is interpreted by others can help shape a more beneficial result. This situational simulation is viewed as a process of “gaining a clear understanding of the situation from the perspective of current and potential customers of a certain service is crucial for successful service design” (Stickdorn & Schneider, 2011). These characteristics found in the sketch models appeared to be desirable because of the population being explored. Being able to demonstrate a simple motion or activity could easily be explained to the older adults as well as the influential stakeholders. The state of the models also would allow for insights as to how to rework features or remove items without the worry of damage to the concept at this stage of the knowledge gaining process.



### 3.3.1.1 Upper v. Lower Body

**Focus.** While the literature suggested that the participation in physical activity could potentially produce benefit for the older adult, it was also clear that there was a tremendous problem producing desirable activity adoption rates among the older adults. The overall physical activity adoption and retention issues with older adults provide the reasoning to examine different approaches through

conceptual development. The goal of conceptual development is to not rearticulate products as they were previously described, but to outline characteristics that can be considered

as needing to evolve or adjust during a possible design development of the concept in the future (Stickdorn & Schneider, 2011, p. 61). To identify the best conceptual design direction, an assumptive design procedure to utilize two separate body regions of focus were to be presented: an upper body focus and a lower body focus.

General considerations of the designs focused on the accommodation of multiple functions for the sake of storage footprints as well as movement patterns that were utilized in competitive products. Because of the difficulties expressed in the barriers concerning access, the designs assumed that in-home use should be provided to limit time spent traveling, while still attempting to provide multiple functions. Therefore, the storage of the concepts was considered as to what their non-use footprint would require in an effort to reduce lifestyle impacts that could clutter the living space. Additional considerations were given as to the potential for indoor activity that fit into community center social activity lifestyle patterns. This incorporated the presence of items such as



*Figure 3.6 Activity Directional Focus: The low rates of participation allowed the assumption that any activity would be beneficial. The passive nature of those individuals in living situations lead to the focus of passive/tablesides activities.*

dining or conversation tables, serving as gathering locations that could be potentially encountered in daily lifestyle.

**3.3.1.1.1 *Upper body considerations for the sketch model.*** Although the literature presented the loss of lower body strength as problem, so to was the general loss of strength and dexterity of the upper body limbs. Because of the frequency of daily interactions, the upper body concept designs focused on the movements and strengthening of the arms, with the shoulders, elbows, wrist, and hands. The potential for the loss of the grip strength and general dexterity of this region was seen to be potentially impactful for the daily activities of the older adult.

Additional reasoning for the clarification of an area of focus related to the overall adoption rate among older adults to physical activity being low. There was not any clear examination of the preference to an upper body or lower body focus. The onsite observations within the community center style settings established that participation in many seated activities

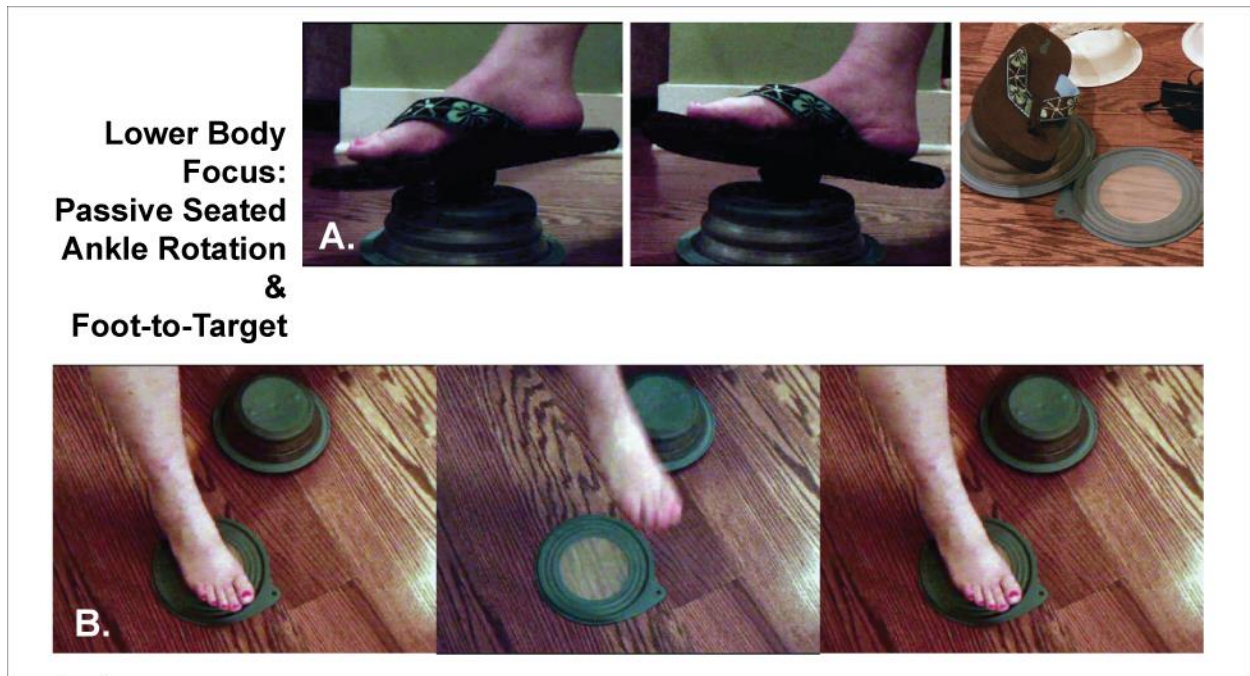
### **Upper Body Focus: Tabletop Reaction Time & Light Cardiovascular Activity**



*Figure 3.7 Initial Upper Body Activity Focus: The initial visits to the community & living centers suggested that the leisure activities such as board games & cards could be enhanced by a tabletop game. The focus of the activity was reaction time & cardio.*

was occurring among the older adults. These activities were utilizing the upper extremities for the participation. Because new approaches were sought and understanding was sought by the designer, the creation of two areas of activity focus were presented in rough sketch model forms to both potential users and field experts. One focused on the upper body with the other focusing on the lower body, designed with guidance from the previously examined competition.

3.3.1.1.2 ***Lower body considerations for the sketch model.*** The lower body focus looked at adopting the same learning from the existing analysis applied to the lower body region. Assumptions were made regarding the focus of movements thought to assist in walking and mobility, revolving around the foot and ankle region. The actions that balance or wobble boards provided led to many of the guiding principles that were pursued, with additional leg activities being included into the device as to again promote activity diversity with a minimal storage footprint. The guidance of the use for the device concept revolved around making the use unobtrusive to a seated activity, where the user could passively operate the device while watching television or playing cards for instance.



*Figure 3.8 Initial Lower Body Group: The Lower Body Focus had 2 activities, A. Ankle Rotation to promote Strength & Flexibility, & B. Foot-to-Target to promote lower body Movement & Proprioception.*

### **3.3.2 Field Test of Stakeholders**

A component of the method for learning and insight in the procedure was a questionnaire. The questionnaire sought to learn not only from the sketch models, but insights from potential users. Areas that were sought to learn in addition to the concept directions from the potential users included their perceptions of the activity they participate in, body regions that are sources of pain, and how they rate the activity level when they participate. These additional factors are sought to add clarity to the needs of the potential user.

**3.3.2.1 Field experts.** The practicing medical community included site specific specialists, general orthopedists, and rehabilitation specialists. These individuals provided a cross-section of knowledge, from the initial diagnosis process, to surgical intervention, and aiding in the recovery and reestablishment of function, allowing for learning from multiple touch points in the medical field. Because of the range, it was

assumed that they would provide a broad scope of knowledge regarding the capabilities of older users.

The sketch models were brought to their offices to be examined. Functions, intentions, and the goals of the project were shared with them to provide context to the nature of the proposals, and the scope of the intent of the project. Clarification was provided if functions or aspects were not fully understood. An example of this would include the target system function not fully understood by the individual could be explained as being similar to another activity they may be more familiar with such as “a Simon-like target system to aim the limb at.”

It should also be noted that, in some cases, the level of input that could be gained from the field experts was limited to their area of expertise. For example, a podiatrist practicing within the limits of their State Medical License could only practice medicine and surgical interventions to areas falling within their level of certification; in this case, a podiatrist may only practice from the ankle down on a patient.

**3.3.2.2 Potential users.** The sketch models were brought to local community centers that serve older adults. With the consent of the individual, the potential users were presented with a demonstration of the intended lower and upper body concepts. The intent, scope, and purpose of the questionnaire and demonstration were disclosed. Those that were willing to participate were asked to evaluate the concepts, and provide feedback through the questionnaire.

In addition to providing the primary goal of insight on the concepts, the visit provided the secondary opportunity to further observe potential users. Both aimed to further develop empathy for the needs of potential users by understanding their daily activities that brought entertainment. Observations included their interactions with other peers, staff, and surrounding environment to expand on insights that may have been overlooked.

Many of the interactions included socializing during games. Board games, dominoes, and playing cards were forms most frequently observed. Of the individuals not playing recreational games, passive entertainment was observed. Many watched television while

sitting as their passive activity. Sitting occurred both at tables, similar to dining tables, and padded chairs, such as couches. These observations helped guide the design process by providing examples of behaviors and how older adults utilized products within the center.

Administrators and workers within the facilities were also able to comment and observe the functions of the concepts. Their feedback was valued because of their observations, interactions, and previous experience with product interactions with the older adults. It was assumed that the experiences they had with the older adults may uncover possible motivations or triggers that discouraged participation, and how they overcame this issues. Addition examples of products or approaches that have success or are used within their facility were also noted.

**3.3.2.2.1 Findings of field test.** Additional details and comments can be found in the Appendix A section at the end of the document. The findings for further exploration were compiled into three groups of themes that emerged from the review process: exploration into activity promotion and tracking, exploration of foot and ankle health, and exploration of balance and mobility.

**3.3.2.2.1.1 Exploration of activity promotion.** The older adult often experiences apprehension to participate in activity. Variety in movements and adding elements of either progress recording or understanding incorporated into solutions should be sought, in addition to accommodation of individual functional needs for use (Bruce, et al., 2008). Aligning with the limited knowledge of activity was the input that suggested the benefit of providing a target on the deck or surface of the solution to guide the user (Kisor & Staff, 2008). The concept presented used the familiar “flip-flop” style foot form and strap to do this, but it was suggested that using an additional horizontally oriented guide would benefit the centering of the foot more accurately among various sized users.

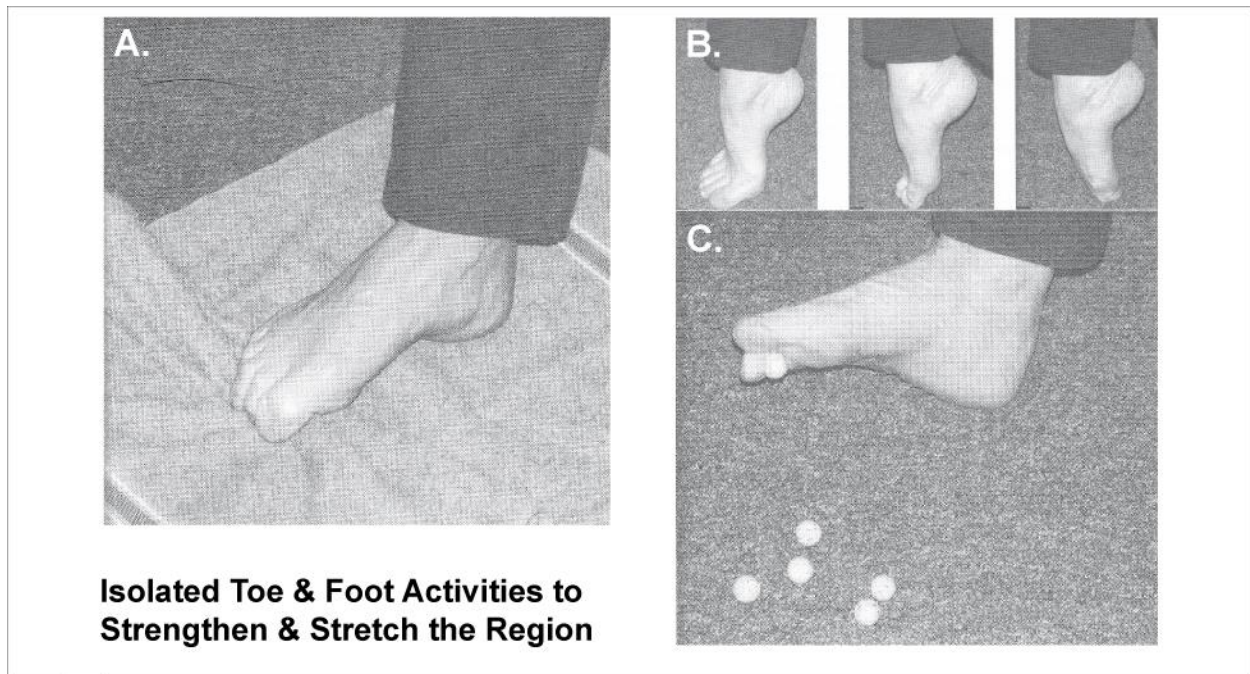
An element that was desired by both potential users and the field experts revolved around the idea of a targeting system that encouraged interaction between the user and the device (Bruce, et al., 2008; Kisor & Staff, 2008). This was described as a “Simon-like” or “dance-dance revolution-like” floor target system, see Figure 3.8. It was thought



that from an improvement aspect that reaction time could potentially benefit; from a usability aspect, it appeared to have a high likelihood of engagement from potential users. Therefore, other movements or components should seek to add a level of promotion, whether it be game-like in nature or pleasure producing, as this example appeared to provide both.

Elements that appeared to be beneficial from the activity were the use of a target system that could guide the user as to what moves or locations needed to be focused on. This should also include the ability to identify a target for the accurate placement of the foot on the deck of the platform to assist in self-directed activity. This targeting was seen as a benefit that should be sought with even the platform activity. Tracking was the final aspect that was seen as a necessary component to improve the promotion of activities (Bruce, et al., 2008). The goals were seen to provide this benefit.

*3.3.2.2.1.2 Exploration of foot health.* Because of the potential discomfort, pain, and medical intervention caused by negative foot conditions, products seeking to improve mobility among older adults should review the potential impacts and interactions of the foot with the proposed solutions to minimize negative interactions (Sheils, 2008; Ciavarelli, 2008).



*Figure 3.9 Isolated Toe & Foot Activities: 3 representations of beneficial toe & foot activities recommended during interviews. A. Towel Scrunch, B. Foot Raises, & C. Marble-Toe-Pickup. These activities attempt to relieve sore arches which tend to flatten in age. (Rose D. J., 2010)*

Of the potential pain sources, it was noted by the podiatrist that an arch problem referred to as plantar fasciitis was a common complaint raised by his patients. An active pain intervention that is recommended by the podiatrist is the rolling of a cylinder; examples mentioned included a soda can or a pill bottle, as some of his at-home recommendations, operating in a back and forth motion along the base of the arch (Ciavarelli, 2008). The motion is trying to elongate the ligaments on the base of the foot in the arch in an effort to alleviate pain. It was explained in another office that pain in the arches is the result of the stresses encountered during the use of the foot; this is the reason the soles of shoes designed for walking include a wider heel on the shoe's sole to reduce the stress and instability during the heel-strike phase of the gait cycle (Sheils, 2008). Additional options for the reduction of this pain can be obtained through the use of an overnight foot sling, which aims to fix the foot position during sleep to limit the symptoms that are present in the morning following sleep (Kisor & Staff, 2008).

As the actions and activities of the roller were discussed, the designer discussed activities that encouraged the use of towels to create circles, or marbles to be picked with



the feet. These were acknowledged at some facilities, especially the podiatrist, as being beneficial to the strengthening of the muscles that originate or terminate in the foot. These muscles, such as the big toe flexors, play a role in the gait cycle, providing spring and propulsion to the motion, as well as support to the arches of the region (Moore, 1980). These areas are not typically the focus of activities that you would find in a typical gym setting, and seem to be practiced in a more rehabilitative setting. This area seems to require further exploration as to its potential.

Additional proprioceptive possibilities such as textures could be added to these solutions, as was mentioned by several observers. Although the stimulation of blood flow was questioned by this type of activity, it was thought that the action of the movement, the leg moving back and forth to roll the foot over the object, could potentially enhance blood flow traveling to the lower leg (Bruce, et al., 2008). Because of the potential benefits of adding a pain reducing, proprioceptive adding element to the program, the addition of a roller style activity should be explored. Additionally, a further understanding of foot activities to elevate or strengthen the health of the foot region from conditions such as plantar fasciitis should be learned and explored.

Suggestions also included the examination of the approach proposed for the platform of a foot device (Kisor & Staff, 2008; Bruce, et al., 2008; Ciavarelli, 2008). The sketch model that was presented utilized a sandal style interface for the foot. An assumption was made by the designer that providing a strap-like aspect would add to the stability for the user, keeping the foot from falling off from a raised surface which was assumed to increase the risk of injury. While no potential user raised any concerns, several field experts did. The potential for disfigured feet is a very real possibility, and it was thought that freeing the foot from an enclosure would be more desirable (Bruce, et al., 2008). It was also mentioned that although arch issues can cause pain, that providing an arched padding similar to a shoe insert onto the surface of the platform would not be necessary or beneficial if the activity was performed in a non-weight bearing seated format (Kisor & Staff, 2008). It was also mentioned that muscle recruitment could be potentially improved by requiring the muscles of the foot to take a more active role in the stabilization of the foot without the strapping. Muscle recruitment is the participation of

the fibers to take action to complete the task; with the foot located outside of a confined strapped-in position, the muscles in the foot and lower leg would be recruited to provide

In addition to the strapping concerns with muscle recruitment, it was noted that there was lack of a sidewall to the sandal-like approach if strapping were a consideration. Similar to a traditional tennis shoe, the sidewall would reduce the potential inadvertent foot slippage by providing a “seat” for the foot. Although the sidewall could potentially deter foot slippage on the surface, the range of users would potentially become limited because of sizing considerations, especially between genders. It was determined that the addition of a sidewall could restrict the anthropometric ranges accommodated, and therefore, the recommendation to remove strapping to the deck of the foot platform was thought to be desirable as a feature consideration going forward.

*3.3.2.2.1.3 Exploration of ankle health.* The need to provide adequate strength promotion in the ankle region was exemplified by the both the texts and field expert visits as a need for promoting balance and mobility; of particular note among the field experts was the negative effect of injury to the region, and with increasing potential for chronic re-injury patterns (Kisor & Staff, 2008; Bruce, et al., 2008; Sheils, 2008). There appears to be a tendency for damage caused by injuries to the soft tissue of the area to be prone to re-injury. The majority of the injuries to the lateral structures are the result of inversion stress accompanied by plantarflexion and/or internal foot rotation (Starkey & Ryan, 1996, p. 88). This would include common injuries such as a “twisted ankle”, and would negatively impact the lateral structures with relationships in that area such as the muscles that help maintain balance and postural control. The functions and shapes of joints in the ankle make the area prone to those injuries in that direction.

Because of the potential for a rehabilitative aspect of the motion in the device, two other conditions would potentially benefit in the ankle region, stiff joints and flexibility (Bruce, et al., 2008). Because of the estimates that flexibility is reduced seven percent for every decade of life after thirty (Jones & Rose, 2005), and chronic pain along with arthritis are both negative aspects of the functional aging process and activity participation, the older adult would appear to benefit from designers considering such features.

Adjustability and seated starting points were suggested as an approach to introducing or integrating product use with an older adult (Bruce, et al., 2008; Sheils, 2008). The adjustability was suggested as a means of allowing those who require it, a path of gradual progression in building adaptability within a training effect in the body system. It was explained that the instability and planes of motion encouraged by wobble boards is rehabilitative in the sense that you are seeking a reaction from the regional muscles (Sheils, 2008). To accomplish this instability with the demonstration model format, the use of a seated posture and a means of controlling resistance and ROM would be desirable features to consider in the designs (Bruce, et al., 2008). The seated posture would provide the training accommodations for an older adult user that have been seen as favorable by Jones and Rose in section 2.11 above.

Also, the ability to detect vibration in the area seems to decline with age. It is thought that this sensation loss of the receptors, especially in the ankle, can be the cause of some falls. This is thought to occur because of the individual to lose some ability to detect their foot position in space, a sense of proprioception of the surrounding environment. It is thought that training or an active lifestyle can counteract this because of the body's ability to adapt to repeated response or a learned pattern through practice and use. The use of the target system was presented as a means of suggesting this type of movement pattern as a method of encouraging the coordination of lower body position and accuracy in placing that feature.

The muscles that are in direct proximity to the ankle provide functions that are seen as beneficial to older adults, stabilization and propulsion during gait and standing posture. The muscles in the region provide stability while upright, while the propulsion occurs during the gait cycle during walking. These activities are explored as elements of need in the section below.

*3.3.2.2.1.4 Exploration of balance and mobility.* The proposed motions and movement patterns were inadequate in the scope of improving mobility among the older adult, and should seek to follow more closely movement patterns and methods that are medically accepted. Although activity patterns can start from modified orientations such as being seated or with support aids to accommodate user needs, the guidelines and products for

older adult mobility should seek to include weight-bearing components that satisfy the full range of motion when at all possible.

One of the orthopedics felt the direction and purpose of the device needs to be clarified (Sheils, 2008). The ability to walk easier, while being mobile and being able to stand with proper balance, are two different approaches. To clarify, if you are seeking to make it easier for someone to walk, you want to remove the instability that accompanies a typical gait cycle. This is why you see a shoe with a wider heel region, or why a foot-immobilizing walking recovery boot has an arc on its bottom; these additions seek to add stability to the walking motion. Conversely, balance training to improve mobility seeks to introduce and increase the instability present in the region. The goal of this training element is the muscle recruitment from the stabilizers in the lower body region, through overload that is specifically targeted at the region to create a training effect. With this understanding, the goals should focus on the controlling of the instability levels to promote an accommodating level of balance development, rather than making walking easier as a goal.

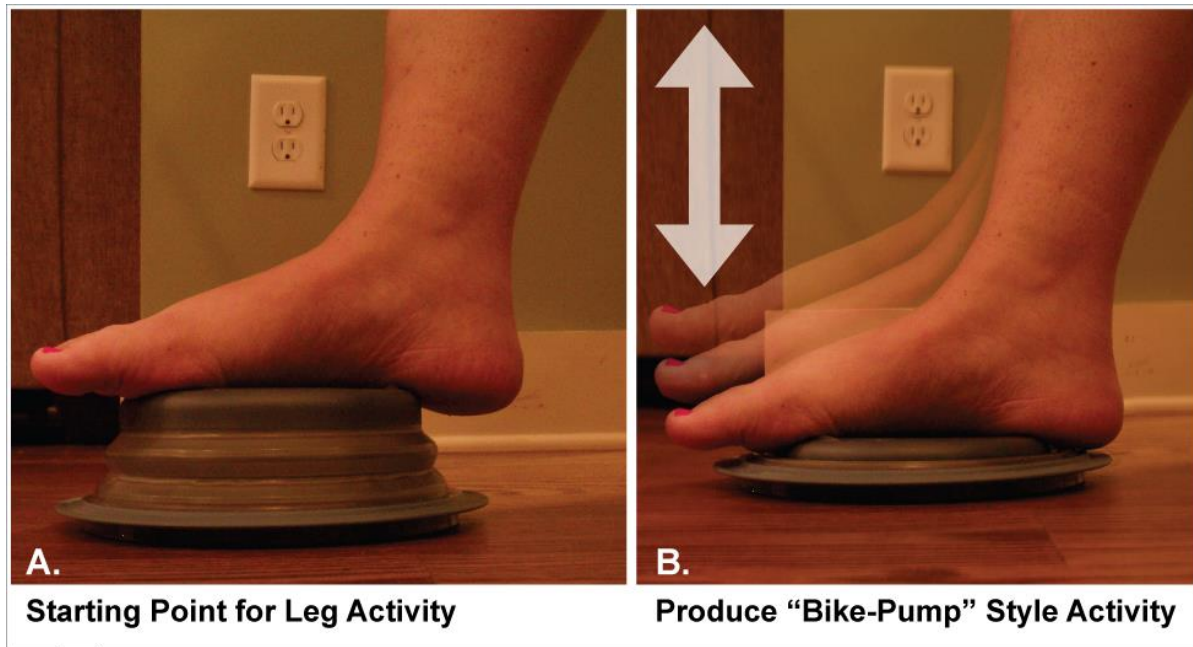


Figure 3.10 Lower Body Sketch Model, Eliminate the "Bike-Pump" Style Movement. The inclusion of the proposed leg strengthening method was viewed unfavorably. Concerns were raised that resistance in this matter might cause more harm than benefit in the older user.

While the idea that stimulating leg activity could be of benefit from a bike-pump-style activity, the input from field experts was that the motion would provide little in muscular gain, and could be problematic if hip pathologies were present (Bruce, et al., 2008; Sheils, 2008; Kisor & Staff, 2008). These hip pathologies would include previous surgeries such as a hip replacement or any other damage that would limit the function of the region. Although the presented leg strengthening for the upper legs to address the aging declines here was not favorable, the ability to provide resistance to the ankle and lower leg was viewed favorably. However, the actions of the platform were seen as being of benefit, even under a proposed resistance; this element was liked by both potential users and field experts. The use of such an element was thought to have rehabilitative qualities, which would accommodate both seated users that are learning the device and those who are in need of the strengthening of the region. This feature would provide a progressive function.

To accommodate these balance and mobility directives, the design considerations should include the following:

The field experts noted that movements should seek to recruit multiple planes. The use of a collar or other forms of rotational limitation can be sought to provide accommodation to the level of challenge presented as well as a progressive training element. The ability to vary resistance through the multiple planes should be explored as an additional progressive training aid and an accommodative feature for the user.

### **3.3.3 Initial Design Opportunities Observations Summary**

The verification of the need to focus the attention on the lower body region was confirmed at both levels of stakeholders, potential users and field experts. While just addressing the lower body with activity was thought to be a general goal, to create a better potential benefit to the older adult, a clear definition of the activity should be sought. Strengthening the muscles in the lower leg and ankle with a certain movement pattern can look very different from activities that provide mobility benefits to those same muscles. To provide this, the focus on needs to delve into several key functions from where the sketch model was at from a functional aspect. The remainder of the product research will seek to identify these areas raised by the field experts.

### **3.4 Additional Sketch Model Development from Insights**

The procedure followed in this stage was comprised of an iterative design development process cycle that sought to gain additional knowledge on how to better serve the older user regarding mobility functions. The design cycle was accomplished through the use of a two-dimensional ideation phase, followed by a three-dimensional sketch model phase with ongoing reviews. The use of an iterative design development process affords the ability to help solve problems found in testing (Stickdorn & Schneider, 2011, p. 61). Stickdorn and Schneider state that this cycle should be repeated as often as necessary, to allow for the design, testing, and then redesign to solve problems found during this testing (2011, p. 61). While sketch models were still utilized, beginning to solidify sections and aspects of the concepts became necessary to validate some of the functionality. The most promising conceptual directions in this design cycle were pursued to mimic the potential functions necessary to promote mobility by the older user, the way in which conceptual designs are suggested to aim to make user needs

understandable (Stickdorn & Schneider, 2011, p. 61). The solutions were reviewed for their merit in the promotion of the acknowledged needs of each individual section, as well as to the direction as a whole.

The refinement at three levels was identified through the previous sketch model review process. The individual areas expanded upon in this section included the promotion and tracking of activities, the possible mechanical solutions, and the exploration of beneficial movements. These areas represent the design needs the older adult user was seen to benefit from for mobility promotion.

### 3.4.1 Activity Promotion Sketch Model

Within the design cycle, the initial sketch model took on the overall theme of seeking to promote activity that focused on the lower body. The ideation that took place in this model focused on several aspects that were assumed to assist activity promotion: user interaction with the platform, tracking, passive promotional activity, and promotion of proprioception in the lower leg. The logic applied to each aspect is detailed below. The concepts were produced into a three dimensional form to be validated for effectiveness for both use and the appropriateness of the movements

Building upon the positive review of the effectiveness of isolating the ankle to provide strength and flexibility progressively, the concept exploration sought to include a communication method to inform the user of tracking. This feature was included into

#### Seated, Single Foot Ankle Isolation & Activity Promotion



In an effort to keep the user from using both feet as was observed, shapes that communicated single foot ankle activity were sought. These efforts included the addition of a ball chase feature around the perimeter of the sketch model.

*Figure 3.11 Seated Activity: The observations suggested that a passive ankle activity could be beneficial. The issue with what was seen was in the use of 2 feet at same time, which was thought to be risky with older users.*

the exploration of ways to reduce the potential for misuse through user error. Both areas additionally sought to reduce apprehension in use by the older adult.

Inspiration for a tracking method looked at the movement to be completed, in this case, as a circular pattern that recruited the ankle to move through a full range of motion. As the movement was considered, the designs noticed the track of movement followed similar motions as a hula hoop and produced a change in elevation as the user targeted movement from plane to plane. The change in elevation looked like the function of a common bubble level hand tool, where the user of the tool is provided visual sensory feedback as to the elevation angle the tool is set at. Along with a circular style of motion, it was assumed that providing a visual sensory feedback method that responded to the elevation change applied by the foot to the ankle could track around the perimeter of the platform surface. The perimeter was chosen to allow for legibility and visibility considerations as to the field of vision the user would have during the use; it was assumed the perimeter area of the device could be viewed unobstructed in a seated position. By including a visual feedback tracking method, it was believed that the user would be afforded an additional method of understanding of use, how applying movement in a direction was satisfying or not satisfying a desired task that they were expected to complete.

Building on this was the need to limit user error. Drawing from the observation that previously used round forms enticed the user to use both feet simultaneously, the concepts sought to eliminate this additional foot placement. By doing so, it was thought that user apprehension could be limited in use by allowing the user confidence that a foot remained placed on solid footing while the other was made instable. The platform shape was explored as how the shape could communicate this single foot use, but now also allow for a perimeter tracking system. The forms sought to limit the surface area that would produce user error beyond the use of a single foot; in this case the proposed use of an elliptical shape could limit the area surrounding the foot and also allow for an object to track around the perimeter when a circular style motion was applied.

The capacity to create a shape that satisfied the visual communication of single-foot use with ability for the user to safely interact and ensure that enough surface area was



provided for the activity required defining that the foot was now a specific interaction point between the user and the device. To allow for the user, the design had to consider the size range for the site of interaction, the foot. The specific guidance for the data that was necessary to apply to the design included the inclusion of two measurement points, (1) the maximal foot length while standing, and (2) the foot breadth while standing, measured at a right angle of the long axis of the foot (Allread & Israelski, 2011, pp. 107-108). This information was applied to the original guidance of looking to the extreme in the population from the human factors literature reviewed, the 95<sup>th</sup>-percentile male, and transferring the proper measurements into the applied solution.

To continue allowing for reduced apprehension to the user during use and to promote a passive aspect of use within their lifestyle, the intended posture was still focused on a seated user. The designs sought to provide for clearance in common seating situations that could occur within the intended use environment, the living situation of a home or community center. These areas included the tables and chairs that could commonly be in place in the intended environment of use. It was also assumed that use could happen concurrently with other leisure activities such as playing cards, or watching TV. The clearance had to place a human factors consideration of the needs of the smallest stature individuals being afforded comfortable use, while also allowing the larger stature individuals the ability to be provided adequate clearance during similar use within the intended environment.

A final consideration that was presented as an assumption in the design was the application of the proprioceptive functions of the lower leg. Within the designs, the base of the concepts allowed for the development of a quadrant system. The visual aspect of this originally secondary feature was thought to satisfy the tracking needs of activity promotion as well as the recruitment of areas that have shown to decline in older adults, proprioception. By moving the lower limbs and placing them into a quadrant, two features were thought to be produced. The first feature provided for the placement of the foot and lower limb allowing the user to develop a sense of space with their foot placement. The second feature sought to understand the previous feedback regarding movement patterns. The pump action of the foot was not as beneficial to the hip and

lower leg. The movement to place the foot by recruiting the muscles of the lower limb including the hip was assumed to be more beneficial to the user, even while seated. By resting in a seat it was thought that apprehension was reduced, and beneficial movement was provided. To move the limbs, the user would be asked to place their foot into one of four quadrants, a single leg at a time, to practice the accuracy of foot placement. It was hoped that this activity would provide the step accuracy practice as well as upper leg hip movement in multiple planes to elicit a benefit to the lower body function.

Activity promotion considerations following review. The review of the concept produced a collection of information that both eliminated and added to the needs.

- Continue with the ball chase.
- Texture is desirable, how else could it be expressed
- How will the unit and accessories store?
- How will the user limit/increase resistance?
- How will the user limit/increase range of motion?
- How can you get the user on their feet, and out of the seated position?

The positive and negative input was received based on the presented concept. Areas that were positive included the ball-chase feature for activity tracking, use of texture for circulation and tactile feedback, and the movement potential of a quadrant activity. The areas needing to be revisited in the design cycle included the intention of the quadrant use in mobility, user interactions with controls, and progressing from seated positions.

**3.4.1.1 Validation findings: beneficial design features.** The tracking of the ball was seen as allowing for the both progress identification and visual feedback for the user during activity on the platform. Ways to further improve the visual location of the chasing system should consider ways that color or contrast could benefit the visual ability to monitor the location of the tracking. The application of texture was also seen as a potential benefit for both tactile identification, as well as potential stimulation of the foot to include circulation and proprioception. Additional areas that a textured surface could provide this sensory feedback were sought. This included the potential for providing circulation to the lower limbs especially the foot through devices similar to competitive products like massage rollers. With more of a self-directed motion, such as

back and forth, the user may actually stimulate blood flow while providing relief. The performance of a quadrant activity was seen as a potential way to involve the lower limbs in beneficial movement while seated, but the progression of the activity with a goal of mobility promotion requires additional considerations.

While the specific goal of the model was to address the activity promotion, general suggestions regarding mobility were raised. The main suggestion that was viewed as omitted involved the use of the quadrant system as it was presented in a seated position for completion. The other areas focused on the interaction and controls to allow the user to change the functions associated with the platform use. These areas were added to the considerations of the subsequent design cycle and future models to improve the goal of developing a mobility device for older adults.

**3.4.1.2 Validation review: reevaluate design features.** The areas needing to be revisited in the design cycle included the intention of the quadrant use in mobility, progressing from seated positions, and user interactions with controls.

The intention of the movements as they relate to mobility promotion were raised during the validation review. The original design direction and intent focused on the passive use that included reducing user apprehension. While both of these considerations were seen as still desired, the goal of mobility promotion should promote the use of features in a weight-bearing, standing posture. The reason for this is the user will never fully gain a desired outcome of improving their mobility by performing all activities while seated;



*Figure 3.12 Texture Exploration: The reduction of the mechanoreceptors in the lower limbs suggested that attempting to stimulate blood flow & sensory stimulus may be beneficial. The feedback seemed mixed as far as the benefit of each.*

the movements must evolve to become more specific to fully promote a training effect through the targeting of the specific muscles utilized in mobility.

The promotion of progression, from seated to standing postures, was elaborated beyond the use of the quadrant, and included the additional movement considerations that could benefit mobility promotion. The demonstration of use in a standing posture contributed to another area to consider that would be functionally relevant to participation seeking to limit falls and improve mobility, the inclusion of an obstacle or hurdle like

feature. As the quadrant review suggested, progression to vertical postures was needed. When looking at what complicates independent living, movement within the environment requires dynamic moves. Kromer (2006) suggests that these activities of daily living fall into groups: pushing/pulling, lifting/lowering, and bending/stooping/reaching (p. 148). These include climbing stairs or clearing fixed ground objects.

Because of the suggestions already in place for the quadrant, it was felt that adding an obstacle avoidance feature could benefit the older adult in several ways. The first is that a feature like this could still potentially be designed in a progressive manner, allowing for the user to gradually build their ability from seated to standing if necessary; however, it has been recommended that to provide support to prevent falls should incorporate the ability to allow for mechanisms that can provide for the maintenance of balance such as assistive aids and chairs (Gardner-Bonneau, 2011, p. 758). By providing



*Figure 3.13 Transition from Seated Passive Activity to Weight-Bearing: As the sketch models developed, the need to promote mobility & weight-bearing activity became developed. The beginnings of this happened as the Quad activity introduced an Obstacle activity.*

the ability to integrate these features within the design of the activity, the designs would be more successful at providing support from a safety standpoint, as well as the confidence that the user may feel less apprehension to performance an activity knowing that assistance is nearby. Additionally, a stepping feature that raised the leg off the ground could help produce balance and strengthening of the ROM of the lower limbs particularly at the hip. These movements would be of a benefit to mobility promotion, and should be investigated for application.

The final areas to reevaluate include the use of the controls. The interaction necessary to provide control to the variable features of the platform device require further exploration. At this stage, the basic functions may perform the desired actions of changing the amount of ROM and resistance, but the use needs improvement.

Both areas of feedback were considered following the review. The considerations were included into the design cycle for further development in the next sketch model which had a primary focus of improving the possible mechanical solutions along with the ongoing feedback.

### **3.4.2 Possible Mechanical Solutions Sketch Model**

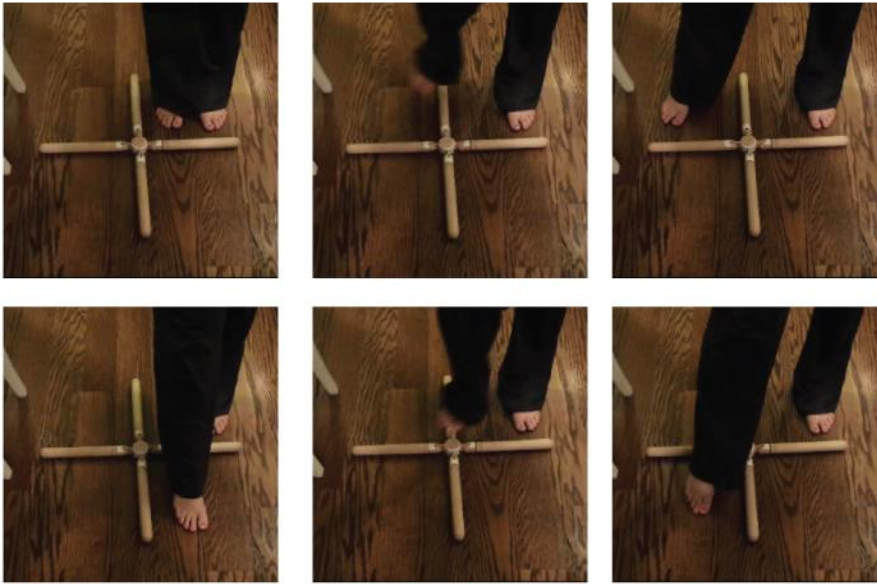
At this stage of the design cycle, the purpose of the sketch model involved addressing the possible mechanical solutions that could improve the use and feasibility of the design concept. The ideation involved in the sketch model focused on the mechanical use of the ROM and resistance feature presented as a solution for controlling the platform experience. Because of the previous feedback, the mechanics of providing additional features included the designs of a quadrant, obstacle, and roller aspect. Reviewing older feedback yielded the addition of another feature assumed to promote mobility considerations, a toe grasping feature. The individual considerations are expanded below with the results and feedback provided from the validation of the sketch model concept.

The exploration of the mechanics that would allow for the control of both range of motion and resistance were explored. The desire to provide a progressive level of control





## Quadrant Participation Sequence



The participation in the quadrant activity sought to allow for greater weight-bearing participation by improving the size of the footprint to allow for larger stature individuals to participate.

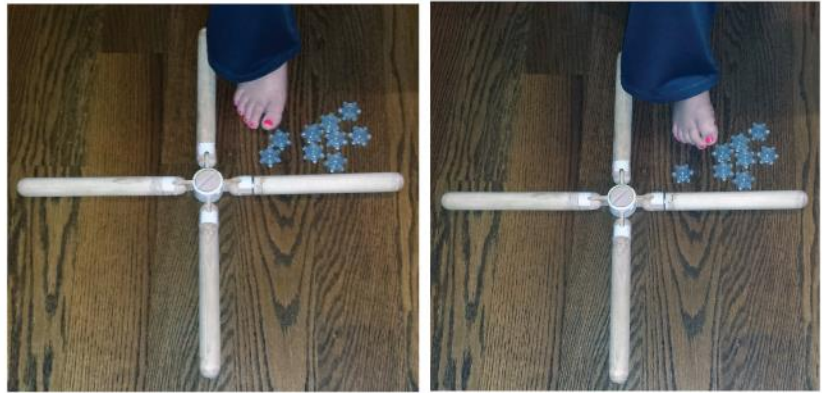
The basic components were also included in the designs for the foot roller & obstacle clearance to improve storage.

*Figure 3.15 Weight-Bearing Quadrant Activity Sequence: The evolution of the Quadrant activity included the weight-bearing component that is sequenced above. The profile of the unit seeks to be minimally invasive to the environment & user in profile height.*

on the ground. The progression of the obstacle was provided so that each leg could be set to a desired level of challenge. By leaving the legs open, it was assumed the use of a secondary base of support could be accommodated by users who were progressing towards unsupported mobility movements.

The creation of new features followed a review of previous feedback from influential stakeholders. The promotion of blood flow and possibly providing a non-medicated form of pain relief was the goal of incorporating a massage roller. This feature was mentioned when texture was introduced in the previous sketch model; additional validation came from the design direction stage feedback provided by a podiatrist. At that time, it was suggested that the use of cylinders, such as pill bottles or soda cans, could provide a level of relief and beneficial stretching to the arches of the foot (Ciavarelli, 2008). This area is commonly sore both after extended time on the feet and when localized conditions such as plantar fasciitis are present in the foot. During this same interview, the subject of toe grasping activities was discussed. The current activities promoting this activity include picking up marbles with the toes, or grasping

### Toe Grasp, Foot Roller, & Obstacle Considerations for Sketch Model



The addition of a toe grasping activity was included during this stage after reviewing the initial stakeholders interviews. The activity attempted to add to the game-like, leisure activities that were popular at community centers. The evolution of the roller to the left allowed for the incorporation of the hurdle (not shown) into the collection of activities built around the quadrant activity.

*Figure 3.16 Revisit Foot Learning: The initial interviews were revisited when the task of expanding activity promoting activities became apparent as the project evolved. The toe grasp activity was originally suggested at the podiatrist office visit & was included.*

towels. The movement was thought to benefit the older user because it could produce both stretching and strengthening of the toe extensor muscles (Ciavarelli, 2008). The link that incorporated the toe grasp and roller functions was designed to store the textured pieces along a rod; the rod also connected the hurdle to reduce the number of components.

The features were presented for validation and the following considerations and concerns were documented.

- Can this function without the need for electronics? If so, how do you “initiate activity”?
- The performance of the resistance seems to function, how can the function of the range of motion improve? Beneficial movement still possible.
- The hurdle form seems to be complicated, can it be simplified in use and still provide safety? Providing variable heights is good, look at footprint.
- A toe-grasp is potentially beneficial, seems complicated. How do you track and store this function? How do you simplify use?
- How does roller store? Potential benefit to pain and blood flow to region.



- In general, how do you approach functions? Movements functions provided have improved.

**3.4.2.1 Validation review: beneficial design considerations.** This section discusses beneficial design considerations following the validation review. The comments regarding the new design focused on movement of platform being still beneficial, variable progression provided, potential benefit to toe, potential benefit to roller, and movement functions improved.

Overall, the movements and functions provided had improved from the previous review. The addition of the hurdle movement that progresses into a weight-bearing stance was viewed most favorably of the three features introduced or redesigned in the concept. The movement of the roller was seen as potentially able to provide relief to sore feet, even though aspects of its design required attention. The toe grasping activity was thought to require further validation as to its beneficial function as presented in its current form. As a whole, the collection of activities' most desirable feature was provided by the ability to allow for progressive development of the functional abilities of the older user, and should continue to be included.

The mechanics involved in the promotion of two additional directions were also explored. The potential use of texture as a means of promoting blood flow was further examined at the mechanical level, as to how the texture would be presented to the user. The form direction that emerged was the form of a roller that would mimic massage. This was introduced as a potential direction during the communication with a podiatrist.

The other movement that required a potential mechanical solution was the means to promote an activity that got the user on their feet, even if that included a secondary base of support such as a cane or chair. The previous model pursued a secondary activity that promoted the proprioception factors that could be achieved by providing a training activity for the placement of the feet while seated. Modifications to allow for the ability to perform the activity while standing required affordance for secondary support devices. Because of the need to provide for this form of clearance, the function required the ability to allow for objects to potentially interact with it.

Many of the solutions here focused on existing products found in the track and field, as well as other run-promoting activities. The use of hurdles here attempt to promote the clearing of the limbs, sometimes at an accelerated rate of speed for athletes during the activity. To accommodate unintentional contact or tripping, these features rely on a rocker style form, where the object rocks away and lays down temporarily to get out the way of the athlete. Because even athletes are expected to potentially make errors during use, mechanical considerations for the older adult population sought to afford a similar ability or modify the movement to discourage this type of action to occur in the first place.

The promotion of clearing obstacles was additionally thought to be a beneficial activity for promoting mobility because the ability for individuals to train for daily activity interactions could be simulated. Just as an athlete needs to clear a hurdle or object in their respective sport, older adults encounter permanently fixed objects that are beyond their control to move. The ability to clear steps, curbs and other items of a similar nature would allow the older adult the potential to maintain personal independence as long as their ability to do so remained intact.

**3.4.2.2 Validation review: reevaluate design features.** The validation review provided insights that were intended to refine features to promote improved usability of the presented features. This feedback focused on initiating activity, improved ROM, simplified hurdle use, simplified toe, as well as roller storage.

Rather than reliance on electronics, the ability to create operational action was sought. While some features could be controlled electronically, it was suggested that seeking a non-powered option for use should be explored further.

While the mechanical function of the potential mechanism to control ROM and resistance was improved in overall size and containment of the components, the quality of the ROM was thought to need to improve. The current arrangement provided a difficult manipulation pattern for the user.

The mechanical solution for the operation of the step hurdle was thought to need improvement. There were too many steps in the sequence of use of in the operation of the feature, and this needed attention through redesign.

The toe grasp function shared a similar need in reduction of features. In this case, the number of parts, their size, and the intended location of their use all played a role in the need to reevaluate the functions in this feature.

The storage for the roller needed to be further investigated. The current setup was seen to be potentially problematic.

### **3.4.3 Beneficial Movement Sketch Model**

To address the ability to avoid electronics, alternatives that may provide a solution that both is understandable by the older adult user as well as address the need to provide direction to the activities were reexamined.

Previous concepts and earlier observations revisited the use of playing cards as the potential solution. Hurley addresses the prevalence of the participation in card and board games among older adults, especially among low energy groups (Hurley, 1988, p. 135). This was also observed in community centers, yet these activities do not provide physical activity. Playing cards do provide several common features that can be beneficial; they provide systems of numbering, symbols, and colors that are recognizable and familiar to many. Additionally, by shuffling the cards, the order and variability can be manipulated allowing for a simply means of adding variety to the activity participation through the randomization of the ordering of the cards within the deck. Providing variety to the activities offered has been mentioned as a beneficial component to activity program designs.

Additional benefits can be afforded to the cognitive learning function to the older users by introducing familiar learning concepts within the system. Because the this represents an information processing system interaction, Gardner-Bonneau (2011) recommends

minimizing the need to learn new skills can involve making use of an intended user groups “well-learned skills”; the observations within the research suggested that playing cards could potentially represent a well learned skill that could be translated into explicit relationships of interaction use within the system activities (Gardner-Bonneau, 2011, p. 759).

The coloring system provides two groups, red and black. The symbols utilized provide four categories with the suits, the symbols club, spade, diamond, and heart are represented. The numbering system provides within the symbols the numbers two through ten, with additional from the suited cards Jack, Queen, King, and Ace of the suits. From a function randomized use, cards can be shuffled to provide variable combinations of the cards presented. In this way, playing cards can provide a low-tech method of direction to the interaction presented when using this system with the various provided functions.

Potential areas of accommodation and need within playing cards used among older adults identified by Hurley include the possible need for large print for individuals with vision issues, as well as space necessary on tables depending on the number of individuals; additionally, Hurley notes the table can provide those with grip issues a place to rest the cards without the need to hold them (1988, p. 136). These areas can allow for adaptations to accommodate users, as well as design considerations that may interrupt use.

To address the complications encountered during the use of the previous step hurdle, a solution was sought to provide a simplified use that additionally was incorporated into the design of existing features. Incorporating the feature within existing features was pursued, developing the step feature within the body cavity of the quadrant feature to provide a storage solution. Since the quadrant activity provides an existing method of alignment on the ground plane, it was assumed that furthering its use within the obstacle feature would assist the user as to how to orient themselves during the use of the feature. The design continued to attempt to provide for the ability for adaption according to the ability of the user in a progressive pattern through an adjustable height design feature.

The application of the toe grasp was also addressed; concerns over the use of smaller pieces, storage concerns, and the potential to lose these pieces were addressed. Additionally, a review of the potential activity performed was addressed. To limit the potential for misplacement, the design of the toe grasp was to now include a tether for the object. The hope of the design was to allow for the participation in the activity, but the attached feature would limit the possibility of misplacing the object. To improve the goal and function of the activity, a system of targets that mimicked similar functions and features of other incorporated device functions was pursued. Reducing the relearning of new features and making design intent explicit has been suggested as a strategy that can improve the cognitive product use within the design of devices (Gardner-Bonneau, 2011, p. 759). By including similar styles of activity with similar icons on the device, the hope was the learning of the overall system could be improved through integrating a family of similar movements using a family of icons. The redundancy of these features could limit the needs of relearning and promote a clear path for understanding. The user would place the object into the corresponding target for placement.

To address storage concerns, the toe grasp became a tethered feature, which provided the ability to more easily store the object when not in use. The storage of the roller was also addressed at this point. The redesign of the toe grasp feature previously used encouraged this action. Because the original direction was to provide the stimulation of pain reduction and potential blood flow to the foot region, the ability to use the roller by the foot was a consideration that remained in place. The potential for the roller to be utilized by other regions that may become sore, while still providing the foot access, drove the design direction of the redesign of this feature. The largest surface for the storage to occur, the platform, was identified as the location with the greatest potential to house this feature. The platform also provided a redundant location for the design of foot interaction features, and therefore was pursued.

Following the review, the following comments were made:

- How do you mimic the walking pattern and improve the hurdle? Marching motion is not desired, but the feedback provided is clear.
- How do you improve the visual cueing for the quadrant? Use of a mat seen as potentially beneficial.

- Liked the targets, tethered object for the toe grasp activity? Are targets visually distracting on the platform deck?
- The storage and ability to remove the roller is good, but is the user function suffering in the handle?
- Can you add an additional plane of motion for the quadrant in the transverse? The trim of feature can separate from background, but what color?
- How do you track the progress quadrant?
- The mechanics of the platform appear to provide sufficient ROM and resistance in a variable progression. The chase appears to provide visual.

### Collection of Beneficial Movement Sketch Models



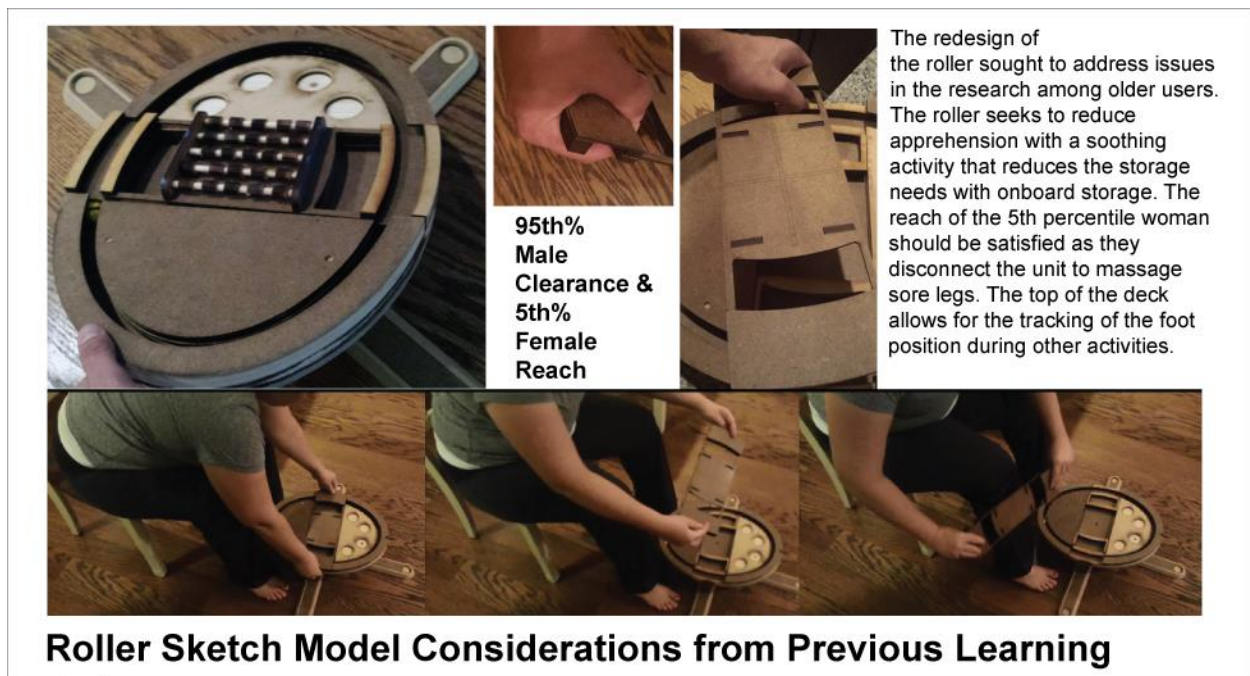
Platform, Toe Grasp, Roller, Obstacle, Quadrant, & Variations

*Figure 3.17 Beneficial Sketch Model Collection: From cardboard mock-ups to interchangeable parts, the beneficial sketch models sought to complete the transition of learning from passive movement to purposeful, activity rich activities.*

#### 3.4.3.1 Validation review:

**beneficial design features.** The comments were considered to be applied to future potential solution directions. The following is a summary of the features and considerations that were considered following the review: Toe grasp tethered and targets, roller storage, marching feedback concerns, the use of two senses, roller storage removal, use of a mat, contrast trim, and the mechanics of the platform.

The redesign to include both a tethered and target feature within the toe grasp activity was seen as a benefit to the use of the feature. The ability for the user to not worry about losing a small part while still gaining benefit was desired. The ability to cue a target and receive feedback that the target was achieved was a desirable addition to the toe grasp activity as it now provided a more functional purpose to the user as a game.



*Figure 3.18 Roller Accommodations Considerations: The activity is an example of the variable needs necessary to address in the older user. Reach, clearance, tracking, & sensory communication are needed; additionally the lifestyle areas of the older user are needed.*

The ability to store and remove the massage roller was also seen as a benefit to the user. The ability to massage the foot was now expanded to allow for the stimulation of other areas that could become sore from use of the product, or in other activities encountered in daily life.

While the second adaptation movement for obstacle avoidance did not receive positive feedback on the movement pattern provided, the feedback function of the activity was seen as beneficial. The feedback in this feature provided both a visual stimulus through the ending location the bar rested at, as well as the audible stimulus of the object clicking into the ending location at rest. Using this combination of multiple feedback sources for the sensory systems was seen as desirable for the older population because it accommodated for the potential loss of sensory function in a redundant pattern.

The use of a mat or similar flat surface to serve as a visual target to aim for on the ground was seen to be favorable in a stepping activity. From the aspect of use, a low profile surface like this, when adding all planes of motion into consideration, could

potentially reduce the chance for user error occurring from a tripping motion during the step. This feature would require the proper surface treatment to the underside of the surface to reduce the chance of it slipping during use. The stepping activity was seen as desirable because of the ability to encourage the lengthening of the stride and flexibility of the lower limbs when performed in a weight-bearing and upright stance. The ability to control the sizing of visual messaging on this flattened surface was also seen as desirable.

Providing a contrasting trim or edge treatment to the surface of objects was viewed favorably. The ability to provide low glare, highly visible colors to distinguish the edges of the feature created the ability to enhance the visibility provided to the older adult.

The movement of the platform was still regarded as beneficial. In this model the ability to limit ROM and provide a range of motion of 15 degrees was afforded to the user. This range would provide limited ROM in limited capacity training as well as provide a range that did not exceed thresholds of ankle capability in all directions of motion.

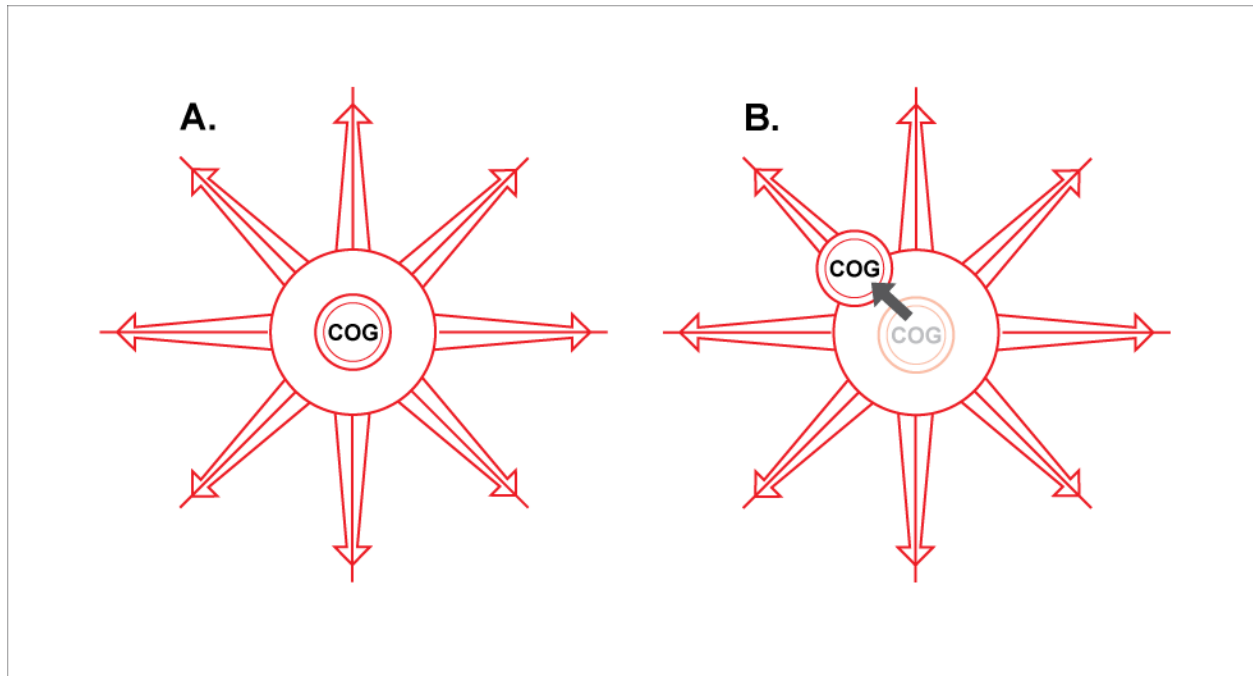
Additionally, the use of a highly contrasting color for tracking the feature around the perimeter of the device allowed for visual and audible feedback while limiting the obstructive view of the tracking system when used in a seated position.

#### **3.4.3.2 Validation review: reevaluate design features.**

A summary of the insights provided in the validation review included: the desire to provide full range of gait stepping that avoids marching method, visual cue of quadrant activity, potential pattern distraction on toe grasp, handle of roller, additional plane considered, and progression of step length.



To fully enhance mobility, the movement will fully require the use of a complete stepping pattern. To achieve this, the movement associated with gait should be the desired outcome. Although the individual may possess physical limitations at the onset of activity adoption, this full range pattern should become the end goal. However, not all individuals are at the same state of ability, nor are they guaranteed to remain at that functioning level. The positive feedback thus far on the movement pattern in the platform suggests that multiple forms of activity offered in multiple manners may be necessary to include in solutions going forward. This would suggest that part of providing promotion through accommodation will require methods that can be undertaken by all skill levels, those with poor balance and those who are more able.



*Figure 3.19 COG Manipulation Example: The need to manipulate the COG is necessary as a weight-bearing goal of mobility. This requires the COG to move in a plane direction away from the typical posture stance. The arrows above show the possible plane directions.*

The cueing for the quadrant should investigate further how the user will interact with this feature in a clear manner. To achieve this, it is necessary to include the proper sensory cues to inform the user of the intent. The use of proper symbols, colors, and sizing can provide this information visually as has been suggested by Allread and Israeski (2011). The need for cueing interactions is important to consider

as the intent is to allow the older adult the ability to perform these activities independently. Understanding where someone has to place a limb to be safe

and where placing that same limb in another nearby location results in injury should be examined as to the ways to provide this form of tracking.

The suggestions applied to the quadrant cueing should also be explored for other features including the toe grasp function. After the review, it was noted that the application of the proposed solution may provide a distracting pattern for the viewing of the platform activities when the toe grasp is not in use. The reduction of the patterns that could cause this type of interference have been suggested (Pirkl J. J., 1994; Gardner-Bonneau, 2011, p. 758). These visual distractions take away from the ability to safely interact with any system; this is even more of a concern in the older population because of the reductions to this sensory system and their ability to detect these distracting visual cues amongst other elements in the environment (Gardner-Bonneau, 2011, p. 758). The ability to fully apply sensory adaptations in solutions going forward will require an emphasis on the areas that are similar to the pattern interference with the all sensory systems.

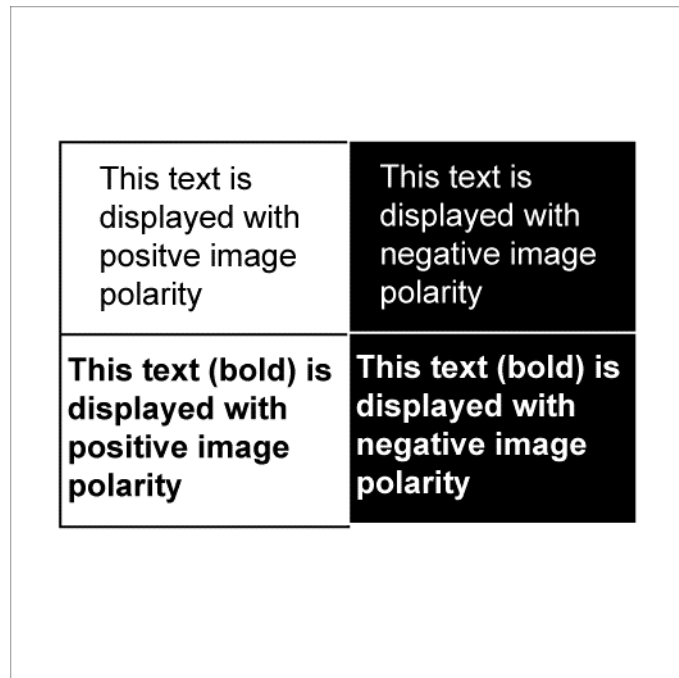


Figure 3.20 Illustration of positive image polarity (left column) & negative image polarity (right column). (Muto & Maddox, 2011, p. 314)

Storage incorporation has been sought to limit the footprint for the device since it is intended to be used outside a formal setting, into an at-home solution. Many of the designs have placed a balance on both the function and this storage consideration. The function of the roller and hurdle in this review, however, is called into question if the function of the movement has suffered. The roller, for instance, was designed into the deck of the board. The incorporation of the handles allowed for the use of the roller as a hand-held device. The function as a hand-held device with this configuration was seen to be awkward, although the foot action provided by the roller was not. A similar finding was seen in the hurdle, where the storage was not a concern, but the function of movement allowed for by the design was seen as hindered. The focus appears to need to place a higher level of design consideration to the design of the intended function, with the storage falling to a secondary consideration. This does not mean that storage should be eliminated as a consideration; it just requires the reordering of the priorities of the intended design features. The function of the features in movement should take precedence because of the intent of the product design as a mobility device for older adults. This would allow for storage to be an accommodation of the lifestyle of the user, not the beneficial function of the feature.

The promotion of the function first can be seen in the review of the quadrant system. Here, the function of an additional plane of activity was seen as a potential benefit to the overall promotion of the mobility process. The additional plane can allow for the additional training of COG placement within a 3 dimensional space. To allow for this, the threshold level of the ground interaction should be eliminated, to reduce tripping concerns. When combined in a redesign of the stepping function, the incorporation of clearance (via hurdle) and step length in multiple planes (via quadrants) can still be provided and potentially achieved.

### **3.5 Product Research Summary**

The procedure to test which region the potential user and the stakeholder desired focus in the activity device yielded results within the sample that suggested there was desire to focus on the lower body with the activity movements. The interaction and observation with the potential users provided confirmation that lifestyle factors were not being

addressed. Additional information was available as to the activities individuals were participating in within a limited sample size.

The observations, interviews, and reviews of the current competitive market showed that there are methods to providing functional improvements that are being applied to a smaller population group that places emphasis on elite performance and ability. Many of the solutions at the user interaction level are the opposite from this, suggesting that applying these techniques in a format that reduced apprehension by modifying performance format could be beneficial to the older adult population.

Validation from both potential users and influential stakeholders provided the feedback that confirmed the need to focus on the lower body, but required further understanding of what is necessary from individual areas of the body, as well as what is necessary out of the device. This began the process of gaining clarity through the understanding and exploration of what movements are necessary, and which ones are ineffective for mobility promotion in an older population. Moreover, the requirements of the user afforded from devices that adapt to the aging process was initiated.

The procedure to develop and refine concepts within a design cycle with validation based reviews was followed. By applying the method of identifying the areas of concern within each cycle and validation review, the function of the physical activity device was addressed within the refinement process as raised by stakeholders and field experts.

The review of the validation process during the activity promotion also provided the understanding that a progressive approach to skill, ability, and function should be applied to create a transition from seated activity into non-supported and independent weight-bearing activity whenever this goal is possible within the user capacity. Even simple methods, such as creating a manipulation of an enclosed ball, can serve as interactive means of engaging the user.

The importance of the movement patterns performed and how they are offered to the older user was identified during the final validation review of the additional sketch models.

The design cycle process identified the larger areas with characteristics that appear to have potentially beneficial impact to the older adult. Having products that can focus their use on the current daily activities of the older adult can help satisfy the lifestyle needs in the home during potential use. To assist this lifestyle fit, optimizing the time spent with the potential benefits could provide important gains in potential participation. This functional focus on specific movements that can progressively challenge and functionally accommodate the older adult should be viewed favorably. To increase the potential quality of these interactions beyond the accommodation of the physical needs of movement for mobility, increased attention should be directed at the interactive needs of the older adult. If the presence of human assistance is not present, then the role of assistance should be expected from the products that are interacted with.

The ability to identify all possible sources and potentials for falls and limiting mobility is certainly difficult to achieve; however, as Rose states, “just because a syndrome source can’t be isolated, it doesn’t mean you can’t intervene” (Rose D. J., 2010). This places the need for intervention into a thoughtful collection of better practices, selections, and identifications to limit the potential for unaccommodative products.

## **Chapter 4 Development of Design Guidelines**

The findings of the literature presented in Chapter 2 and the product research conducted in Chapter 3 have yielded insights into the difficulties and benefits of providing mobility activities among older adults. The variability within the physical functioning of the older adult and how the need to adapt product solutions to accommodate this variability should occur was explored to promote beneficial outcomes. The adaptations that should occur going forward should accommodate the needs, abilities, and resources of the older adult. The accommodations should include three areas that have shown to promote benefit or reduce negative outcomes: lifestyle, physical activity, and ergonomic accommodations. These three categories will be examined individually to identify key areas of need within each in order to provide design guidance.

The information gathered thus far has shown that the development of activity devices requires the adaptation of accommodating features to provide the user the greatest opportunities for inclusion when utilizing the designed devices. These adaptations require the acknowledgement that certain factors are unamendable, and require efforts by designers for them to be fulfilled to the best of their ability. Although the factors themselves are not modifiable, it is possible to attempt to provide accommodations that can enhance necessary features for the benefit of the impaired user; many times these enhanced features that make the product easier to use by the impaired are made easier for all as a result of the application of good design practices (Kroemer, 2006; Pirkle J. J., 1994). In an effort to promote good design in the promotion of mobility products for older adults, the enhancement of the physical activity requires the understanding that unmodifiable physiologic processes must occur in order for physical activity to be of benefit to the older adult.

## **4.1 Identification of Design Constraints in Physical Activity**

The development of design solutions require designing within constraints that are beyond the scope of control by the designer. The areas that have been shown throughout the research in both literature and product study have involved providing the potential for functional improvement within the older adult population. The definition of who is classified as an older adult constrains the designer to characteristics unique to that population.

There are tasks necessary in physical activity that must be satisfied, and are above influence from design. These constraints involve those areas that allow for functional transformation. In the case of physical activity promotion, these areas involve physiological changes that are required of the body systems at the biological level. These changes are controlled by the training effect.

### **4.1.1 Providing for a Training Effect**

Participation in any program, device, or system that seeks to create a change to the body through activity will require a training effect, as described in section 2.11 above.

Reaching overload and specificity by the area trained is a requirement that has to be provided through the program. However, it also is necessary for the participant to produce the effect through individual sessions and on an ongoing basis. Because of the variability that has been demonstrated in the literature, this becomes an important design consideration for the overall design experience the older adult can expect from potential solutions. The variability requires the application of techniques that address the barriers presented by older adults' constraints accommodation to multiple aspects of the user found in the lifestyle, mobility, and ergonomics needs. In activity, this was specifically called for in section 2.11 in the design of the activity program. The application of techniques that address the barriers is a method that can potentially improve the overall user experience during use.

A balance is necessary then in potential solutions to balance the need of the activity within their accommodated interactions with the product to do so. Because of the site

specific results and the goal of the promotion, the interactions that require accommodation balance will include those body regions requiring training for mobility promotion, and the potential interaction locations to be identified by the design process.

The need to specifically target sites in need of activity was first demonstrated in the initial concept development sketch model that aimed to provide a bike pump motion. Although the region was in focus, the lower limbs, the specific forms of movement that would benefit the older adult in the promotion of mobility were not addressed in that training format.

#### **4.1.2 Providing for Progressive Activity**

During the product research in Chapter 3, the evolution of each sketch model led to the theme of developing progressive or adaptive activity progression by the older user. Many of the competitive products reviewed in section 3.2 above currently available on the market required the possession of either the necessary functional physical capabilities or the assistance or guidance provided through the involvement of a trainer. The evaluation of how to more easily provide these movement benefits while still encouraging the building of self-confidence among older users was investigated. The low levels of activity self-confidence was named as a personal barrier in section 2.3.1, creating the need to identify this area. Self-confidence was encouraged to be included in potential new solutions in section 2.14 above; this led to the investigation of minimum movement requirements necessary in activity solutions promoting mobility. The understanding that unique circumstances surround the capabilities of each individual as they age requires an application of empathy to the use of design solutions, as well as the adaptations necessary to modify their movements in activity. As designers, Pirkel suggested that these modifications should be included in the product so that a user does not have to make these enhancements on their own. Because the literature highlighted the need for the activity instructor to modify movements based on the functional status of the client in section 2.11, this effort should be combined into the effort of the design process solution. This is especially needed to allow an older individual to carry out the activities within their home, in a self-directed manner in accordance to their lifestyle needs.



An isolated example of this progressive progression during training could be seen through the use of platform activities. As each model focusing on this activity sought to provide training to the ankle, the benefits that could be achieved by designs that provided the user to make individualized adjustments to the difficulty in both resistance and ROM were viewed favorably by input from experts on exercise movement throughout chapter 3. The modifications available to a user based on their current level of functioning were further enhanced by allowing for the participation in a seated activity. Although the goal is to ultimately get the user into a full weight-bearing level of function without the need for supportive aids, the goal is also to allow for provisions that accommodate the widest range of users, with limited apprehension during participation. By modifying an athletic function offered on competitive product that promote gains in balance in modified format, the limited function individual could begin to promote these same gains themselves. As confidence and ability of the specifically targeted muscles adapt to the increasing challenges, progression to additional activities following similar training paths can promote improved outcomes. Because of the needs of the older adult and the recommendations and insights thus far, designers need to make progressive training a requirement of their solutions promoting activity for older adults.

#### **4.2 Providing for Accommodation**

The associations that have been established in the research have been characterized by the establishment of priorities of multiple disciplines. These disciplines share a common goal of providing accommodation to the user. The components of accommodation share elements that when combined can lessen restrictions that can potentially hinder the older adult from activity participation. The individual components of accommodation seek to provide the adaptations necessary for the variability of the older adult population to be addressed. Accommodating for lifestyle requirements improve conditions that discourage the ability to travel to or utilize fully objects and systems that can potentially improve their physical functioning.

The importance of providing accommodative features for physical activity for older adults revolves around the potential of improvement to reaching the necessary training effect components of activity. Only when these are achieved can the benefits be gained;

however, if the ability for the individual is not enhanced to ease the use, those with the greatest to gain from the features of physical activity in the older adult community will not be realized.

The idea of providing for personal individualization, whether a result of functional necessity or as a result of personal preference as to use, was found to be a reoccurring theme across multiple disciplines and areas of focus. At the physical activity level, this concept was promoted in general recommendations, as well as in specific detail in the development of activity programs in section 2.11 through an exercise lens. Pirkl discussed these areas in section 2.13 through a design lens. Discussion of overcoming the barriers presented in section 2.3 looked at social lens. The findings that are beneficial to the creation of a set of guidelines will be reviewed individually to provide justification of their need as discovered in the research process.

#### **4.2.1 Identification of Lifestyle Accommodation Needs**

The areas that contributed to lifestyle accommodation considerations balanced the reported barriers to physical activity that older adults reported through the literature, and the confirmation of many of these factors during the product research process. Although numerous individual examples were presented, effort was placed on seeking the key themes that were leading to the prescience of the barriers. One of the key lifestyle barrier themes was found to be access. Access in this thematic sense includes access defined in terms of physical place, as well as access defined in terms of physical affordance. In this way, the theme of access as a lifestyle accommodation for older adults becomes identifiable for the designer to address physical activity solutions.

The expectations the older adult should have when considering activity participation should center on satisfying the user process of interacting with the product. The interaction includes the physical interacting in use and storage in addition to the social and environment interactions that have presented barriers previously among activity systems. The fit within the user daily activities includes how they travel, their living, abilities to interact, with what they are informed, and how they start, even at the simplest level.

The potential that access to the ability to travel freely is limited creates the need to approach the home environment as a source of not only housing but mobility promotion. Because of variable conditions in older adults, the location of the solution should not limit the social abilities of the older adult, and therefore should not limit the ability to transport. This allows older adults, at a minimum, access to mobility activities within a living environment, and at best the ability to access the system within the accommodation of their lifestyle needs.

The ability to manipulate the object that is interacted with by a user to suit their lifestyle needs requires the ability to use the product in a manner that suits their preferences of use, abilities, and location, with minimal disruptions to their existing activities. To provide for the lifestyle of the older adult observed in the study thus far, requires based on purpose, these accommodations to include the need to accommodate the user's ability to assemble, store, and transport these items. To do this requires application within a population whose abilities can include those with diminished strength and ability.

An example of the storage and assembly needs found during the concept model developments was the toe grasp activity, Figure 2.1. The literature and interviews with doctors suggested that this would be a beneficial movement to promote activity. The application of the original activity through the proposed solution revealed that many of these assembly concerns would negatively affect those with functional limitations. Many loose parts that are found on the ground have the potential to be lost or misplaced because of poor sensory abilities. As the design progressed, the activity was still able to be provided through a tethering of the small object and understanding the user abilities through improvements to the applied design. The user was able to only keep up with a single tethered object which reduced the parts, simplifying set-up; the activity took on a purpose that the user could track and identify with using a target system through a variety brought about incorporating playing cards. With modifications such as these to other components, designers are able to provide the modifications to the interactions within the use of

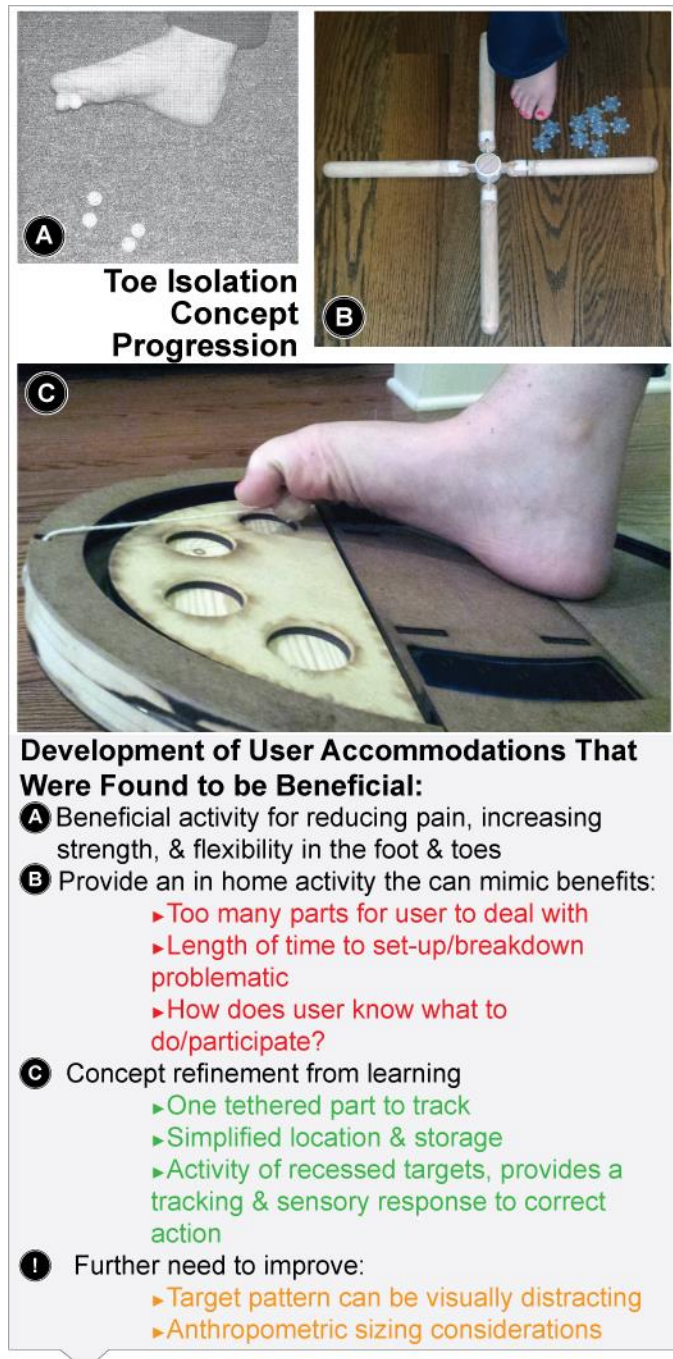


Figure 4.1 Example: Developing Older User Accommodations, Toe Grasp: Modifications for the older adult have been shown to be needed. Application is demonstrated through the design cycle of Toe Grasp Feature, A) Insight, B) Development, C) Refinement, & (!) Evaluation

the product and where it is used to benefit the promotion of mobility activity.

The considerations of the lifestyle access for older adults then shift to their expectations of the use beyond social and environment to their personal access requirements from use and participation. The use will require a starting point of capability and an ability to understand progress overall and within individual sessions as this capability changes over time. To access the greatest range of individuals, the accommodation of functional ability requires the need to start at minimum from a seated posture. This would accommodate the rehabilitative nature of this type of activity as mentioned in the initial product research (see Appendix Interviews). Then progression through the stages can occur. Some may not require this extension, but allowing for this also allows for temporary changes such as surgeries and the like.

#### **4.2.2 Identification of Mobility Needs from Physical Activity Accommodations**

The literature provided the guidance to explore the limitations from the lower body. The product research demonstrated the importance of understanding that simply recruiting the use of muscle groups was not sufficient when the goal involved the promotion of mobility, the application purpose of the muscular involvement was necessary. These needs required the additional application of the design constraint that included specificity; in this case, the specificity of beneficial movement patterns, muscles, and other body systems involved in mobility activities. The inclusion of these body regions and movements was identified as a requirement when the specific activity outcome goal involved mobility promotion in the older adult.

The additional detail of determining the activity goal need was made apparent during the interview process at the initial stages of product development. The insight from the medical staff began the process of understanding the difference of introducing the promotion as either improving walking or improving balance, because the directions of implementation would vary between the two goals. One would seek to involve instability as a means of training, and one would seek to eliminate instability as an outcome directive. Because of the desire to improve mobility in the older adult, the need to

require adaptations to allow for instability as a training specific directive would become necessary, and will be addressed in section 4.2.2.1 below.

To satisfy the needs of a training effect in activity, the focus of the activities provided has to become specific to the desired outcome of mobility. Within mobility there are training needs to satisfy that are of greater significance and are more specific to the older adult. This becomes increasingly necessary as time limitations create barriers, requiring a more specialized focus to the desired outcome, which is unassisted personal independence afforded through mobility. This is provided by focusing on how the individual can move freely in multiple directions in their environment, overcoming obstacles, all while producing a safe and efficient walking speed. Providing this type of training should additionally seek to reduce the stresses that may be present, both physically and mentally in function, as a product of accommodating the varying needs of the older adult.

For mobility, the ability of the older adult needs to progress from simply maintaining a controlled upright posture to safely manipulate his or her COG in multiple directions. Daily activities that allow for personal independence require such movements such as avoiding individuals in a crowded entryway at a supermarket. Therefore, to optimize this ability in a limited time format requires focused efforts to practice these movements to develop the necessary adaptations that will allow for the improvement or maintenance of these skills.

As the explorer Columbus showed, the world is not flat, but is comprised of elevations and obstacles that cannot be altered to allow for easier travel. Therefore, the ability to practice the abilities that allow for avoiding tripping, which can lead to the negative repercussions associated with falls among the aging, would provide a beneficial skill in a limited time format activity. The practice of these movement skills can assist older adults in transitioning their existing sensory and physical abilities into functional coordination patterns that compensate for the potential limitations among their relationships in the body.

The ability to navigate daily activities requires the ability to do so with sufficient speed, strength, power, and endurance. Because of the interaction with the ground and the forces that must be generated in a walking gait, the function of the feet and ankles should be targeted for improvement in a limited time format specific activity goal promotion of mobility among older adults. At minimum, these areas are required to produce postural stability and balance during simple upright static stances. As the need for movement becomes more dynamic, the generation and maintenance of power is needed to accomplish daily activities. The length of time that individuals can spend accomplishing these activities is dependent on their ability to produce an adaptation level of ability in their body systems to produce this performance.

The limitations among older adults go beyond their physical needs and also includes the sensory needs of translating task demands into actionable decisions in a continuous feedback loop of information processing. This is especially critical during situations that introduce increases in stress, such as those that may occur during physical activity, depending on functional levels, and those at the intellectual level, depending on their function. Therefore, it is necessary for safety considerations to include accommodation for the tasks asked to be accomplished as a constraint as to the number of tasks required for completion. By doing so, the ability to safely interpret task information and act with an accurate an appropriate response can be improved.

**4.2.2.1 Providing movements.** The needs of the activities provided to older adults have been shown to have characteristics that are found in components that have been identified as beneficial to promoting mechanics that are completed during the walking motion. The analysis of the biomechanics and the gait cycle in section 2.7 yielded the information that the function of the lower body limbs is a coordination between the functioning of neighboring body segments. The need for dynamic components was exemplified in the product research with the sketch models in section 3.3.2.2.1 with the feedback that was provided from the medical community stakeholders.

In that case, the proposed bike-pump activity for recruiting the strengthening of the muscles in the upper leg was discouraged as a method of promoting strengthening that would be relevant to mobility Figure 3.10. While isolation of a muscle group for

## Transition into Beneficial Movement Needs Development for Mobility



The need to shift from seated to weight-bearing activity transitioned one step farther during this office visit. The need to manipulate the COG was included as necessary rather than to continue to focus on marching activities.

The planes on the floor above right demonstrate the various planes that should be thought of to promote the development of dynamic balance, like the type that is necessary for older users to seek if they truly desire to remain personally independent.

*Figure 4.2 Movement Transition in Research: The final visit to Total Rehab provided clarity to the weight-bearing needs, & the speed of the science adoption. The manipulation of COG would more closely provide the functional activity for time spent participating.*

strengthening could take place and has a place in muscle development, the focus of that movement for older adults should not be the primary focus. Their time in participating in muscle activity that could benefit mobility required a more purposeful and specific movement action such as those actions that occur in a more dynamic activity. The need for a dynamic range of motion was reinforced in the additional sketch model phase in section 3.4.3 as providing beneficial activity was explored. During this area of the product research, the original observations of simply providing passive seated activity were replaced with the insights that the end goal, while potentially differing from the starting point of the older individual, was to get them up, and onto their feet in a weight-bearing capacity.

Ultimately the validation of the concepts yielded that by providing for the training effect through a progressive training process, beneficial movements could be provided to older adults. The kinetic cycle of movement expressed this point, and suggests that a strengthening pattern to the movement dynamically should be provided.



### **4.2.3 Identification of Ergonomic Accommodations**

The final area identified as promoting beneficial accommodations for designs involved the application of ergonomic factors. In order for the user to safely complete any beneficial movement, the proper considerations of the abilities of the user interaction must be addressed. The inclusion of sensory, physical, and anthropometric design considerations could lead to improving these potential product interactions as shown in both the literature and the conceptual development and validation in the product research of Chapter 3.

The benefit maintaining mobility in older age affords individuals is the potential extension of personal independence. Because of the statistical likelihood that older adults may face a period of life unassisted by others such as a spouse or family, the ability for products to accurately interact with older users becomes increasingly important. Both the individual and society can benefit, particularly financially, from providing a method of self-directed activity. The evidence that this form of intervention is preferred among many in the older population, and is equally as effective at producing decreases in the risk for falls, as approaches that include participation outside the home with additional personnel staffing suggests that all interested stakeholders in mobility promotion of older adults can benefit from considering self-directed mobility promotion strategies (Rose D. J., 2015, p. 27). The reliance on their personal abilities in self-led activities illuminates the need to provide product interactions that accommodate older adults' capabilities, which have clearly been shown to likely diminish. The capabilities, both physically and sensory, when optimized for the user, can potentially limit errors and improve use. The focus on the interactions should include those that affect the quality of the inputs received in order to provide the feedback loop decision and action process accurate information, in addition to the physical considerations that are specific for progressive mobility training to occur.

To provide the safe interactions that can be expected during self-directed activity, the interactions of the senses that interpret response that are most necessary in activity are vision, hearing, and touch. The quality of their communication can affect the reaction response negatively in older adults. The senses are also needed to provide the

information needed to move the body in these interaction. The movements require the physical application of the reductions of the aging process, especially the specific needs during mobility promotion. The range of size and ability to interact with the surroundings requires the provision of accurately sized items, at appropriately assigned levels of interaction. By applying sensory redundant features that place an emphasis on the quality of the visual needs, sensory interactions can provide the necessary physical needs of reach and clearance in solutions.

The reduction or loss in function of one or more of the sensory functions among older adults has been shown to be likely during the aging process. While many of these functions are not modifiable within the individual, accommodating for them through thoughtful design considerations is modifiable. By providing multiple methods for interpreting a product, the older adult is afforded the ability to rely on the method that best suits his or her individual capability. This also removes the need to modify products after the fact in order to allow for improved use.

The sensory input source that allows for the fastest reaction time and is the source for the greatest amount of input for decisions is vision. Because interactions with the environment of use will require the older adult to identify where to produce movements and what is needed for the task, the improvement of elements within the physical design should be improved. The areas that should be included in considering the optimization of this potentially diminishing resource should include the colors, location, and materials offered in potential design solutions. Colors that create distracting effects when used, as well as those that limit the quality of the communication of their intent, should be excluded during the design considerations for application. Two colors of similar visual wavelength that create such conflicts are the colors in the blue and violet family, and therefore should be eliminated from consideration.

Even when colors that are problematic are omitted from designs, the remaining colors and information are required to provide legible communication. The ability to improve legibility and visibility require the use of contrast. The contrast of the elements should allow for distinguishing of the elements from the background they interact with.

As the individual is asked to perform progressively challenging movements, the ability to identify objects and interpret information from the environment should occur within an area that optimizes the potential for the user to accurately locate this information. The area that contains the visual information the eye can translate occurs within the individual's field of vision. The changes occurring in the eye that effect this ability reduce the information that can accurately be viewed in the peripheral regions of the field of vision. This reduction creates a viewing field of a smaller degree. When this information is combined with the challenges to balance that can occur when older individuals are asked to visually locate information above their eye level, the viewing area is reduced further. Designs considering visual reductions will benefit the user by placing information and tasks in front of the older adult user.

The creation of hot spots can accompany the use of shiny surfaces that are highly reflective. The speed of the older eye to recover from the introduction of this effect is slowed, which creates a temporary limitation in vision similar to a temporary blindness. Material selection can reduce this effect and improve use by seeking to provide characteristics that are more matte in surface finish and texture.

The introduction of tasks that are required to accomplish to perform functions, movements, and other aspects of the product features should understand the effect that short-term memory plays in the achievement of these activities. The memory necessary to perform a task can be reduced if the tasks are appropriately timed. Increasing the time in between the completion and demand to act creates the potential for users to potentially forget to take the next required action. Therefore, the tasks should create a pattern of use that incorporates an immediate act and response approach to limit potential user error in the older population.

The physical considerations also should include the variability in the sizes of the individuals in the population. This should specifically include the considerations that are required for older adults to perform the movements and interactions required in the use of potential design solutions. These solutions should also account for the need to provide for the accommodation of functional physical abilities needed to provide progressive activity training that are based on individual capabilities. The

accommodations should include those who require seated, or supportive, assistance as their abilities progress. The features should consider the reach and clearances necessary to perform movements and use features.

The limitations to the flexibility and dexterity of the older adult can negatively affect their ability to perform activities that are placed in areas outside their reach. These situations can affect their balance as the COG is asked to extend beyond a safe zone of control. Additionally, the ability to operate essential features and make adjustments can be compromised when designs fail to consider the placement of the interaction. To limit these concerns, the characteristics of the product that require interaction should be designed to include the widest range of users. When reach is considered, the individuals that would have the greatest difficulty reaching within a zone of operation would be those who are the smallest in stature. The data identifies these individuals to be female with a user profile that falls within the 5<sup>th</sup> percentile of the population.

During use, size envelopes will require the use of openings, and potential obstructions should be considered. These envelopes of use should accommodate for the clearances needed for comfortable and safe operation for task accomplishment during movements. To avoid unintended contact that could create problems in use, the application of accommodation should consider the widest possible range of potential users' sizes. With clearances, those individuals who are largest in stature are the group that would have the greatest potential for conflict. Therefore, the design solutions should include the accommodation of the largest segment of potential users, the males falling within the 95<sup>th</sup> percentile of the population.

The information from the findings of this section represents the considerations that have been identified during the research process from both the existing literature and the knowledge gained during the product research process. The information that has been found in this research process to be significant to the promotion of mobility in older adults. This information is intended to assist designers that are seeking to create systems that are focused at this specific population, with the specific desired outcome of promoting mobility among older adults. That information will be used to create a set of guidelines that designers can potentially use to create potential design solutions that

promote mobility activities among the older adult population. The elements that comprised the accommodations within the lifestyle, mobility, and ergonomic areas of the older adult will be itemized into categories that share similar consideration characteristics for the older adult guidelines.

## **Chapter 5 Design Guidelines for Mobility Products**

Product designers may refer to the guidelines provided in the following individual sections to implement strategies that can assist in the design of products for older adults. The guidelines are arranged into three sections: Lifestyle, Mobility, and Ergonomic Accommodations. Use of the guides will require cross-identification of some factors as they interrelate with one another to fully describe the factors necessary. Implementing these guides can allow for improved mobility design solutions for the older adult defined as chronologically age 50 or older.

The guidelines represent an approach that was found to be beneficial for designers when considered. The collection of guidelines do not represent the only possible way to achieve this result for designers; they represent a path that was found to be successful in this pursuit.

### **5.1 Lifestyle Accommodations Guidelines**

The initial application of guideline accommodations involves the Lifestyle of the older adult. The goal at the completion of the application of this section of guidelines will satisfy accommodations that will promote factors that can enhance the use of the designed product into the daily life of the older adult. To accomplish this, the guides seek to simplify the use of the product in the older adult's activities, considering the location(s) of use. The remainder of the guidelines in the Lifestyle Accommodation section seek to provide enhancement of interaction and use of the product based on providing considerations of the older adult's user abilities.

#### **5.1.1 Lifestyle Accommodation Guideline: Set-up**

*Design Guideline: The design should easily set up and break down without the need for special tools for use in the home living environment.*

### **5.1.2 Lifestyle Accommodation Guideline: Transportability**

*Design Guideline: The design solution should be easily transportable for use in another location.*

### **5.1.3 Lifestyle Accommodation Guideline: Weight of Solution**

*Design Guideline: The design solution should provide handles and should not exceed a weight of 25lbs (11.34kg).*

### **5.1.4 Lifestyle Accommodation Guideline: User Interaction**

*Design Guideline: The application of materials in the design solution should provide obvious user interaction for the ability to see, hear, and feel.*

### **5.1.5 Lifestyle Accommodation Guideline: Tracking System**

*Design Guideline: The design solution should provide a tracking system to inform the user of his or her status in the use of the solution*

### **5.1.6 Lifestyle Accommodation Guideline: Seated Foot Isolation**

*Design Guideline: The design solution should afford the ability to isolate a single foot during the performance of a seated activity*

## **5.2 Mobility Accommodation Guidelines**

The accommodations the older adult benefits from that involve mobility are based on movements that provide enhancements to the functional abilities that are beneficial to the performance of the lower body. These role of these movements is meant to enhance areas of the lower body that are negatively affected by the aging process that are beneficial to the contribution of mobility mechanics.

### **5.2.1 Mobility Accommodation Guideline: Center of Gravity Manipulation**

*Design Guideline: The device should provide movements that manipulate the center of gravity in a minimum of 2 planes*

### **5.2.2 Mobility Accommodation Guideline: Obstacle Clearance**

*Design Guideline: The device should provide an obstacle clearance movement with 3 or more difficulty levels*

### **5.2.3 Mobility Accommodation Guideline: Ankle Function**

*Design Guideline: The device should provide movement so that the full range of motion of the ankle is utilized with the affordance of increasing resistance*

### **5.2.4 Mobility Accommodation Guideline: Isolated Toe Extensor Function**

*Design Guideline: The device should provide movement that isolates the toe extensor muscles for developing strength and flexibility*

### **5.2.5 Mobility Accommodation Guideline: Limits to Movement Tasks**

*Design Guideline: The device should provide movements that are limited to 4 or fewer tasks at a time*

## **5.3 Ergonomic Accommodation Guidelines**

The final section of accommodative design guidelines places focus on improving the Ergonomic factors that are beneficial to the designs utilized by older adults. Within this section, focus is placed on the needs that benefit sensory and physical functions. The enhancement of the sensory functions place a focus on the input factors that benefit functional limitations that have been identified as potentially diminished in ability among the older adult population. In the same way, the physical abilities that can potentially diminish with age are identified to enhance the design solutions that are implemented.

### **5.3.1 Sensory Ergonomic Accommodation Guideline: Sensory Provisions**

*Design Guideline: A minimum of 2 out of 3 sensory inputs must be provided within the design solution. The input hierarchy of vision, hearing, & tactility should be followed*

### **5.3.2 Visual Ergonomic Accommodation Guideline: Elimination of Blue & Violet Colors**

*Design Guideline: The use of blue and violet colors with short-wave length characteristics should be eliminated*



### **5.3.3 Visual Ergonomic Accommodation Guideline: Contrast Ratio**

*Design Guideline: The contrast ratio of 7:1 should be applied to the use of high luminance colors against low luminance colors, or vice versa*

### **5.3.4 Visual Ergonomic Accommodation Guideline: Field of Vision**

*Design Guideline: Objects should be located in front of the user within 140 degrees of vision field, and should be placed at eye level or below*

### **5.3.5 Visual Ergonomic Accommodation Guideline: Surface Reflectiveness**

*Design Guideline: The use of reflective finishes and materials should be eliminated*

### **5.3.6 Cognitive Ergonomic Accommodation Guideline: Task Response**

*Design Guideline: Immediate action and response should be used for tasks performed in an operational format*

### **5.3.7 Physical Ergonomic Accommodation Guideline: Reach**

*Design Guideline: Reach should minimally accommodate the 5<sup>th</sup> percentile female user*

### **5.3.8 Physical Ergonomic Accommodation Guideline: Clearance**

*Design Guideline: Clearance should minimally accommodate the 95<sup>th</sup> percentile male user*

## **Chapter 6 Application of the Design Guidelines**

The created design guidelines for older adult mobility products will be applied to a potential scenario exemplifying their use. As the focus of the guides is to aid in the front-end of the product development process, the solutions presented will be conceptual in nature. The application presented represents a potential solution; the conceptual solution that results from the design guideline application does not represent the only possible direction nor solution that is capable of satisfying the design guidelines. Rather than suggesting the presented concepts represent a single solution, the evaluation will place a focus on the assessment of a single component within the activity system. It is assumed that the evaluation of the remaining components would yield similar results based on their application to the designed beneficial movement intend to offer the older adult. The goal of the evaluation is to provide designers insight through demonstrated application as to how to apply the guidance to their own design projects that have a similar desired outcome within the older adult population. The evaluation of each of the categories will demonstrate the findings as they have been found to be necessary through the literature and product identification within the study.

### **6.1.1 Concept Component Evaluation with Design Guidelines**

The created guidelines were used to perform an evaluation of the obstacle component of the potential solution. The evaluation will provide the designer the opportunity to apply the guidance offered through the individual considerations to their designs in the concept development cycle. The evaluation will also present an example of how designers in the future can implement the guidelines into their design process when they seek to create solutions for the aging who require mobility promotion. The design concept will be examined against the three categories of accommodations provided in the guidelines. The information that results from the evaluation will be offered as recommendations that can be utilized to guide future design changes to the concepts.

As a reminder, the need to provide progressive training through the intended movements should seek to allow for an improved path to reaching a training effect that is required for beneficial adaptations in the specifically targeted body systems of the older adult to achieve the greatest potential for benefit to their mobility promotion. This is necessary to understand throughout the evaluation process of the obstacle component utilizing the design guidance provided in Chapter 5.

### **6.1.2 Component Evaluation with Design Guidelines: Lifestyles Accommodations**

The application of the Lifestyle Guidelines place the focus of the user interactions with the system and the ability for the system to transition smoothly into their daily needs and roles as they age; the user of the obstacle performance will be evaluated.

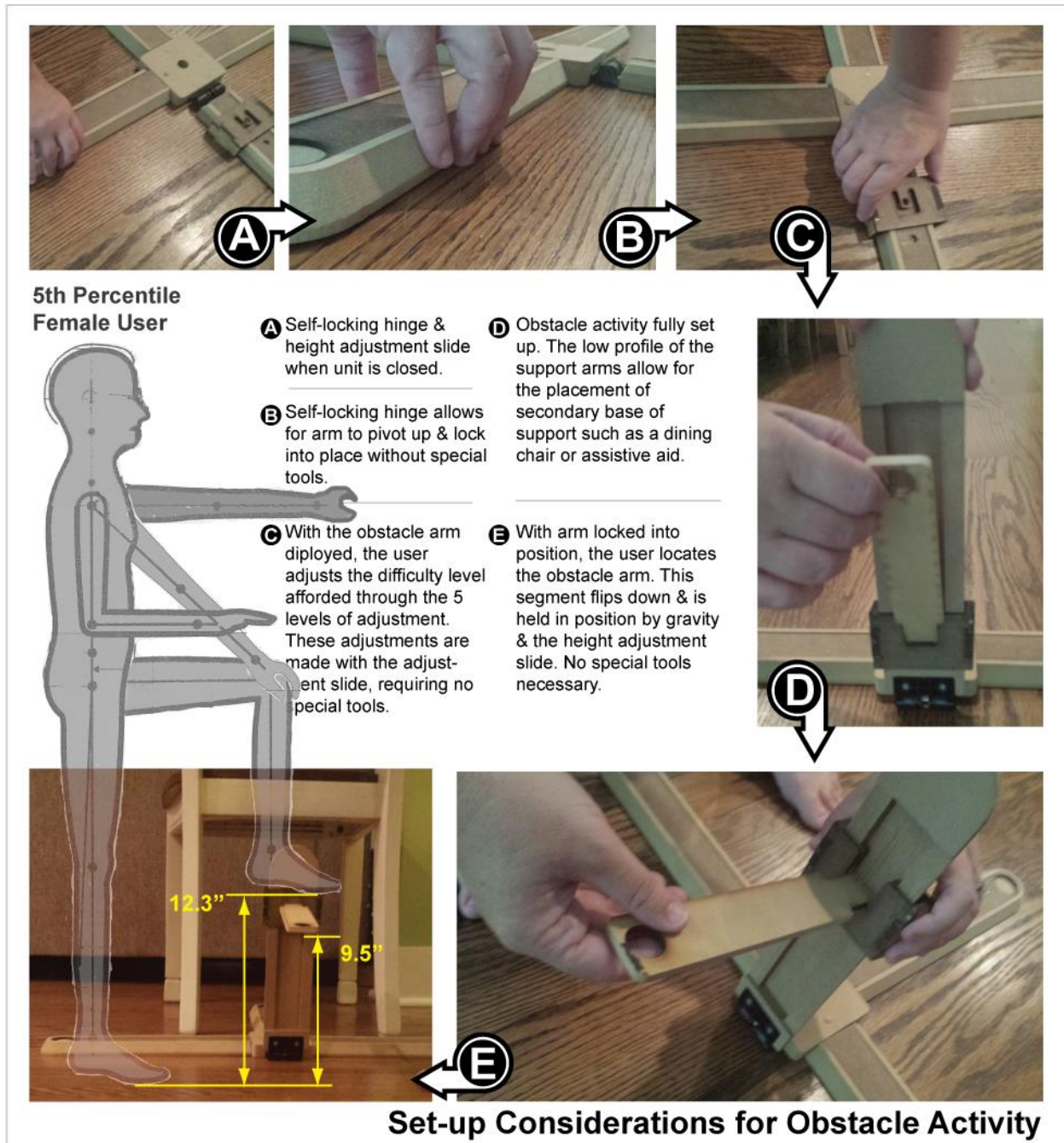


Figure 6.1 Set-Up Considerations. The process for the user to configure the device is outlined. The ability to not require tools as well as accommodate the 5th percentile female regarding clearance needs are addressed.

**6.1.2.1 Lifestyles accommodations evaluation: set-up.** The evaluation of the obstacle component evaluates the performance of the ability for the user to set-up and breakdown the component, see Figure 6.1. The first observation of the evaluation notes that the use of special tools does not appear to be needed in the operation of the device.

Without requiring additional tools, additional purchases and steps to interact with the solution are minimized. The minimization of the necessary set-up tasks limits time expenditure on these tasks, which has been noted as limited by older adults when activity participation is involved. To further reduce time waste, the evaluation of the capability of the solution to allow for in-home use is noted to be satisfied. By limiting set-up time, and reducing time lost in travel to participate in activity, the presented solution appears to provide the necessary accommodations to improve its potential use among the older adult population.

**6.1.2.2 Lifestyles accommodations evaluation: transportability.** The ability to transport the device is allowed for by the size and weight of the currently presented offering. The size of the object is 24” (60.96cm) in length at its longest point; with these dimensions, the device provides the ability for a user to enter and exit standardized interior and exterior entry doors found in the building codes used in both residential and commercial applications in the US.

Similar expectations for travel through transportability of the component can be expected as the need for travel within the lifestyle of the older adult sometimes requires. The size provided in the obstacle component should be expected to satisfy the needs for the device to enter and exit thresholds encountered in motorized transportation such as cars or buses. Because these types of transportation should be expected to be available to older adults, the need for solutions to allow for this finding of the research should allow for the satisfaction of these needs.

**6.1.2.3 Lifestyles accommodations evaluation: weight of solution.** The evaluation of the characteristics of the obstacle component require the definition of the overall weight that is present in the component parts of the design solution. By using a scale, the measurement of the individual obstacle component and its parts find that the weight is 3lb (1.36kg).

The satisfaction of the weight of this component of the design guideline affords the user interaction a level of satisfactory weight expectation when lifting the object. Keeping the weight to a minimum will also assist the first guideline on simplified set-up by reducing

## Sensory Feedback During User Interaction

Examples of the application of redundant sensory feedback cues within the operation of the Obstacle Activity.

Applications should seek to provide for the visual aspects first in the hierarchy, with a minimum of a second feedback source to guide the user to key elements of needed interaction.

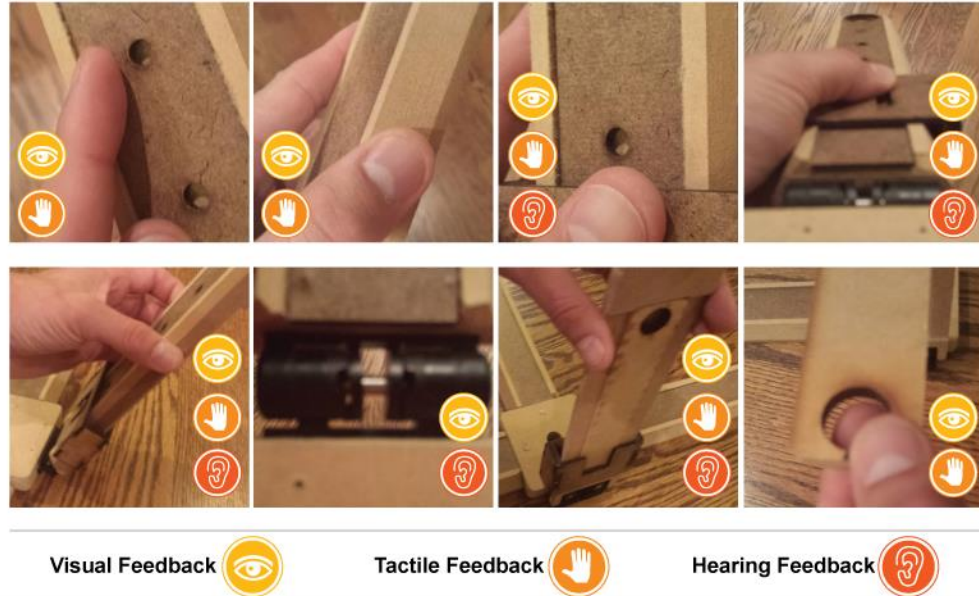


Figure 6.2 Seeking Sensory Redundancy: The need for providing 2 or more sensory feedback sources has been shown to be beneficial to improve the accuracy of the information received. The observed interactions are outlined in the evaluation of the Obstacle Activity.

unnecessary energy expenditure during that process. The need for older adults to lift objects was shown to require accommodation by the research findings suggesting that the reduction of the capacity for strength and dexterity in the aging process in section 2.8.2 and again in chapter 3, should be expected by designers creating design solutions. Limiting weight can help this process by reducing the potential of injuries caused through overexertion. Improvements to the self-confidence beliefs within the older adult can benefit from reducing apprehension of using a product that they are not comfortable handling. From a lifestyle accommodation, the limitations of excessive weight make the solution easier to use.

**6.1.2.4 Lifestyles accommodation evaluation: user interaction.** Application of user interaction within the lifestyles guidelines requires the designs that are created to utilize obvious communication through their material selections. The evaluation of the present concept will look at the three communicative modes, vision, tactile, and sound, with the selections that were applied, Figure 6.2.

With vision, the communication of the areas that are intended to use to complete the task of obstacle clearance are evaluated first. The activity requires the ability to adjust the height to a minimum of three levels of variability; to allow for this variability, the user requires the ability to have some form of interaction that allows for the selection of the difficulty level to be adjusted to their current level of need. This guidance to interaction visually is provided through the use of an asymmetric difference in the look of the arm that contains the adjustment mechanics that allow for the difficulty setting required of the device. The visual difference this feature provides helps guide the user to the understanding that this region, although similar in material and shape application, has a different function; this is caused by the grouping of these feature elements on the arm section of their intended use. This form of visual communication will ease the set-up time by visually guiding the user to the location necessary for adjustment.

The tactile needs are provided for by two means, changing the texture on the materials used in a smooth/rough texture combination, and recesses on the surface that communicate the position of the mechanical slide. To create the first texture, a rough texture and a smoother texture combination is employed. This difference in texture suggests to the user that the different areas of the surface represent different areas of interaction for the user. The rougher surface along the outside of the arm that needs to be picked up during setting use provides a greater ability to grip the surface through an increasing of surface area; the increased surface allows for the limiting of slipping of the fingers during interaction. The recesses that provide a seat for the slide mechanism also allow for the user to feel the number of setting steps that are remaining in either direction of path the mechanism travels along; these recesses are a change in the surrounding surface which can translate a feedback to the user that the slide is located in a particular position.

The ability to hear the selection made is provided from a sound produced from two hinges: a locking hinge and a living hinge. The locking hinge provides the user the ability to pivot the arm from the ground plane to a vertical position; in this position, the hinge clicks to lock into position, producing a feedback sound for the user to understand the completion of this motion. From this vertical position, a second interaction allows

the user to then select a difficulty setting. By moving a slide that travels in a linear path to multiple setting positions, the user is able to vary the difficulty by sliding the mechanism that incorporates the second hinge which is a living hinge. This living hinge allows the vertical setting of the difficulty needed for the requirements of an obstacle in section 5.2.2

The hinge locks the selected difficulty setting in place; to allow for setting movement the slide travels between settings, the living hinge flexes upward. When the slide reaches the next difficulty setting, a click is provided for by the slide as the living hinge comes to seat in the recessed cavity. The click that is provided allows for the redundant sensory feedback combination needed in section 5.3.1, the sound of the click and the visual location of the setting for the user.

By applying three forms of sensory feedback, older users who may possess limited function are provided a greater range of sensory input from their interactions with the system. The redundancy of features has been shown to be beneficial to the improvement of the communication the aging can rely on without requiring additional acknowledgement of deficiencies; these features are applied for them through designer selections seeking to accommodate.

**6.1.2.5 Lifestyles accommodation evaluation: tracking system.** The evaluation of the ability to track activity occurring during participation was next to evaluate. The ability to monitor progress is provided through a slide mechanism that sets the mechanism into place. The level of this adjustment provides the user feedback that can be tracked as to the difficulty setting that is in place for the obstacle clearance during the session of use. The height of the obstacle as it raises provides the user encouragement through visual tracking of progress during the time spent in the activity. The visual progress and encouragement can assist the designer in creating an ability to provide self-confidence building among the user.

Along with the other features, the utilization of the playing card system is the overall tracking system that is in place for the activity. Here, the user draws the card to provide



the action needed, the number of repetitions, and the user tracks the completed repetitions performed as seen in Figure 6.7, and 6.8.

**6.1.2.6 Lifestyles accommodation evaluation: seated foot isolation.** The need to provide for the seated foot isolation was intended to allow for those with functional limitations the ability to participate, and gradually build their ability. The method that allows for this is the progressive training approach that was suggested later in the sketch model phase. The goal is to get the older adult on their feet, in a weight-bearing independent nature. Because of this, the various heights that can be established to clear the obstacle were established, to accommodate the various positions in activity progression, and abilities that may be present. The various heights showed in Figure 6.3 allow both the most able of those with the smallest stature, the 5<sup>th</sup> percentile US female, and those who may be larger in stature but not as physically able the ability to participate.

Although the obstacle allows for the accommodation for seated use, the goal of the activity is not fully expressed in the seated foot isolation guidance. This type of activity would have more of a role potentially with movements that focus more closely to the ankle function. As it has been previously stated, the ability for a singular solution to provide all movement patterns may not be feasible; this requires a secondary feature to accomplish this task. Within the presented solution accommodation for this movement was provided for in another activity, the platform activity that first drove the product research process in the initial direction establishment in section 3.3.

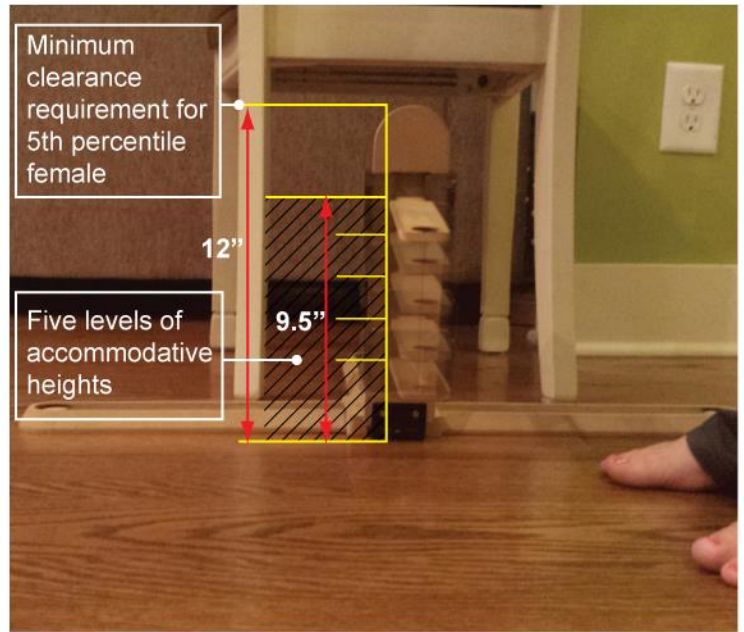
### **6.1.3 Component Evaluation with Design Guidelines: Mobility Accommodations**

The evaluation of the design guidelines that focus on the mobility accommodations were applied to the proposed obstacle activity design concept. In the guidelines, the goal of the solutions it to provide the older adult user the opportunity to develop gains in the functions that benefit the mobility of the lower body of the user. The ability to provide all movement patterns within the use of a singular, all-encompassing design solution may not be feasible; therefore, the application of several systems that provide for these

## Accommodations for Obstacle Clearance Activity

The obstacle activity requires the ability to accommodate users of multiple functional levels.

These levels accommodate the smallest stature population



*Figure 6.3 Obstacle Clearance Accommodations: The ability to accommodate the variable function of older users requires the demonstrated adjustability.*

individual movement pattern needs may need to be employed. In this potential solution, the use of several systems was employed to provide for these movement patterns. This evaluation places the obstacle clearance movement as the pattern that will be examined for its provision in accordance to the design guidelines.

**6.1.3.1 Mobility accommodation evaluation: obstacle clearance.** The necessary movement patterns that promote mobility in older adults requires the provision of the movements through the designs offered. Evaluation of the movement pattern proposed to be offered in the conceptual component of this device placed focus on the obstacle clearance movement pattern presented in the design guidelines for mobility.

The need to accommodate the variability of physical function likely to occur in the older adult requires the ability for the modification of the device to match the capability of the intended user. This was stated in regards to the obstacle clearance activity during the design review interviews; the movement is beneficial, as the staff attempts to prescribe it to their older clients, but there is an apprehension to the performance of the activity by

the older user (Evans & Mann III, 2014). The ability to provide potential to overcoming these barriers was stated in the literature of section 2.11, provide accommodations. Therefore the guidelines attempt to provide for these concerns regarding performing an obstacle activity by accounting for the variability of function and emotional state regarding their performance through variable challenge levels.

Within this design concept, the attempt to provide such accommodation appears to exceed the minimum needs required to satisfy this guidance. The minimum need set forth in the guidelines places a need of three levels of difficulty be afforded through the design solution; the maximum height of the obstacle however must satisfy the clearance ability of the 5<sup>th</sup> percentile US female, see Figure 6.3. The evaluated example provides for the allowance of the user to set the difficulty level at five such levels, satisfying the guidance of the mobility accommodation of this movement pattern. Additionally, the maximum height for the obstacle is 9.5 inches, which is less than the 12 inches of clearance required by the 5<sup>th</sup> percentile female. The additional settings allow for the adjustment of difficulty levels at smaller increments which creates smaller step levels between level settings. The smaller increases in difficulty settings can allow the user to progress at smaller levels of challenge between changes in settings, offering progressive training that is less dramatic in expressing change of challenge to the user; this could assist the limiting of user apprehension discussed as problematic throughout the study.

#### **6.1.4 Component Evaluation with Design Guidelines: Ergonomic Accommodations**

The final category within the design guidelines places emphasis on the accommodations necessary in the products designed for older adult use to include ergonomic modifications in the sensory and physical interactions with the solutions. The evaluation of the component that focused on the obstacle clearance functions were evaluated against the set forth guidelines to determine their performance against them.

**6.1.4.1 Ergonomic accommodation evaluation: sensory provisions.** The first evaluation of the ergonomic design guidelines seeks to analyze the provision that the inclusion of multiple sensory feedback sources are in place for the user; this guideline

seeks to improve through redundancy the sensory feedback that is offered so that accurate input information is received. The redundant sensory feedback that is provided through the materials has been covered in section 6.1.2.4, and a more detailed review can be found there along with review of Figure 6.2.

**6.1.4.2 Ergonomic accommodation evaluation: elimination of blue and violet.** To

satisfy color application needs, the design guidelines seek for solutions to eliminate the application of blues and violets within the materials and color selections made. The use of these

short-wave colors were shown to be problematic in communicating clear legibility of the intended task demands, see Figure 6.1. These colors are also likely to be misidentified because of the yellowing of the lens of the eye, creating a color that can be interpreted incorrectly; these colors could include the blue of a control to be interpreted by an older adult user as green. This is a result of the blue component and the yellow lens of the eye inaccurately applying a perception of a green color to the user. The evaluation of the obstacle components shows that the negative interpretation of the short-wave colors does not occur because its presence has been omitted from the potential solution, satisfying this guideline.

**6.1.4.3 Ergonomic accommodation evaluation: contrast ratio.** The application of graphics and materials in the design solutions require the ability to improve the legibility of the visual communication through a provision of contrasting. The contrast between the foreground and background when at high levels can reduce

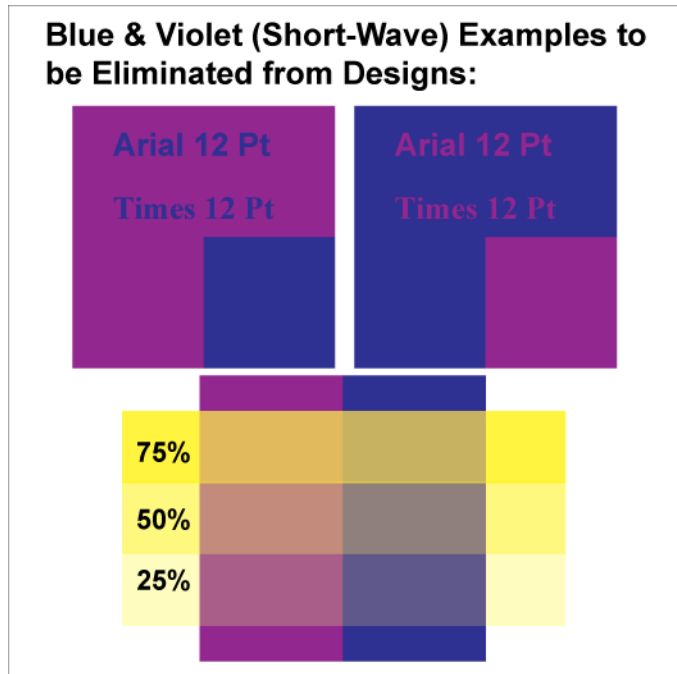


Figure 6.4 Elimination of Blues & Violets: Negative Interactions with Yellowing Lens. The use of the colors of blues & violets should be eliminated. They have been shown to be difficult to see due to their short-wave length. The yellowing concerns displayed below.

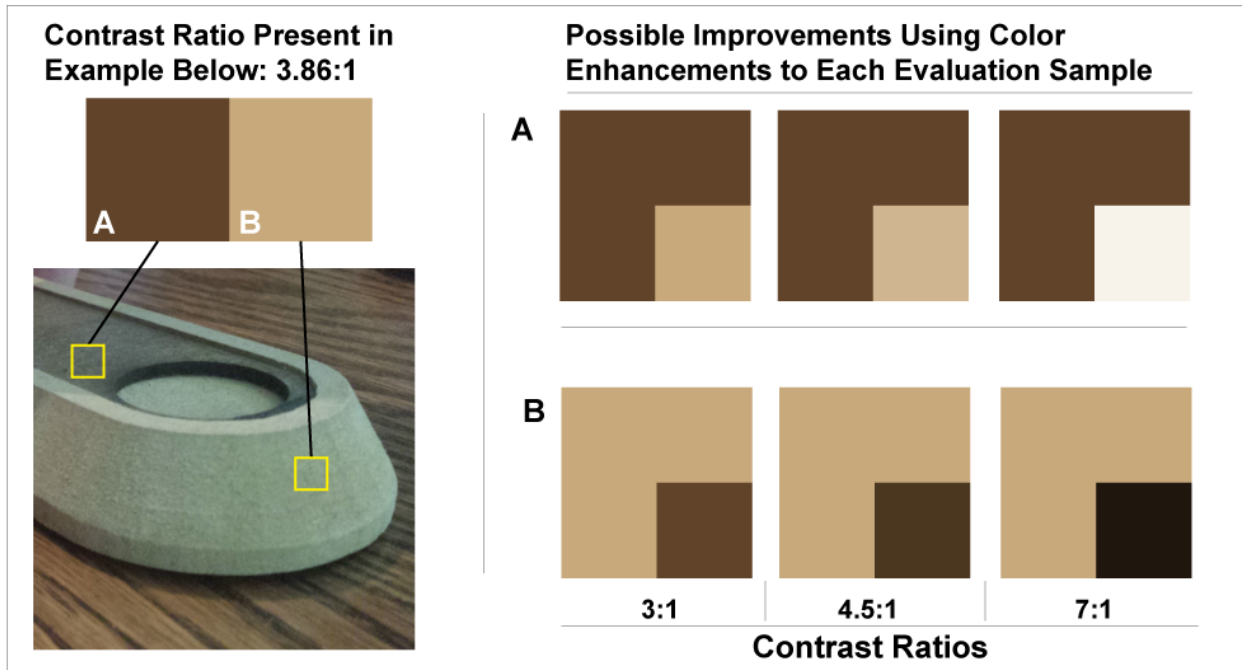


Figure 6.5 Evaluation of Contrast Ratio & Suggestions: The contrast ratio was found to be 3.86:1 in the evaluation. Suggestions are provided to the right for both Color Samples A. & B. if they were necessary to use going forward.

the misinterpretation of the information that is to be communicated. The contrast of the system and the surrounding environment can additionally assist the user determine the location of the system more accurately. While the control of the contrast ratio and the surrounding environment cannot be controlled, the ability to provide this provision within the product is possible, allowing for the accommodation modifications that were recommended to be included in the products in section 2.13.

The contrast ratio provided in the obstacle clearance concept reveals that there is a relationship between the tones of wood products that were applied in a light and dark format of brown colors. To determine the ratio, the colors were entered digitally into an online ratio calculator tool, Color Contrast Checker; the purpose of this website and similar sites, is to provide the developers of websites the ability to test color combinations in their designs against the adoption of World Wide Web Consortium (W3C) guidelines (Snook, 2015; Juicy Studio, 2015).

These formulas generate data that rates the proposed color combinations of foreground and background colors against visual display standards that are becoming adopted by websites to ensure that those with visual deficiencies are provided legible visual information. Numbers that represent the color formula, the components of the color, are entered for each the foreground and the background colors that are to be used and the resulting contrast ratio is provided.

When these brown colors present in the design were entered, the results were produced. These results found that the lightest color (#FF9966) and the darkest color (#993333) produced a 3.48:1 contrast ratio relationship. Although the contrast ratio at this level would satisfy the Web Content Accessibility Guidelines (WCAG) 2.0 guidance for large text (18pt or larger) for visual displays, the ratio would require an increase in the levels to produce the required color contrast ratio for normal text on visual displays (Snook, 2015). If the brown colors were necessary to remain as a part of the design, the use of the lightest and the darkest would represent an example of a full satisfaction of the contrast ratio. This does not suggest that the use of brown is the only design possibility, it merely suggests that color combinations used should require a higher contrast ratio application to improve the visual communication. This is especially true if the designer feels that lighting control of the intended environment is not easily manipulated to increase the illumination of the area of activity. Higher contrast ratios can assist the older user built-in accommodation if designers are able to identify these needs and address them.

This is especially necessary as the intent of the design guidelines is to provide the older adult user the independence of not requiring secondary assistance in the form of a trainer to make these choices for them, as was shown to be the case in many of the previously successful program interventions in the literature. The ergonomic fit through improved contrast can make the solution safer to use, which has shown to be necessary in self-led programs, as well as easier to use, which assists their lifestyle needs as well.

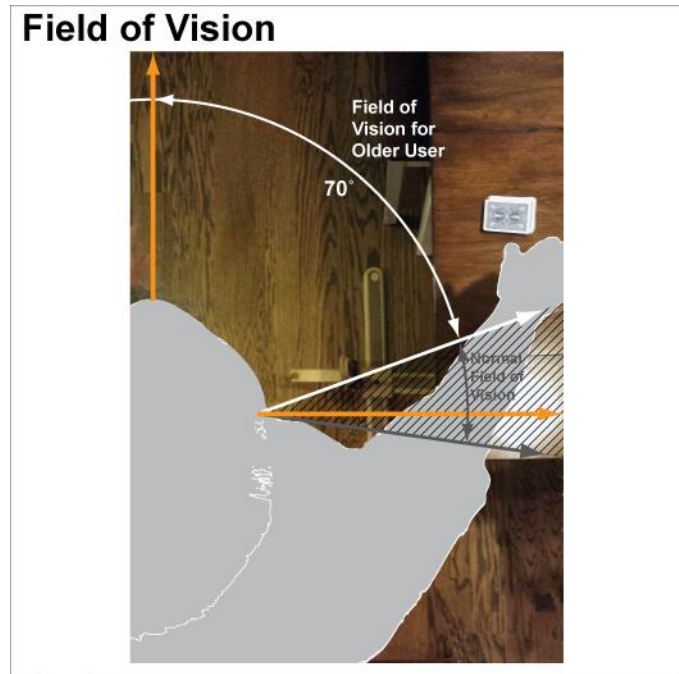
**6.1.4.4 Ergonomic accommodation evaluation: field of vision.** To continue with the visual considerations the guidance seeks to provide, the evaluation includes the observations made regarding the use of the obstacle component of the system and the

visual field guidance. The system was set-up to simulate the intended location and use that would be expected of the user; the proximity of the components were then measured to determine the location within the visual field that these interactions would potentially take place. When set-up and starting the task, the initial observation is that the components are all located below the eye level of the older adult user, which satisfies the

need of the design solutions to be located at eye level or below. By locating the system below the eye level, the designer can be confident that the suggested complications found in section 2.13, such as losing balance because of disorientation, that can occur when an older adult is asked to look above eye level would be minimized or eliminated with design solutions that are placed on the ground plane.

The other area that needs to be evaluated within the design guidance of field of vision covers the viewing angles that can be expected during operation. With the system placed, the user would be positioned in the quadrant closest to them to begin the activity; this would apply if the user was utilizing their left or right leg, the starting point would be the area closest to them. With this starting position, the designer can expect the user to have the unit fall within the 140 degree viewing field.

**6.1.4.5 Ergonomic accommodation evaluation: surface reflectivity.** The materials and finishes applied to the surfaces of the unit should seek to eliminate those that have reflective characteristics; examples of these reflective characteristics would include polished chrome or glossy paints where the finish produces a shine which



*Figure 6.6 Field of Vision for Users: During the aging process, the sensory changes to the eye reduce the size of the field of vision to 140 degrees. This requires the placement of activities to accommodate this reduction.*

produces hotspots of highlights on the surface of the features that possess these finishes. The evaluation of the obstacle concludes that the finishes present are minimally reflective, producing only minor satin-style reflections of ambient light. By eliminating these hot-spots, the aggravation of slowed color adaptations of the aging eye would be reduced. These effects were seen to be aggravated by sudden transitions from bright to dark, such as walking inside on a bright day into a dimly lit interior room; this effect can also be seen in photography as a flashbulb effect, where the sudden temporary blindness occurs, and remains until the eye adapts.

**6.1.4.6 Ergonomic accommodation evaluation: task response.** The sensory guidance evaluation now transitions from the visual, tactile, and sound inputs and moves toward the internal processing of this information through the cognitive senses. The guidance component in this area seeks to limit the stresses that are introduced to the older user in the form of the information or tasks that are asked by the device to be completed to satisfy the activity. This was shown to be of importance in the older population because of the limited physical function that may be present, becoming more stressed based on the tasks that were asked to be completed. When these tasks become to numerous, the quality of the short-term memory that is potentially negatively effected in the aging process can be reduced further. The additional mental stress can lead to potential user error through steps of the task process becoming omitted by the user, which can lead to user error and in the case of physical activity increase the potential for falls or injury in the older user.

In the evaluation of this guidance against those tasks required obstacle clearance, the sequence of intended use was analyzed. The sequence of the intended use was broken down into the steps needed to complete the operation. The sequence breakdown observed that a task pattern of (1) draw playing card, (2) locate obstacle position, (3) step over obstacle, and (4) return. The receiving of the task demand (1) is followed by the identification of the challenge placed (2) which is executed by the user (3) and then repeated based on the instruction (4). The steps needed to complete the task are then seen to satisfy the design guidance to limit the demands placed on the older adult. In this way the activity simulates a situation that may be placed in the daily activities of the



## Task Response Sequence of Obstacle Activity



Figure 6.7 Task Response: The ability to limit the number of short-term tasks is desired. The ability to have these tasks carried out in an "act & respond" method limits the possibility of forgetting the task to be accomplished.

older adult; an example could include asking for guidance on a city street as to the location of a store. The instructions to the location are given, the identification of the presence of a curb is identified, the elevation change is cleared as the foot is placed, and the adult continues onto the desired location.

**6.1.4.7 Ergonomic accommodation evaluation: reach.** The ergonomic guidance shifts from the sensory needs to the physical requirements of the system to allow for the safe use of the system. To allow for the widest range of sizing accommodations for the reach and the clearance guidance that follows in section 6.1.4.8 and Figure 3.18, the identification of the individuals who would require the maximum amount of accommodation is necessary to understand. Provisions are based on the group that would be seen as the least able to possess the size necessary to complete the task. The provisions additionally require the identification of the regional information of the intended user population. In the scope of these physical accommodations application, this group is regionally identified as the US population, both male and female. By

selecting the region, the data used will more accurately represent the size characteristics of the population.

In this way, the reach accommodations require the inclusion of the least able to reach an inappropriately sized object, those with the smallest size stature the 5<sup>th</sup> percentile US female user. The capability of the 5<sup>th</sup> percentile user to reach an object is based on the size range of the limbs and their ROM that is available at the given joint to complete the necessary tasks. Because of the smaller stature, users in this group would require the object interaction to occur at a closer range than those who are larger in stature.

In the evaluation of the obstacle clearance, the observations require the identification that the interactions occur within the 5<sup>th</sup> percentile US female user. Because the movement asks the user to complete a stepping activity that includes the height of an obstacle, the height of the obstacle must be designed to allow for the 5<sup>th</sup> percentile US female to step over the object within a ROM that falls within the capability of their hips and knees. These body regions are necessary to complete the kinetic chain activity that would simulate the clearing of a stair step for example.

The reach considerations also have to allow for the ability of the upper body limbs to reach the objects that need to be interacted with. The upper body reach considerations need to include the interactions with the objects on the ground as well as those interactions necessary to communicate the task demands from the playing card method of act and respond. Because of the need to accommodate those individuals that require the use of a seated stature, the reach considerations should be measured ensure the guidance satisfies the 5<sup>th</sup> percentile US female in this manner. The ability to move and place the obstacle device near the area that activity is desired to take place allows the user to make the comfort adjustments that allow for interactions to occur within a comfortable reach zone. The comfortable upper body reach zone of the 5<sup>th</sup> US percentile female is included by providing the ability of the low threshold profile of the device to be placed near a location that the playing cards can be placed on, such as a dining room table. Because both the playing cards and the device can be moved and placed where they are comfortable to reach, the ability to satisfy the reach considerations of the 5<sup>th</sup> percentile US female user can be achieved.

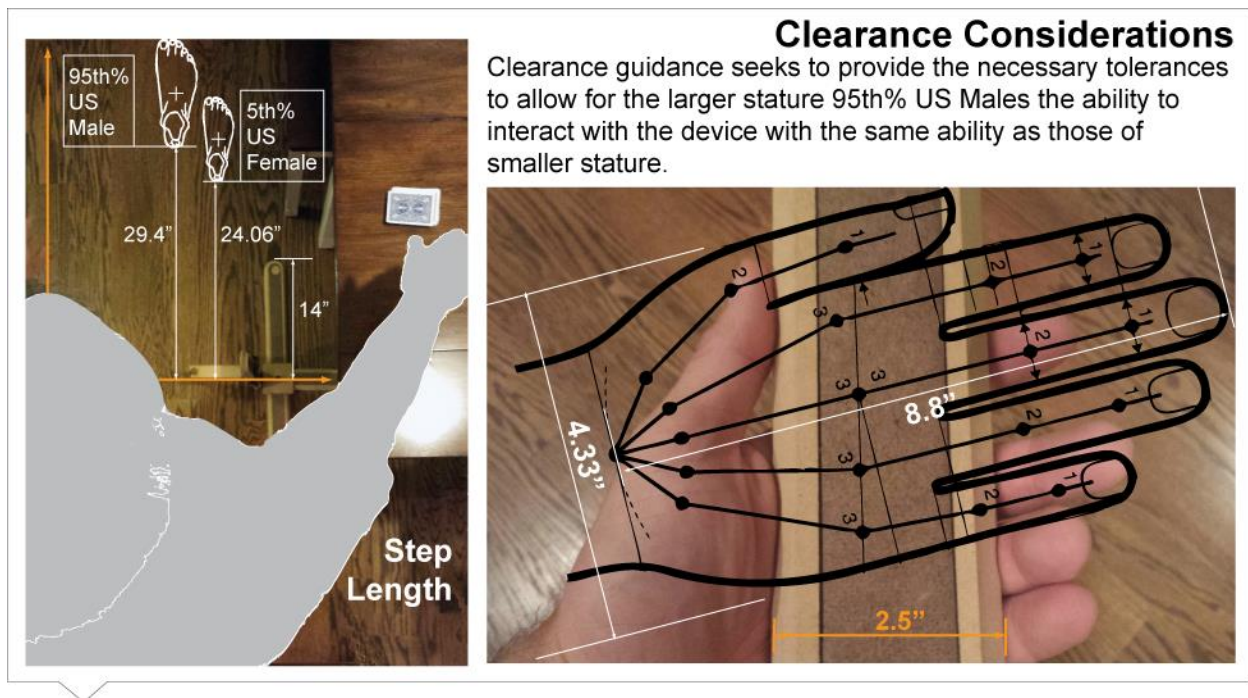


Figure 6.8 Clearance Considerations for Users: The interactions that occur with the largest stature users, the 95th% US Male, allow for the minimization of inadequate tolerances within the product. This improves use for all users.

#### 6.1.4.8 Ergonomic accommodation evaluation: clearance.

The final ergonomic and physical accommodation that is evaluated in the obstacle system is the need to provide the 95<sup>th</sup> percentile US Male the necessary clearances to safely interact with the device. These clearances include those that occur in both the lower and upper body interactions of the task. Because this group possess larger size characteristics in the body parts, additional space and tolerances are needed to prevent unintended interactions that interfere with the fit. The additional clearance is needed to account for an increased step length in the lower body, and the capability to manipulate objects with the hands in the upper body interactions.

Because the height of the obstacle allows for the 5<sup>th</sup> percentile US female to safely use the device the ability for the 95<sup>th</sup> percentile US male is already in place. The use of their step however requires the ability to allow for them to safely step over the obstacle and have enough space to complete the motion. The ability to step requires the interaction of

the feet and lower limbs to be sized into the space necessary for the task completion. The evaluation of the obstacle when considering these body parts observes that there are no limiting space considerations that would prevent the 95<sup>th</sup> percentile US male from completing the stepping motion with any interference. The lack of any ground interference before or after the obstacle allows for this stepping transfer to occur without unintended interference from the system, satisfying the guidance for the lower body clearance of the 95<sup>th</sup> percentile US male.

The final level of clearance necessary from the interaction with the obstacle system requires the ability for the 95<sup>th</sup> percentile male to manipulate interactions with their fingers, hands, and upper limbs to control the necessary interactions such as setting up and adjusting the device. Since the items are within the reach of the 5<sup>th</sup> percentile US female reach range, the male should be able to easily interact with items in the obstacle without interference. The interference that would be of concern would include the evaluation of the adjustments, to ensure that they allow for the increased size of the body parts.

## **6.2 Findings of the Application of Design Guidelines: Evaluation of the Obstacle Function**

The evaluation of the design guidelines against the obstacle clearance activity demonstrated the ability to provide designers a tool and method of assessing products that are aimed at the older adult market that place an emphasis on mobility promotion. The guidelines provide a process that encourages the focus on providing accommodation to the varying function of a growing segment of the population. The ability to accommodate applies focus on overcoming and designing for barriers that may complicate the design process; the ability to provide this focus on the multiple areas of the user, lifestyle, mobility, and ergonomic, promotes a well-rounded user-centered design approach to allow for the consideration of these limiting factors early in the design process. By addressing these issues early on, the complications that could arise further into the development process can be reduced.

### **6.3 Recommendations for Future Application of the Design Guidelines**

Further use of the design guidelines should place a focus on several areas that were seen to be the site of improvements. The first would be in the application of the contrast ratio through the selection of materials or color finishes that would enhance these features. Higher contrast ratios would lead to a better visual feedback experience for the older user. Within the materials selected, the use of proper texture should be applied as well. This would further enhance the application of the secondary redundant features that would aid the feedback available to the user.

In the use of the product, the selections should seek to perform at the reach functions, especially when located on the ground, for those individuals in a smaller stature population group. This is a balance for designers because when objects have to be located on the ground to be used, optimizing the reach features needed to satisfy wide range of user needs becomes complicated. The balance has to be in the benefit to the user in comfort, or the needs of the functions of the product. Either way, it is felt that this area would benefit future design outcomes with minimal effort in the design process.

## **Chapter 7 Conclusion**

The findings of the research were that a set of guidelines could be formulated to encourage the designs of devices that were intended for use by an older user population that was age 50 or older. The guidelines were able to provide for the addition of the accommodations that can potentially improve the older adult ability to achieve a training effect when the focus of the activity is mobility. This placed the focus on the understanding of the user, and seeking missing elements in the interactions that would benefit their personal use of physical activity systems, improving their opportunity for the desired personal independence.

### **7.1 Research Findings**

At the beginning of the research, a set of research objectives were identified as questions that were sought to be answered through the exploration of the problem of older user activity participation especially those including mobility promotion. The following questions were posed:

- 1) What are the problems with the physical activity product interactions that older adults currently encounter?
- 2) What guidance would benefit designers to improve the interactions of older adults utilizing activity devices for mobility?
- 3) How are the activities that benefit mobility in older adults currently offered?
- 4) What is needed in mobility promotion for older adults?

The following answers were found in regards to these questions.

- 1) The research was able to identify that the problems with physical activity interactions currently encountered by older adults have multiple sources. Many of the directly modifiable interaction issues were involving the barriers to the physical activity process that were reported. Some of the interactions are caused by the aging process and genetics, which do not currently have corrective measures for the conditions themselves;

however, the research has also shown that these declines can be gathered and accounted for during the design process, the early in the process these can be identified, the more complete the design solutions can potentially be.

The reductions in the sensory system and the physical systems appears to be an area that with continued use rather than disuse, are regions that are capable of maintaining functions. The improvement of interactions in either of these areas from a physical standpoint, have the potential for designers to directly modify fairly easily.

An area that was discovered within the individual included their belief, self-confidence, self-efficacy, and general activity experience in both their current state and in their personal life history. Designs that understand that providing gradual increases to difficulty as well as the ability to provide physical beneficial movements in a psychologically beneficial manner would also have to be seen as desirable for designers to seek in overcoming the barriers to the older users. The proper use of human factors along with these considerations should be viewed as favorable in overcoming the challenges.

2) The guidance that would benefit designers to improve the interactions of older adults using the activity devices would involve a multi-level approach to identifying potential solutions. The multi-level approach should include the collaborations between the fields of medicine, exercise, and design in direct contact with the older user who is the intended focus. The knowledge base of all parties would be beneficial because many of the same principles are in place, the difference is in the use of terminology or ranking of importance to the process. With direct contact with the older user, the current and ever evolving needs of this population can be more appropriately focused on.

3) The activities that benefit mobility are currently offered in a variety of instructor/secondary assisted led formats that seek to promote activity and identify potential health complications that are occurring during activity. Although the diversity of the programs is clear, the components that appear to be beneficial include many of the following components:

- Variable/modifiable to the current functional state of the older individual who is participating in the program
- Progressively built to build confidence and ability within the individual to seek to establish a long-term habitual behavior pattern that includes activity integrated into their daily schedule
- Variety of activities that allow for different skills to be developed, and different areas of the body put into focus to continue to challenge the body into creating ongoing adaptations in the functions of the various body regions

4) The needs of mobility promotion in older users requires a combination of ongoing collaboration between the older users, the medical field, and the design fields to provide a mixture of the each to the process. The needs and desires of the older user will require continuing understanding and definitions as each group entering the stage of life will possess unique knowledge of beliefs and technological understanding. The knowledge of the medical field will grow as their testing abilities improve and greater focus of the beneficial activities is further established. The designers will need to translate these into design that continue to satisfy both, but increase the quality of the interactions of the product interactions.

### **7.1.1 Limitations of Research Findings**

Several factors proved to be limitations to the research. Sample size, location, and training focus method used by the older adult were several of the limitations of the study. Sample size of the research was limited to those in the immediate geographic area in the Southeastern region. The size of the population examined can create bias that is not widely expressed. This can occur because of the geographic views vary from those of other areas. Climate and lifestyle habits may vary between these geographic regions and may result in differing views. The ability to test these findings within differing geographic locations may further the research that was discovered.

In addition to reducing geographic bias, the inclusion of different regions may produce a larger pool of individuals to improve the quality of the results achieved. When these results are shown to be present in larger population samples, the information can be more readily relied on.



The focus on the issues of an at-home population rather than those that may occur in a formal class setting should also be noted. The ability for secondary training was not the focus, and the needs required in these settings might require the investigation of different training strategies and approaches implemented by those instructors and their participants.

Time in any intervention strategy appears to play a significant role in the determination of the proposed solutions. The greater the time provided for results to transpire, the greater the opportunity for the results to be relied upon. In this study, sufficient time for studying the effects of the final solution may not be sufficient to produce definitive results, and the results may differ if the study with these guidelines is conducted over a greater time horizon.

The definition of older age used in the study can limit the results. In this study, the use of age 50 was applied to conform to both the WHO and ACSM physical activity guides as they related to older adults. As the research explained, the definition of older age continues to effect results reporting. This is caused by inconsistency that a set of concrete methodologies can use when determining the effectiveness of solutions. Additionally the use of the guides for physical activity recommendations are fluid and change over time as new information is confirmed and adopted into practice. The limits that exist because of the potential changing of recommendations, especially in a population that lacks a clearly defined age range, should be considered.

## **7.2 Recommendations for Future Research**

The use of technology should continue to be explored. Reassessment of the cultural roles should be explored to improve product interactions. As generational transitions and characteristics will evolve, so too will the experiences the groups as a whole enter into later life with.

As exercise and geriatric research progresses, product designers should reexamine the findings to seek more specific prescriptions needed for application of activities. The data that would be most beneficial is both the amount and types associated with the activities that are beneficial for the older adult during mobility. Currently, this information is

general and assumptive, making it difficult to accurately design products. A greater specific range will allow for more appropriately designed products that can potentially improve use and participation. This information would also improve accuracy and standards, which are ultimately necessary to prove or disprove the quality of the design quantitatively based on tracked results.

Design should also seek to include a broader range of medical and science understanding in the educational training of product designers. The research process unveiled the difficulties that designers can encounter when seeking information on areas of medical understanding. These areas include specific concepts and terminology used in the fields of medicine and science. These concepts are used in these fields to communicate the movements, motions, and body regions that are present in the actions provided by the various regions of the body. Much of the current information designers have at the disposal involve static measures such as those in the anthropometric and human factors fields of study. Simplified texts and illustrations of the more detailed concepts would allow designers to provide improved communication with these fields when collaborations occur. The growing population and the growing needs of individuals suggests that these collaborations are going to become increasingly more common and necessary to provide medical design solutions for these groups and society in general. Such resources would be beneficial to occur in publically accessible venues so that access is readily available if necessary or desired in the design development. The information would also benefit designers beyond activity and medical design, as this information could be applied to other solutions requiring the movement interactions of humans and products to occur.

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## Appendix

### Appendix A:

Interviews Conducted with Podiatrists, Orthopedics, and Therapists about Initial Lower Leg Exerciser

**Purpose:** The following locations were visited to review the features that were presented as a part of the Initial Sketch Model Development process. The concepts were brought along to describe both visually and verbally the intention of the functions based on the information that was developed. The participants were able to provide questions and input as to the quality of the assumptions that were presented in the conceptual models. The input received from each location is summarized below.

Dr. Paul Ciavarelli, Alabama Foot Care Center, Opelika, AL (Ciavarelli, 2008)

### Interview Responses:

1. The most common problem that he sees with patients are problems with the arch of the foot, a symptom known as *plantar fasciitis*
2. Common relief for plantar fasciitis overnight are fixed boots that prevent foot drop; the fixed, flatten foot position allows the patient to experience less pain in the morning because of keeping the ligaments elongated overnight
3. Another typical prescriptive relief plan is the rolling of a round plastic bottle ( Ex. an empty pill bottle) back and forth along the bottom of the foot arch; the motion helps elongate the ligaments of the bottom foot
4. Recommended light use of heat/cold for therapeutic effect; suggested the use of a material that could be used as both heat/cold, something that could be put in the microwave or freezer for instance
5. Thought that a texture surface could help with things like proprioception and awareness on the area; was not sure that the addition of texture would increase blood flow to the foot region
6. Mentioned the need for sanitation of the device if it were to be used barefoot by individuals
7. Because of the license structure in the state of Alabama, podiatrists here are only allowed to perform services from the start of the ankle down; some states allow podiatrists to

perform services from the knee below; because of this, Dr. Ciavarelli was not able to answer as many questions pertaining to the lower leg

Dr. Todd Sheils, Orthopedic Clinic, Opelika, AL Branch (Sheils, 2008)

### **Interview Responses:**

1. Need to determine whether product would be for walking comfort/ease or rehabilitation
2. Had no knowledge of heat/cold/texture research or information pertaining to these practices in medical field; In regards to temperature, patients generally can be expected to tolerate it for about twenty minutes
3. Wobble boards on the market currently are *rehabilitative* because these devices take the foot through different planes (dorsiflexion, inversion, etc.); This is rehabilitative because the product is adding strength on the different muscles, you are forcing the muscles to react
4. This device would be more athletic/rehabilitative in function because the movement is not *linear* like an activity such as walking
5. Suggested looking at *New Balance*<sup>TM</sup> shoe that has a rocker bottom; the reason the shoe would be significant is the arc of the rocker shoe makes walking easier because it alleviates pressure/strain on the arc of the foot
6. The reason walking shoes have wide heels on the soles of the shoe is it trying to eliminate instability ( this is something that my product is trying to add); adding instability when you are talking about improving walking ability is pointless because you are tightening the muscles
7. If you want to make walking over a long distance easier, remove the instability from the movement
8. Especially with older persons, mid foot arthritis is an issue that is aggravated by the walking motion(see diagram of foot)
9. There are lots of products currently on the market for plantar fasciitis

Dr. Steve Kisor and Staff, Rehabworks, Auburn, AL (Kisor & Staff, 2008)

### **Interview Responses:**

1. *Posterior Tibulitis* or *Tibullus Posterior* is something that a device such as this could work on
2. Need to incorporate a sidewall or a fix the foot in some nature to reduce the liability of incident in the shoe/sandal
3. Maybe a fixed place for the foot with a resistance band not tube that is fixed to the toe region of the foot to enable the user to work on movement the foot through different planes of motion

4. On the B.A.P.S.<sup>™</sup> board, look at the plane name that runs under the foot imprint (the place on the board that signals the user to place the foot on this section of the board, in this manner)
5. The target of the concept idea is fine
6. Texture is not going to stimulate blood flow to the foot or lower leg region, the movements themselves will accomplish this; texture will however help in *proprioception*
7. It is debatable within the medical community whether the need for a soft/rounded arch support for the foot would be necessary because it is a non-weight bearing activity; it would be more of a concern if it were in fact a weight bearing activity
8. Not opposed to a collar limiting the range of motion activity of the movement
9. Told the doctor I wanted to keep the cost under \$50; told also that this was not geared toward athlete but as an initial step to lead into more intensive wobble activity, beginners level
10. The fixed toe device looked like the products that limit plantar fasciitis overnight (see example)
11. The motion below is what the doctor said would be of benefit to a senior user
  - a. The *concentric* and *eccentric* motion in this plane depending on the movement would be beneficial
12. There was again no real input/benefit expressed on the “bike pump” action of the mock up

Dr. James F. Bruce, Dr. Daniel Guy, Dr. Robert R. Comerford, Dr. Brian Terry, H. Greg McCollum, PA-C, Deborah Thompson, RN,CFNP Southern Orthopedics, La Grange, GA (Bruce, et al., 2008)

### **Interview Responses:**

1. Recommended looking at fitterfirst.com, a Canadian company that manufactures some of the wobble boards that they utilize in their office; also had products based on stones/texture as a therapeutic effect
2. They thought that the concepts could be used in conjunction rather than two separate concepts
3. They like idea of reaction times, one of the employees did research on declining of reaction time with age; did not however have any info on improving with a product or approach (examples like DDR<sup>™</sup> or Simon<sup>™</sup>)
4. Look to add some sense of accomplishment to the product; if they feel/see improvement more likely to participate/achieve goals; Different levels/band color, etc.
5. Integrate a plan or schedule into the device; people like to be told what and how to do it
6. When designing for the elderly, make sure they can manipulate aspects of the device with fingers and hands as well as visually recognize those aspects because of the high rates of arthritis and vision issues
7. Rather than implying that the device will cure/fix an ailment, suggest rather that it will improve strength, balance, and flexibility

8. Definitely market for elderly, can possibly achieve universal design market in rehabilitation
9. Maybe utilize simple hooks around the perimeter of the sandal/shoe that could hold rubber bands in place for the resistance aspect because they are inexpensive and readily available
10. Keep the toe open if possible to accommodate gnarly toes, etc. that are more common in individuals who are older; a strap might be all that is necessary
11. Do not think that “bike pump” action is going to be beneficial because of potential knee/hip problems; additionally the movement does not seem to have much potential to improve any particular aspects
12. Like the idea of having a platform or some area that acts similar to a platform with a target for the user to aim for; Suggested that the base of the unit should be bigger for stability
13. Look at changing the half sphere on the bottom of the foot to allow for it to be change incrementally or adjusting the level of difficulty of the feature
14. This is the second office that encourages the seated activity of the wobble for the start of severe ankle issues
15. They believe the target market for the product is elderly individuals with any of the following conditions: weak ankle, balance issues, pain, stiff joints

## **Appendix B**

Interview Conducted with Rehabilitation Facility and Review of Sketch Model:  
Beneficial Movements

Dr. John Mann III, and Tom Evans Total Rehab, Auburn, AL (Evans & Mann III, 2014)

### **Introduction:**

The pre-prototype was set up for Dr. John Mann III and Dr. Tom Evans in their office. The functions of the activities that we would like the older adult to perform in an at home or community center setting were demonstrated. The functions were individually performed and demonstrated, and were further explained as to the goal that was desired to be achieved by the end user. The following comments and concepts were the result of the demonstrated use of the pre-prototype activity device for the older adult. Additional comments, concepts, and activities were explored as we viewed some of the current practices, activities, and equipment within the rehabilitation office; we reviewed these as they could relate or be incorporated into the design concept.

### **On quad stepping activity:**

Liked the idea of moving through multiple planes. They utilize a similar approach via a duct taped pattern that is placed directly on the carpeted floor. The pattern is approximately 7' square in the space it occupied. Talked about the transversal plane being ignored in general through training. This is an additional plane that adds a 45 degree diagonal to the current design with four 90 degree angled quadrants. The stepping towards this direction in the transversal plane allows for the dual recruitment of the lateral and linear activity muscles simultaneously. This provides the ability to progress from the front plane to the lateral plane in forward stepping to have a plane along the way; this would allow the individual to build toward a more full range of motion that would be necessary in daily activities and mobility development.

### **On Step Height Activity:**

They did not like the motion pattern of the “Marching” style activity. Found the verbal description of “functional movement pattern” when discussing the approach of moving the clearance target to the back of the vertically hinged leg; this is the movement pattern that was viewed as more favorable by Dr. Sefton in which the goal of the activity is to recruit the full stepping pattern while clearing an obstacle. The activity recruits more muscles and function that are necessary in daily activity. However, both agreed with that convincing the “older adult” user to participate in the stepping activity would be very difficult; said they don’t even try with patients that are 65-70 years of age or older because of the unfavorable response. Seems that the activity is favorable but the design needs to be tweaked to encourage a higher level of confidence out of the older adult user in order for them to be more likely to use the activity.

### **On Platform Activity:**

Liked the chasing the ball activity, very visual response to the activity being performed for the older user. The suggestion/question of can the activity be performed standing with a base of support if necessary seems to play on the favorable view that activity being performed under the force of gravity is beneficial to this population. Activities that could provide this progressive aspect could be seen as beneficial in future development considerations or guidance.

### **On Roller Activity:**

The function provided by the roller would work; however, it does not offer much in the area of improvement to overall mobility. These device activities are pretty available on the market. Can stimulate blood flow, reduce soreness through self-massaging, and also stimulate senses, which should be viewed favorably. Although the mobility does not benefit, the stresses caused by discomfort either from activity participation or from daily activities could benefit.



## **On Toe Pull Activity:**

Liked the target aspect of the tethered pull. They utilize a marble into a can activity. This type of activity is Isokinetic or Isokintonic (double Check). The tethering without resistance seemed to be viewed favorably. Putting the activity under resistance seemed alright other than the possibility of “snap-back” when tension was released by a user.

## **In general:**

- How are you marketing this? If you were to flip through a catalog, what describes or portrays the activities being proposed and presents them in an easily understood form.
- What is the target of the activity? Is this a “Foot and Ankle” device for the improvement of those areas or is this a “Balance” improvement device. The reason is that there are essentially two types of training thought being presented in my current device; new school and old school training thought. The stepping in the quadrants for instance is new school thought. The utilization of gravity over several planes is attempted. The plane of activity that is most important, and which has been overlooked the most to this point has been the ***transversal plane***. (The planes are the saginal or linear style plane, the planer or side to side style plane, and the transversal or full circle plane).
- Think about the time spent over in activity area of office... the stepping/toe point style of activity that is taking place on expanding concentric circles. The “reach of the toe point” can be tracked to view progress.
- Remember that the key to developing balance is getting them up, like what Dr. Sefton wants you to do. You are not going to develop sufficient motor recruitment from seated activity. The older adult could benefit from progressive training from seat, to stand.
- The action of the walk is more rotational than you think, turning in of the calculeus joint, the inward flex of the knee, the rotation of the pelvis through as the other side gathers the momentum to fire the other side through the motion. Look back at the kinetic chain for more insight.
- Number one prescribed activity is walking, number two is balance. That wasn't the case even 5 years ago. This suggests that balance, and those activities that promote it should be viewed as an important aspect in the training activities. This could explain the importance of the additional plane of motion, where it allows for the manipulation of balance in multiple directions, this is more similar to daily life.
- When doing the quadrant style activity, they will sometimes call on the arms to be going towards a different plane to start to add degree of difficulty to the movement patterns. This addition of the arms going into a different direction allows for increased challenge. This comes from the user needing to adjust their

COM to adapt for this change. This recruits different muscles in the core section and elsewhere in the lower and upper body to participate in the stabilization that is necessary in postural control and balance. Greater control of these aspects could lead to greater control of mobility based on the improvements in the strength gains in balance.