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Review of intrinsic factors related to fall risk in individuals with visual impairments

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Abstract—Abundant information in the geriatric literature emphasizes the factors relevant to maintenance of independent mobility and reduction of fall risk. However, while some researchers have attempted to identify the relationship between chronic health and visual impairment, few studies have systematically explored the impact of physical interventions that aim to remediate reduced health and function in adults with visual impairments. This review identifies intrinsic physical factors that negatively affect health and independence in adults with visual impairments. By highlighting these factors, we hope to provide a basis for future exercise interventions that will target reductions in the rate of physiological decline while preserving and potentially restoring independent functioning. Because the aging population is increasing and the basis for and subsequent formulation of exercise programs for maintaining mobility and quality of life have not been definitively ascertained for individuals with declining vision, exploring the intrinsic physical factors most amenable to physical rehabilitation becomes relevant.

Key words: aging, chronic health, fall risk, falls, health, independence, physical functioning, physical rehabilitation, sensory impairment, visual impairment.

INTRODUCTION

This article provides a critical review of the intrinsic physical characteristics associated with decreased physical functioning in individuals with vision loss. In this review, we specifically examine the literature pertaining to factors amenable to physical rehabilitation (overall health, gait, lower-limb power, functional assessment, and balance). Recommendations for future scientific inquiry pertaining to improvement of physiological functioning and the need for studies that systematically explore the impact of interventions aimed at improving independence are discussed. Based on research in older adults, evidence supports the notion that sensory compromise, particularly visual impairment, is an attribute contributing to frailty [1]. Equally important, improving physiological characteristics of individuals throughout the life span plays a vital role in maintaining function and independence late into life [2]. Physical deficiencies that one acquires early in adulthood can persist, resulting in frailty and sarcopenia as one ages [3]. Numerous studies have highlighted deficiencies in physical performance by individuals with visual impairments [4–6]; however, little effort has been directed toward exploring rehabilitative interventions aimed at meeting the specific physiological needs of individuals with profound vision loss. At the time of this review, we identified only one case study that used therapeutic exercise (tai chi) as an intervention to improve dynamic posturography in adults with visual impairments [7] and one randomized trial that attempted to decrease falls in older adults with vision loss [8].

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From the literature pertaining to sighted older adults, the ability to perform daily tasks is known to be affected by age-associated declines in muscle mass, strength, balance, and power [6,9]. Inadequate muscle strength and loss of lower-limb power can make walking labored and climbing stairs or rising from a chair difficult [10]. Changes in balance and gait can negatively affect an older adult's activity level through self-imposed barriers to independence, compounding the cyclical nature of physical decline [11–12].

OVERALL HEALTH

The limited available research shows that individuals who are visually impaired are less physically active than sighted individuals [4] and that chronic diseases appear to be accelerated by the magnitude of vision loss [13]. Visual impairment is thought to be associated with decreases in leisure activities as a result of compromised mobility, social functions, and morbidity [14–15]. The reduced mobility and decreased leisure activities contribute to obesity, which often is the source of chronic diseases such as diabetes, hypertension, and cardiovascular diseases. This observation implies that obesity results in physical function decrements and that aging adults with visual impairments tend to experience obesity and chronic health conditions at a greater prevalence than aging adults without significant vision loss [16]. Older individuals who are visually impaired have more health problems than their sighted peers, including lower femoral-neck bone mineral density; less maximal strength; and higher rates of stroke, osteoporosis, depression, hypertension, heart disease, arthritis, and diabetes [4,17]. The Framingham Study found that the risk of hip fracture doubled for women with poor or moderately impaired vision [18]. The Auckland Hip Fracture Study noted that the risk of hip fracture increased by 40 percent in individuals with poor visual acuity [19]. Diabetes, which is strongly associated with obesity and hypertension, would therefore be expected to be prevalent among individuals with significant visual impairments [16]. The research indicates that vision loss leads to increased inactivity that results in increased chronic disease prevalence. No studies have focused on the use of activity programs to reduce the risk of chronic health conditions among adults with visual impairments.

GAIT

For older individuals who are visually impaired, the simple task of walking perhaps demonstrates the most fundamental form of dynamic balance that can become compromised because of an inability to preview the environment. Ambulation requires integration of the multiple components that interface balance and gait. Independently distinguishing the contributions of each component to the performance of daily tasks is difficult. The ability to walk without falling depends on the successful shift of body weight between single- and double-limb support phases as the body moves forward. Completion of most daily activities often demands a minimum effort at independent ambulation. Hence, older adults with decreased visual acuity are more likely to be physically dependent and placed in a nursing home [20–22].

The aging process absent of vision loss includes physiological changes that predispose an individual to gait difficulties. Documented deficits in the neurological, vestibular, visual, and musculoskeletal systems are critical to postural control [23–25]. These control parameters, in turn, are highly related to performance in gait [26–27]. Such physiological changes can be manifested in reduced gait velocity, decreased stride length, and reduced single-support stance time [28–30]. Slowed gait velocity is significantly related to fall risk [1,31] and affects an older adult's independence. Gait and balance abnormalities in older adults are also typically associated with increased fall risk and poor balance confidence [11–12]. In a 2-year prospective study, older adults who reported poor balance confidence at baseline experienced a greater increase in balance, gait, and cognitive disorders over time than those with greater balance confidence at baseline [12]. Reduced peak hip extension, increased anterior pelvic tilt, and reduced ankle plantar flexion range of motion and power are physiological abnormalities that relate gait and balance deficits to increased risk of falls [23]. Consequently, sighted older adults who fall tend to walk slower, have a shorter stride length, have a wider base of support, and spend more time in double-support stance during gait, similar to the characteristics presented by individuals with visual impairments [32]. Unpublished data from our laboratory indicate that walking speed and step length in individuals with visual impairments are reduced (**Table**, Ray et al. [unpublished]). Furthermore, the mean gait speed for individuals in their 40s and 50s who are visually impaired is similar to that of sighted subjects over the age of 80 [33].

Table.
Intrinsic factors related to fall risk in individuals with visual impairments. (Data shown as mean ± standard deviation unless otherwise indicated.)

Study Design: Intrinsic Factor(s)	Study	*N*	Statistics: Group	Statistics: Value	Respondent: Findings
Observational: Lower-Body Peak Torque at 90°/s (N•m)	Horvat et al., 2004 [1]	30	Legally Blind M	Q: 143.9 ± 32.8 H: 82.5 ± 19.6	Clinician measured: When normalized for body weight, lower-body strength significantly reduced compared with age- & sex-matched sighted peer group ($p < 0.01$).
			Legally Blind F	Q: 113.8 ± 58.6 H: 53.2 ± 40.3	
			Sighted M	Q: 182.5 ± 53.9 H: 102.9 ± 35.0	
			Sighted F	Q: 173.3 ± 39.3 H: 97.3 ± 16.5	
Observational: Lower-Body Mean Power at 180°/s (W)	Horvat et al., 2004 [1]	30	Legally Blind M	Q: 138.3 ± 33.1 H: 85.0 ± 20.2	Clinician measured: When normalized for body weight, lower-body power significantly reduced compared with age- & sex-matched sighted peer group ($p < 0.01$).
			Legally Blind F	Q: 115.5 ± 79.1 H: 62.0 ± 50.6	
			Sighted M	Q: 191.4 ± 60.7 H: 116.1 ± 47.3	
			Sighted F	Q: 171.1 ± 41.5 H: 104.3 ± 20.7	
Observational: Quadriceps Strength (kg)	Lord & Dayhew, 2001 [2]	156	Nonfallers	29.7 ± 11.7	Clinician measured: Significant difference between multiple & nonmultiple fallers ($p < 0.05$) but not significant after controlling for age.
			1 Fall	27.9 ± 12.0	
			2+ Falls	24.5 ± 10.4	
Observational: Dynamic Posturography (SOT Composite score)	Ray et al., 2008 [3]	46	Visually Impaired	76.3 ± 12.6	Clinician measured: Significantly reduced postural stability compared with age- & sex-matched sighted peer group ($p < 0.05$).
			Sighted	83.3 ± 4.41	
Observational: Sway (mm squares traversed by swaymeter in 30 s)	Lord & Dayhew, 2001 [2]	156	Nonfallers	159 ± 79	Clinician measured: Significant difference between multiple & nonmultiple fallers ($p < 0.01$).
			1 Fall	143 ± 70	
			2+ Falls	229 ± 112	
Case Study: Tai Chi Intervention to Improve Balance (SOT Composite score)	Ray et al., 2005 [4]	2	Faller: Participant 1	Pre: 58; Post: 78	Clinician measured: 10 wk intervention (2 d/wk, 90 min/session); improved overall postural control in both participants.
			Participant 2	Pre: 81; Post: 84	
Clinical Trial: No. of Falls & Injuries	Campbell et al., 2005 [5]	391	Home Safety Assessment	Incident Rate Ratio: 0.59	Self-report: Home safety program reduced falls; home exercise program was ineffective at reducing falls, although strict adherence resulted in fewer falls ($p = 0.001$).
			Exercise Program & Vitamin D	1.15	
Observational: Reaction Time (ms)	Lord & Dayhew, 2001 [2]	156	Nonfallers	267 ± 43	Clinician measured: Significant difference between multiple & nonmultiple fallers ($p < 0.01$).
			1 Fall	278 ± 52	
			2+ Falls	311 ± 80	

Table. (Continued)

Intrinsic factors related to fall risk in individuals with visual impairments. (Data shown as mean ± standard deviation unless otherwise indicated.)

Study Design: Intrinsic Factor(s)	Study	*N*	Statistics		Respondent: Findings
			Group	Value	
Observational: Functional Assessment	Ray et al., 2007 [6]	30	Visually Impaired	TUG: 7.99 ± 3.86 STS: 16.87 ± 5.94	Clinician measured: Significant difference between visually impaired & sighted matches on TUG & STS performance ($p < 0.05$).
			Sighted	TUG: 4.86 ± 0.84 STS: 23.00 ± 8.22	
Observational: Comfortable Gait Speed (m/s)	Ray et al. (unpublished)	23	Legally Blind	0.76 ± 0.18	Clinician measured: Comfortable gait speed comparable to individuals in 80–102 range (Lusardi et al., 2003 [7]).
			Totally Blind	0.81 ± 0.22	

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F = females, H = hamstring, M = males, Q = quadriceps, SOT = Sensory Organization Test, STS = Sit to Stand (repetitions in 30 s), TUG = Timed Up and Go (s).

LOWER-LIMB POWER

The ability of muscles to generate and sustain strength and power is of principal importance to the maintenance of a reasonable quality of life in older adults because lower-limb power is important for functional tasks [10]. Low levels of lower-limb power make climbing stairs or recovering from a fall difficult. Difficulty climbing stairs, in turn, can negatively affect an individual's use of any form of transportation. Without adequate lower-limb power, an older adult may not be able to safely cross a busy street in the time allowed. Mechanical power, defined as the force applied to an object multiplied by the velocity of movement of the object, is also equivalent to the amount of work per unit time [34]. If less work is performed in the same amount of time, mechanical power is reduced. Muscle power, the product of muscle force and contraction velocity, is affected by several age-associated changes. Mechanical power, in turn, is affected by the amount of muscle power an individual can generate. Considering that muscle power is the product of muscle force (strength) and contraction velocity and that strength decreases 7.5 to 8.5 percent per decade during adulthood while contraction velocity decreases 7.0 percent per decade, these combined changes compound the loss of lower-limb power by 35.0 percent per decade (mean ± standard deviation range = 213 ± 51 W to 80 ± 49 W over 24 years) [35].

Significant relationships among lower-limb power, walking speed, stair-climbing speed, and stair-climbing power have previously been established in sighted older adults [10]; moreover, reductions in lower-body isokinetic strength and power have been observed in adults with visual impairments compared with a sighted control group (**Table**) [36]. These initial studies provide cross-sectional data indicating that individuals with vision loss are more susceptible to reductions in lower-limb strength and power. However, no work to date has explored the rate of loss, how aging compounds this rate loss, or the extent to which an intervention can positively affect this deficiency.

FUNCTIONAL ASSESSMENT AND BALANCE

Individuals with visual impairments must place greater demands on somatosensory and vestibular information to establish movement patterns, whereas positions in space are compromised by minimal or no vision [37]. Data from our laboratory indicate that vision loss results in reduced postural control during the NeuroCom Sensory Organization Test (**Table**) [24]. For movement, individuals with visual impairments must depend on sensory information other than vision to initiate changes in the center of gravity and base of support. While most individuals require vision to maintain postural stability, others can maintain an upright position accurately without visual information [38]. However, balance with vision is more efficient and skillful than balance without vision, especially in changing conditions [38]. Common problems associated with visual impairments are the use of other sensory information to establish and connect movement patterns and adjust to positions in space [39]. Standing balance is diminished, because the loss of vision affects postural control via the lack of visual feedback [28,40].

This reduction in standing balance is also apparent because individuals with visual impairments use proprioception as a substitute for vision when completing balance tasks [39]. In addition, other mechanisms must provide the compensatory sensory input that can be used to initiate movement if vision is not available or is restricted. Concurrently, sighted individuals must respond to changes in the environment by modifying and self-correcting their movement. For example, when encountering obstacles or changes in terrain, sighted individuals adjust their gait pattern to accommodate these changes. In contrast, individuals with visual impairments negotiate obstacles as they are encountered without the benefit of prior visual information. Individuals with visual impairments have been observed to be more cautious and have more difficulty performing tasks when their center of gravity is outside of their base of support [37]. Thus, on clinical assessments (30-second Sit to Stand and Timed Up and Go), individuals in their 40s who are visually impaired performed these tasks similarly to participants in the 70- to 80-year-old range [41].

DISCUSSION

As the population ages, the number of individuals with visual impairments is expected to increase. The evidence presented in the **Table** supports the notion that vision loss has a negative effect on an active lifestyle, which adversely affects the physical functioning of individuals with visual impairments. A preponderance of the focus from those providing rehabilitation to individuals with low vision emphasizes efforts to maintain or regain vision, life skills, and mobility. The available evidence suggests that these programs neither effectively improve the physiological functioning or chronic health of this population nor propose to do so. While the literature is replete with studies reporting negative outcomes associated with living with vision loss [1,4,6,14–16,20–22,24,36–37,40–41], little systematic or exploratory work has been done to understand the causative factors or underlying mechanisms that contribute to these declines. For example, we have observed reduced postural stability, reduced lower-body strength, and slower reaction time, which we suspect are due to an inactive lifestyle; however, we have yet to quantify even the basic changes associated with efforts to increase activity within this population. Furthermore, no work has explored adapting vestibular therapy or resistance-training programs so that we might measure their effectiveness or adherence among populations with compromised vision. Increased knowledge about the specific physiological and functional deficiencies in individuals who are visually impaired is a prerequisite that can lead to novel and evidence-based exercise interventions resulting in the remediation of these vision loss and age-associated changes. Improvements in balance, lower-limb power, and gait may ultimately yield reductions in physical disability and falls, thereby conferring greater independence and enhanced quality of life to older adults with visual impairments. The inclusion of unique exercise interventions that target older adults with declining vision will enhance the effectiveness of the treatment plan by improving the individual's overall health and physical function.

This previous work suggests that adults with vision loss show signs of impaired health and reduced functioning compared with their sighted peers. However, we do not know how aging exacerbates this physical decline and whether the resultant impact produces legally blind older adults who have increased indexes of sarcopenia, frailty, and premature mortality. Furthermore, no interventions have been systematically studied or developed to restore function and address the unique physical needs of individuals who are visually impaired. Valuable information is still needed.

LIMITATIONS

The studies reported in the **Table** suggest that our ability to acquire knowledge regarding physiological and functional capabilities in older visually impaired adults has been hampered by (1) the paucity of quantitative data focused on intrinsic physical factors (most data have been contributed by three investigative teams); (2) the variance among intrinsic factors and the measurement units used to report them; (3) varying sample sizes; and (4) differences in participant attributes and, consequently, inconsistencies in findings. Collectively, these sporadic data speak to the obvious need for concentrated and systematic study of attributes among adults with visual impairments throughout the life span. This must lead to the development of evidence-based interventions that improve independence by increasing physical functioning and reducing the intrinsic factors that contribute to increased fall risk and reduced health.

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE INQUIRY

From this review, the reader should note that the preponderance of research is either cross-sectional or epidemiological. Noticeably absent from the literature are interventions aimed at remediating health and improving independence within this population. Parenthetically, the role of divided attention (multitasking) as a modifier of fall-related events among legally blind older adults has not been studied either, and this important oversight must be addressed in subsequent trials aimed at improving health and function while reducing fall risk. The two studies that focused on physical interventions to improve postural control [7] and reduce falls [8], found positive results when the subjects strictly adhered to the exercise protocol. Future work must measure the impact of physical interventions and how they translate to increased independence in older adults with vision loss. Accordingly, clinicians and researchers interested in developing a deeper understanding of physiological functioning in adults who are visually impaired can consider the following questions to generate provocative but important research topics:

1. What is the role of divided attention in maintaining postural stability in individuals with visual impairments?
2. Can high muscle-velocity training improve power output and decrease muscle latency in individuals with visual impairments?
3. What is the effect of improved fitness on chronic health and independence in individuals with visual impairments?
4. Are individuals with visual impairments at increased risk of developing sarcopenia, frailty, and premature mortality later in life?
5. What are the benefits of therapeutic exercise on fall risk in individuals with visual impairments?

Among these queries, our future efforts will be specifically directed toward exploring novel interventions that combine strength, balance, and endurance to optimize independence in older adults who are visually impaired. We will also be exploring the extent to which sex and divided attentional demands modify the effectiveness of such interventions.

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